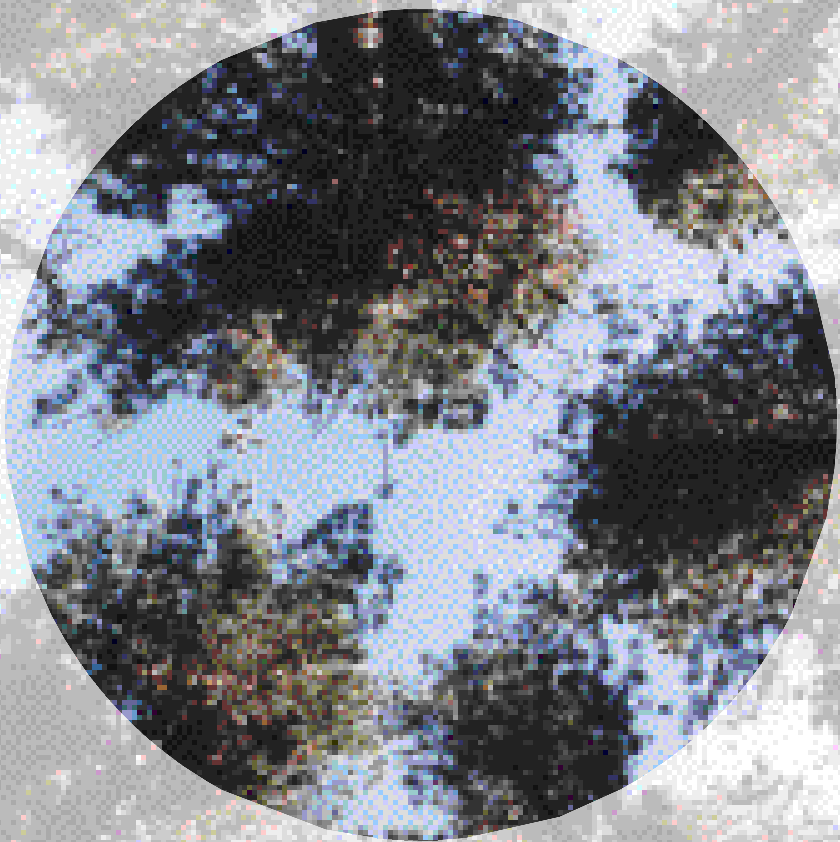
IEA Bioenergy

Task XV/25

Greenhouse Gas Balances of Bioenergy Systems



Proceedings of the Workshop

Effects of the Kyoto Protocol on forestry and bioenergy projects for mitigation of net carbon emissions

9 and 13 March, 1998

Rotorua, New Zealand

B. Schlamadinger and R. Madlener (eds.)

April 1998

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Radiata pine forest, Rotorua/New Zealand (courtesy of Reinhard Madlener)

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Foreword by the Editors

IEA Bioenergy is an international collaborative effort towards an environmentally sound, cost-competitive, and sustainable use of bioenergy that provides a substantial contribution to meeting future energy demands. It was set up in 1978 by the International Energy Agency (IEA) to improve international co-operation and exchange between national bioenergy research, development and demonstration (RD&D) projects.

The goal of the IEA Bioenergy Task “Greenhouse Gas Balances of Bioenergy Systems” (tagged as “Task XV” from 1995-97 and as “Task 25” since 1 January 1998) is to investigate, on a full fuel-cycle basis, all processes involved in the use of bioenergy systems, with the aim of establishing overall greenhouse gas balances. For a detailed description of the history of the Task and its achievements see the Task XV Final Report in the Appendix of this report.

The Proceedings in hand contain most of the presentations given at the workshop "Effects of the Kyoto Protocol on forestry and bioenergy projects for mitigation of net carbon emissions", which took place on 9 and 13 March 1998 in Rotorua, New Zealand.
While the closed session on March 9 served administrative matters, the session on March 13 was organized as an open event. The workshop has been the fourth in a series of international events organized within the IEA Bioenergy Tasks on "Greenhouse Gas Balances of Bioenergy Systems", taking place once or twice a year (1995 in Graz/Austria, 1996 in Stockholm/Sweden, 1997 in Vancouver/Canada). The next workshop in this series will be held 9-11 September 1998 in Nokia, Finland.

The focus of the Workshop in Rotorua was on the consequences of the Kyoto Protocol on forestry and bioenergy projects, aimed at either the reduction of carbon emissions or the enhancement of carbon sinks. Taking place in the “homework phase” after the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto/Japan in December 1997 (COP3), a particular issue addressed at the workshop was that of "baselines" - both in terms of reference land uses and reference energy systems - needed as a benchmark to derive the net carbon benefits of forestry, bioenergy, or other land-use related projects.

Many of the workshop participants also made use of the opportunity to attend a seminar "Bioenergy in the Environment" (organized by the New Zealand Energy Efficiency and Conservation Authority, EECA) on March 10 and to join a field study tour to a biomass co-generation plant and various forestry sites, organized by Forest Research on March 11 and 12 for IEA Bioenergy Task XII (Biomass Production, Harvesting and Supply).

We would like to express our sincere gratitude to the local host and organizer, Forest Research, and particularly Justin Ford-Robertson, to the authors, and last but not least to every workshop participant - as they all contributed to making this meeting a success. Also, we would like to acknowledge the extra effort undertaken by Piers Maclaren, who spontaneously agreed to prepare a personal summary of the workshop, which is also included in this volume, and to Josef Spitzer for chairing the workshop sessions. On the editorial side, we would like to thank Anton Stachl for his active support with regard to the design of this report and Michael Waupotitsch for the final layouting of the text. Needless to say that the responsibility for the accuracy of the scientific content of the presentations rests with the authors alone.

For more information on the Task and its various activities see, for example, the Final Report of Task XV in the back of these proceedings. Also, you may want to pay a visit to the WWW homepage at http://www.joanneum.ac.at/IEA-Bioenergy-TaskXV, or contact one of the editors at: Joanneum Research, Elisabethstrasse 5, A-8010 Graz, Austria (phone +43 316 876 1340, fax +43 316 876 1320, e-mail: reinhard.madlener@joanneum.ac.at).

Bernhard Schlamadinger and Reinhard Madlener

April 1998

Presentations

Sinks and the Kyoto Protocol - interpretations, implications and unfinished business

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Abstract

"Sinks" were included in Articles 3.3 and 3.4 in the protocol in a very constrained manner viewed as the "least best" by major forestry countries. The language may be interpreted in different ways. Until clarified and settled by the Parties this will be a problem. This presentation (by an official who was "in the negotiating room") will give the background to the way sinks were included. The presentation will discuss possible interpretations, the implications of these and propose a science based approach that is in keeping with the (apparent) intent of negotiators. It will also outline key areas of unfinished business that will engage and challenge forest technical experts and officials working in the climate change arena for many years.

SINKS AND THE KYOTO PROTOCOL

INTERPRETATIONS, IMPLICATIONS & UNFINISHED BUSINESS

Murray Ward,

Ministry for the Environment

New Zealand

KYOTO PROTOCOL ARTICLE 3 (3)

The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I.

WHAT IS THE BACKGROUND TO THIS LANGUAGE CONSIDERED AS "LEAST BEST" BY MAJOR FORESTRY NATIONS

Science / Methodology uncertainties
Incomplete data reporting
Fear / Ignorance
Politics of targets and levels of effort on gross emissions
Sinks as a 'cop out' (ENGO Shame and Blame)

Overarching context was

For now, let's let in the minimum amount of sinks possible.

INTERPRETATION 'CHALLENGES'

The <u>net changes in</u> …etc
- hangover of the Australian land clearance issue

<u>reforestation</u>

<u>deforestation</u>

REVISED 1996 IPCC GUIDELINES DEFINITIONS

Reforestation: *Planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use.*

Afforestation: *Planting of new forests on lands which, historically, have not contained forests.*

Common theme: *LAND USE CHANGE (SINCE 1990)*

so Deforestation: *Removal of forest for alternative land use.*

What about forest *harvesting* and *regrowth*? (discuss using FRI 30 year rotation graphics - slides from George Hooper, ie why shouldn't be included)

RAMIFICATIONS OF THE KYOTO PROTOCOL SINKS LANGUAGE IN ARTICLE 3 (3)

'Existing in 1990' sinks in essence ignored unless they're deforested.

For most forestry countries, inclusion of sinks under the Kyoto Protocol language will have minimal effect in the first commitment period; New Zealand different.

USA target 0%, -7%, -2% ???

UNFINISHED BUSINESS (THAT PREVENTED A BETTER OUTCOME ON SINKS)

Definition of Anthropogenic (concerns about 'man' taking credit for what nature's doing)

Complete inventory methodological work:

harvested wood products (who gets the harvesting emissions and when)

inventory guidelines for land use change and forestry suitable for legally binding commitments

UNFINISHED BUSINESS (DECISIONS TO BE TAKEN BY THE PARTIES)

Work off existing activity base and "since 1990" and add additional activities?

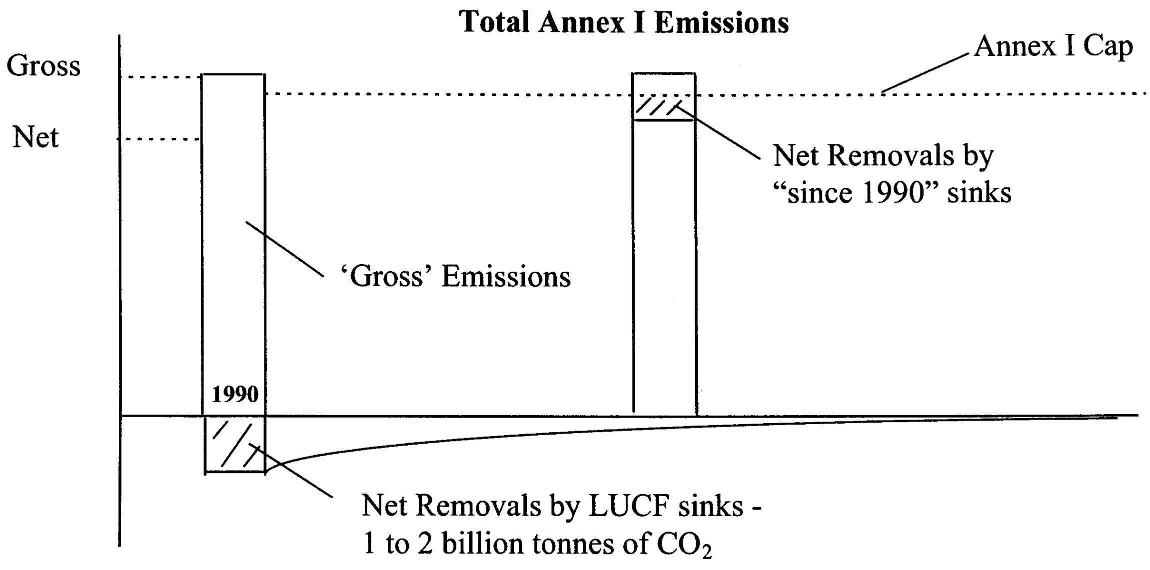
Work off existing activity base, add additional activities and drop the "since 1990" constraint?

Complete methodological work and revisit /relitigate the entire sinks package consistent with the all-inclusive trend in IPCC inventory guidelines?

If so, when to affect this change?

What about targets? Would these be changed?

WHAT IS THE 'ENVIRONMENTAL HIGH ROAD?



Some technical issues regarding land-use change and forestry in the Kyoto Protocol

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Abstract

This paper describes the implications of the Kyoto Protocol for the land-use change and forestry sector and addresses some of the technical issues that merit further consideration before the treaty comes into force. Although the phrasing is sometimes ambiguous and the opportunities limited, the Protocol considers some limited forest-related activities to be used to meet emission-reduction commitments. To implement the forest related portions of the Protocol, most importantly: 1.) a clear definition for the word "reforestation" is required, 2.) contradictory wording in Article 3.3 should be clarified, and 3.) some thought should be given to the last sentence of Article 3.7 (establishing different rules for countries with a net carbon source in the forestry sector in 1990), with respect to countries reporting a net carbon sink for 1990 despite deforestation.

Keywords: forestry, carbon sinks, deforestation, afforestation, reforestation, carbon accounting, Kyoto Protocol

1. Introduction

1.1 The Kyoto Protocol

Delegates from over 150 countries met in Kyoto, Japan, from 1 to 10 December 1997 and agreed on a Protocol to limit future emissions of greenhouse gases. Annex I countries (developed countries listed in Annex I of the Framework Convention on Climate Change) are called to reduce their emissions of six greenhouse gases, relative to emissions in 1990, by a certain percentage (some countries are allowed to increase their emissions) in the period from 2008 to 2012. The total emissions of Annex I countries should be reduced by 5.2 %. The Protocol text can be found at www.unfccc.de.

The Protocol is open for signature for 1 year beginning on March 16, 1998. It also has to undergo ratification by the individual countries.

1.2 Land-use change and forestry

The land-use change and forestry (LUCF) sector has often been cited as i) being a source of net emissions of greenhouse gas emissions to the atmosphere, for example from deforestation, and ii) offering opportunities to reduce net greenhouse gas emissions to the atmosphere or increase the net uptake of greenhouse gases from the atmosphere. Many observers thus felt that it was desirable to include the LUCF sector in a binding treaty limiting greenhouse gas emissions. Several options were discussed before and at the Kyoto conference, including total omission of LUCF from the Protocol. Many considerations, including data uncertainty, verifiability, equity between countries, etc., played a role in forming the Protocol text. Appendix I of this paper contains Articles 3.3, 3.4 and 3.7 of the Kyoto Protocol, all of which discuss LUCF and are dealt with in this paper. The Kyoto Protocol was drafted under severe time pressures and the phrasing in a number of places leaves room for interpretation. The discussion below is based on our interpretation of the Protocol language and points out places where we feel the language is particularly unclear.

The scope of this paper includes two main issues:

I. some observations on the Kyoto Protocol regarding land-use change and forestry, and
II. some problems / questions / issues to be resolved.

2. Some observations on the Kyoto Protocol (final version as available 3 March, 1998) regarding land-use change and forestry

2.1 The land-use change and forestry sector is included, limited to specified activities.

Human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation, since 1990, "shall be used to meet the commitments" (Article 3.3). Land-use change and forestry are, however, not included among the sectors listed in Annex A for inclusion in calculating “aggregate anthropogenic carbon dioxide equivalent emissions” (Article 3.1). In other words, it appears that emissions from LUCF are not included in the 1990 emissions baseline for a country but can be used to meet the countries’ commitments in the first commitment period (2008-2012). Article 5.1 would seem to require that a country report all emissions by sources and removals by sinks, and Article 3.4 clearly calls for a report of the “level of carbon stocks in 1990", but the net of emissions from land use change and forestry is not included in the 1990 baseline on which national obligations are based (with an exception outlined in Article 3.7 and discussed in section 3.3 below). The bottom line is that “direct human-induced” afforestation and reforestation initiated since 1990, measured as “verifiable changes in carbon stocks in each commitment period”, shall be used to meet emissions commitments. Another key word in Article 3.3 is “verifiable”. The framers of the Kyoto Protocol were clearly concerned with our ability to document the amount of carbon stored in sinks and explicitly require that only “verifiable” changes can be credited.

We interpret a “change in carbon stocks” in the first commitment period to be the difference between the stocks on 31 December 2012 and on 1 January 2008.

2.2 The text clearly calls for assessing the changes in carbon stocks.

Article 3.3 states that emissions and sinks from land-use change and forestry activities will be "measured as verifiable changes in stocks in each commitment period" and Article 3.4 asserts that each Annex I country shall provide data to "establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years". This implies that an assessment of only the net carbon fluxes to and from the atmosphere (i.e. carbon fluxes to and from other parties not considered) is no longer a viable choice. The assessment of carbon exchange with the atmosphere was proposed for the IPCC Guidelines (Harvested Wood Products Module) in 1996 but rejected at the 12th IPCC Session in Mexico City (Sept. 1996). There has been considerable discussion (see, for example, Winjum et al., 1998; Apps et al., 1997) whether carbon emissions from land-use change and forestry should be measured as the net carbon flux between forest reservoirs and the atmosphere ("assessment of atmospheric fluxes"), as is done for fossil-fuel combustion, or whether the net change in carbon stocks ("assessment of changes in carbon stocks") is a more appropriate choice for renewable reservoirs.

The choice makes considerable difference for parties who buy or sell harvested wood products. For example, the stock change assessment places emissions from burning biofuels in the account of a party practicing non-sustainable forest harvest rather than in the account of the party burning the harvest as a fuel. If biofuels are produced sustainably, both producer and consumer would report zero net carbon emissions. With the wording of the Protocol the choice seems to have been definitively made in favour of a stock-change assessment.

2.3 Harvested wood products are not mentioned.

The Protocol does not mention wood products. Short of careful crafting of additions to the IPCC methodology, it appears that the Protocol does not permit credit for a carbon sink when carbon is stored in long-lifetime wood products. If the IPCC can find appropriate phrases to include this carbon sink within the constraints of Protocol language, it appears that (in order to be compatible with the forestry sector calculations) a carbon source or sink in wood products will have to be represented by the change in carbon stocks in products rather than as some measure of the flux to the atmosphere from oxidation of wood products (see section 2.2).

2.4 More "human-induced activities" can be added.

Article 3.4 states that the meeting of the Parties "... shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities [besides afforestation, reforestation, and deforestation] related to changes in greenhouse gas emissions and removals by sinks in the agricultural soil and land-use change and forestry categories shall be added to, or subtracted from, the assigned amount for Parties included in Annex I". Any such decision shall apply in commitment periods after the first except that a Party can choose to apply them in the first commitment period. This provision leaves open the possibility that credit can be obtained for other carbon sinks but current limitation to the three listed activities reflects concern that credits be limited to those activities that can be best documented ("verifiable") and that credits be awarded for actions and not circumstances (for example, fertilization of forests by increasing atmospheric CO_2 is not a direct human-induced change that could be credited against future commitments).

3. Some problems / questions / issues to be resolved

3.1 What exactly does "since 1990" mean?

Article 3, Paragraph 3 specifies that emissions from sources and removals by sinks in the LUCF sector will be "... limited to afforestation, reforestation, and deforestation since 1990 ...". In the cases of afforestation and reforestation, does this mean that only projects that were initiated since 1990 can be counted, or does it also include carbon uptake after 1990 in projects that were initiated prior to 1990? Our interpretation is that the intent is the former (projects initiated since 1990), but if this is what the delegates had in mind, the word "initiated" should be added to the text.

It is also not completely clear whether “since 1990” includes the year 1990. Although it appears that the intent here was to indicate times following the end of 1990, definitions of “since” in Webster’s unabridged dictionary include contexts in which 1990 would be included.

The phrase “since 1990" creates an additional problem in that while deforestation in 2008 could release the bulk of the contained carbon to the atmosphere in 2008, reforestation in 2008 would provide a continuing carbon sink for many years thereafter but with an annual carbon stock change per hectare that is very much smaller than the annual stock change per hectare from deforestation. This important difference in time rate of carbon flux is discussed further in sections 3.2 and 3.3 below. In Appendix III an example is given for the relative sizes of land under afforestation and deforestation needed in order for the two effects to cancel out in the commitment period.

3.2 Should reforestation be considered, and how?

The Kyoto Protocol permits consideration of “afforestation, reforestation, and deforestation” without providing definitions for these three words. The words “afforestation” and “reforestation” (but not “deforestation”) are defined in the glossary of the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, and since the Protocol refers to these Guidelines for estimating national emissions, we assume that these definitions are those that should apply. The words afforestation and deforestation seem not to create any severe problems and the intent of the Protocol seems consistent with conventional definitions of these two words. It appears, however, that the intent of this phrase was to limit credits to cases where there is a clear change in land classification and where we can clearly verify that this change in land-use has occurred. Accepting this link to the IPCC methodology, the framers of the Protocol used “afforestation” to identify establishment of forest where forest had not historically existed whereas “reforestation” was used to suggest establishment of forest where there was forest previously but the land had been converted to other uses. It is not clear how long a time lapse between forest harvest and forest regrowth is required in order to qualify as reforestation.

In Appendix II we reproduce some published definitions of “reforestation” and these make it clear that many foresters would include the natural or assisted regrowth of trees immediately following harvest to be included in “reforestation”. To the UN Forestry and Agriculture Organization (FAO), for example, reforestation includes immediate replanting or regrowing of forests following harvest or a natural disturbance such as fire. Using the FAO definition of reforestation would thus imply that no emissions are to be associated with forest harvest and yet emissions reductions could be credited for the reforestation that follows. Using the IPCC definition of reforestation, guidance is required to distinguish between forest management and the potentially linked activities of deforestation and reforestation. The distinction is particularly important in the initial phase of the Protocol where it is possible that deforestation could occur prior to the commitment period while reforestation and regrowth would occur, and provide sequestration credits, during the commitment period.

If credits could be obtained for reforestation (as defined by the FAO), then harvest should lead to debits/emissions. Otherwise clearing old-growth forest with the purpose of replanting fast-growing monocultures could lead to significant credits from the beginning of such an undertaking, despite net emissions to the atmosphere. If credits are obtained for reforestation (as defined by the IPCC methodology) the converse process needs to be identified as “deforestation” rather than harvest and there needs to be a clear understanding of the length of time that land resides in other land uses before it qualifies for “reforestation”. The question is the point at which a forest or land-use change activity causes the land to enter the accounting framework. Clearly the Protocol does not intend, at this point, to provide credits for activities that increase the carbon density of forests without changing the land classification, nor does it intend to count emissions where forest degradation leads to lower carbon density in the forest so long as the land maintains its classification as forest. It appears that the framers of the Protocol intended that land enter the accounting framework at the point that there is a change in land classification to or from forest land. This intent is not completely consistent with the traditional definitions of “reforestation”, nor is the philosophy consistent with inclusion of credits for reforestation without debits for harvest.

We suggest that there are four options for confronting the ambiguity of what is meant by “reforestation”. Although the first option is the one consistent with literal reading of the Protocol language and the IPCC definition of reforestation, the other options are suggested by other definitions of “reforestation” and/or if minor amendments to the Protocol are eventually made.

Option 1: Include in the Protocol, or supporting documents, a more precise definition for "reforestation" that includes a minimum time period for non-forest land use, one that differs from traditional definitions by excluding replanting or revegetation activities that immediately follow harvest or natural disturbance.

Option 2: Use something like the FAO definition of reforestation and include "harvest" in the accounting.

Option 3: As in option 2, but in addition include regrowth from pre-1990-harvest.

Option 4: Omit "reforestation" from the accounting.

Option 1 is based on the assumption that the delegates drafting the Kyoto Protocol had in mind a definition of reforestation similar to that given in the IPCC Guidelines. Extension of the definition is needed to make clear that this is land that was deforested earlier with no expectation that the land would be returned to forest. A minimum time period between deforestation and reforestation could be mentioned. Appropriate definitions could be:

Reforestation: establishing forests on lands which have, historically, previously contained forests but which have been converted to some other use. This “other use” must have prevailed for at least 20 *(or other number to be chosen)* years, or, alternatively, the “other use” can be shorter if the land has been counted as “deforested” within a commitment period under the Kyoto Protocol.

With this definition for reforestation we can define

Deforestation: conversion of forest land for other land use.

Note that “establishing” is used instead of “planting” (the original expression in the IPCC Guidelines glossary), because this avoids a discussion whether “human assisted natural revegetation” is included. By adding the phrase “or, alternatively, ... under the Kyoto Protocol”, we make sure that once a piece of land has been classified as “deforested” in a commitment period, it can be counted as “reforested” even after less than 20 years, without creating a loophole for emissions to the atmosphere.

At least it should be clear that accelerated deforestation prior to the first commitment period, followed by reforestation within the commitment period, is in violation of the spirit of the Protocol.

Option 2 would mean that all managed forests harvested and replanted after 1990 would become part of the accounting. For the sake of this discussion, consider a country with one hectare of land (with 100 tC ha^{-1}) cleared and reforested each year and with the rate of regrowth at 1 tC ha^{-1}. Thus, in 1991 the system of carbon accounting would include one hectare harvested and the same hectare regrowing; in 1992 one hectare would be harvested and 2 hectares would be regrowing, in 1993 again 1 hectare would be harvested but 3 hectares would be regrowing, etc. Starting in 1991, a country would get a debit (carbon emission) of 100 tons each year. The credit would be 1 tC in 1991, 2 tC in 1992, 3 tC in 1993 and so on, with the total balance in 1991 being a net emission of 99 tC, in 1992 of 98 tC etc. A key point here is that harvest can occur in a single year while reforestation occurs over decades. Note from the example in Appendix III that if the same total amount of land is reforested that is deforested each year after 1990, there will be a net loss of carbon stocks in the accounts reportable to the Protocol for many years, until the system reaches equilibrium.

Option 3 would solve the problems presented in option 2 by the different time rates of carbon flux during harvest and reforestation by, in addition, considering regrowth from harvest (or other human-induced activities) in 1990 and before. This approach would recognize the long-term balance of a sustainable forest management system but would contravene the statement on "direct human-induced activities since 1990" in the Protocol. The accounting in option 3 would thus involve all managed forests (this would, in essence, be the "gross-net approach" proposed by New Zealand in Kyoto) and this has important implications regarding equity between different national commitments.

Option 4 would avoid the problems encountered in options 2 and 3 by excluding reforestation from the accounting for carbon sinks.

The problem with the current phrasing in the Protocol is that it relies on a non-traditional (and not sufficiently detailed) definition of the word “reforestation” and the effort to include a limited list of land-use change and forestry activities creates a melange of diverse incentives for behavior by those seeking to optimize their source-sink balance. Most of the problems can be solved by clarification of the apparent intent of the word “reforestation" as suggested under “option 1” above.

We note that clarification of the definition of “afforestation” may be needed to make clear whether establishment of fast growing tree plantations with short rotation period is intended to be included.

3.3 Countries with net carbon emissions from land-use change and forestry in 1990 are treated differently than countries with a net carbon sink in 1990.

The last sentence of Article 3.7 contains the phrases “land-use change and forestry” (first part of the sentence), and “land-use change” (last part of the sentence). The following text was written under the assumption, that “land-use change and forestry” constitutes one category in the Protocol as it is the case in the IPCC Guidelines, that it is an expression that is not meant to be divided into “land-use change” and “forestry”, and that the words “and forestry” should be added to the last part of this sentence.

Article 3.7 of the Protocol (see Appendix I) provides that countries for whom LUCF constituted a net source of greenhouse gas emissions can include those net emissions in the 1990 baseline from which their obligations are calculated (while still following Articles 3.3 and 3.4 as the other countries). It was perceived that this sentence was necessary to avoid inequities between countries and to make it possible for countries with a net source in the LUCF sector to meet part of their commitments through a reduction in net emissions from LUCF. In Appendix IV, example 1, we show with a simple calculation (using two hypothetical countries) how application of this sentence does indeed produce an equitable balance between two countries with comparable emissions from fossil fuels and comparable effort to improve land-use management over the interval 1990 to 2008/2012, when one had deforestation in 1990 and the other did not.

Whereas the final sentence of Article 3.7 creates equity for a country with deforestation in 1990, the same principles that necessitate the sentence create problems in its application to a country with both deforestation and a carbon sink elsewhere in its forests in 1990. The need for this sentence arises ultimately from the inherent difference between afforestation/reforestation or other sink effects on the one hand and deforestation on the other hand, i.e. the difference in time rate of carbon flux introduced in section 3.1 above (see also Appendix III). Carbon emissions originating from a constant rate of deforestation from 1990 to 2010 will result in a constant flow of debits (emissions). Carbon uptake occurring at a constant rate from 1990 to 2010 will create no credits (sink) in 2010 to the extent it results from afforestation prior to 1990, or to the extent it is not due to afforestation/reforestation, but due to other sink activities. In other words, if we move from 1990 to subsequent years with no change in behavior, all of the emissions from LUCF remain constant while most of the credits suddenly disappear because of the “since 1990” requirement, the difference in the time dependent behavior of the two types of fluxes, and the limitation of sinks to afforestation /reforestation. In Appendix IV, examples 2 and 3, we show with another simple calculation how the sentence impacts a country with both deforestation and a carbon sink elsewhere in its forests in 1990.

If a literal interpretation of "since 1990" is maintained, rephrasing of the last sentence of Article 3.7 seems necessary to recognize that the time dependent flow of C is potentially very different between reforestation/afforestation (or other sinks) and deforestation and that this impacts not just countries with net emissions from LUCF in 1990, but all countries with any emissions from deforestation in 1990.

Whereas the following rephrasing of this sentence appears to be the most straight forward way to address the problem of the time rate of change in C stocks, it might be judged politically unacceptable because it serves to raise the 1990 baseline against which commitments will be measured for countries with gross deforestation in 1990, and changing the Protocol might not be a choice until it has entered into force. By using not the net emissions determined from a full national accounting of LUCF in the 1990 baseline, but solely emissions from deforestation, without consideration of afforestation/reforestation or other carbon sinks, the calculated commitment would be more equitable for countries with both afforestation/reforestation (or other sinks), AND deforestation in 1990. The effects of this rephrasing on the examples 2 and 3 are shown in Appendix IV.

Article 3, Paragraph 7, last sentence:

Those Parties included in Annex I with deforestation ~~for whom land-use change and forestry constituted a net source of greenhouse gas emissions~~ in 1990 shall include in their 1990 emissions base year or period the aggregate anthropogenic carbon dioxide equivalent emissions from deforestation *(or an agreed upon share of those emissions)* ~~by sources minus removals by sinks~~ in 1990 ~~from land use change~~ for the purposes of calculating their assigned amount.

If eventually developing countries take on emission limitation commitments, there are likely to be more countries with both deforestation and afforestation (or other sinks) in the base year, so that the issue described in this section could become increasingly important.

3.4 The emissions baseline: should it be based on 1 year or a longer period?

For a country with net emissions from LUCF in 1990, Article 3.7 outlines that LUCF net emissions in 1990 are to be incorporated in the baseline. Emissions in 1990 can be considerably different than emissions in 1989 or 1991. For example, wood removals in Germany in 1990 were almost twice those in 1989 or 1991, mainly due to natural events (windthrow). It would be desirable that for LUCF the initial source/sink (or emissions from deforestation, see section 3.3) be determined for a base PERIOD (e.g. 1988 to 1992) rather than for a single year.

3.5 Leakage from forestry projects under the "Clean Development Mechanism" can circumvent project objectives.

Consider a project in which an Annex I country aquires emission credits for a forest-based mitigation project in a non-Annex I country. If the sequestered or protected carbon is released to the atmosphere after the project lifetime (perhaps 20 or 30 years), it is so far unclear which party would assume responsibility for this net emission (Marland et al. 1998). Under the Protocol, a non-Annex I country has no commitment for emissions limitations. It would thus not make sense to assign those "unplanned" emissions from a CDM project to the host country.

One option is to assign this net emission to the piece of land from which it occurred. In case another CDM project wants to use that land it has to take on that net emission as an initial debit. Another possibility is for non-Annex I countries to accept emissions commitments that cover only the LUCF sector. For example, Articles 3.3, 3.4 and 3.7 (last sentence only) could eventually be extended to cover (some) non-Annex I countries, thereby also providing additional participation in the Protocol commitments by developing countries. Some non-Annex I countries have considerable net emissions from deforestation and some have a great potential for afforestation.

3.6 Countries may be allowed to include or exclude certain parts of LUCF

The last sentence of Article 3.4 leaves the decision to individual countries whether to report the carbon sources and sinks from "additional human-induced" activities during the first commitment period. Countries with increased carbon stocks in the respective categories would likely tend to report this, whereas countries with a net source of carbon might choose not to report.

3.7 Does afforestation, deforestation, and reforestation include carbon sequestered in soils?

The Protocol does not explicitly say whether soil and litter carbon-stock changes can or shall be accounted for in afforestation, deforestation and reforestation. Presumably the controlling word here will be "verifiable" and changes in carbon stocks can be used to meet the commitments to the extent that they can be verified. However, there would be no incentive to verify and report negative stock-changes, e.g. in deforestation. Thus, if carbon gains are eligible, a reporting and verification of such carbon losses would have to be made obligatory, or at least it would have to be shown that no loss of soil carbon occurred.

3.8 The Protocol asks countries to establish the “levels of carbon stocks in 1990”.

Article 3.4 calls on Annex I countries to “provide data to establish their level of carbon stocks in 1990”. Such data are not asked for in the current IPCC Guidelines, nor are they required to establish or evaluate compliance with the commitments under the Kyoto Protocol. Performance under the Protocol requires only an accounting of the carbon stocks on 1 Jan 2008 and 31 Dec. 2012, and so far only for forests impacted by afforestation, deforestation, or reforestation since 1990.

3.9 Afforestation and reforestation: A full carbon accounting is required in subsequent commitment periods.

There is a distinction made in the Protocol between forests that existed in 1990, and forests that have been or will be established since 1990. Any stock change in pre-1990 forests appears to be left out from the accounting. However, according to Article 3.3, a stock change in afforested or reforested areas can be credited towards a country’s commitments. It appears that for these “since 1990" forests, the full carbon accounting has to be continued in the second and in future commitment periods, even if there are no further increases in stocks. If this is not the case, a Party could, for example, claim credit for increasing the stocks in standing trees from 0 to 100 tC per ha, but then avoid reporting a subsequent decrease, perhaps resulting from increased harvest levels.

3.10 Which other land-use activities or land-use changes should be considered to be added to the Protocol?

Other "additional human-induced activities... in the agricultural soil and land use change and forestry categories" can be added to the Kyoto Protocol at the first meeting of the Parties after entry into force of the Protocol. Again, the requirement that changes in carbon stocks be verifiable, is likely to play a major role in the acceptance of other activities for offsetting emissions in meeting a country’s commitments. All of these additional activities would be accounted for on a project by project basis. Activities that might be accepted include:

I. Changes in forest carbon stocks (compared to a baseline scenario) due to changed forest management practices. Examples are: selective logging instead of clear-cutting, reduced impact logging, or increases in the harvest-cycle time. Comparison with a baseline scenario is important because even without additional human-induced activity a forest carbon stock might change (see also Schlamadinger and Marland, 1997). Note that the definition of a baseline scenario also appears to be required for Joint Implementation and Clean Development Mechanism projects (see sections 3.11 and 3.12).

II. Changes in soil carbon stocks on agricultural land due to changes in tillage or other farming practices. Again, a baseline scenario will be needed.

Note that, whereas Article 3.3 mentions “DIRECT human induced land-use change and forestry activities”, the word DIRECT is not used in the phrasing of Article 3.4.

3.11 What activities can be included under Joint Implementation forestry projects

Article 3.3 clearly sets limits to activities that can be accounted in meeting commitments from domestic sources and sinks of carbon. Article 6 of the Protocol addresses Joint Implementation between Annex I countries by saying:

"For the purpose of meeting its commitments under Article 3, any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy..." (Article 6.1)

"Any such project provides a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to any that would otherwise occur;" (Article 6.1 (b))

Article 6 explicitly includes sources and sinks in LUCF, but does not limit them to the activities afforestation, deforestation and reforestation since 1990 (as does Article 3.3). This leaves open the question, whether other human-induced activities, such as silvicultural measures to increase carbon stocks in existing forests (which would also fulfill the "additionality" requirement) can be credited in JI projects. Although the text does not specifically limit JI to the same activities as listed for domestic activities, a strange paradox could arise if this were not applied in practice. Without this limit, country A could pursue a project (other than afforestation, reforestation, or deforestation) within country B and country B could pursue the same kind of project within country A, and both would receive more credits than if they pursued the same projects at home.

3.12 What forestry activities can be conducted under the Clean Development Mechanism?

In defining the Clean Development Mechanism, the Kyoto Protocol provides incentives for Annex I countries to assist non-Annex I countries in achieving the objectives of the Protocol by developing emissions reduction activities within the non-Annex I countries. Article 12 of the Protocol states:

"Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol." (Article 12.3 (b))

and

"... Reductions in emissions that are additional to any that would occur in the absence of the certified project activity. (Article 12.5 (c)).

The only other requirement for these certified emission reductions is that they provide "real, measurable, and long-term benefits related to the mitigation of climate change" (Article 12.5(b)). However, unlike in Article 6, for Joint Implementation, no specific mention is made in Article 12 (describing the Clean Development Mechanism) of "removals by sinks". At this point it is not clear whether this omission was intentional. Even if it was intentional, this would still allow for the inclusion of emission REDUCTIONS in forestry, for example by reducing or preventing deforestation. As in the case of Joint Implementation projects, additionality is required for CDM projects and there is no specific limitation whether sources and sinks in the LUCF sector (if included at all) are limited to the activities afforestation, deforestation and reforestation since 1990. Carbon sequestration in existing forests is not explicitly excluded for CDM projects. In contrast to JI projects, including activities beyond afforestation, reforestation, and deforestation does not introduce an obvious paradox. For CDM projects a clear baseline for mitigation projects would have to be established in order to calculate the “additional C sequestration” (see text section 3.13) and the condition of verifiability would have to be observed.

3.13 What are the baselines against which emissions from direct, human-induced activities are to be measured.

It appears that the baseline for domestic afforestation, reforestation and deforestation is a zero baseline (i.e., no afforestation, no deforestation, etc.). Land-use change and forestry activities are not included in the emissions calculation for 1990 on which commitments are based, and there is no “additionality” required. An exception is made for countries for which there were net emissions from the LUCF sector in 1990, and for these countries the “aggregate anthropogenic carbon dioxide equivalent emissions minus removals in 1990" forms part of the 1990 baseline. Although credits against commitments are limited to afforestation, reforestation, and deforestation during the commitment period, it does not appear that the 1990 baseline is limited to this list of activities (see section 3.3).

For activities outside of the national borders, whether pursued under the Clean Development Mechanism or as Joint Implementation activities with other Annex I countries, there is a requirement of additionality. That is, credits can be passed on to another country only when they are in excess of what would have accrued without the specific project (baseline scenario). As an example, it appears that if abandoned agricultural land returns to forest by natural regeneration, CO_2 emissions credits could be claimed for reforestation of domestic land but there would be no emissions credits to be traded through either a JI or CDM agreement.

3.14 There is a logical inconsistency in the language of Article 3.3.

In Article 3.3, the main body of the first sentence reads: "The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities ... shall be used to meed the commitments under this Article ...". This specification that improvements in the LUCF sector can be used to meet commitments is limited by two additional clauses. One clause in this sentence specifies that these net changes in emissions will be "measured as verifiable changes in carbon stocks in each commitment period". To appeal to the fundamentals of calculus, the "changes in carbon stocks" will be the first time derivative of the stocks and will have dimensions of tons per year. On the other hand, the "net changes in greenhouse gas emissions ... and removals ..." will then necessarily be the second time derivative of the stocks and will have dimensions of tons per year per year. In other words, "changes in stocks during the commitment period" cannot be used to measure "the net changes in ... emissions ... and removals ...".

The words "net change" should be deleted at the beginning of Article 3.3 to assure clarity of the Article. The same problem occurs in the middle of Article 3.4.

4. Summation

In the area of land-use change and forestry the Kyoto Protocol tried to do several things. Recognizing that LUCF has very large potential as a CO_2 source and significant potential as a CO_2 sink, the Protocol tried to include consideration of LUCF in order to minimize net emissions from this sector and thus from human-induced activities as a whole. In addition to their desire to reduce net CO_2 emissions to the atmosphere, it appears that those who drafted the Protocol were guided by 3 principles: 1.) to provide credits against emissions commitments only for activities that could be reliably measured and verified, 2.) to provide credits against emissions commitments only for direct human-induced activities, and not for advantageous circumstances, and 3.) to treat the various Parties to the Protocol in an equitable way. This proves to be a daunting challenge; not the least because forestry is based on a cyclic, potentially renewable and sustainable, system of growth, harvest, oxidation and renewal; and that these processes proceed at widely different rates.

The Protocol tried to optimize on some parts of the total system; verifiable, human-induced changes in carbon stocks in the biosphere. It was perhaps inadvertent, but we believe that the choice to focus on assessment of changes in carbon stocks, also provides incentive for efficient use of renewable biofuels and, perhaps, durable wood products (see Apps et al., 1997). But hoping to optimize the system by optimizing on a part of the system is likely to produce perversities or inequities somewhere. It appears that these have inevitably occurred, some because of time pressures in drafting of the Protocol and some because of focus on the 3 objectives listed above. Our hope in compiling this document is to identify the worst of the oversights and perversities and to shed light on how some of them might be fixed and how others might be minimized even if not eliminated. The Protocol does appear to be a very good beginning.

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Acknowledgements

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Appendix I

Paragraphs addressing sinks in the Kyoto Protocol (version retrieved from the UNFCCC homepage, www.unfccc.de, on 3/3/98)

Article 3, Paragraph 3. The net changes in greenhouse gas emissions from sources and removals by sinks resulting from **direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in stocks in each commitment period,** shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

Article 3, Paragraph 4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide, for consideration by the Subsidiary Body for Scientific and Technological Advice, data to **establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years**. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amount for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods. **A Party may choose to apply such a decision on these additional human-induced activities for its first commitment period, provided that these activities have taken place since 1990.**

Article 3, Paragraph 7. In the first quantified emission limitation and reduction commitment period, from 2008 to 2012, the assigned amount for each Party included in Annex I shall be equal to the percentage inscribed for it in Annex B of its aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A in 1990, or the base year or period determined in accordance with paragraph 5 above, multiplied by five. **Those Parties included in Annex I for whom land-use change and forestry constituted a net source of greenhouse gas emissions in 1990 shall include in their 1990 emissions base year or period the aggregate anthropogenic carbon dioxide equivalent emissions by sources minus removals by sinks in 1990 from land-use change for the purposes of calculating their assigned amount.**

Appendix II

Definitions for afforestation, reforestation and deforestation

1. from http://faov02.fao.org:70/0gopher_root%3a[fao.fra]def_uk.txt
(concepts, definitions and methodology of the FAO Forest Resources Assessment 1990)

Forests is defined as "ecological systems with a minimum of 10% crown coverage of trees and/or bamboos, generally associated with wild flora, fauna and natural soil conditions, and not subject to agricultural practices".

Deforestation refers to "change of land use from forest to other land-use or depletion of forest crown cover to less than 10%". Changes within the forest class which negatively affect the stand or site and, in particular, lower the production capacity, are termed forest degradation. Thus degradation is not reflected in the estimates of deforestation.

2. From "State of the World's Forests", FAO, 1997, pp. 173 - 174

Afforestation/reafforestation: The establishment of a tree crop on an area from which it has always or very long been absent. Where such establishment fails and is repeated, the latter may properly be termed reafforestation.

Reforestation: Establishment of a tree crop on forest land.

Deforestation (developed countries): Change of forest with depletion of tree crown cover to less than 20 percent.

Deforestation (developing countries): Change of forest with depletion of tree crown cover to less than 10 percent. (Changes within the forest class, e.g., from closed to open forest, which negatively affect the stand or site and, in particular, lower the production capacity, are termed forest degradation and are considered apart from deforestation.)

3. From IPCC Guidelines, Reporting Instructions (Vol I), Glossary, pages 1 and 16:

Afforestation: planting of new forests on lands which, historically, have not contained forests. These newly created forests are included in the category Changes in Forest and Other Woody Biomass Stocks and in the Land Use Change and Forestry module in the emissions inventory calculations.

Reforestation: planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use. Replanted forests are included in the category "Changes in Forest and Other Woody Biomass Stocks" in the Land Use Change and Forestry module of the emissions inventory calculations.

A somewhat diverging definition, used in a different context (to explain "plantations") is in the Reference Manual of the Guidelines, p. 5.14:

Plantations are forest stands that have been established artificially, to produce a forest product "crop". They are either on lands that previously have not supported forests for more than 50 years (**afforestation**), or on lands that have supported forests within the last 50 years and where the original crop has been replaced with a different one (**reforestation**) (Brown et al., 1986: Brown S., A.E. Lugo and J. Chapman (1986), Biomass of tropical tree plantations and its implications for the global carbon budget", *Canadian Journal of Forest Research* 16: 390-394).

Appendix III

Example describing the inherent difference between afforestation and deforestation with respect to the time rate of change of carbon stocks.

In this example we estimate the size of land under afforestation, that is required for a country to offset deforestation, given that the rate of deforestation in the same country is 1 ha yr^{-1} (carrying 100 tC) in 1990 and in the commitment period. The country in our example had a net carbon sink in LUCF in 1990, so that the last sentence of Paragraph 3.7 does not apply. We assume that forest stands in an afforestation program grow with 1 tC ha^{-1} yr^{-1}.

The emissions in the commitment period from deforestation amount to 100 tC annually. In order to offset this carbon source, an average of 100 ha land with “new forest”, growing at 1 tC ha^{-1} yr^{-1}, are needed in the commitment period. This requirement is also fulfilled if there are 80 hectares in the year 2008, 90 hectares in the year 2009, etc, and 120 hectares in the year 2012. In other words, an afforestation program involving the planting of trees on 10 ha each year, starting on 1 January 2001, could exactly offset deforestation of 1 ha land per year in the commitment period. If, however, the afforestation program started five years later (1 January 2006), then an annual planting of 20 hectares would be required.

This suggests that the land PUT INTO afforestation each year has to be 1 order of magnitude (factor 10 or 20, depending how long before the commitment period the afforestation begins) greater than the land deforested annually in order to gain positive carbon credits. This factor will become lower, the longer the accounting system is in effect, and eventually approach 1. The area BEING OCCUPIED with afforestation projects in a given year has to be 2 orders of magnitude greater than the land deforested in the same year. This factor will not change over time.

Appendix IV

What Article 3.7 of the Kyoto Protocol does and what it should do (see section 3.3): some examples

Example 1 (see also Table 1):

Country A: Emissions from fossil fuels in 1990 are 10 units, and the LUCF net SINK is close to zero.
Country B: Emissions from fossil fuels in 1990 are 10 units, and the LUCF net SOURCE is at 2 units.

By 2008/2012 both countries improve their LUCF balance through human-induced action since 1990 by 1 unit. Country A does this via afforestation initiated after 1990 and country B by reducing deforestation. Both countries have an emission reduction target of 5%.

Country A gets a "credit" for its sequestration of 1 unit, and thus is allowed to increase its fossil fuel emissions from 10 to **10.5 units** (so that with the LUCF credit the total emissions are at 9.5 units, 5% below the 10 units of 1990).
Country B has a 1990 baseline of 12 units, and the debit for LUCF activities - namely deforestation - is 1 unit. This debit would have been 2 units if country B had not reduced deforestation by 1 unit. The target for fossil-fuel emissions (before credits for LUCF) in the 2008 to 2012 period is 11.4 units (95% of 12), and with the LUCF debit of 1 unit the fossil-fuel target is **10.4 unit**, almost the same as for country A.

Without the addition in Article 3.7 ("Those Parties included in Annex I for whom land use change and forestry constituted a net source ..."), country B would have had a 1990 baseline of 10 units, and with the 5% reduction and the 1 unit debit from LUCF the reduction target for fossil-fuel emissions would have been 8.5 units (an inequity compared with country A).

Example 2 (Table 1):

Country B is as in example 1, except that there is deforestation of 4 units in 1990 and net sequestration in its managed forests of 2 units in 1990. The total LUCF balance in 1990 is exactly the same as in example 1, a net source of 2 units. Country B reduces its rate of deforestation by 1 unit by 2008/2012, and the carbon uptake in its managed forests remains unchanged. This carbon uptake occurs in afforestation projects initiated prior to 1990 or in managed forests, and thus does not count (according to Article 3.3).

As in example 1 for country B, the 1990 emissions baseline is 12 units and the target is 11.4 units. Direct human-induced activities in LUCF in the target period are 3 units of deforestation per year, so that fossil-fuel emissions have to be at **8.4 units** in the target period, 2 units lower than in example 1.

With the suggested modification to Article 3.7 of the Protocol (see section 3.3) , the numbers in example 1 remain unchanged. However, the results of example 2 for country B are as follows (numbers in brackets in Table 1): the 1990 emission baseline is 14 units, the emission target is 13.3 (95% of 14), and including the debit of 3 units for deforestation in the target period results in a target for fossil-fuel emissions of **10.3 units** (very close to the target of 10.4 units in example 1).

Example 3:

This case is exactly as in example 2, except that country C has an even larger sink in its managed forests in 1990 and 2010 than in example 2. This makes the country a total net sink in the 1990 baseline year so that Article 3.7 would not be applied at all. It can be seen that the disadvantage for country C is even greater than for country B in example 2. Again, the number in brackets in Table 1 reflect the effect of modifying the last sentence in Article 3.7 as proposed in section 3.3.

Table 1: Article 3.7 of the Kyoto Protocol applied to examples 1, 2, and 3 described in the text. The numbers in brackets under examples 2 and 3 are derived using the modified version of Article 3.7 (see section 3.3). All units are tons (or Mtons) of carbon per year.

	example 1		**example 2**	**example 3**
	country A	country B	country B	country C
1990 fossil fuel emissions	10	10	10	10
1990 LUCF total	0	2 source	2 source	1 sink
1990 deforestation	0	2	4	4
1990 sink in managed forests	0	0	2	5
1990 baseline for QUELRO	10	12	12 (14)	10 (14)
2008/12 QUELRO	9.5	11.4	11.4 (13.3)	9.5 (13.3)
2008/12 LUCF (human activity)	1 sink	1 source	3 source	3 source
2008/12 deforestation	0	1	3	3
2008/12 new afforestation	1	0	0	0
2008/12 sink in managed forests	0	0	2*	5*
Target for fossil fuels	**10.5**	**10.4**	**8.4 (10.3)**	**6.5 (10.3)**

*) Not counted under the Kyoto Protocol

Silvicultural carbon sequestration options under the Kyoto Protocol

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(Presentation given on behalf of the Canadian Pulp and Paper Association)

Abstract

The Canadian Pulp and Paper Association is now preparing an estimate of the potential impact of afforestation and reforestation activity on the first commitment period. Also, we are estimating the impacts of several forest management initiatives some of which seem to fall within Kyoto's measurement criteria, and some which do not. There is no consensus here on whether to introduce the latter.

Canadian Forestry Industry

Some Viewpoints on Kyoto Protocol

- Our understanding of Kyoto
- Significance vs Canadian CO_2 inv.
- Forestry Impacts
  - afforestation, reforestation, genetics, spacing, forest protection
- Energy Impacts
  - energy consumption, fuel substitution
- Focus areas for future

Background to Protocol

- Limit anthropogenic emission of greenhouse gases
- Protect and enhance sinks and reservoirs
- Report national inventories of anthropogenic ghg emissions and removals

Kyoto Protocol
- Canada

- reduce anthropogenic emissions of ghgs by 6% from 1990 emissions by 2008-12
- net emissions reduced by human-induced land use change and forestry
  - afforestation, reforestation, deforestation
  - since 1990
  - verifiable changes in stocks
  - in 2008-2012 (1st commitment period)
- negotiation on additional activities to reduce net emissions

Carbon Storage
& Comparative Impacts

	MM Ha.	MM T C
Soils		76,404
Forests	418	11,952
		88,356
Insect Defoliation (1994)	11.6	
Fire p.a.	6.3	
Harvest/Reforest p.a.	0.2	

Carbon Offsets

"In" COP3- Kyoto

- 1990+ Forest
  - afforestation
  - reforestation (incl. genetic enhancement)
  - deforestation
- fuel switching
- energy reduction

"Not yet In" COP

- Enhancement of pre-1990 forest
  - spacing,thinning
  - fire protection
  - pest, disease
- Lengthen Product Life
  - yield improvement
  - product substitution

Areas of Consensus on Forest Management Benefits

Afforestation in Canada

	MM Ha.	
Canada	**997**	
Forests	**418**	
Cleared Agric. Land	**70**	
Avail. for Afforestation	**8**	estimate only

- Definition of land available for afforestation is key
- "Time restrictions" would isolate lands that would best serve society forested
- Measurement is key (Provincial statistics under-estimate potential growth: 1.5M^3pa/ha vs 5-7)

Reforestation Issues

Harvest	800	
- Plant	370	45%
- Seed	30	5%
- Natural	400	50%

- reforestation should include "natural"
- eg. "any process /operation whether by planting, direct seeding, coppice, root sprouting, or natural seeding which establishes a new forest stand after harvest

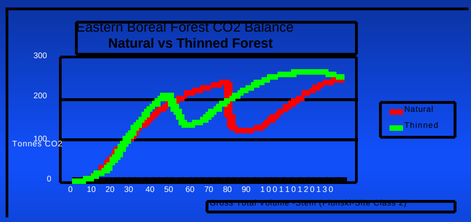
Other Forestry Measures

- Variety of silvicultural operations can impact carbon storage, eg
  - genetic improvement
  - spacing
  - thinning
- Some may have meaningful impact (we are reviewing potential)

Genetic Enhancement

- “tree breeding” designed to create faster growing plants
- volume increase 10% East, 30% West (first generation orchard seed)
- by 2005, 50% national plant = 1st gen.
- 370,000 ha pa plant = 167,000 M^3 pa
- 2nd generation seed by 2025
- great potential in the long term

Juvenile Spacing
of 12-year-old Stands

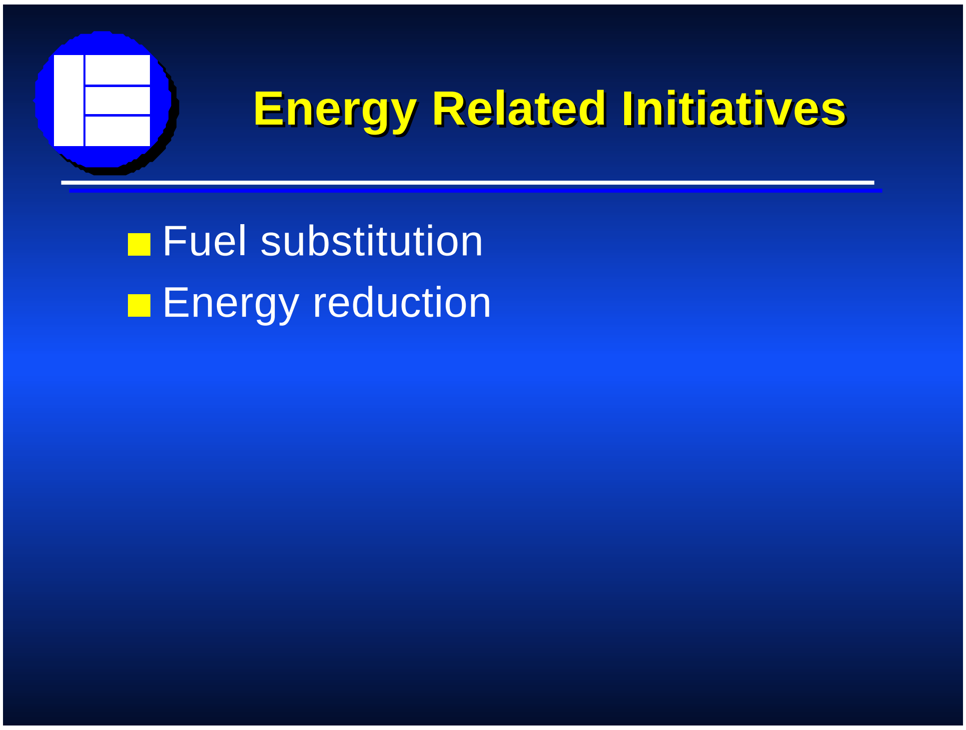


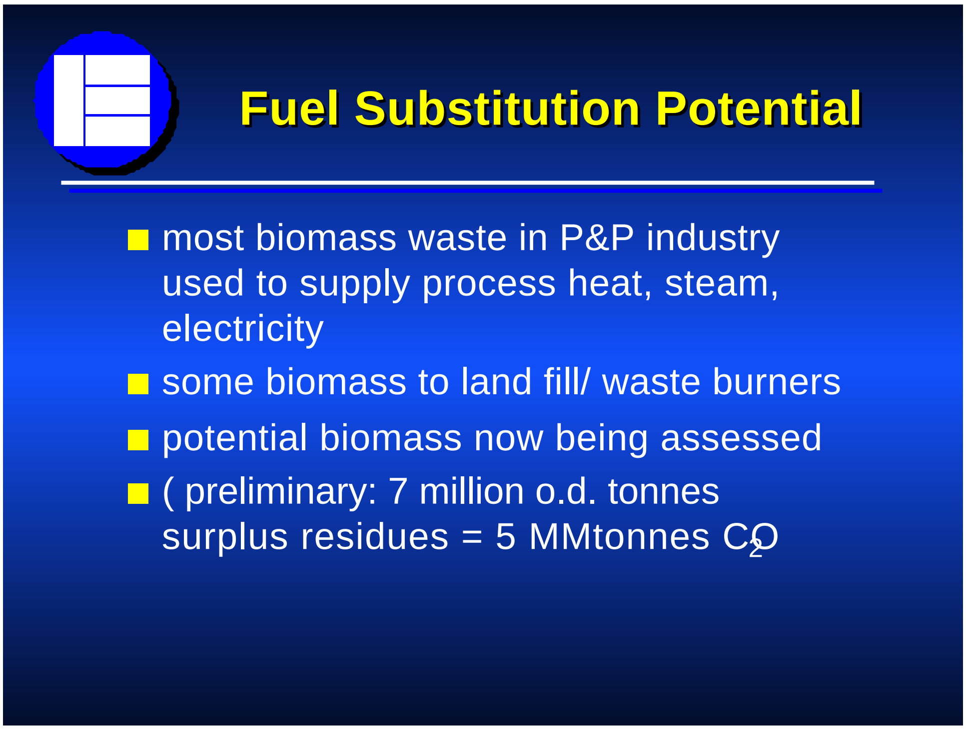
- ready for harvest after 49 yrs (instead of 70 yrs)
- store fibre in long term storage/ reforestation immediately
- 17,000 ha pa available
- not helpful in 1st commitment period but is a long term gain

Commercial Thinning
(eg. Jack Pine on 52 Year Rotation)

M^3/ ha.	Thin	Main	Total
Unthinned		236	236
Thinned	147	236	383

- benefit either
  - fewer ha. to produce same wood products
  - fuel savings substituting biomass thinnings for fossil fuel


Energy Related Initiatives
Fuel substitution
Energy reduction


Fuel Substitution Potential
most biomass waste in P&P industry used to supply process heat, steam, electricity
some biomass to land fill/ waste burners
potential biomass now being assessed
(preliminary: 7 million o.d. tonnes surplus residues = 5 MMtonnes CO_2

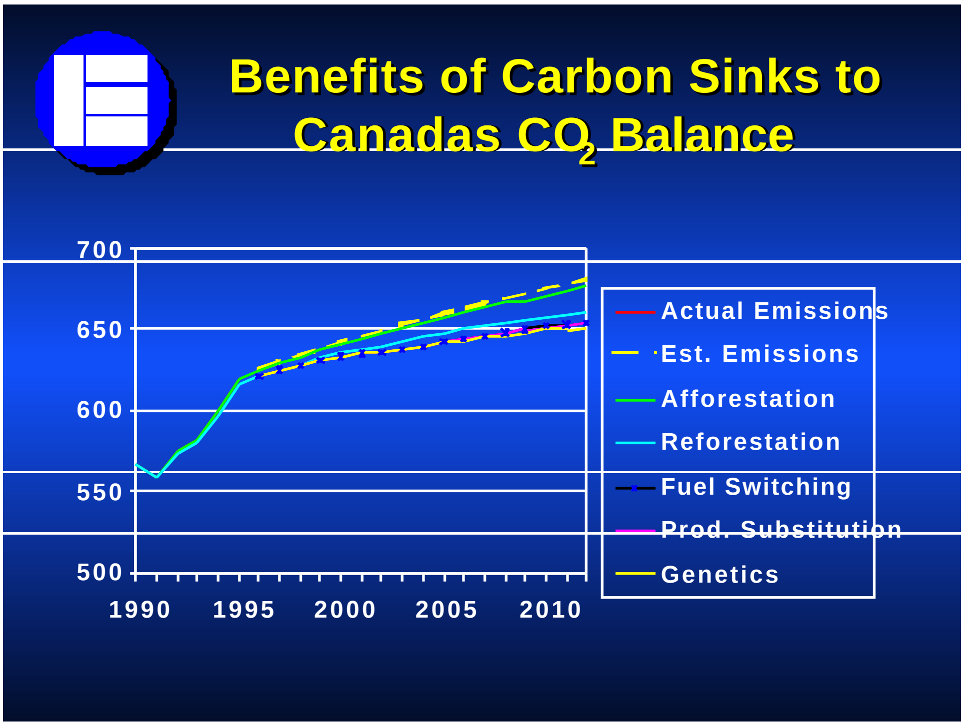
Energy Consumption
(Forest Products Industry)

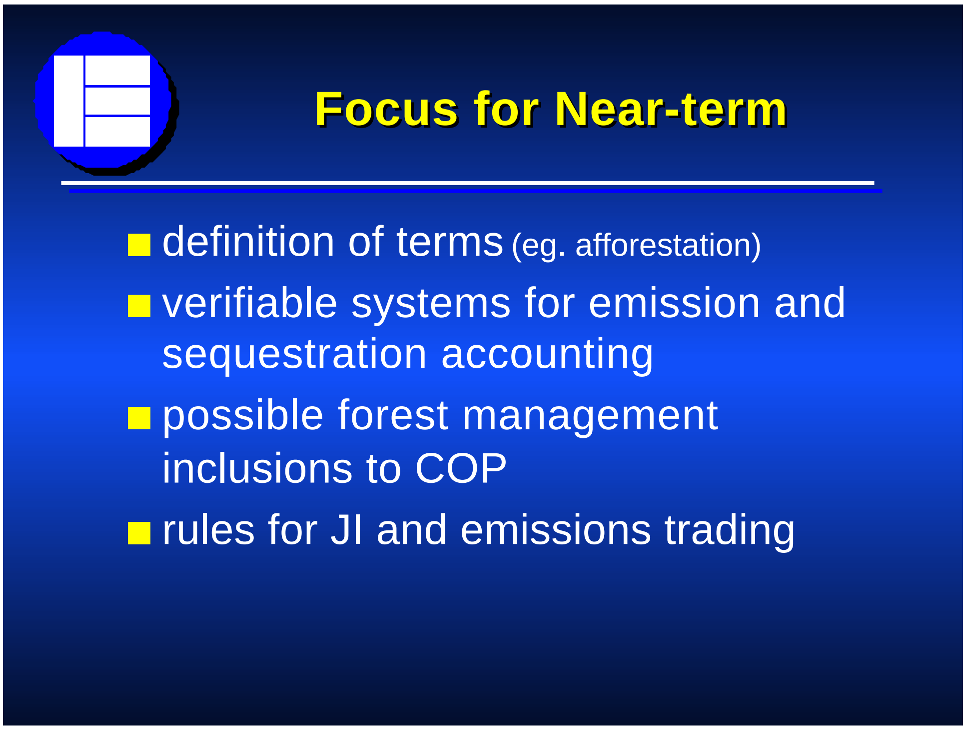
- Canadian forest products industry has made significant progress in reduction of fossil fuel use through voluntary programs

	1990	1996
Prod'n 000 t	24,719	28,911 +17%
CO_2 emissions 000 t	13,838	12,219 (12%)

Forest Protection
(Fire)

- fire protection has been responsibility of provincial gov'ts
- fire protection has reduced CO_2 emissions; led to overmature forest, more prone to fires, insect attack
- loss through fire/insects a natural part of Canadian forests
- avg 9,500 fires pa, 817,000 ha pa loss
- 93% receive full response, saving 6MM ha. pa
- relevance re Kyoto difficult to assess


Benefits of Carbon Sinks to Canadas CO_2 Balance
700
650
600
550
500
1990
1995
2000
2005
2010
Actual Emissions
Est. Emissions
Afforestation
Reforestation
Fuel Switching
Prod. Substitution
Genetics


Focus for Near-term
definition of terms (eg. afforestation)
verifiable systems for emission and sequestration accounting
possible forest management inclusions to COP
rules for JI and emissions trading

Implications for forestry of government commitments under the FCCC

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(Presentation given on behalf of the New Zealand Forest Industries Council)

Abstract

Implementation of a Tradeable Carbon Certificate (TCC) scheme as a means fulfilling Governments commitments under the FCCC could influence forest land prices and consequentially the level of investment in forest planting. The treatment of existing and new forests may differ, leading to a differentiation of forest values unrelated to forest productivity. TCC's could alter the current financial and economic basis of the forest industry in response to society's reevaluation of the environmental externality associated with the production of competing products.

Ladies and Gentlemen

I have been directly and peripherally involved in the debate surrounding anthropogenic climate change for over ten years, first through provision of advice to the Minister of Science, and more latterly in producing forest industry commentaries on a succession of Government „policy responses“, „discussion documents“, „option impact studies“ etc.

I have been asked to comment upon the implications for the forestry industry of Government's commitments under the Framework Convention on Climate Change. I don't really need the thirty or so minutes allocated to me because the absence of any definitive interpretation of commitments made at Kyoto makes your guess as good as mine! What do lawyers say about signing agreements without reading them? A request of our Ministry for the environment elicited that „Decisions have not yet been made on the interpretation of Article 3.3 and the precise nature of what CO_2 emission or removal actions will be counted toward meeting New Zealand's commitments under the Protocol.“ „In the interim, it is probably safe to assume that CO_2 removals by new forests planted after 1990 will be 'counted'. Similarly, permanent changes in land use away from forestry would also be likely to 'count' as emissions.“

Tradeable Carbon Certificates

The initiative being considered by the New Zealand Government (and others in the international community) is the capacity to trade in carbon absorption. In essence, by planting a forest I am removing carbon dioxide from the atmosphere. Every tonne of carbon dioxide removed from the atmosphere provides an opportunity for the emission of another tonne through the combustion of fossil fuel, with no net adverse effect on the global climate system. So far so good.

Concerns of the forest industry with this apparently elegant answer to meeting New Zealand's climate change obligations include:

1. The Influence of Land Price

You can't grow trees without land. Somewhere between two thirds and four fifths of the cost of producing a log is the holding cost of the land on which it grew. Land is in 'inelastic' supply, or in the words of Mark Twain „buy land young man, they just aren't making it any more". This inelasticity couple with New Zealander's appetite for fossil fuels suggest that under a TCC (Tradeable Carbon Certificate) regime the environmental cost associated with burning fossil fuel to meet New Zealand's FCCC obligations will rapidly translate into an escalation in land price.

A perverse outcome of a TCC scheme could be less forest planting, rather than more. With the opportunity for a windfall gain from the sale of carbon credits coming only once, landowners will be tempted to hold off selling until they are sure the true value of the credit can be realised.

A real possibility exists that the beneficiary of a TCC regime will be the owners of clear land suitable for afforestation, rather than the forest industry. It is worth noting that many of the landowners likely to benefit under a TCC scheme were paid a subsidy by our Government in the 1970s to clear it of bush. The so-called Marginal Lands Development Scheme.

2. Appropriation by Government of the Carbon Sink Value of Existing Forests

A key 'Article' from the Kyoto Agreement for New Zealand plantation forestry is 3.3, which reads:

> *„The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each party."*

I have interpreted the article as constraining the conversion of pre-1990 plantation forest lands to an alternative use. To do so is to reduce New Zealand's total carbon store.

Government's commitments, confirmed at Kyoto, relate to emissions of anthropogenic greenhouse gases from 1990. The net effect of a 1990 baseline for forestry is that the carbon sink potential of forests planted prior to 1990 can not be realised by way of the sale of credits.

Superficially, the inability to claim credits for forests established prior to 1990 can be seen as reasonable given that the 'value' inherent in their calculable sink potential did not exist at the time the forests were planted. The sale of the embodied carbon absorption value of existing forests would be a substantial (potentially huge) windfall to existing forest owners, and would likely lead to calls for other carbon stores to be similarly treated ie Southland's lignite coal deposits.

However, selective treatment of areas of forest on the basis of the date they were originally planted represents a significant inequity for existing forest owners to the extent that:

- Such forests cannot be harvested without the payment of a carbon tax, harvest representing a net reduction in New Zealand's overall greenhouse gas balance. (Note; it should not be forgotten that plantation forests have been planted and tended with the express intent of being harvested. Such forests have never been considered a permanent natural feature in the same way as coal or oil deposits.)

- Opportunities to modify forest management practices in response to the carbon absorption market (ie growing the forest on to take advantage of a substantially greater carbon sink per unit area) may be precluded or constrained, and

- The current property right allowing a landowner to change land use from forestry to a less carbon intensive alternative (eg dairying) is appropriated without compensation. Such conversion could not occur without the payment of a carbon tax.

Note that an alternative interpretation of Article 3.3 is that it has no application to plantation forestry established prior to 1990. This could presumably lead to distortions in the land market where forest owners will have an incentive to clear existing forests and re-establish them elsewhere on pasture in order to qualify for a carbon credit. On-seling the cleared forest land to a third party could see the original forest being re-established and a carbon credit issued.

1. Risk Management Implications

It is worth noting that some TCC regime proposals require that the unintended destruction of forest through fire or flood would require the payment of a carbon tax. The risk premium inherent in forest ownership would presumably be substantially increased. This is particularly concerning where the carbon emission risk of a fire within an existing (pre 1990) forest is not offset by the capacity to own/sell the carbon absorption value creating that risk.

2. Markets for Tradeable Carbon Certificate

The New Zealand Forest industry does not dispute the use of market mechanisms as a means of fairly and accurately pricing environmental externalities.

The example which everyone uses is the market in sulphur emissions operating within the US, which by all accounts works well.

Closer to home, New Zealand's experience with electricity market reform has demonstrated pitfalls where limited numbers of players and/or unequal access to information does not lead to clear pricing signals.

The potential for less than transparent pricing of a TCC could arise if the market was reduced to a few big companies within a domestic setting. Owners of small land/forest blocks may not have adequate information and or dominance to ensure a fair return for any credit sold. (Bear in mind they are selling an obligation to maintain a forest in perpituity!)

Internationalisation of the TCC market would certainly improve the competition for available credits and therefore promote more accurate pricing. An interesting outcome of internationalising the market for TCC's is that it makes predicting the market price of carbon credits a matter of conjecture. Upward price pressure to a level commensurate with that payable by those emitters facing the highest taxes/abatement will be offset by emitters' access to the cheapest emissions displacement/absorption options globally. The value of TCC's could eventually be dictated by the futures market and people's best guesses as to the price and availability of non-fossil fuel energy at different times in the future.

Restricting any TCC trade to those Annex 1 countries that have accepted an obligation under the FCCC could see New Zealand emitters of carbon face a price commensurate with the higher carbon tax rates levied in Europe. (Someone suggested the carbon tax levied in Scandinavia is of the order of $US50 per tonne)

3. Forest Asset Management

The ability to realise a substantial return on investment in forestry through the sale of carbon absorption will presumably influence forest management practices. It is possible to calculate a theoretical value for a TCC which equals and exceeds the realisable value of a forest for its wood fibre content. Very rough calculations suggest this cross over occurs at a carbon sink value of between 90 and 120 dollars New Zealand per tonne. It is reasonable to assume that once this value is reached current forest management practices such as planting with improved genetic stock, pruning, and harvest will be foregone in the interests of maximised carbon absorption. Why incur the cost of careful planting and tending when aerially top dressing an area with *Pinus contorta* yields the same dollar return at a fraction of the cost?

In view of the theme of this conference being bioenergy it is worth contemplating rapid growing forests as a feed stock for bioenergy based co-generation or liquid fuels plants. Perhaps FRI should be considering closing down their genetic improvement and fibre utilisation research divisions in favour of an all out focus on rapidly growing Buddliea or some other weed?

Wood Fibre As A Commodity

My wife and I are currently involved in building a wooden framed weatherboard house. As someone who has probably „consumed“ hundreds of times more wood in the last four months than the average citizen I am in a good position to attest that at no stage have I contemplated buying wood per se. Floor joists, weatherboards, roof trusses, purlins, doors, joinery etc etc etc. In every one of those purchasing decisions we had non-wood options to consider.

Products made from wood can be made just as easily from non-wood alternatives. Many of the alternatives to wood, (for example concrete, aluminium and steel) represent a significant environmental ‘externality’ in terms of the greenhouse gases produced during their manufacture. Conversely wood based products are (on average) a near neutral greenhouse gas alternative.

It has never been clear to me why Government is contemplating the complicated, high transaction cost policy response to climate change of a Tradeable Carbon Certificate regime when forestry, and the downstream processing of forestry products, are not part of the problem. It appears counterproductive to penalise (albeit indirectly) the producer of wooden beams because there is an environmental problem associated with the manufacture of steel ones. I say this because <u>if</u> my earlier prediction about the value of Tradeable Carbon Certificates being translated into increased land prices is correct, then the cost of logs to the saw mill will rise in proportion. As a forest owner, I won’t want to incur the cost of producing saw logs unless the financial returns are better than those from the sale of carbon credits or biofuel.

If Government deems the emission of anthropogenic greenhouse gases from the burning of fossil fuels to be a serious climatic threat (and I’m not doubting for a minute the predictions of scientists and other experts in this regard) then deal with that problem by constraining the burning of fossil fuel.

A substantial rise in the cost of fossil fuel will presumably create an economic incentive for people to consider alternatives. Returning to my wood versus steel beam analogy, a carbon tax should lead to an increase in the price of steel beams resulting in an increased demand (in theory at least) for wooden substitutes. By implication there will be a corresponding increased demand for forest planting. Presumably the same logic can be applied to liquid fuels where, subject to the available technology, an increase in fossil fuel price will engender the development of commercially viable bioenergy based alternatives, again with positive implications for forestry.

Some have speculated that the Government's enthusiasm for Tradeable Carbon Certificates is based on a fear of electoral retribution against those politicians responsible for increasing the cost of fuel to the average voter. The fuel crisis of the 1970s demonstrated how 'addicted' New Zealanders are to fossil fuels, at least for transport. The average motorist would much prefer to reduce other expenditure than limit consumption of petrol. Carbon taxes, as with most measures designed to protect the (German study) environment are (to use the jargon), 'socially regressive'. Poor people get hit hardest.

I am <u>not</u> a cynic and am completely persuaded that the Tradeable Carbon Certificate regime represents a least cost alternative for 'New Zealand Incorporated' to fulfil its obligations under the Framework Convention on Climate Change.

Discussion of the need to exempt a number of large fossil energy intensive industries from climate change obligations is simply a reflection of the real world pragmatism of our politicians given the international market realities existing between Annex I countries with Greenhouse Gas emission obligations, and non-Annex I countries with no such commercial impediments.

Pity the poor wooden beam producer, paring margins to accommodate the TCC levied costs associated with steel production, <u>and</u> competing against a steel producer <u>exempt</u> those same costs.

There has been no suggestion (to my knowledge) that the extent of any exemption be indexed to the marginal nature of the electorate within which the exempt industries are located!

Conclusions

It has yet to be demonstrated that any system of Tradeable Carbon Certificates will have benefits for the New Zealand forest industry, <u>as we currently know it</u>. There are a number of significant issues to be resolved before accurate assessments of costs and benefits can be made. It is not possible to predict whether there is scope for a complete 'paradigm shift', with wood as a bi-product of the carbon absorbing industry.

Our initial analysis indicates that the proposed FCCC 'system' could undermine the international competitiveness of the forest industry – a major driver of New Zealand's economic growth and prosperity, through increased input costs (eg higher land values) and/or for stronger price competition from substitute product manufacturers located in non-Annex 1 countries, or Annex 1 countries which have created a sector specific exemption (eg steel industry).

If New Zealand and perhaps western society has, as has been suggested, an unhealthy addiction to the use of fossil fuel, then introduction of any measure which doesn't reduce this use is a diversion from the real 'problem'. Politicians, scientists and environmentalists cannot shy away from the economic, social and political consequences associated with our current patterns of fossil fuel use if they wish to seriously address the issue of human impact on the global climate.

Thank you.

Does the Kyoto Protocol make a difference for the optimal forest-based C mitigation strategy? Some results from GORCAM

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Abstract

The Kyoto Protocol was agreed upon by more than 150 nations in December, 1997 and (if and when ratified) will establish international commitments to reducing emissions of greenhouse gases to the atmosphere. However, under the Kyoto Protocol, only some of the components of the land-use change and forestry sector can be counted toward a country's commitments for emissions reductions. In addition to impacts of land-use practices on fossil fuel emissions, only stock changes in forests (possibly including forest soils) caused by the direct human activities afforestation, reforestation and deforestation, and taking place in the "first commitment period" (2008-2012) are of interest under the Kyoto Protocol. Credits are limited to projects initiated since 1990. For actions taken as part of the "Clean Development Mechanism", banking of emission reductions is allowed beginning in the year 2000. An adapted version of the model GORCAM has been used to asess eligible carbon credits under the Kyoto regime and to illustrate how the optimal forest-based strategy for carbon mitigation might change under the provisions of the Kyoto Protocol.

Keywords: Carbon accounting model, Kyoto Protocol, forestry, bioenergy, climate change, carbon stocks

1. The Kyoto Protocol

Delegates from over 150 countries met in Kyoto, Japan, from 1 to 10 December, 1997, and agreed on a Protocol to the United Nations Framework Convention on Climate Change (UNFCCC, 1998). This Kyoto Protocol is designed to provide binding, quantitative limits on future net emissions of greenhouse gases to the atmosphere. Countries listed in Annex A of the Kyoto Protocol (39 developed countries) are called on to reduce their emissions of six greenhouse gases, relative to emissions in 1990, by a percentage specified in the Protocol (some countries are permitted small increases in emissions). Commitments are to be measured by comparing emissions in the "first commitment period" (and in subsequent commitment periods) with those in 1990 (1995 is used as the baseline for three of the gases). The Kyoto Protocol permits a limited list of activities in the land-use change and forestry sector to be used to meet the national emissions commitments by subtracting the amount of carbon that is, within the commitment periods, sequestered from the atmosphere by reforestation or afforestation, while adding emissions from deforestation. In particular; reforestation, afforestation, and deforestation initiated since 1990; "measured as verifiable changes in carbon stocks during each commitment period, shall be used to meet the commitments." (Kyoto Protocol, Article 3.3). There are many portions of the text that are open to interpretation and the details, ambiguities, and our interpretations are discussed in Schlamadinger and Marland, 1998. The full text of the Kyoto Protocol can be found on the worldwide web at www.unfccc.de.

Although permitting that carbon sinks in growing forests could be used to offset greenhouse gas emissions from other sectors, the negotiators in Kyoto limited the LUCF activities for which credit could be claimed. There appear to have been 3 motivations involved in defining the activities and the details of the permitted carbon sinks.

1.) Activities have to be "direct human-induced". That is, the intent is to reward activities that were motivated by an interest in reducing net greenhouse gas emissions and not to provide credits for circumstances such as the fertilization of forests by increasing atmospheric CO_2.

2.) Activities have to provide "verifiable" increases in carbon stocks in the biosphere. Some negotiators were concerned that it is difficult to measure and confirm increases in carbon stocks in the biosphere and that it would be difficult to evaluate claims of carbon sequestering.

3.) There was interest in equity among Protocol participants and in assurance that activities undertaken to sequester carbon would not permit Parties to avoid actions to limit emissions from other sectors.

Schlamadinger and Marland (1996) have described the impact that land-use change and forestry activities can have on the global carbon cycle and Schlamadinger et al. (1997) have discussed the principles that should be observed to estimate the greenhouse gas implications of forest and bioenergy systems. These two papers, and others, demonstrate the importance of examining the full system of impacts when alternative forest management approaches are evaluated with respect to their net impact on the global carbon cycle. Decisions on land-use and forest management can affect the global carbon cycle through their impact on the 1.) amount of carbon stored in the biosphere, 2.) amount of carbon stored in durable wood products and landfills, 3.) amount of fossil fuel not burned because biofuels are used in their place, and the 4.) amount of fossil fuel not burned because forest products displace other, often more energy-intensive, products.

The point is that optimizing the impact of forestry activities on the global carbon cycle requires examination of the full, integrated system that is impacted by LUCF decisions; and yet the Kyoto Protocol provides credit toward meeting emissions commitments for a limited set of the activities within this system. As pointed out in Schlamadinger and Marland (1998), it is inevitable that this effort to optimize on a subsystem will create perversities or non-optimal outcomes for the full system. In this paper we examine a series of scenarios for forest/land-use management, show the full-system impact on the global carbon cycle, and discuss how the Kyoto accounting system only deals with part of that full system and thus might lead to sub-optimal decisions for the global carbon cycle. Our intent is not to find fault with the Kyoto Protocol nor its motivations, but to call attention to the implications thereof. In another paper (Schlamadinger and Marland (1998)) we conclude that although the Kyoto Protocol contains a number of ambiguities and perversities, it is a very good beginning toward achieving the objectives of the Framework Convention and providing incentives for the activities that the Convention would hope to encourage. By understanding the implications and perverse incentives provided by the text of the Kyoto Protocol we should be best equipped to minimize their importance and thus to serve the intent of the Framework Convention on Climate Change.

2. GORCAM

To examine and illustrate the impact of the Kyoto Protocol on LUCF decisions we have used the Graz/Oak Ridge Carbon Accounting Model (GORCAM, Figure 1) to analyze five scenarios. The scenarios involve: 1.) post-1990 afforestation followed by forest protection, 2.) post-1990 afforestation with ultimate harvest of the standing forest, 3.) deforestation during a commitment period, 4.) harvest and replanting of a mature forest during a commitment period, and 5.) harvest and replanting of an immature (still growing) forest during a commitment period. The GORCAM model is a spread-sheet model that attempts to keep account of all of the carbon stocks and flows impacted by forest management decisions. The model is described in detail in Schlamadinger and Marland (1996). Our intent here is to use the model to illustrate qualitatively the interaction of the Kyoto Protocol with net carbon balances of LUCF decisions and the reader is cautioned not to lay too much significance on the exact numeric outcomes of the five detailed scenarios chosen for illustration. Model parameters, for example describing forest growth rates or the efficiency with which biomass is converted into products or useful energy, are in the range of values reported in Schlamadinger and Marland (1996).

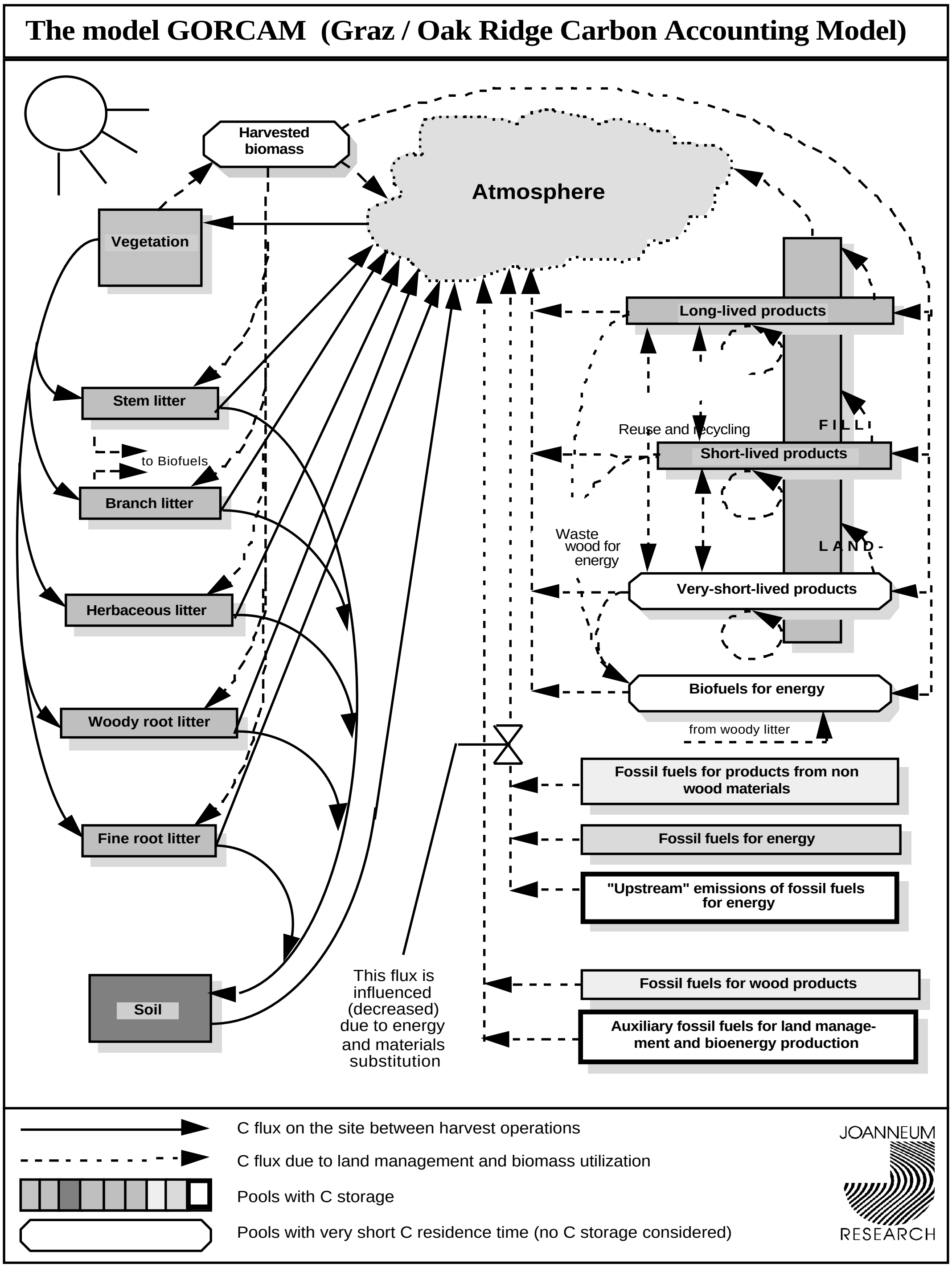


Figure 1. Carbon stocks and fluxes as described by the model GORCAM

3. MODEL RESULTS

3.1 Afforestation (or reforestation)

Figure 2 describes the cumulative changes in carbon stocks over 100 years when a forest stand is established on land not previously in forest. The scenario describes a circumstance where growth of forest is accompanied by slow accumulation of carbon in the forest soil and litter. The Kyoto Protocol suggests that if this forest stand were established "since 1990" the increase in carbon stocks during the commitment period could be used to offset carbon emissions in meeting a national commitment. Whereas the Protocol does not specifically state whether or not the accumulation of carbon in soil and litter can be accounted in addition to the accumulation in the aboveground biomass, presumably all can be counted if the carbon accumulation can be verified. It becomes a matter of being able to reliably estimate the amount of carbon accumulating. It is, in fact, the annual increase in stocks that is of concern and in Figure 3 we show the annual stock change derived from the cumulative increase in carbon stocks shown in Figure 2. Figure 3a shows the annual increment over the next 50 years while Figure 3b emphasizes that the first commitment under the Kyoto Protocol is for the period 2008 to 2012 and all that really counts is the stock change over this 5 year period. It is also clear in Figures 2 and 3 that the stock change is positive for each of the 100 plus years following establishment and that presumably the stock changes in these later years could be used to meet commitments in subsequent commitment periods. The annual increment does decrease in the later years as the forest stand begins to approach maturity and the net annual growth decreases.

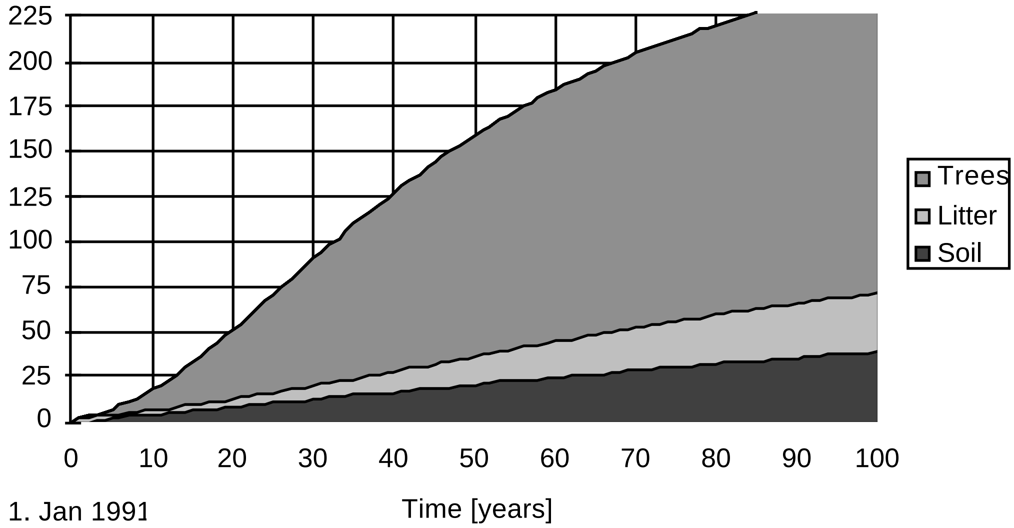
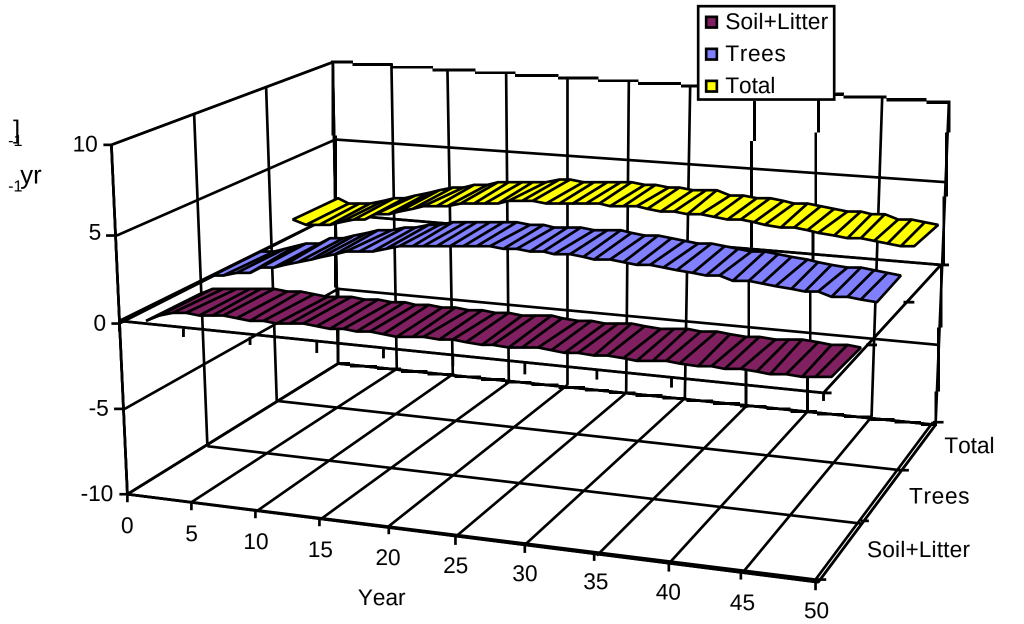


Figure 2. Cumulative carbon-stock changes for an afforestation scenario.



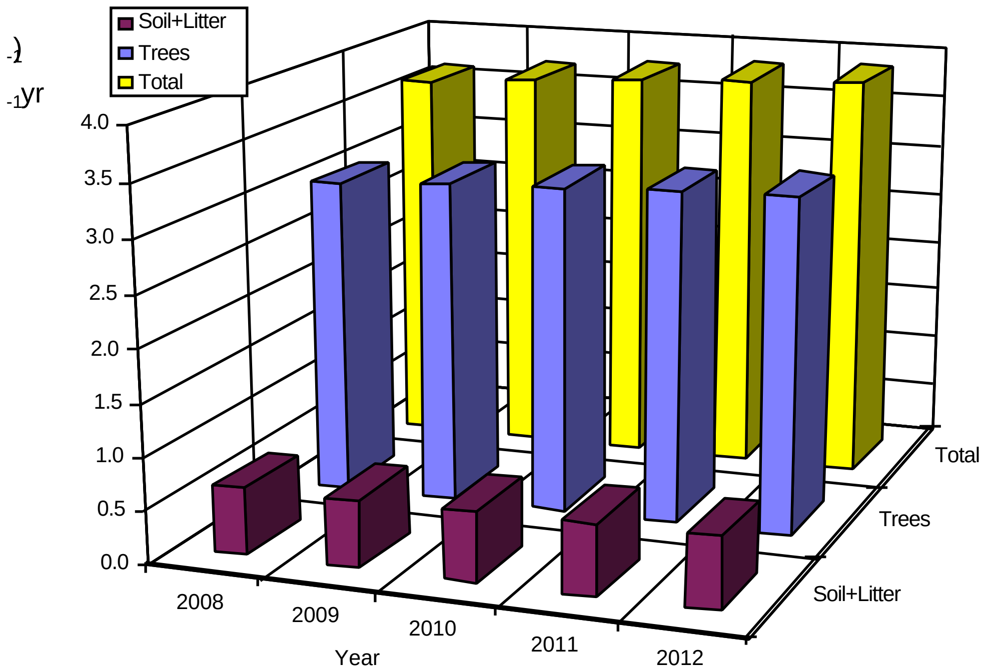


Figure 3. Annual carbon stock changes within 50 years (top - Figure 3a) and in the first commitment period (bottom - Figure 3b) for the afforestation scenario in Figure 2.

It should be noted that if the forest stand described in Figures 2 and 3 was planted in 1990 or earlier, none of the increases in carbon stocks could be used to meet emissions reduction commitments under the Protocol. Even though carbon accumulation can continue for well over 100 years, only stands planted after 1990 can be used to meet Kyoto commitments. Figure 4 presents the interesting scenario of an afforestation project in which 100 ha is converted to forest by planting 2 _ ha/yr for 40 years, beginning in 1971. In Figure 4a, the GORCAM output shows the total cumulative carbon sequestration over time whereas Figure 4b shows the fraction of the total for the forest that could be used to meet Kyoto commitments, i.e. the fraction of carbon sequestration that comes from parcels afforested since 1990. It appears that the Kyoto Protocol would give full credit for carbon stock increases in afforestation (or reforestation) to the extent that the activity began since 1990 and the stock change is verifiable.

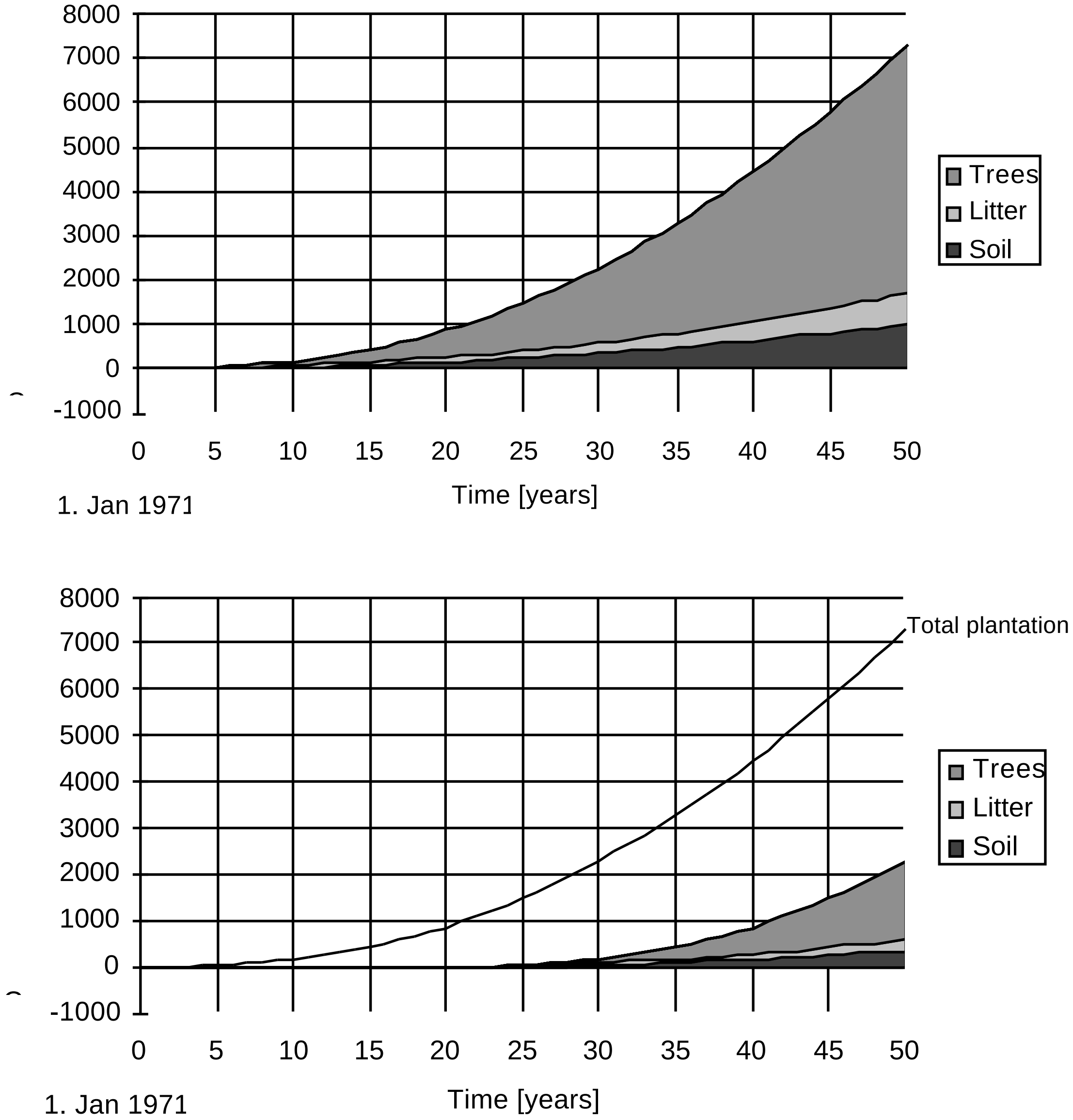


Figure 4: Cumulative carbon stock changes in an afforestation project with 40 parcels planted annually since 1971 (top - Figure 4a) and portion of the same project that “counts” under the Kyoto Protocol (bottom - Figure 4b).

3.2 Afforestation (or reforestation) with later harvest of the standing stock.

The scenario represented in Figure 5 is identical to that shown in Figure 2, except that the new forest stand is harvested in the fortieth year in order to produce a conventional mix of forest products. Figure 5 illustrates the full impact on the global carbon cycle, including the suggestion that harvested material avoids emissions from fossil fuels because some of the biomass is used as a fuel in the place of fossil fuels and because the production of wood products displaces alternate materials that often require greater fossil fuel input for their production and use. The assumption in this figure is that timber replaces a mixture of concrete, steel, and glass in construction (see Schlamadinger and Marland, 1996, for details). If all of this activity occurs in a single nation (or project), the country will, after year 40, suddenly have less carbon stored in standing trees but net emissions to the atmosphere may be small if the carbon finds its way into durable products or landfills and if emissions from fossil fuels are correspondingly reduced.

The question posed here is what happens to reportable carbon stocks under the Kyoto Protocol. With afforestation starting since 1990, this country has presumably claimed carbon sequestration credits for forest growth during the first, and perhaps subsequent, commitment periods; but this carbon is no longer stored in the forest. It appears that although the Protocol limits accounting to afforestation, reforestation, and deforestation; and although negotiators in Kyoto specifically chose to exclude forest harvest; once a parcel of land comes into the accounting system through one of the listed activities a full accounting must be maintained from then on. An interesting challenge is that a full accounting of the carbon for which credit was taken during an earlier commitment period can require accounting for wood products, in which case we would be left to distinguish between products produced from "since 1990" forests as opposed to products from forests that already existed in 1990 and are hence not to be counted. A procedural alternative would be to neglect carbon-stock changes in wood products, and the accounting would be on the "safe side" with respect to emissions of carbon to the atmosphere. Note that if we are discussing short-rotation forestry, it is conceivable that a forest stand planted since 1990 would be harvested during the first commitment period and hence the stock change in the aboveground biomass during the first commitment period could be negative.

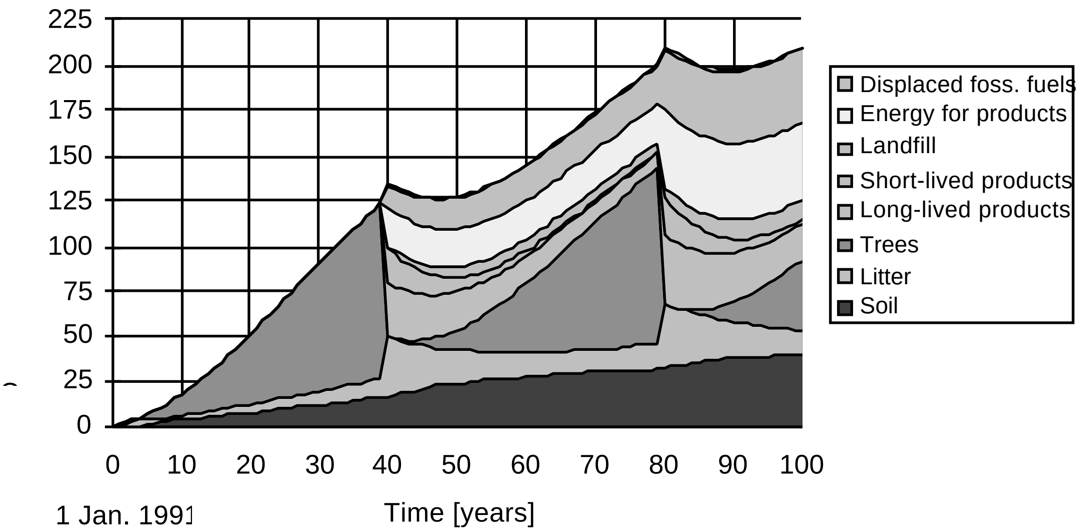


Figure 5: Cumulative carbon-stock changes for a scenario involving afforestation and harvest.

Figure 6 represents the annual changes of stocks for the scenario shown in Figure 5. Annual changes of tree, soil and litter carbon stocks are exactly as in Figure 3a until year 40, which is the time at which a harvest occurs. At the time of harvest, there is a negative stock change for trees, and stock changes for soil, litter, wood products, and displaced fossil fuels are positive. The diagram is truncated at plus and minus 10 MgC/ha, so that the stock-changes at the time of harvest cannot be seen to their full extent.

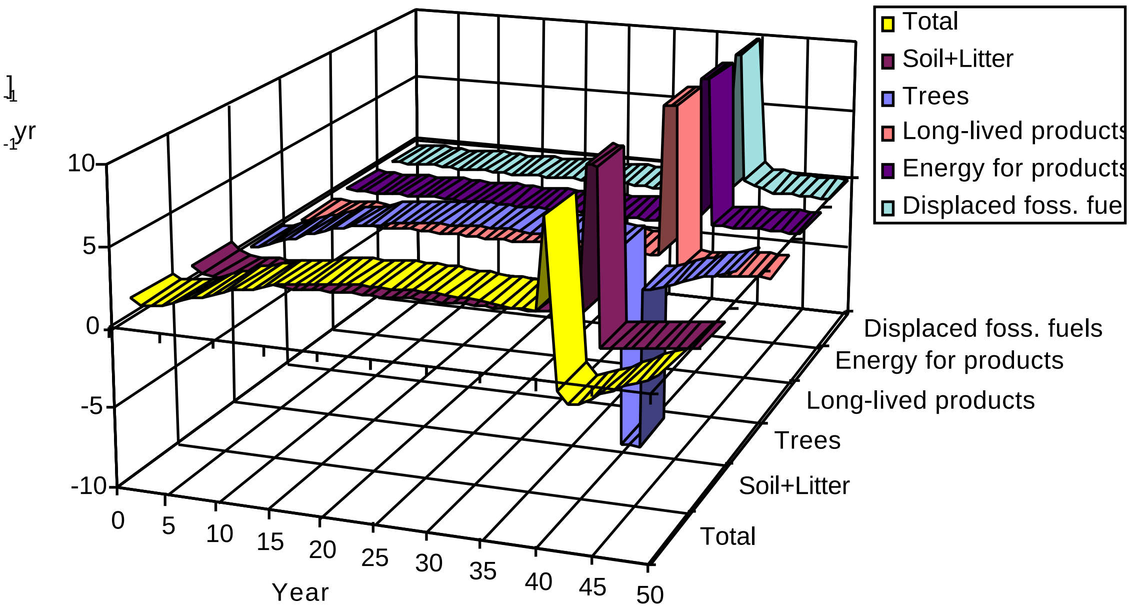


Figure 6: Annual carbon-stock changes within 50 years for the afforestation and harvest scenario in Figure 5.

3.3 Deforestation

Figure 7 illustrates the cumulative change in carbon stocks for a forest (with a standing stock of 160 Mg C/ha) presumed to be deforested during the first commitment period. The Protocol would require that the annual (actually the five-year total for 2008-2012) stock change be included with CO_2 emissions from other sectors in meeting national commitments. Presumably the net national emissions would be reduced to the extent that the harvest from deforestation is used to reduce use of fossil fuels. It does not appear to us that the Protocol would acknowledge that some fraction of the harvested carbon might increase the national store of carbon in durable wood products. If this deforestation were to occur during the interval 1991 to 2008, with the land converted to, perhaps, pasture, the loss of carbon stocks from aboveground biomass would not occur during a commitment period and would not in any way affect the country’s commitments to emissions reduction. A literal reading of the Protocol, however, would suggest that if deforestation in 1991 to 2008 results in continuing loss of soil carbon during the commitment period, that this decrease in soil-carbon stocks ought to be included as an emission in the commitment periods. Figure 8 illustrates the annual carbon losses from stocks during the first commitment period when deforestation occurs in 2008. It is striking that the loss of carbon during 2008 for deforestation of 1 ha is 150 Mg C while the increase in carbon stocks during 2008 for afforestation of 1 ha is on the order of 3.5 Mg C (see Figure 3b). This imbalance in the time rate of flow of carbon for deforestation vs afforestation guarantees that a country with an areal balance between deforestation and afforestation would report net carbon emissions for many years under the Kyoto reporting structures (see also Schlamadinger and Marland (1998).

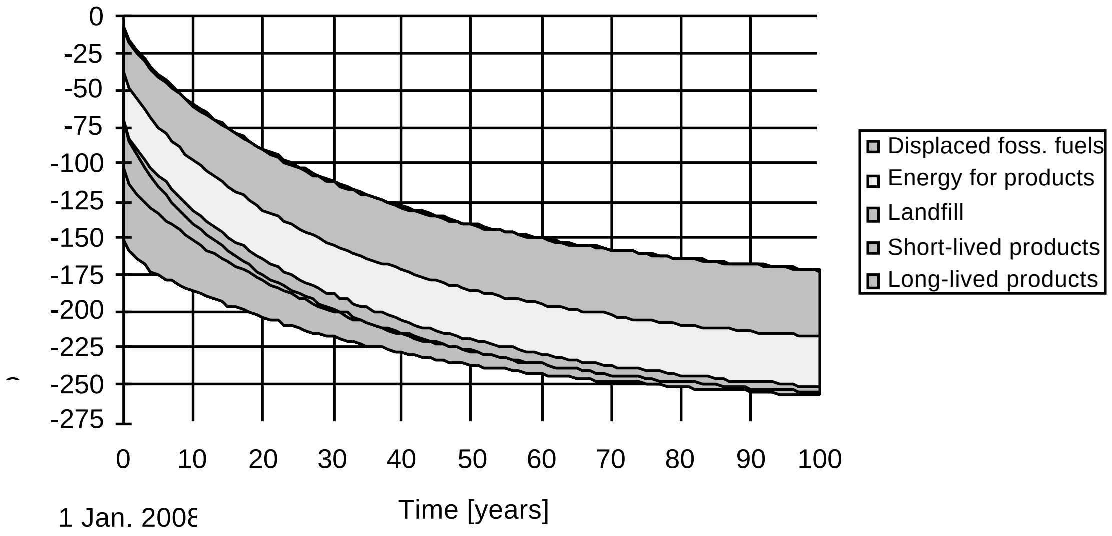


Figure 7: Cumulative carbon-stock changes for a deforestation scenario.

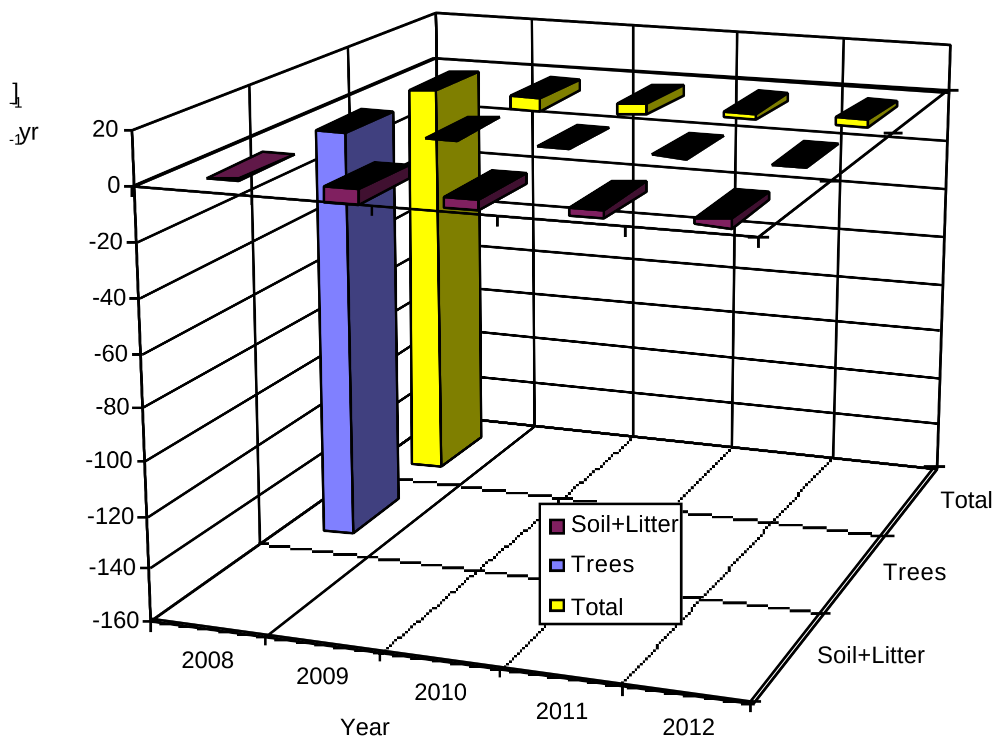


Figure 8: Annual carbon stock changes in the first commitment period for the deforestation scenario in Figure 7.

3.4 Harvest of mature forest followed by replanting

When a mature forest stand (here assumed to be at 160 Mg C/ha and with no net annual growth) is harvested, the carbon in aboveground biomass is reduced to zero while some fraction of this carbon is distributed to forest litter and a variety of forest products, and some fossil fuel is saved because of the substitution of forest fuels and other forest products (Figure 9). In the scenario illustrated there is no change in land use and hence the land parcel does not enter the accounting prescribed by the Kyoto Protocol. If this harvest were to occur in an Annex I country the only event that would impact the commitments under the Kyoto Protocol is that fossil fuel use is reduced. The Protocol provides no incentive for protecting the stock of carbon in the forest, the incentive is to harvest and use the harvest to displace fossil fuels or fuel-intensive materials. In the scenario represented here, the net cumulative carbon stock withheld from the atmosphere is positive after 30 years (top line of the diagram) and becomes slowly more positive with time. This suggests that when the full system is considered (and future carbon emissions reductions have the same value as current emissions reductions) the net effect on CO_2 emissions will be more favorable after 30 years if the forest is harvested than if the forest is left to stand. In fact, the top line of the plot in Figure 9 is very sensitive to a variety of parameters used in the model and sensitivity analyses by Marland and Schlamadinger (1997) show that the advantage is to harvest and use forest products when the growth rate is high and the harvested material is used efficiently. When the forest growth rate is low and/or forest harvest is used with low efficiency, there is long term advantage in letting the forest stand and store carbon. Under the Kyoto Protocol, there is always advantage to carbon accounts if forest is harvested to displace fossil fuel use.

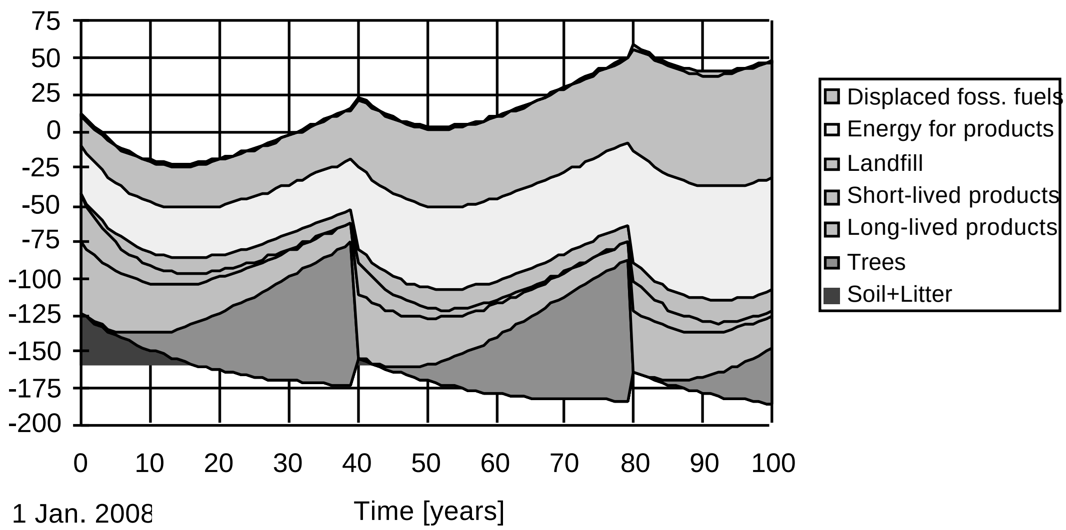


Figure 9: Cumulative carbon-stock changes for harvest and replanting of mature forest.

The carbon-accounting consequences of the scenario described in Figure 9 may be different if the harvest and replanting occurs in a non-Annex I country. The Protocol prescribes in Article 12 the Clean Development Mechanism (CDM), whereby Annex I countries can obtain from non-Annex I countries “certified emission reductions” and can apply these reductions to achieving compliance with their reduction commitments. Although the details of this process are to be worked out in subsequent meetings by the Parties to the Protocol, the only requirements for these certified emissions reductions that are specified in the Protocol are that they yield “real, measurable, and long-term benefits ...” and that the reductions are “additional to any that would occur in the absence of the certified project activity." With the current restraints on the CDM, it appears that if the "no action" alternative is deforestation in a non-Annex I country, certified emissions reduction credits could be generated for any reduction in emissions that is more favorable than this, i.e. either for forest protection or for forest harvest with efficient use of harvested wood products.

3.5 Harvest of second-growth forest followed by replanting

In this scenario (see Figure 10) we assume that a forest stand contains 100 Mg C/ha and is continuing to grow and accumulate carbon in aboveground biomass. The consequence of these assumptions for the carbon scenario represented in Figure 10 is that there is an opportunity to protect the forest so that it does continue to accumulate carbon. This opportunity is shown by the "opportunity curve" in Figure 10. The scenario shown also differs slightly from that in Figure 9 because we assume that with no change in the pattern of management there will be no long-term change in the amount of carbon in soils or forest litter. It is the loss of soil carbon that causes the base of the Figure 9 diagram to continue to decline over the 100 year time interval represented, and the base of the diagram in Figure 10 stays constant at the point of loss of 100 Mg C from the initially standing aboveground biomass.

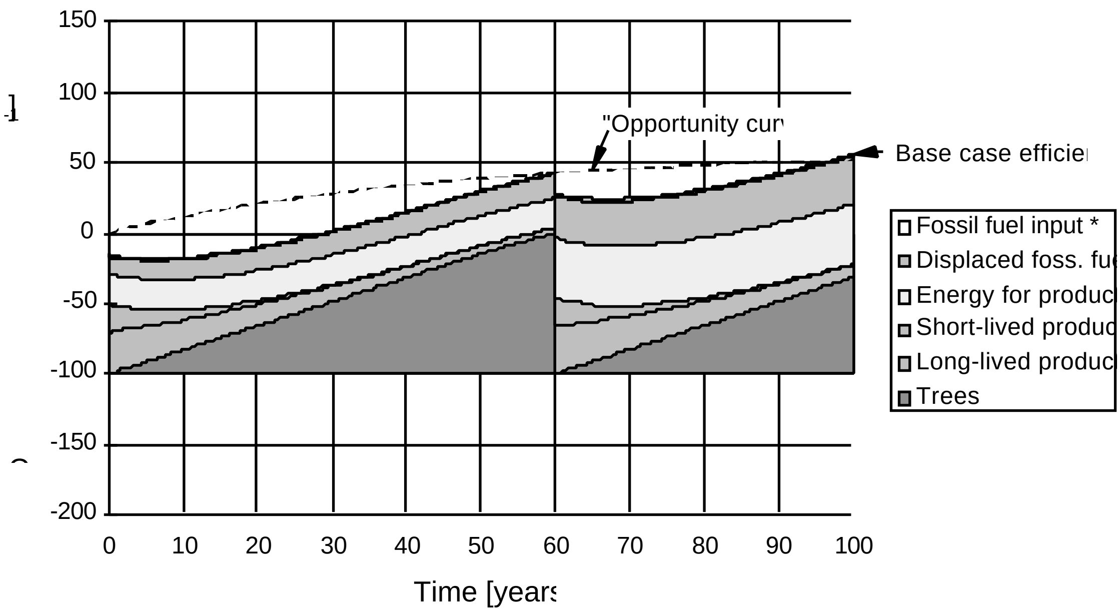


Figure 10: Cumulative carbon-stock changes for harvest and replanting of a second-growth forest stand.

As in the preceding scenario, the only way that this continuously-managed forest can yield credits toward emissions commitments under the Kyoto Protocol is through harvest and direct or indirect displacement of fossil fuels - and yet there is an opportunity to increase carbon storage in forest stands that, given the set of assumptions in this scenario, produces greater net carbon benefits out to 100 years.

In the scenarios discussed so far, we have focused in each case on a 1 hectare forest stand (excepting Figure 4). Although this provides a useful perspective on the changes in carbon stocks for different land management alternatives, it is not the same as looking at a full forest that is being managed for a constant, sustainable flow of forest products. We consider, then, a normal forest wherein 100 hectares of forest is managed on a 60-year harvest cycle. Different stands within the forest are at all levels of development, 1/60 of the area is harvested and replanted each year, and the forest sustains a constant flow and a constant stock of forest products. The net cumulative changes in carbon stocks for the full forest are shown in Figure 11. The stock changes for the single parcel harvested in year zero is exactly as seen in Figure 10. In the full forest (Figure 11) the drop in the bottom line of the diagram represents the harvest of trees existing prior to time zero while the wedge of the diagram labeled “trees” represents the accumulation of carbon in tress planted in time zero or later. The top of the “tree” wedge is perfectly horizontal at zero; there is no net change in the total amount of carbon standing in the full forest over time. There is also no net change in carbon stocks in forest products, and consequently this segment is not seen in Figure 11. The principal feature of Figure 11 is the continuing accumulation of carbon reduction “credits” as fossil fuels are continually saved because biofuels and biomaterials are used in place of alternate fuels and products. This flow of credits will be gained even within the Kyoto Protocol, that is if forest harvest were stopped, emissions from fossil fuels would go up. What the Kyoto Protocol will not give credit for is the opportunity to forgo harvest and to increase carbon storage in the forest, as represented by the “opportunity curve” in Figure 11. The incentive from the Protocol is to harvest and use forest products. And, indeed, this may be the best choice for the full carbon system for many forest systems or for long time periods. But, it is not the best choice under circumstances of low growth rate, poor efficiency in harvest and use, or shorter times.

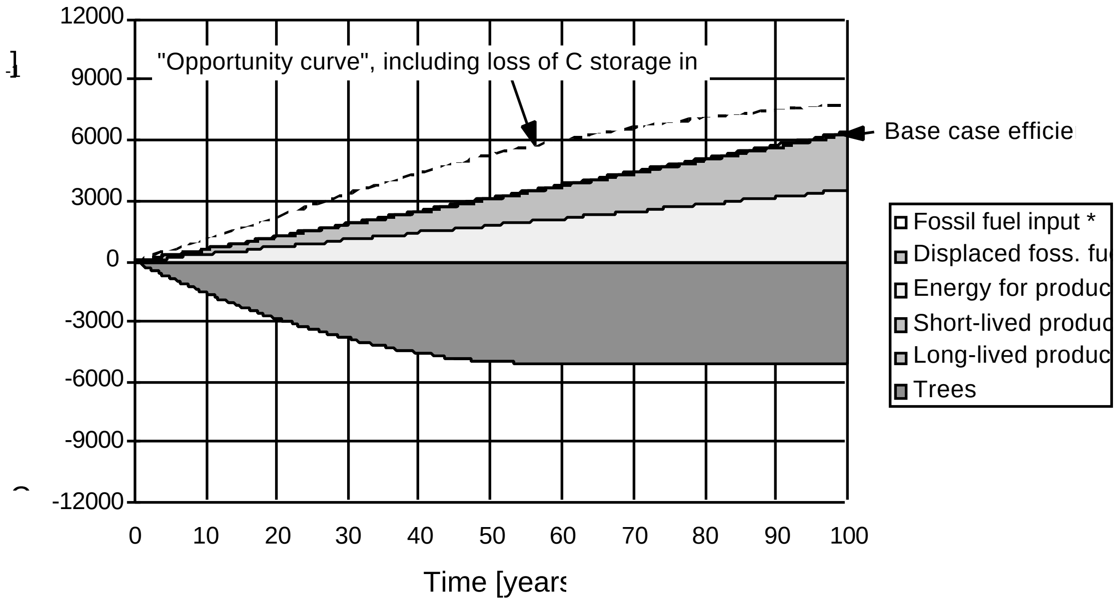
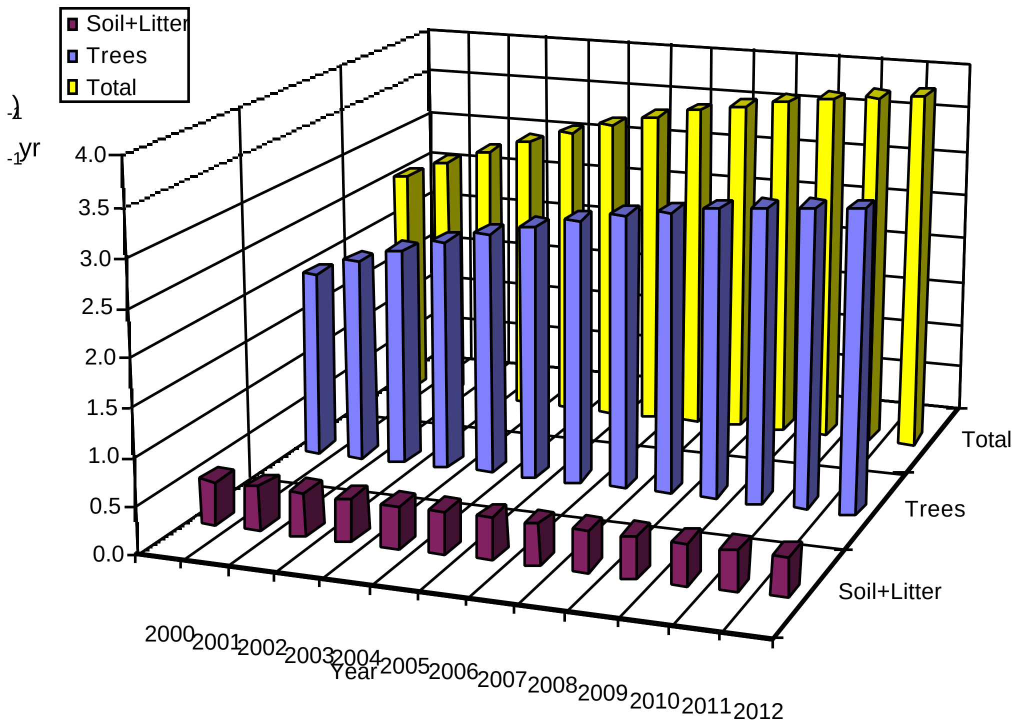


Figure 11: Cumulative carbon-stock changes for continued harvest and replanting of a plantation system of 60 parcels on 100 ha of land, each parcel being managed as shown in Figure 10, but with a time shift of 1 year between parcels.

4. The Clean Development Mechanism

As pointed out in Section 3.4, the Clean Development Mechanism (CDM) seems less constrained with respect to the range of activities that might be used to generate credits for emissions reductions. Although the rules for CDM projects are specifically to be drafted at a later date by a meeting of the Parties of the Protocol, and it is not yet clear whether net removals of carbon such as afforestation projects will be allowed under the CDM, some guidance is provided in the Kyoto Protocol and, at least for now, we can consider the full range of activities that yield long-term benefits related to the mitigation of climate change, constrained only by the requirement for “additionality”.

Projects undertaken under CDM are offered a unique feature not found in domestic afforestation projects, the possibility of banking certified emission reductions. “Certified emission reductions obtained during the period from the year 2000 up to the beginning of the first commitment period can be used to assist in achieving compliance in the first commitment period” (Article 12.10 of the Kyoto Protocol). For domestic forests, only the increase in carbon stocks during the 2008-2012 first commitment period can be used to offset emissions from other sectors. For CDM projects the increase in carbon stocks during the 2000-2012 could be transferred to an Annex I partner to offset emissions from other sectors. Figure 3b shows the emission offsets available from an afforestation project undertaken in an Annex I country. Figure 12a shows the emission offsets available from the same project if the project is undertaken in a non-Annex I country. The difference is shown diagramatically in Figure 12b.



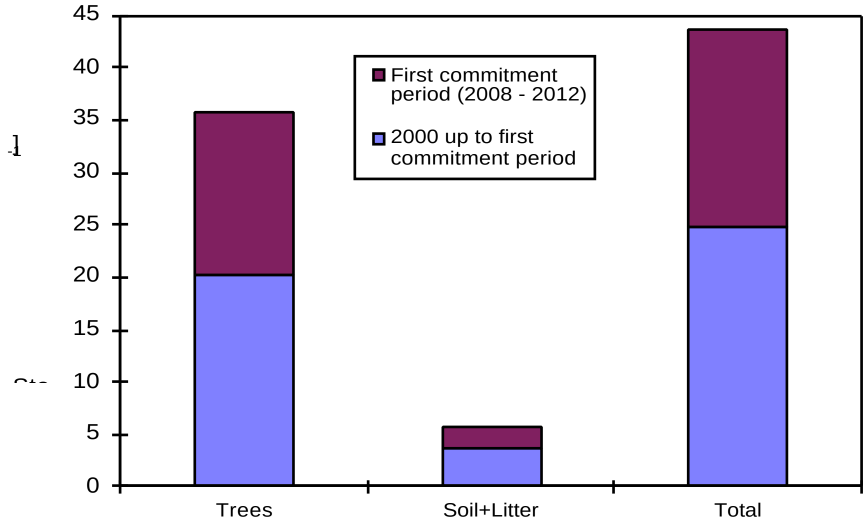


Figure 12: Annual carbon stock changes beginning in 2000 and during the commitment period for an afforestation project in a non-Annex I country under the Clean Development Mechanism (top - Figure 12a) and the shares of these stock changes before and during the commitment period (bottom - Figure 12b).

5. Does the Kyoto Protocol make a difference for the optimal forest-based C mitigation strategy?

The simple answer to the question posed by our title is “yes”. In retrospect it is inevitable that a system of rewards (allowing some activities to be counted against CO_2 emissions commitments) will provide some perversities if it rewards only a subsystem of activities within the larger system of land-use change and forestry. Table 1 shows, in matrix form, a list of carbon pools that might be affected by a given project, and a list of the types of projects discussed above and the time span over which a project might be initiated and executed. It is shown that there are some categories of carbon stocks that change during the commitment period yet provide no credits or debits under the Kyoto Protocol. The table does not present an explicit forest protection scenario, but it is clear from the “forest management” scenario that there is no incentive provided to protect or increase the amount of carbon stored in existing forests. In almost all cases the incentive under the Kyoto Protocol is to harvest and replant forest and use the harvest in ways that decrease the use of fossil fuels. As clearly stated in other papers (Marland and Marland 1992, Marland and Schlamadinger 1997) this is often a good choice, in terms of the global carbon cycle, but in many other cases forest protection or alternative management regimes provide greater benefit in net CO_2 emissions to the atmosphere. The Protocol may provide greater incentive to pursue forestry projects in non-Annex I countries than in Annex I countries, while providing fewer guarantees about the long-term commitment to these projects (see also Marland et al. 1998). The Kyoto Protocol provides no incentive to improve forest management so long as a parcel of land maintains its classification as forest.

Table 1: Summary of the scenarios described in this paper.

	Afforestation, no harvest		Afforestation and harvest		Deforestation			Forest management (higher/lower/const. stocks)	
Carbon pool / **Initiated in**	**pre 90**	**post 90, comm. period**	**pre 90**	**post 90, comm. period**	**pre 90**	**post 90**	**comm. period**	**pre 90, post 90**	**comm. period**
Biomass	2	3	2	3	1	1	3	2	2
Biomass (oppt. cost)								2	2
Soil+Litter	2	3?	2	3?	2	3?	3	2	2
Wood Products			2	3?	2	2	3?	2	2
Energy subst.			2	3	1	1	3	2	3
Materials subst.			2	3	1	1	3	2	3
Fossil fuel inputs			2	3	1	1	3	2	3

1 C pool affected but not during com. period
2 C pool affected during commitment period
3 C pool affected AND in Kyoto account
3?C pool affected AND in Kyoto account?

Forests have significant potential to discharge carbon to the atmosphere or to withdraw carbon from the atmosphere. It has been widely acknowledged that this potential is not sufficient as a total response to increasing atmospheric CO_2, and yet most analysts agree that it can play a significant role, at least in the short term (Nilsson and Schopfhauser 1995, Sampson and Hair 1992). It is important that the Kyoto Protocol does acknowledge the role played by the forests and the biosphere, and the Protocol makes a bold attempt to provide incentives for purposeful management of forests in such a way as to minimize CO_2 emissions to the atmosphere. Now it is important to understand the perversities introduced by the precise language of the Kyoto Protocol and to supplement the Protocol with definitions, interpretations, or agreements that bring optimal benefit to forest management and the global carbon cycle.

6. Acknowledgments

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Some issues related to including biotic carbon offsets in a GHG emissions trading system

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Abstract

The Australian Greenhouse Challenge program was established in 1995 as a joint initiative of industry and the Commonwealth to mitigate greenhouse gas emissions. It encourages voluntary action by companies, and has enlisted the cooperation and support of more than 160 industry associations and Australian companies. Some of these companies currently include new carbon sequestration projects in their "action plans" under their Greenhouse Challenge cooperative agreements. A Sinks Workbook is being developed for the Greenhouse Challenge program. The workbook will explain methods of monitoring and measuring carbon sequestration. Preparation of the Workbook is being undertaken in order to help companies quantify and report the greenhouse gas benefits of vegetative management projects included in their Greenhouse Challenge action plans. Projects types to be included in the first edition of the Workbook centre around increasing the amount of growing vegetation through new plantations, environmental plantings and improved management of existing plantations. The Workbook is aimed at projects within the Greenhouse Challenge program framework, rather than at certifying offsets within the context of emissions trading or Joint Implementation. Nonetheless, the workbook is written in a way which will acquaint companies with some of the issues potentially involved in creation of tradeable carbon emissions offsets from the forest sector in case they might want to participate in such arrangements in the future. Preliminary to the finalized workbook, expected to be completed in May 1998, a Discussion Paper and a Draft Workbook have been prepared to promote dialogue and elicit stakeholder views on a range of methodological issues related to the creation of forestry offsets. The Draft Workbook and Discussion Paper, which will be described in this presentation, discuss methodological and other issues involved in the quantification of the greenhouse benefits of vegetation management projects as carbon emissions offsets or credits. Issues covered include those related to baseline determination, leakage and project boundaries, reporting and accounting conventions, project duration, monitoring and verification.

My presentation today focuses on how to integrate GHG emissions offsets or credits from the land use sector in a domestic or international fossil fuel emissions trading system designed to implement the United Nations Framework Convention on Climate Change (UNFCCC). Many of these ideas were put forward in a discussion paper prepared for and with the Australian Greenhouse Challenge Office (GCO) in October 1997 as well as in a draft workbook for GCO forestry sequestration projects completed earlier this month. Copies of both of these papers are available. Some of the material in those documents, including much of what is presented here, was intended to stimulate dialogue and should not be taken to represent the views or policies of the Australian Commonwealth.

I contributed to the Australian GCO issues paper and the draft workbook as an independent consultant. In my presentation today, I represent only myself and not the Australian government.

Australia's greenhouse challenge program

Australia’s Greenhouse Challenge program was established in 1995 as a joint initiative of industry and the Commonwealth to mitigate greenhouse gas (GHG) emissions. It has enlisted the support and cooperation of more than 160 industry associations and Australian companies. The program is intended to be voluntary, comprehensive and self-regulatory. By comprehensive is meant that all sources and sinks of GHGs will be included.

Figure 1. Australia´s greenhouse challenge program

Companies participating in the program sign five year agreements, subject to renewal, with the GCO. They undertake company-wide inventories of GHGs emissions and sinks; forecast expected emissions reductions; and report annually on their progress. As part of their efforts to reduce emissions, they agree to implement "action plans" consisting of specific additional project related reductions. Some of the participating companies have included sequestration activities in their action plans.

Purpose of the sinks workbook

A workbook detailing methods of monitoring and measuring carbon sequestered in forestry projects is being prepared by the GCO to help companies quantify and report the GHG benefits of forest sector, or sinks, projects included in their GCO action plans. The GCO reporting requirements include an annual estimation and reporting of carbon sequestered by the project plus on-site measurement, and revised carbon storage estimates based on this measurement, at the end of each five year GCO agreement. The workbook is specifically designed to measure and estimate net carbon sequestered on the project level as opposed to a company-wide or national inventory level.

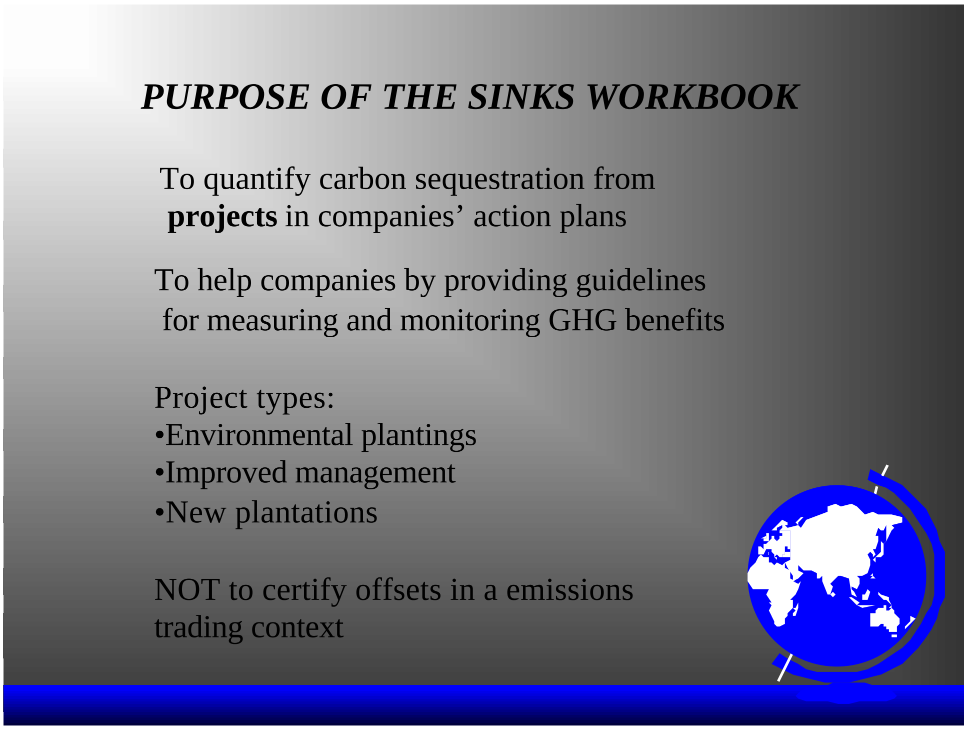

Figure 2. Purpose of the sinks workbook

The workbook is aimed at meeting the reporting requirements of the Australian Greenhouse Challenge program and not at determining offsets or credits recognized in an international or domestic trading system or other regulatory context. Nevertheless, a paper was prepared preliminary to the draft workbook, to stimulate discussion on issues related to the inclusion of forestry sequestration projects as part of an emissions trading system. The paper was reviewed by a group of Australian stakeholders from government, private companies and academia. Some of these concepts were also included in the draft workbook to acquaint Australian companies with some of the issues potentially involved in the creation of tradeable emissions offsets from forestry projects, in case they might want to participate in such arrangements in the future.

Three project types are included in the first version of the workbook: new plantations; environmental plantings and improved plantation management. Some of the projects in companies' action plans will likely involve the expansion of areas under plantation. Environmental plantings include shelter belts, plantings to prevent erosion and to mitigate salinity problems, to link natural vegetation and improve wildlife habitat. These are being promoted by the Australian government and by LandCare Ltd., a private company. Management projects could include thinnings, enrichment plantings, longer rotations and new harvest techniques.

The international context

From the beginning of the negotiation process leading to the UNFCCC, a contentious debate has surrounded the inclusion of land use mitigation options. One of the objections of critics of forestry-based compliance options is the inadequacy of estimation of net emissions from forests. While the error bands around estimates for national land use emissions inventories are often plus or minus 100%, carbon storage at the project level can be estimated with much higher and more credible levels of certainty. Even for national inventories, additional resources devoted to data collection and estimation procedures could significantly reduce the error margins around the emissions estimates.

An emissions trading regime that includes forestry offsets could provide the resources for the additional data collection and monitoring required to develop more precise national emissions inventories. Credible national level land use emissions inventories are essential to including forestry offsets in an emissions trading system and to documenting progress in achieving overall emissions mitigation goals.

Objections that forestry offset projects conflict with national sovereignty, or control over critical natural resources, arise from the long duration of land use offset projects which could dictate land use patterns for decades.

Another objection to land use mitigation options arises from a moralistic stance of some critics. In this view, fossil fuel use is wrong and polluters shouldn't be allowed to buy their way out of solving their fossil fuel environmental problems with cheaper land use mitigation options.

Yet another objection is that forestry projects alone can not solve the problem of climate change; energy generation technologies must be changed. Therefore, forestry based compliance options are not so important.

It is clear that land use mitigation options will be only a temporary and partial solution and, realistically, technological advances in energy generation must be achieved. However, it doesn't make sense to disallow land use compliance options entirely when 20% of anthropogenic emissions come from land use, when sequestration potential is large, and when other environmental benefits are often associated with these options.

Finally, there has been concern that the wrong kinds of projects, i.e. non-sustainable projects might be used to sequester GHG emissions, such as eucalyptus plantations covering Central America. Countries where projects are located could address this through domestic regulations as any participation is voluntary. In addition, certain types of projects could be disallowed by the UNFCCC.

The Kyoto Protocol leaves many questions unanswered regarding the role of forests in compliance with the UNFCCC and in its economic mechanisms. Article 3 addresses the quantified emissions limitation and reduction commitments of Annex I Parties (developed countries and economies in transition). It states that human-induced land use changes since 1990, restricted to deforestation, afforestation and reforestation, as measured by changes in stocks in each commitment period shall be used by Annex I Parties to comply. It is not clear exactly what is meant by this. Exactly what activities are included? How are afforestation, reforestation and deforestation defined? Are forest management and preservation projects included? Are these activities to be counted at the project level for selected projects as well as aggregated at the national level for all activities in each type?

The language seems to imply that forestry-based offsets credits can be created for compliance purposes. Thus, activity specific accounting of carbon sequestration and emissions from all activities included by the definitions should be undertaken to provide estimates accurate enough to include in compliance determination and an emissions trading system. Emissions from these aggregated project level activities should also be integrated with national land use emissions inventories.

Article 6 states that Annex I Parties may transfer among themselves “emissions reduction units” associated with specific projects that provide “a reduction in emissions or an enhancement in removal by sinks additional to what would have otherwise occurred.” This specifically includes land use options for what could be called “Joint Implementation” among Annex I Parties. “Emissions reduction units” are also introduced. The additionality criteria is somewhat confusing here as Bernhard Schlamadinger has already pointed out in his presentation on "technical issues".

Article 12 establishes the Clean Development Mechanism (CDM) to create “certified emissions reductions,” generated by projects in developing countries without emissions limitation commitments, that can be applied toward the commitments of Annex I Parties. It does not explicitly mention forest or land use but allows any project that has “real, measurable and long term benefits relative to the mitigation of climate change” and that is “additional to what would have occurred in the absence of the certified project activities.” Are land use projects to be included? Given the goals of the treaty as articulated in Article 2, an argument can be made for including sustainable forestry management and protection and enhancement of sinks.

Article 17 also allows Annex I Parties to participate in emissions trading to achieve their limitation commitments. The rules are to be defined by the Conference of the Parties.

The Kyoto Protocol clearly allows for the possibility of trading carbon offsets from forestry or land use projects at a minimum from deforestation, reforestation and afforestation activities through Articles 3 and 17 (emissions trading), Article 6 (“emissions reduction units” or JI among Annex I Parties), and Article 12 (the Clean Development Mechanism or “certified emissions reductions” from developing countries.)

The main objective of resolving the issues to be presented in my talk is to credibly integrate forestry offsets into a fossil fuel CO_2 emissions trading system. This can be done by developing standard rules and procedures at the project level. This clearly must be done for the Clean Development Mechanism as well as for emissions trading and JI among Annex I Parties. Ultimately, the objective should be to obtain the resources to establish systems for monitoring and precise estimation of forest emissions at the national and global levels. When national level emissions can be estimated with a much narrower confidence band that is currently the case, then the credibility of generating credits for project level offsets can be verified by overall forestry sector emissions growth. Some of the methodological issues involved with determining project level emissions benefits will be less critical because change in national level stocks related to all projects of a given type and for national forest sector emissions can be determined credibly.

Methodological issues related to project level forestry carbon offsets

The methodological issues to be discussed related to project level offset determination include the following: baseline determination; project boundaries and leakage; pools to be counted and how; project duration or how long should carbon be stored to count as a fossil fuel emissions offset; methods for accounting for the carbon credits over time; and what to do about the carbon stored in wood products.

Baseline determination

I assume that most people here are familiar with the concept of a project baseline. An offset project reduces emissions compared to a “business as usual” scenario, or the most likely emissions scenario without the project. In the wording of the Kyoto Protocol, the credits claimed would be “additional to what would occur otherwise” or “additional to what would occur in the absence of the certified project activity.” (Articles 6 and 12). For Article 3.3, the baseline concept might be introduced in the definitions of afforestation, reforestation and deforestation and the delineation of which activities are to be included.

Figure 3 illustrates a simple example of a new forest planted or allowed to regenerate on marginal cropland. Net new sequestration is assumed to be zero in the agricultural case. The project benefits are the difference between the carbon sequestered as a result of the new trees and that of the agricultural case. This shows the cumulative benefits over time.

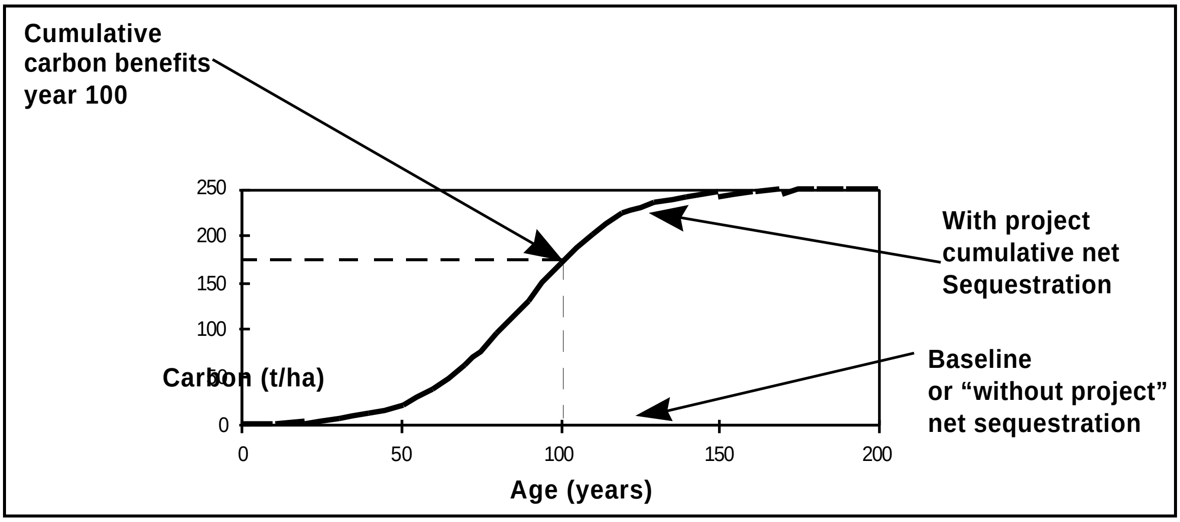

Figure 3. Example of baseline: forest growth on marginal cropland

One of the main problems with determining baselines for forestry offset projects is that they are done on a project by project basis. In the context of the climate treaty, nations are the units of responsibility. A country’s overall net emissions or sequestration from human-induced forestry activities is what should be counted. If the only evaluation of forestry GHG benefits is on a project level, as in the CDM, Article 12, then forestry offsets could be created in countries whose overall land use emissions are growing substantially.

A major problem with determining the project level baseline assumptions relates to their long term duration. How can one see 50 years or more into the future and guess the most likely outcome for the use of a specific site or determine what would have happened without the project?

Regardless of these problems, for forestry offset projects to be feasible especially under Articles 6 and 12, standardized rules are needed to reduce uncertainty about a project’s carbon benefits, encourage investment and reduce transactions costs. Without clear, easy to apply rules regarding baseline determination, each project would need to be evaluated individually with resulting high transactions costs.

Should the baseline assumptions be re-evaluated over time or should it remain in place once the project is established? The consulting team for the Australian workbook felt the answer to the latter question should be yes, that is, the original baseline assumptions should remain in place whenever feasible.

For example, suppose a company implements a new non-standard harvesting practice that results in fewer carbon emissions. Twenty years after the specific project began, the new technique has become standard practice. Should the original project still be allowed to claim credit? One approach would be to allow the project to generate credit throughout its life, if at the time it was implemented the practice was not widespread. The standard harvesting practice at project commencement would serve as a baseline. However, if some time the new practice becomes standard or is clearly on its way to becoming standard, then implementing this technique could no longer count as a carbon mitigation option for new projects. The advantage of not re-evaluating baseline assumptions over the project life for a specific project is that it provides more certainty as to the potential carbon credits generated by the project investment.

Some possible criteria for baseline determination include “intentionality”, or would the project sponsors have done the project anyway, and financial viability, which is another way to get at intentions. The assumption is that if the project is financially viable it would happen anyway. Both of these criteria are difficult to assess. A project may appear to be financially viable but may not be implemented for a host of political or other reasons such as availability of capital.

The next set of possible criteria are easier to document and assess because they are based on fact. They include the land use history of the site, current land use and management practices and trends. For example, if a plantation is expanded to marginal cropland, a baseline rule of thumb might be that the land has not been forested for 20-25 years. This would rule out the possibility that trees were cut to generate carbon credits. The idea is to develop simple rules like this for each project type.

Project boundaries and leakage

Leakage occurs when emissions are claimed to be avoided or removals are claimed to be enhanced as a result of a project, but at the same time emissions go up or removals disappear elsewhere accordingly. Two examples are: A preservation project protects some land from logging but the logging company simply goes a few miles away and logs on another site; A new forest plantation is started on cropland but the farmer goes somewhere else and destroys a forest to replace his agricultural land.

This issue also arises because of the project specific nature of the forestry offsets. If there were complete accountability for human-induced land use emissions throughout a country (or in some cases region) the issue of leakage would not be a problem.

There are ways of estimating these effects. Also, there are ways to prevent or minimize the probability of leakage – for example, coupling a preservation project with sustainable employment opportunities for the people who live on the land; or including a plan for the farmer to use monetary compensation to start a new business.

A key element is whether the logging company that goes elsewhere or the farmer who cuts down trees is accountable for the emissions consequences of the actions. If there is no accountability for the emissions, then leakage is a problem. If overall national emissions from human induced land use change are estimated with a higher confidence level, then at least it will be known to what extent leakage is occurring.

Pools to be counted and how

Figure 4 illustrates an accounting or tracking model that was used as the framework for addressing what pools to count in the GCO discussion and draft paper. Biotic carbon pools of trees & roots, litter, soil and other vegetation were included as well as pools for biofuels, fossil fuels and wood products. The latter three were included so that the model would be comprehensive enough to consider carbon benefits from the use of biofuels to replace fossil fuels and from long term storage in wood products, although the first version of the workbook does not address these.

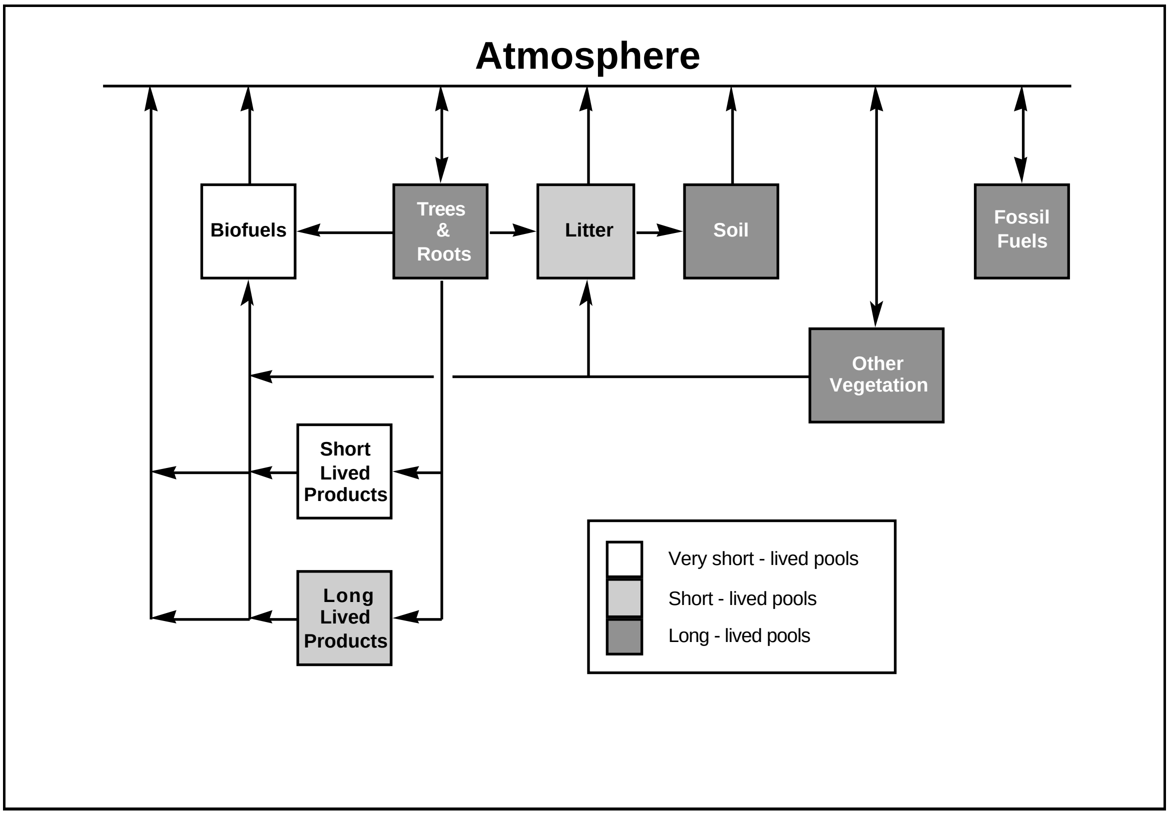

Figure 4. General carbon accounting model

To determine which pools should be counted for a specific project, the decision matrix depicted in Figure 5 was used. The size of the pool, the rate of change and the direction of change were taken into consideration for each relevant pool. The decision rule is that all pools that are large and change relatively rapidly are important. However, the direction of change is also a consideration. In general, if the change is expected to be additional sequestration, then the pool must be measured only if carbon benefits are to be claimed.

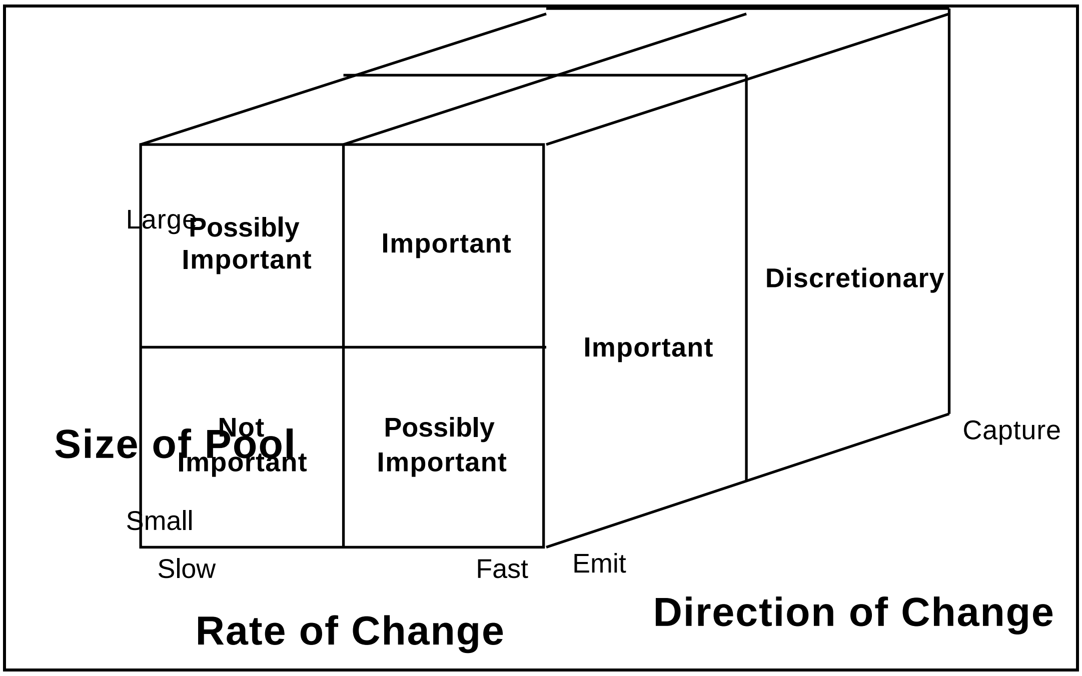

Figure 5. Decision matrix for which pools to count

For example, in afforestation or reforestation projects on marginal cropland, the trees and roots pool will be counted because it is the major source of credits claimed. It meets all the criteria in the decision matrix. It is also expected that the direction of change of the soil pool (or the soil plus litter pools) will be positive. In this case, measuring the soils pool becomes discretionary and would only be required if credits were to be counted. However, if the change in a carbon pool is expected to result in emissions, such as the clearing of other vegetation from a site prior to the project, then it must be measured. This decision rule is important in reducing transactions costs and allowing the investor to determine if the additional carbon credits are worth the measurement costs.

Below are some conclusions that were agreed upon by the consultants working on the GCO workbook:

- Trees and roots pool usually is sufficient for project types in the first version of the workbook (decision matrix).

- Soil carbon cannot be assumed to increase without evidence.

- Carbon claimed should represent lower 90-95% confidence interval of mean value measured; “Conservative” default values.

- Physical site inspection and after-the-fact monitoring are critical.

- Monitoring of baseline site conditions is often as important as those of the project.

- Frequent measuring is not necessary.

Project duration and accounting methods

One critical question is how long must biotic carbon be sequestered to count as a fossil fuel emissions offset? An answer to this question would help provide needed guidance for establishing carbon offsets from forestry projects. However, accounting and crediting procedures can get around this question if they require reporting and monitoring of the projects for an indefinite, open ended time period.

The offset duration could depend on three considerations:

- Legal or economic feasibility—legal contacts establishing commercial agreements do not last forever nor is it feasible to require that land be tied up in a certain use forever.
- What is a reasonable estimate for the time it will take for technological advances in the energy generation to solve the climate change problem?
- What is the atmospheric lifetime of CO_2?

An additional issue is what accounting procedures should be used for crediting the carbon benefits from projects with periodic harvest and replanting? Two methods that were discussed are real time and average standing biomass. For projects without a harvesting component the real time approach applies.

Figure 6 illustrates these two approaches for a new commercial plantation on marginal cropland. Simplifying assumptions were made for purpose of the illustration. Only the trees and roots pool is included. A sixty year project duration was chosen as time frame with harvests every 20 years. The carbon stored in wood products is not counted, so that all carbon in harvested biomass is counted as emissions.

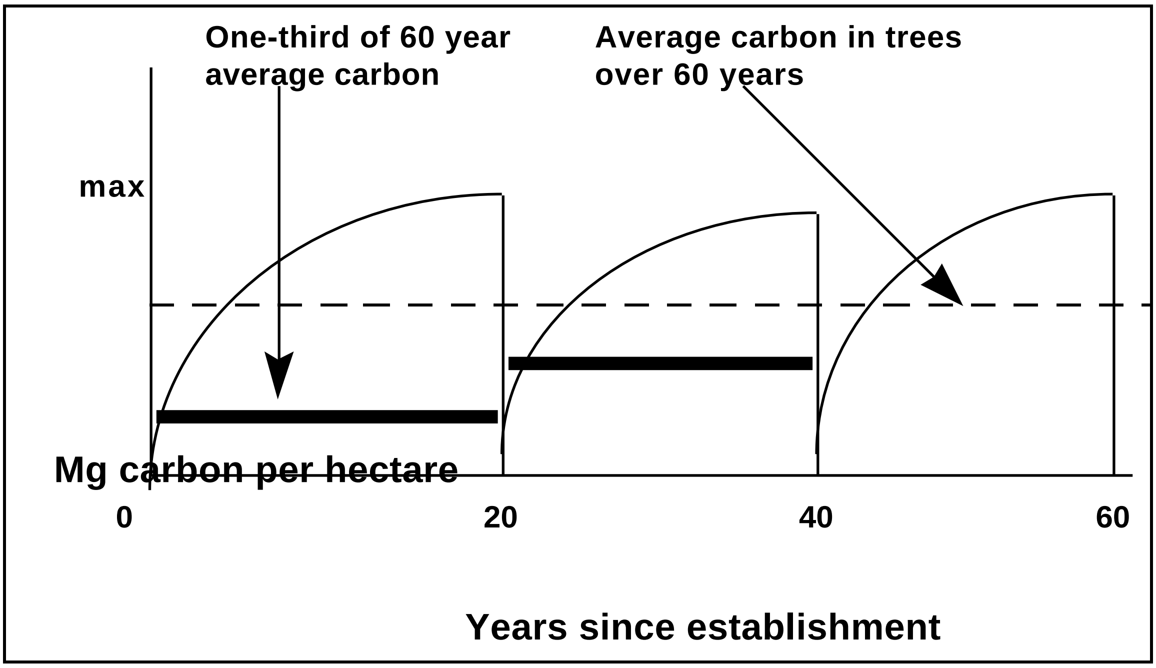

Figure 6. Example of accounting for "credits" from a new commercial plantation on marginal cropland

The real time method, simply count credits for the growth increment when sequestration occurs and count debits when emissions (harvest events occur). If companies that receive the credits sell them, then they would have to acquire credits from elsewhere to cover in years of harvest. This is rather burdensome and involves multiple transactions.

Another approach is a one time credit for average standing biomass. In this case, projects with harvest and replanting would receive credits up to the average increase in biomass carbon in the stand. These credits can be transferred. Project monitoring and reporting must continue throughout the required project duration or indefinitely but credits must be given back only if a harvest event is not followed by reforestation. Adjustments might also be made if actual sequestration in a given rotation is different from the estimated value.

Wood products

Should carbon benefits of wood products be included? This will enhance carbon benefits from new plantations, but it is difficult to monitor and track what happens over time. For a specific project, how much of the harvested wood ends up in long lasting products? Can decay curves be developed that could apply to specific projects? Or could a certain percentage be used? How is the change in the total wood products pool affected by a specific project?

Greenhouse gas emissions avoidance through fire management - theory and proposed methodology for estimation

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Abstract

The Kyoto Protocol states that Parties in Annex I shall protect sinks and reservoirs of greenhouse gases, and include in their quantified emission limitation and reduction commitments emissions and removals from afforestation, reforestation, and deforestation only. Fire, a huge source of emissions, currently is not included in the Protocol. Fire is part of the natural forest cycle but without management may have increased due to increased human activity. In non-Annex I countries, fire management might be needed to help protect forest resources. So should fire management be considered as a "Clean Development Mechanism"? This paper explores a theory and proposes a methodology for quantifying carbon emissions avoided through fire management including a baseline. It shows using examples that fire management has the potential to avoid large amounts of emissions rapidly for a land-use project, but if the management program is temporary, the benefit will be lost as regrowth occurs.

Keywords: fire, greenhouse gas, emissions, avoidance, management

Introduction

The Kyoto Protocol states in Article 2, paragraph 1, subparagraph ii states that:

> *"Each Party included in Annex I in achieving its quantified emission limitation and reduction commitment under Article 3, in order to promote sustainable development, shall*
> *a) Implement ... measures ... such as:*
> *(ii) Protection and enhancement of sinks and reservoirs of greenhouse gases."*

Further in Article 3, paragraph 3 the Protocol limits the emission limitation and reduction to

> *"... net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period ..."*

Finally in Article 13 paragraph 3, it is stated that:

> *"3. Under the clean development mechanism:*
> *(b) Parties included in Annex I may use the certified emission reductions accruing from such project activities ... under Article 3, as determined by the Conference of the Parties..."*

Not withstanding the above I argue that from strictly a greenhouse gas point of view, fire management should be included as a "clean development mechanism" because;

1. it is the protection of a reservoir from a form of short-term loss;
2. it is a form of sustainable forest management; and
3. fire occurrence may have increased as a result of direct human-induced land-use change and forestry activities

Fire management should definitely be included if forest management is included.
What remains is the development of a simple methodology for estimating and verifying emissions with and without the project activity. This paper presents such a methodology.

Theory

The modelled response of a fire on a hectare of mature forested stand is shown in Figure 1. The initial conditions for the mature stand are:

Above ground biomass (AGB) - 250 MgC/ha;
Roots - 49 MgC/ha;
Litter - 32 MgC/ha total
(foliage - 17, woody - 4, fine roots - 8, woody roots - 3); and
Soil - 248 MgC/ha.

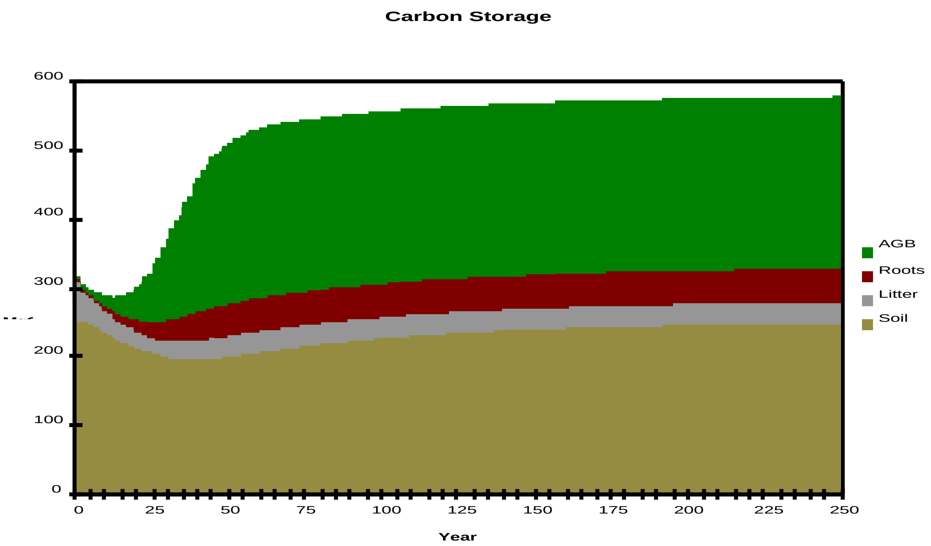

Figure 1: Modelled response after forest fire

There is a fire during Year 0, and immediately after the fire the carbon storage is:

Above ground biomass (AGB) - 5 MgC/ha;
Roots - 4 MgC/ha;
Litter - 55 MgC/ha total
(foliage - 0, woody - 0, fine roots - 12, woody roots - 43); and
Soil - 248 MgC/ha.

Note that all above ground litter is assumed lost, the difference in root mass becomes below ground litter, and that the fire is not so intense as to affect soil carbon loss.

The regrowth of the stand is modelled using a simplified version of GORCAM (Schlamadinger et al, 1997). This includes two above ground litter pools (foliage and woody litter), two below ground litter pools (fine root and woody root litter), and a logarithmic relationship between roots and AGB (Kurz et al, 1996).

The modelled annual emissions from this carbon profile are shown in Figure 2. There are large emissions in the first year due to the fire, followed by smaller emissions as the large below ground litter pool decays. With time the stand regrows and sequestration (negative emissions) takes place.

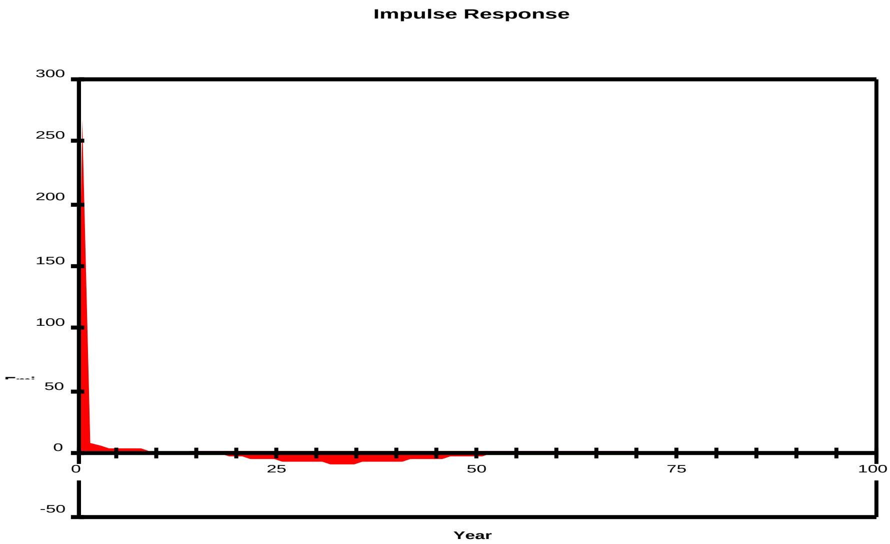

Figure 2: Modelled emissions after fire

Consider the fire loss as a time series, then the annual emissions after a fire are the impulse response to an event. The total annual emissions due to fire loss are given by;

e(t) = f(t) Ä i(t) (1)

where e(t) = annual emissions function (MgC),
f(t) = fire loss function (ha),
i(t) = impulse response function (MgC/ha) and
Ä denotes convolution.

Fire management can effect annual emissions by changing both the fire loss and the impulse response functions. In general the annual emissions with fire management can be given by:

$$\boldsymbol{e}(t) = \boldsymbol{f}(t) \otimes \boldsymbol{i}(t) \qquad (2)$$

where $\boldsymbol{e}(t)$ = annual emissions function with fire management,
$\boldsymbol{f}(t)$ = fire loss function with fire management and
$\boldsymbol{i}(t)$ = impulse response function with fire management.

The emissions saved, s(t), through fire management are given by the difference of the equations 1 and 2 or;

$$s(t) = \{ f(t) \otimes i(t) \} - \{ \boldsymbol{f}(t) \otimes \boldsymbol{i}(t) \} \qquad (3)$$

Equation 3 is greatly simplified if the fire management program concentrates on reducing the area lost annually and not replanting or altering the natural regrowth profile. In this case, equation 3 becomes:

$$s(t) = \{ f(t) - \boldsymbol{f}(t) \} \otimes i(t) \qquad (4)$$

Equation 4 can be extended to account for emissions saved through fire management on different vegetation types by:

$$S(t) = \Sigma_j \{ f_j(t) - \boldsymbol{f}_j(t) \} \otimes i_j(t) \qquad (5)$$

Practice

In practice, estimation of emissions saved through fire management using equation 4 requires estimation of the two fire loss functions on an annual basis;

$f(t)$ - fire loss without management, the baseline, and
$\boldsymbol{f}(t)$ - fire loss with management.

It also requires measurement of the impulse response function, i(t), which is independent of action (so is neither part of the baseline or action).

Baseline, f(t)

The baseline, f(t), is a forecast of fire loss in the future without management. By reviewing satellite images, analyzing past fire records, and weather data a relationship between weather and fire loss can be developed. Using this, the baseline can be calculated from current weather phenomena.

If complete weather and fire data are not available, then the baseline can be set as the average annual fire loss from the past. Note that this is susceptible to weather variations.

Therefore;

$$f(t) = f(t), \text{ before project commencement} \qquad (6)$$
$$= F\,[\text{weather}(t)], \text{ in the future}$$

Actions, *f*(t)

Annual review of new satellite images and confirmation through ground-truthing can be used to create ***f***(t). Since the impulse response function is causal (i(t) = 0 before t = 0), knowledge of future areas lost with fire management is not required. Thus;

$$\boldsymbol{f}(t) = f(t), \text{ before project commencement} \quad (7)$$
$$= \boldsymbol{f}(t), \text{ after project commencement}$$
$$= 0, \text{ in the future}$$

Impulse response function, i(t)

The impulse response function can be estimated by carbon measurements on the mature forest and sites at various stages of recovery after fire. These have been identified during estimation of the baseline.

A potential problem is C_0, the carbon stored prior to the fire. An unbiased estimate would be the spatial average carbon storage per hectare of the forest. It assumes that the chance of fire is independent of age.

Modeling (Figure 1) suggests that carbon losses from the soil and litter are relatively small compared to the losses from above ground biomass and roots. The soil carbon drops to a minima of 193 MgC/ha from 248 MgC/ha at 38 years. Monitoring of these pools is optional since:

1. omitting these pools leads to an underestimation of emissions avoided, and
2. these pools can never be more than the initial conditions.

Leakage

There will be carbon emissions from fire management depending on the fire management techniques used. These must be calculated and removed from the estimated carbon savings. These have not been included in the preceding examples. Leakage might include emissions from:

- controlled burns of litter;
- deforestation to create fire breaks, and
- fossil fuel use to combat fire.

Example 1 - Permanent fire management

The area of mature forest lost annually to fire over the previous fifteen years has been estimated from satellite images. It was found that on average 997 hectares were lost annually (standard deviation = 90 ha). During this period a relationship between fire loss and annual rainfall was evident. This is used to create the baseline in future years.

In Year 0 a trust is established to operate a permanent fire management program. The program effectively reduces the area of mature forest lost annually to fire to an average 911 hectares (standard deviation = 105 ha).

The two fire loss functions until Year 100 are shown in Figure 3. As shown, there may be years when the fire loss with management is greater than the base line.

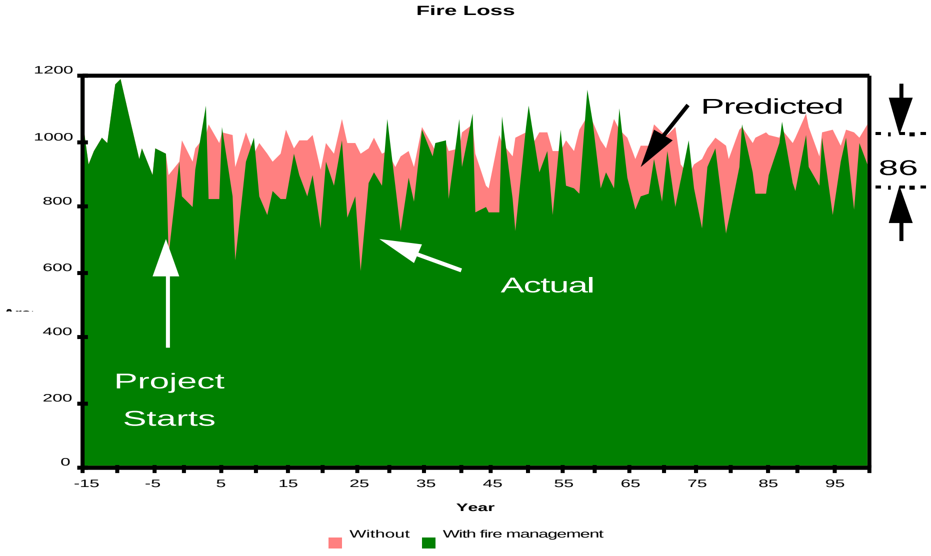

Figure 3: Permanent fire management - fire loss functions

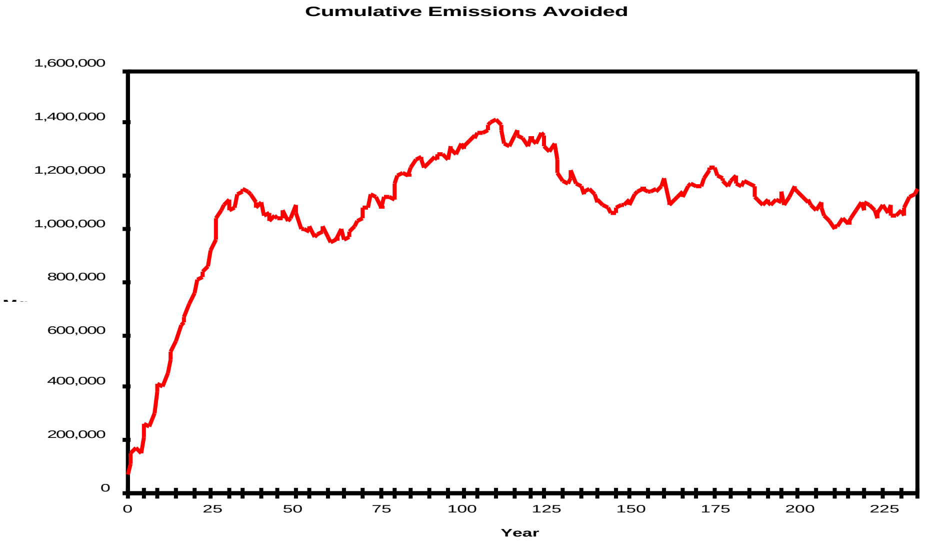

Figure 4: Emission avoidance profile - permanent fire management

The cumulative emissions avoided from the difference of these two time series are shown in Figure 4. There is a sharp rise in total emissions avoided in the first 30 years. At this time the total emissions avoided are ~ 1,150,000 MgC. Due to a group of high fire loss years (year 35 - 75), there is are net emissions over this period, but the cumulative emissions never fall below 950,000 MgC.

As seen in figure 4, the increase in cumulative emissions avoided after the initial thirty years is small.

Example 2 - Temporary fire management program

Example 1 suggests that the first 30 years contribute most to the emissions avoidance potential of fire management. In this example, the effects of a temporary fire management program are investigated.

The same fire loss function without management is used as a baseline. The fire loss function with management is identical for the first 30 years to example 1, after which it returns to the baseline over the next 10 years.

The two area lost functions until Year 100 are shown in Figure 5.

Figure 5: Area lost functions - temporary fire management

The emission avoidance profiles for this example are shown in Figure 6. It clearly shows the importance of continued fire management even though, as seen in Figure 4, the majority of the emissions are avoided within the first 30 years.

The total emissions avoided peak in Year 35 at ~ 1,115,000 MgC. The loss of carbon benefits after this point is caused by sequestration due to regrowth that occurs in areas that were previously lost to fire.

Conclusion and Discussion

This paper has developed a simple theory and methodology for calculating carbon emissions avoided from a fire management program. It shows that significant emissions can be avoided rapidly through fire management, but that management needs to be maintained throughout time to assure permanency.

There are other items that must be considered when discussing fire management. Firstly, fire is part of the natural forest cycle and so is fire management a benefit to the natural system? Secondly, by managing fire loss there is the chance of more severe fires when they do occur. Finally, there is the enormous risk of fire loss if the management system fails.

Should fire management be considered as a Clean Development Mechanism? In countries with undisturbed forests one would think not. In countries with little natural forest remaining, increased deforestation and forest management, perhaps fire management is needed.

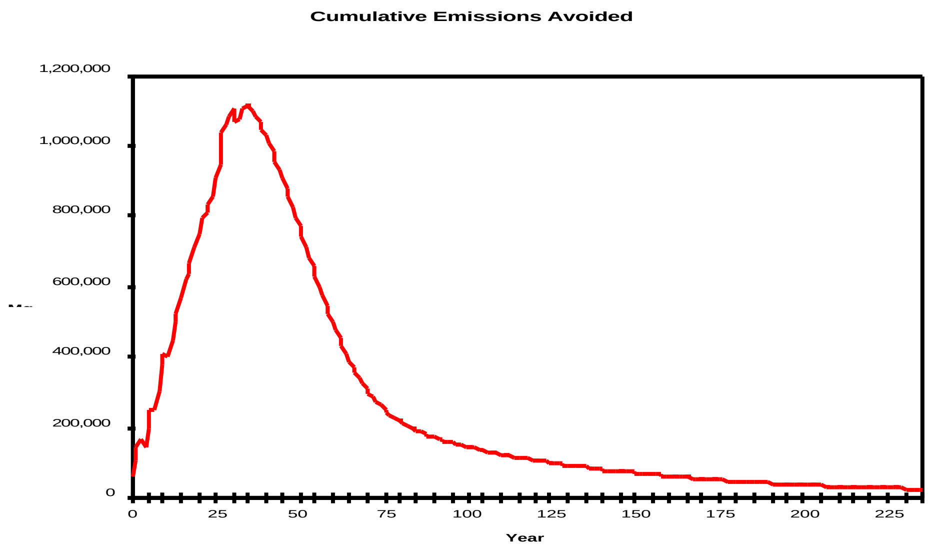

Figure 6: Emission avoidance profile - temporary fire management

References

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Kurz WA, Beukema SJ, and Apps MJ (1996) Estimation of root biomass and dynamics for the carbon budget model of the Canadian forest sector. Can. J. For. Res. **26**: 1973-1979.

Replacing fossil fuels with forest fuels - baselines, CO_2 reduction and mitigation cost

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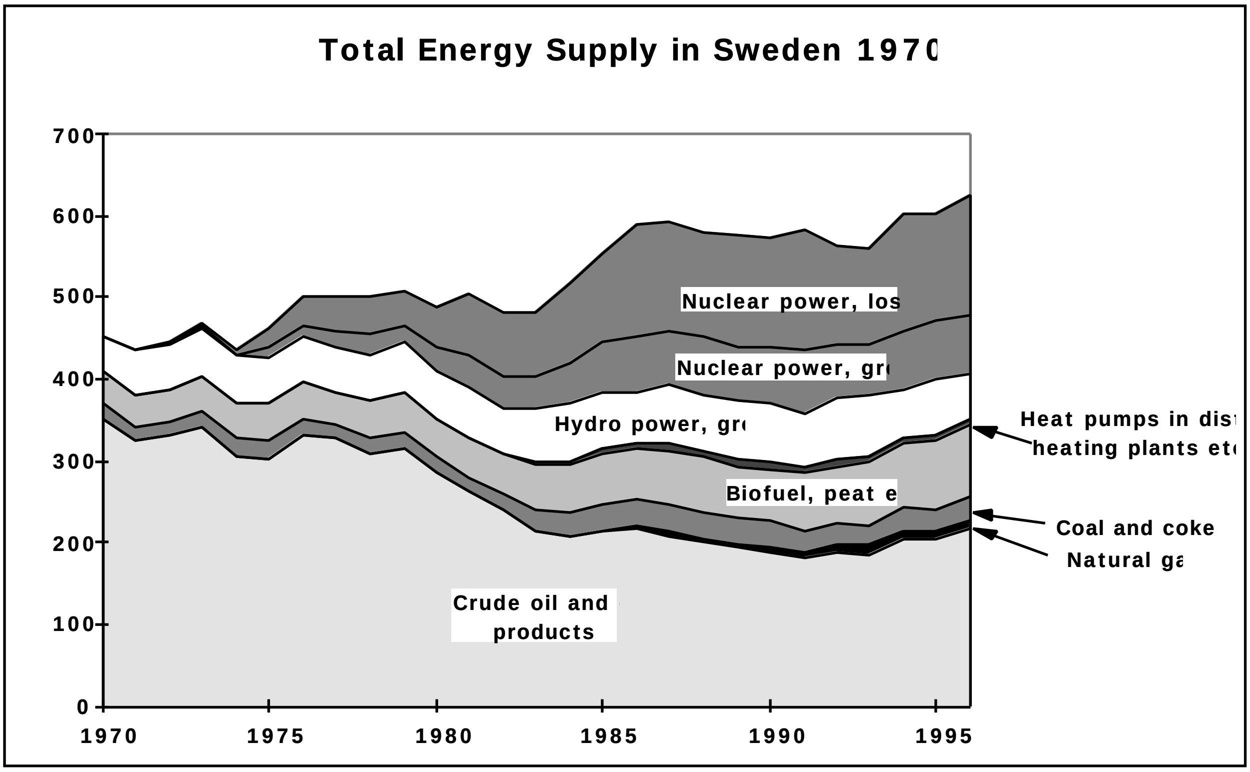
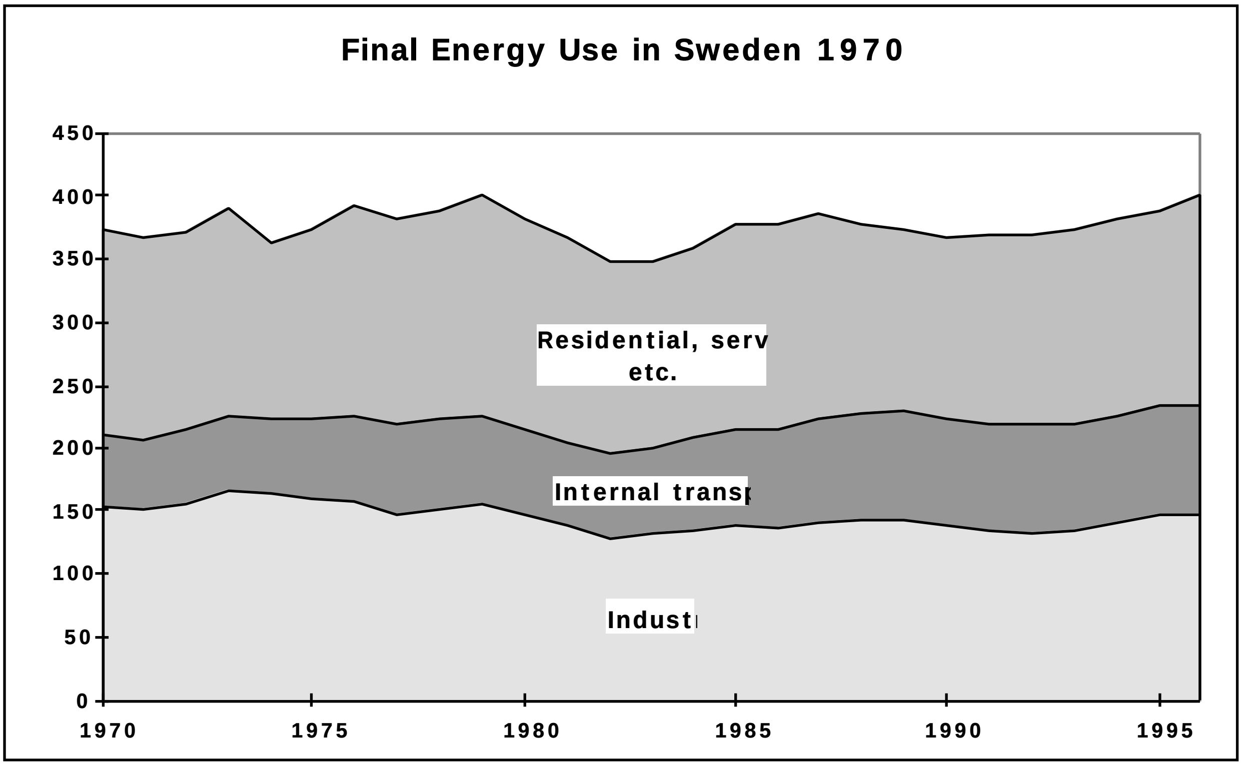
Abstract

The CO_2 reduction and the CO_2 mitigation cost, when fossil fuels are replaced by forest fuels, varies for different fossil fuels and energy systems. Power plants burning natural gas have a low fuel-cycle CO_2 emission, high conversion efficiency and low investment costs. Thus, the CO_2 reduction is typically lower and the mitigation cost higher when natural gas-fired power systems are replaced by biomass systems, compared with when oil- or coal-based systems or heat production systems are replaced. The replacement of transportation fuels, however, is more costly and results in a lower reduction of CO_2 due to high conversion losses and costs when forest fuels are converted to transportation fuels. New biomass technology under development, such as integrated gasification and combined cycle technology (IGCC) will increase the CO_2 reduction compared with current technologies. Fossil energy systems with decarbonisation is another option for reducing CO_2 emission. The CO_2 reduction, however, is higher for biomass-fired power plants systems using IGCC technology than for natural gas systems using decarbonisation, as long as the carbon neutrality when recovering forest fuels is above 0.8, but the mitigation cost may be higher.


Total Energy Supply in Sweden 1970
700
600
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995
Nuclear power, los
Nuclear power, gr
Hydro power, gr
Heat pumps in dis
heating plants et
Biofuel, peat e
Coal and coke
Natural ga
Crude oil and
products


Final Energy Use in Sweden 1970
450
400
350
300
250
200
150
100
50
0
1970
1975
1980
1985
1990
1995
Residential, serv
etc.
Internal trans
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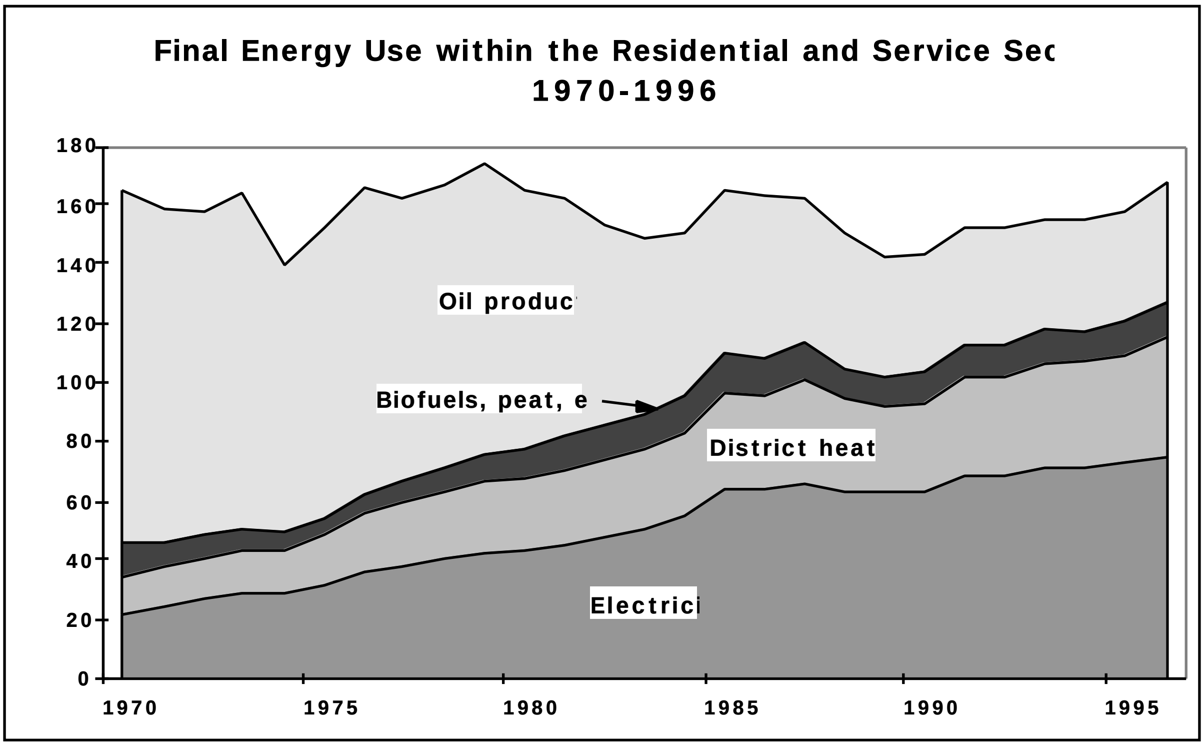
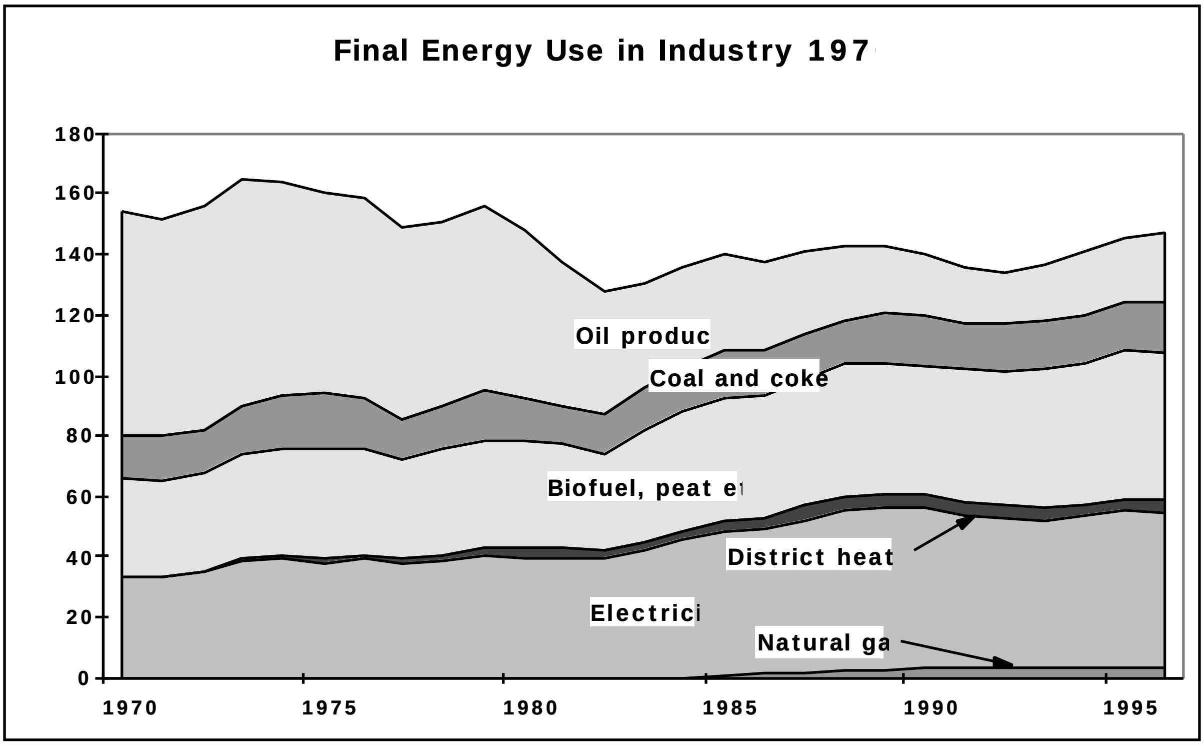
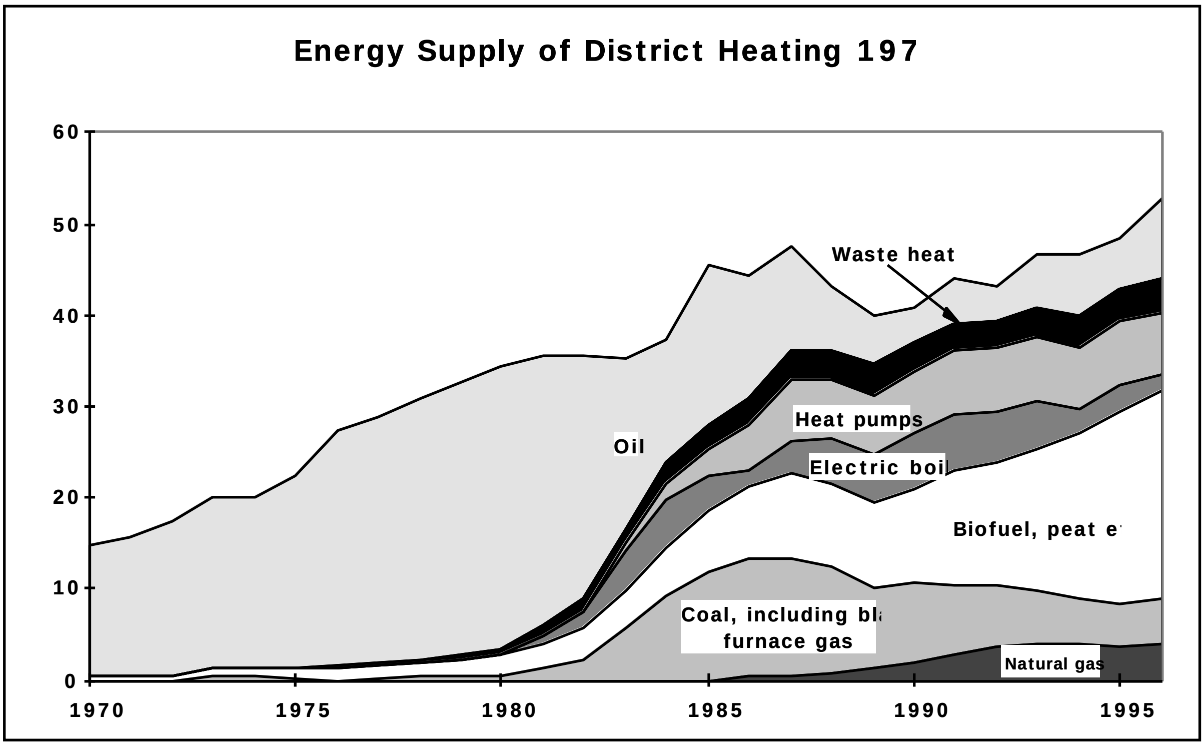
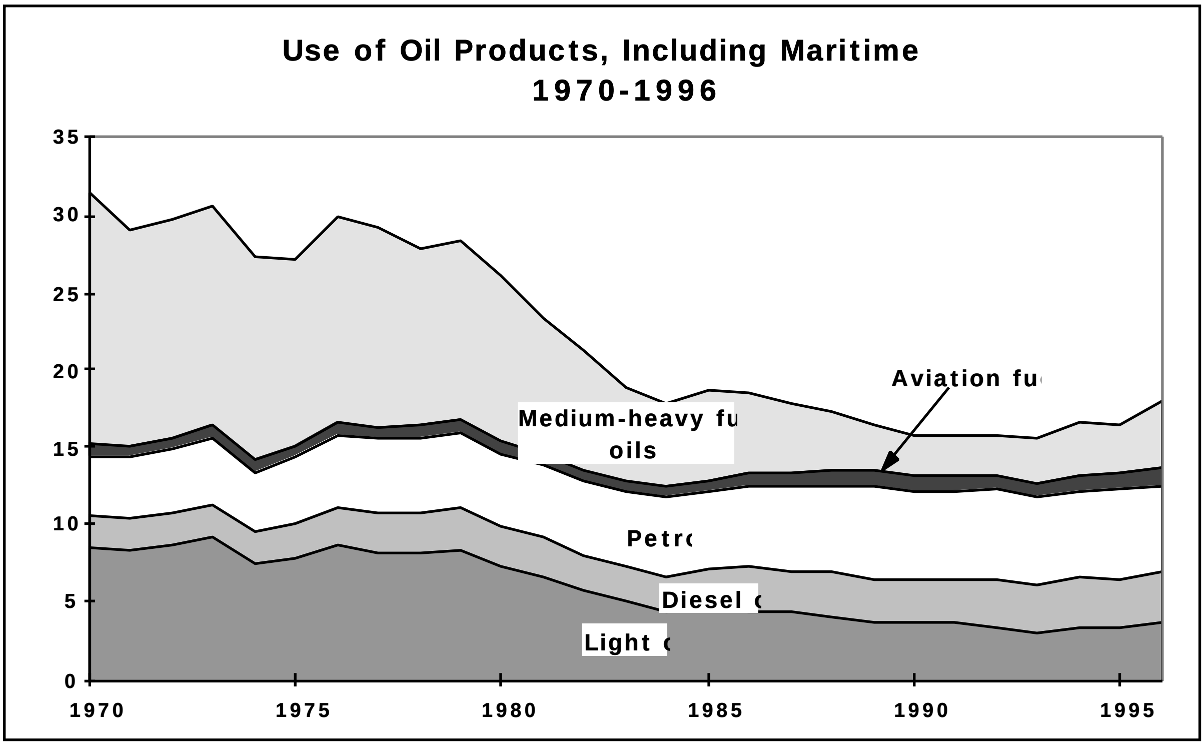
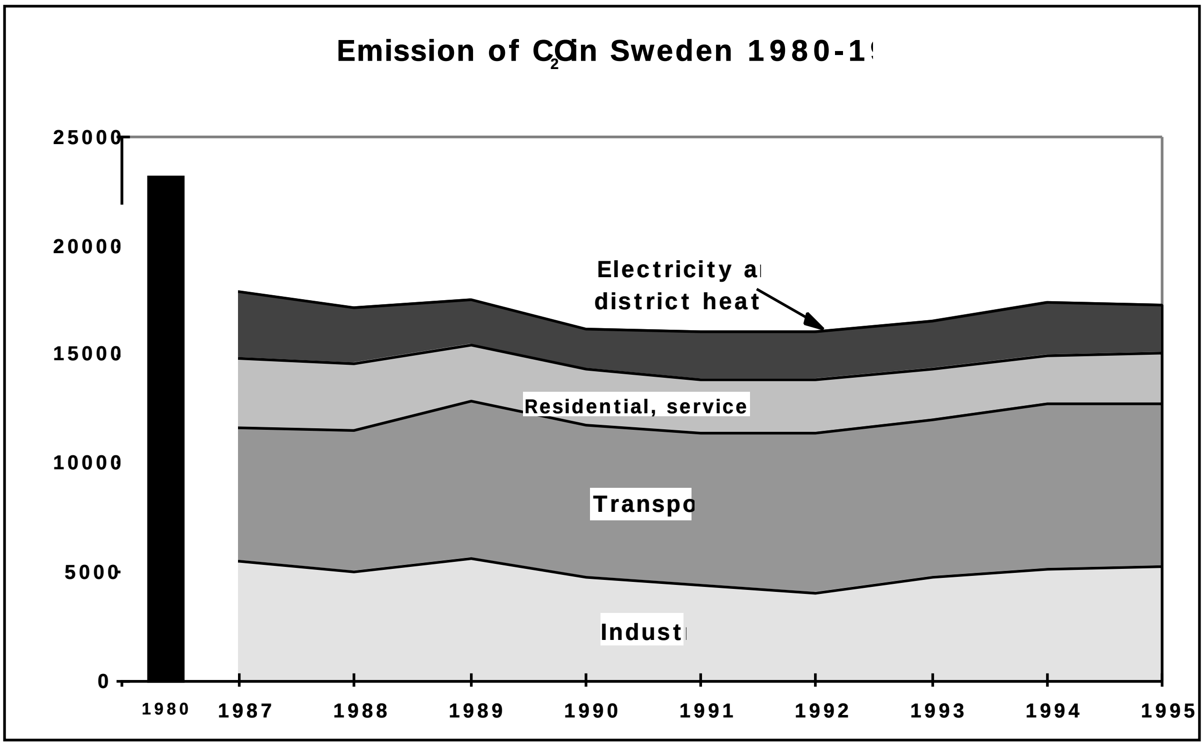

Final Energy Use within the Residential and Service Sec
1970-1996
180
160
140
120
100
80
60
40
20
0
1970
1975
1980
1985
1990
1995
Oil produc
Biofuels, peat, e
District heat
Electrici


Final Energy Use in Industry 197
180
160
140
120
100
80
60
40
20
0
1970
1975
1980
1985
1990
1995
Oil produc
Coal and coke
Biofuel, peat e
District heat
Electrici
Natural ga


Energy Supply of District Heating 197
60
50
40
30
20
10
0
1970
1975
1980
1985
1990
1995
Waste heat
Oil
Heat pumps
Electric boil
Biofuel, peat e
Coal, including bla
furnace gas
Natural gas


Use of Oil Products, Including Maritime
1970-1996
35
30
25
20
15
10
5
0
1970
1975
1980
1985
1990
1995
Aviation fu
Medium-heavy fu
oils
Petro
Diesel o
Light o



Existing energy supply system (base-lines)

A. Old coal-fired power and heat plants

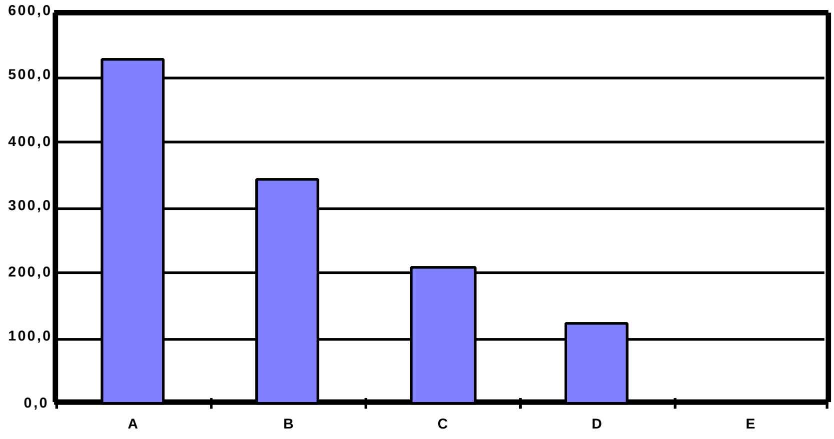
B. Coal-fired power and oil-fired heat plants

C. Natural gas-fired power and oil-fired heat plants

D. Natural gas-fired power and biomass-fired heat plants

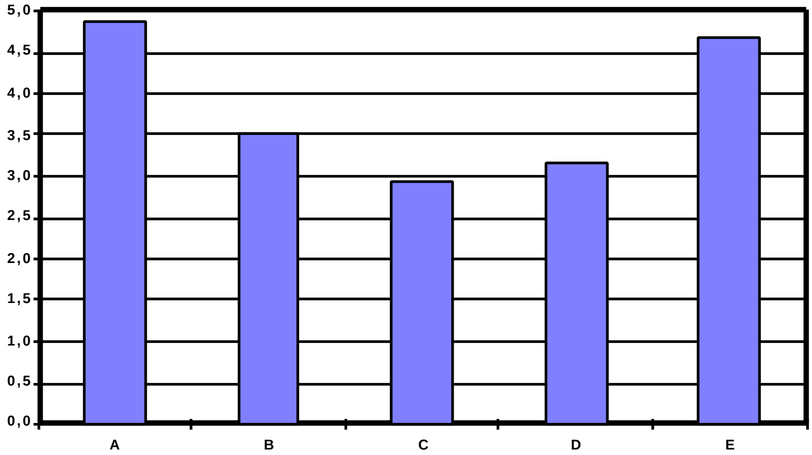
E. Nuclear power and biomass-fired heat plants

Carbon dioxide emissions for the production of 1 MWh electricity and 1 MWh heat different energy systems



A. Old coal-fired condensing and heat plants
B. Coal-fired condensing and oil-fired heat plants
C. Natural gas-fired condensing and heat plants
D. Gas-fired condensing and biomass-fired heat plants
E. Nuclear power and biomass-fired heat plants

Fuel consumption for the prodution of 1 MWh electricity and 1 MWh heat with different energy systems



A. Old coal-fired condensing and heat plants
B. Coal-fired condensing and oil-fired heat plants
C. Natural gas-fired condensing and heat plants
D. Gas-fired condensing and biomass-fired heat plants
E. Nuclear power and biomass-fired heat plants

New bioenergy systems

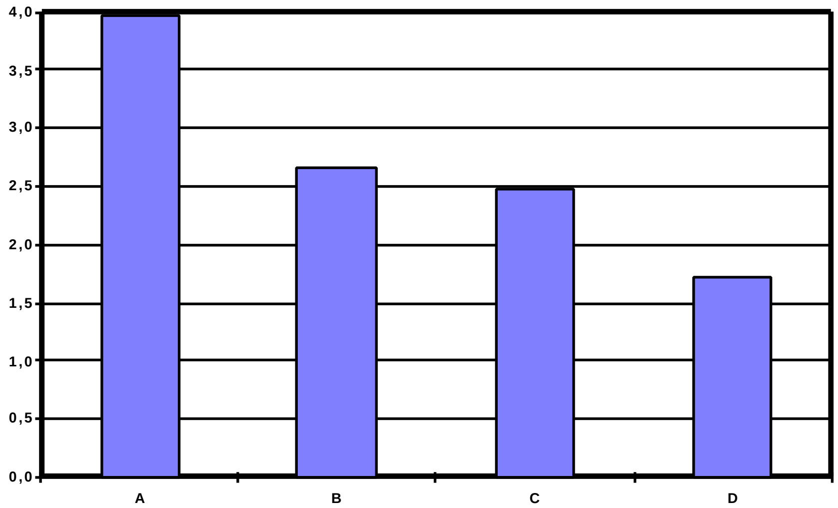
A. Biomass-fired power and heat plants

B. Construct a district-heating system (DHS) with biomass-fired cogeneration plants and biomass-fired power plants

C. Construct a DHS with biomass-fired cogeneration plants using new technology

D. Increase the end-user's energy efficiency, construct a DHS with biomass-fired cogeneration plants using new technology

Fuel consumption for the production of electricity (1MWh) and heat (1MWh) with different bioenergy systems



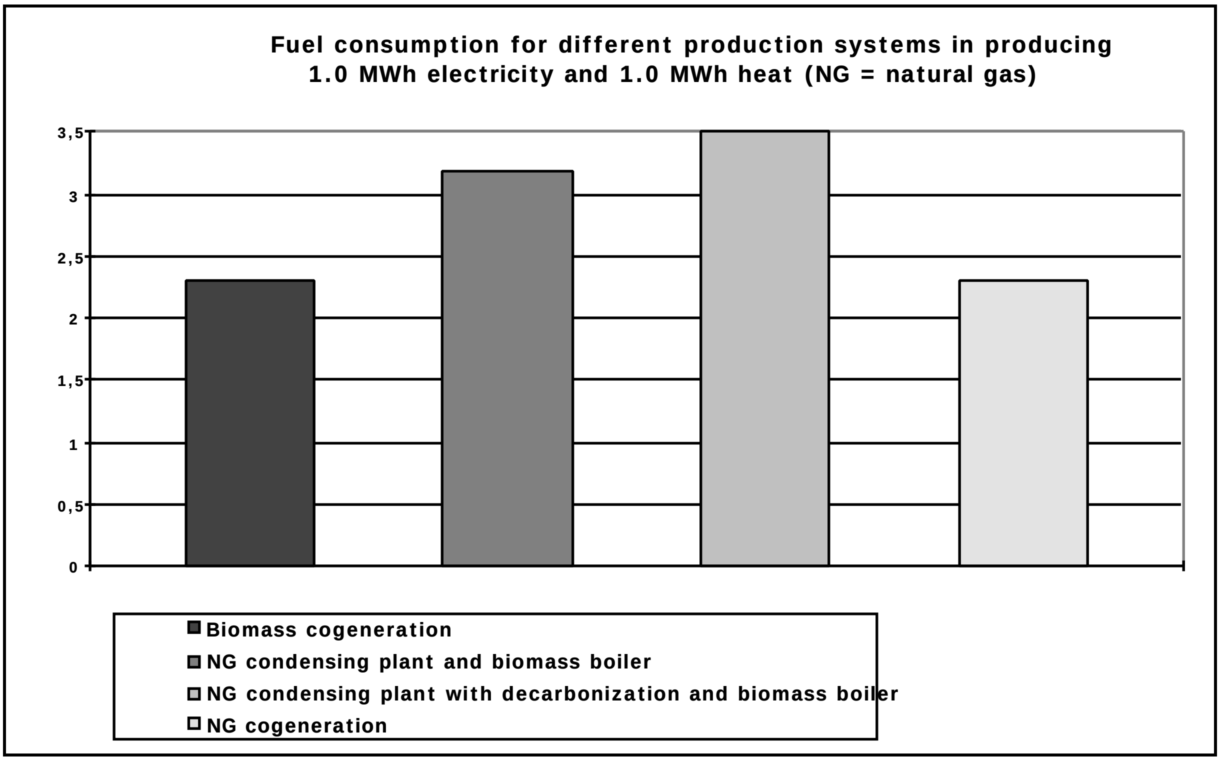
A. Condensing and heat plants
B. District-heating system (DHS) with cogeneration
C. DHS with cogeneration using combined cycle (CC) technology
D. DHS with cogeneration using CC technology & energy efficiency

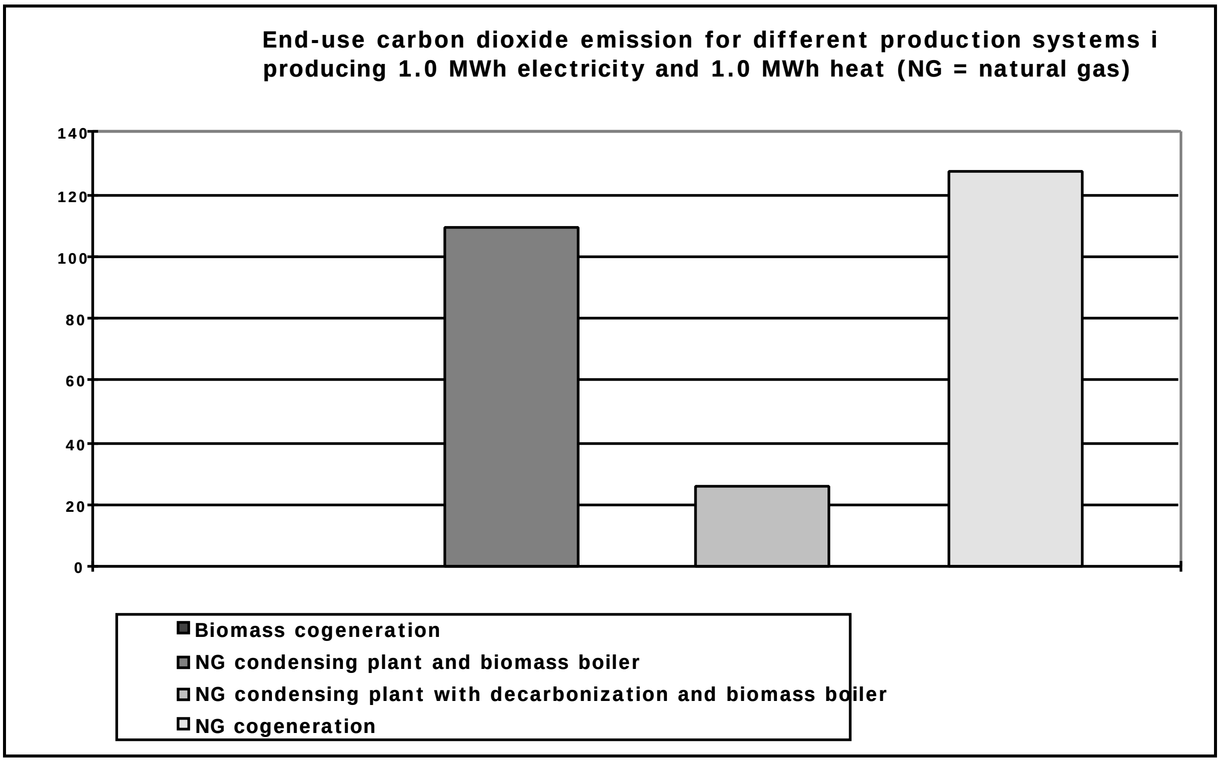
Reduction of carbon dioxide emission in the Swedish context

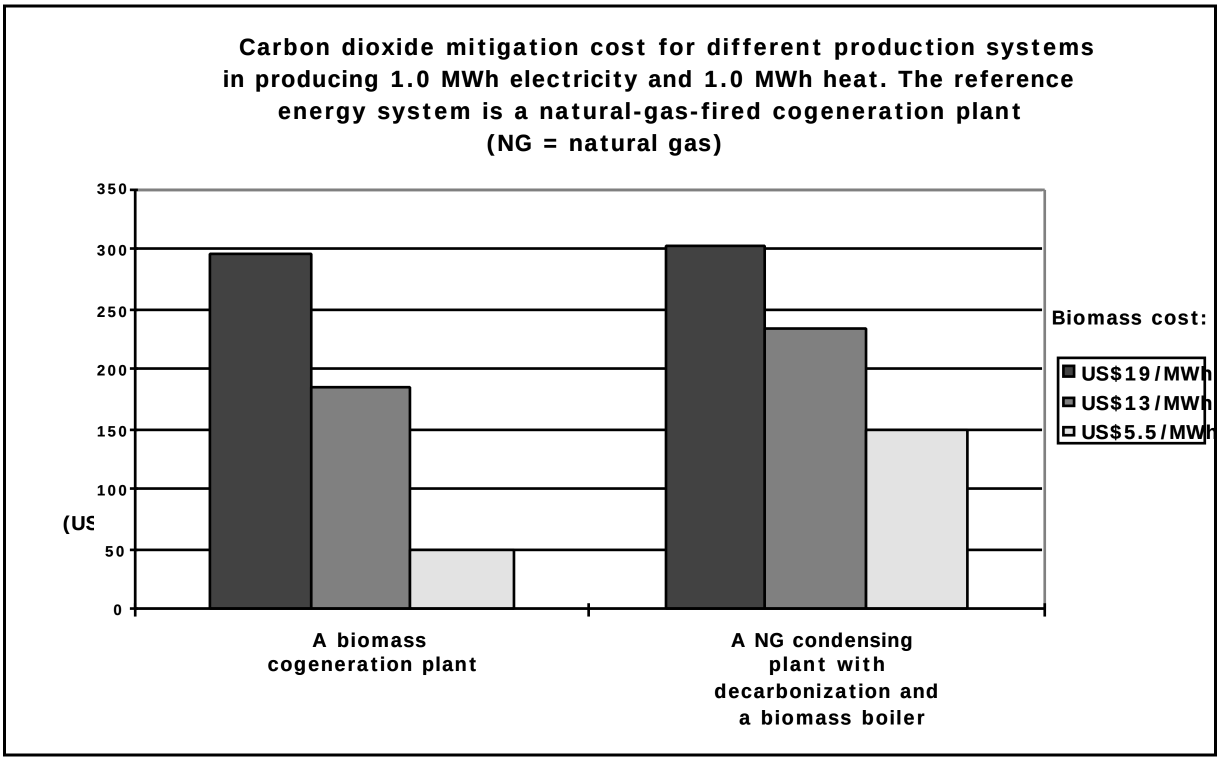
- **Increase the end-user’s energy efficiency**
- **Increase the energy efficiency in the supply system**
- **Increase the use of renewable energy sources (bioenergy, wind power)**
- **Substitute energy intensive materials**
- **Use fossil fuels with decarbonisation**

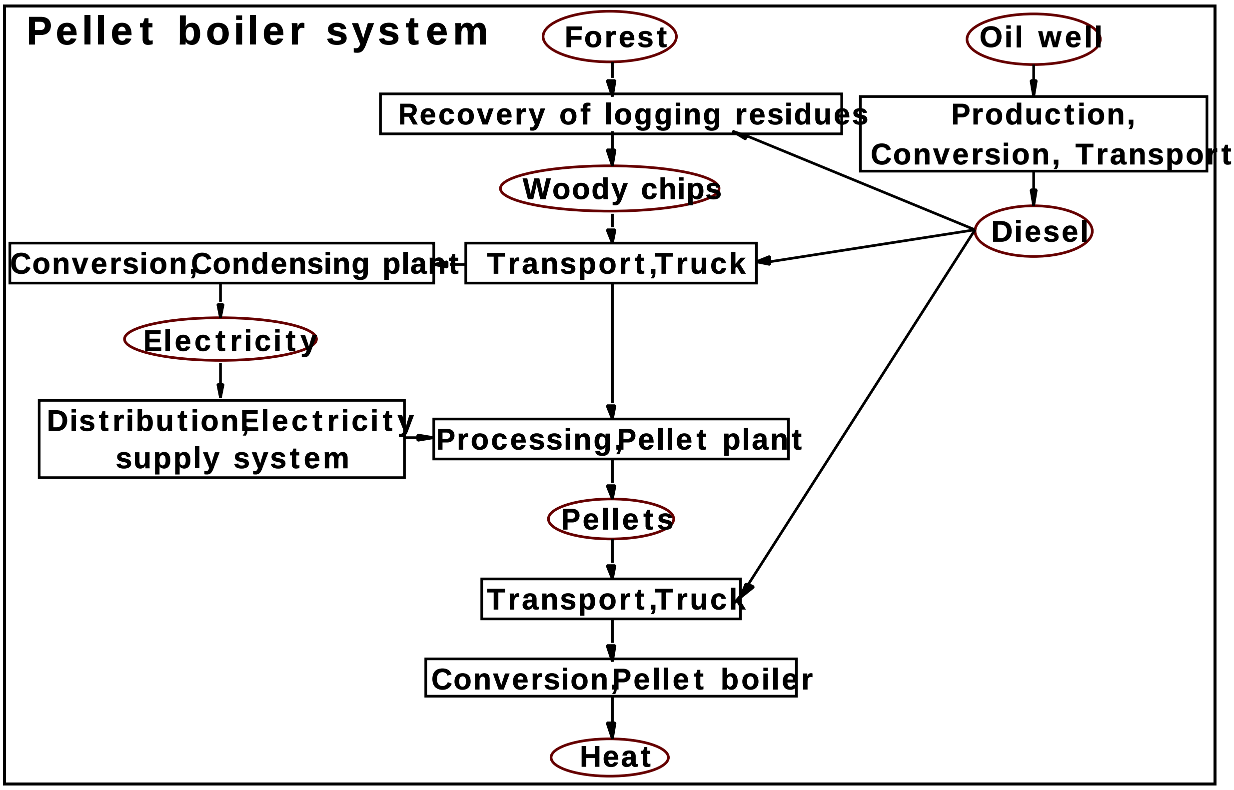
Increased energy efficiency in supply systems

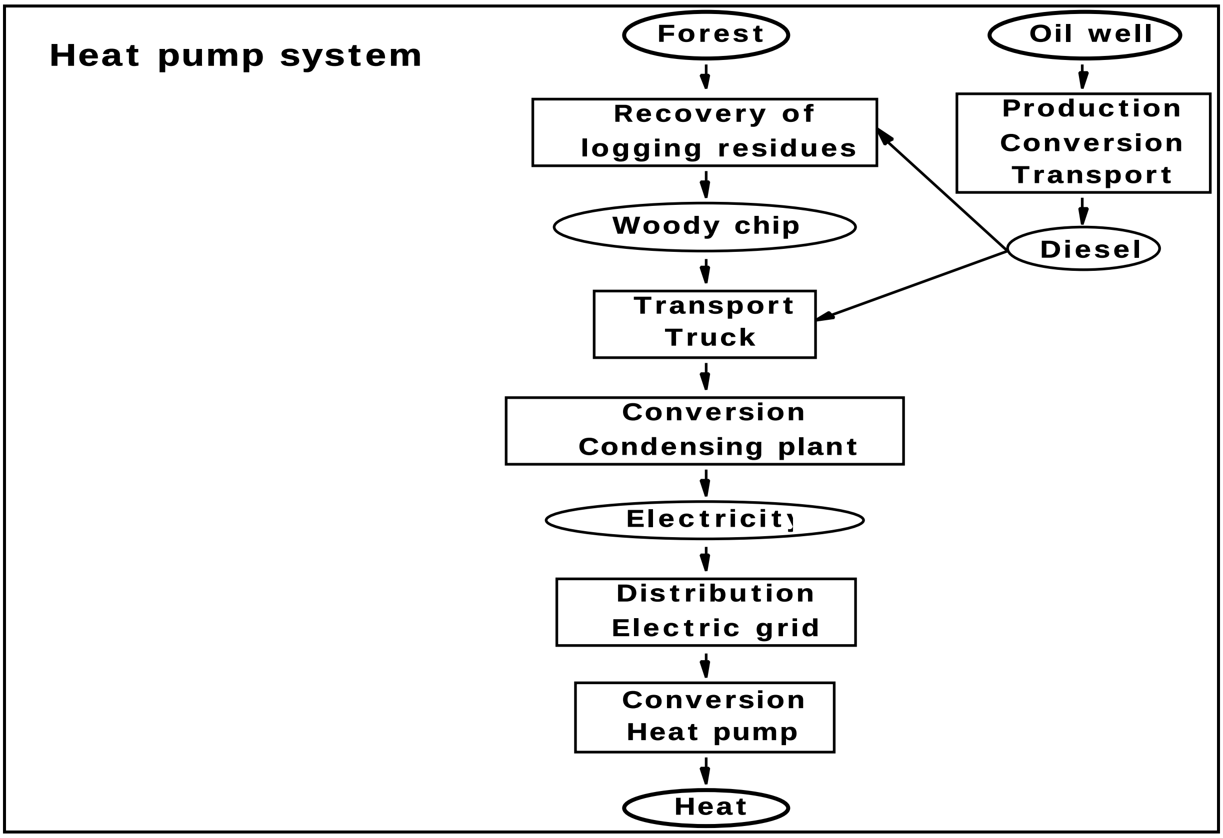
- **Structural changes, extend the use of district-heating systems (DHS)**
- **Produce as much electricity as possible with cogeneration in DHS and in the pulp industry**
- **New biomass technology (gasification and combined cycle technology)**
- **Energy-efficient bioenergy chains for heat production (heat pumps instead of heat boilers when cogeneration is not feasible)**


Fuel consumption for different production systems in producing 1.0 MWh electricity and 1.0 MWh heat (NG = natural gas)
3,5
3
2,5
2
1,5
1
0,5
0
Biomass cogeneration
NG condensing plant and biomass boiler
NG condensing plant with decarbonization and biomass boiler
NG cogeneration

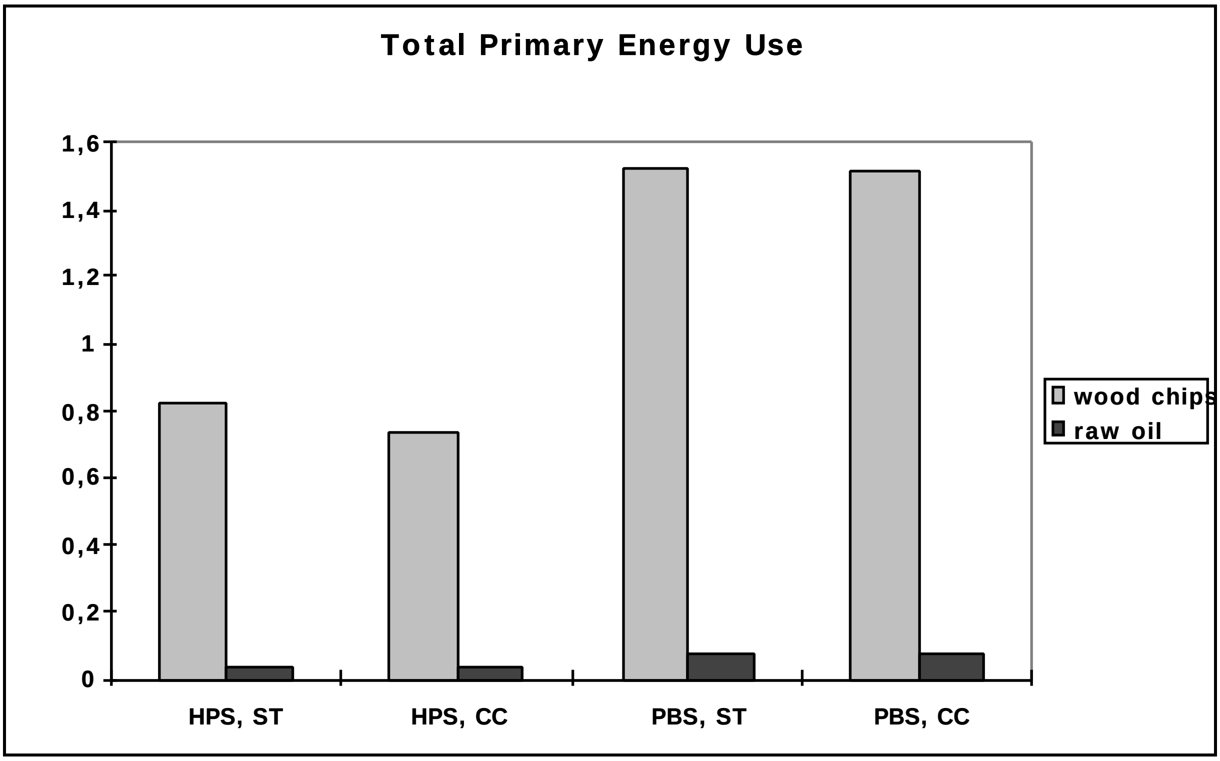

End-use carbon dioxide emission for different production systems i producing 1.0 MWh electricity and 1.0 MWh heat (NG = natural gas)
140
120
100
80
60
40
20
0
Biomass cogeneration
NG condensing plant and biomass boiler
NG condensing plant with decarbonization and biomass boiler
NG cogeneration


Carbon dioxide mitigation cost for different production systems in producing 1.0 MWh electricity and 1.0 MWh heat. The reference energy system is a natural-gas-fired cogeneration plant (NG = natural gas)
350
300
250
200
150
100
50
0
(US
Biomass cost:
US$19/MWh
US$13/MWh
US$5.5/MWh
A biomass cogeneration plant
A NG condensing plant with decarbonization and a biomass boiler


Pellet boiler system
Forest
Oil well
Recovery of logging residues
Production, Conversion, Transport
Woody chips
Diesel
Conversion,Condensing plant
Transport,Truck
Electricity
Distribution,Electricity supply system
Processing,Pellet plant
Pellets
Transport,Truck
Conversion,Pellet boiler
Heat



Heat pump system
Forest
Oil well
Recovery of logging residues
Production Conversion Transport
Woody chip
Diesel
Transport Truck
Conversion Condensing plant
Electricity
Distribution Electric grid
Conversion Heat pump
Heat



Total Primary Energy Use
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
HPS, ST
HPS, CC
PBS, ST
PBS, CC
wood chips
raw oil

Bioenergy and forest industry after the Kyoto Protocol

Kim PINGOUD, Antti LEHTILÄ, and Ilkka SAVOLAINEN

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Abstract

The structure of primary energy supply varies considerably among countries mainly according to indigenous energy resources. The percentage of biomass fuels of total primary energy supply is relatively high in some forest-covered countries like in Austria, Finland and Sweden where the share is close to 15 %. The percentage of biomass-based electricity is in most countries below 3% of total electricity generation, but in Finland about 10 %. This high share in Finland is mainly due to the cogeneration of electricity and heat within forest industry using biomass-based by-products and wastes as fuels. Also for the domestic and tertiary sectors the cogeneration of electricity and heat based on biomass fuels is important. Although the forest industry is a large user of bioenergy, it is also a large user of fossil-based energy, taking into account both own consumption of fossil fuels and the use of fossil fuel-based electricity from the public grid. About 28 % of total primary energy consumption in Finland takes place in forest industry causing about 16% of the total fossil carbon dioxide emissions. The emission reduction requirements shared among the EU countries on the basis of the Kyoto protocol are likely leading to a change in the energy use and production processes within the forest industry. The forest is a renewable source of raw-material and energy, and it can also act as a sink of carbon dioxide. Many other requirements are also given for the forest, e.g. those concerning biodiversity and conservation. There are trade-offs among the raw-material, energy and carbon sink uses of the forests. E.g. in chemical pulping the lignin part of the wood can be used as an energy source, but smaller amounts of end-products are obtained than in mechanical pulping. In a modern chemical pulping plant a surplus of energy can be generated in the pulping process. However, as more wooden raw-material is needed for a given amount of end-products, the increase of the share of chemical pulping would cut down the carbon sink impact of the forests.

Introduction

According to the UN Framework Convention on Climate Change, the atmospheric concentrations of greenhouse gases should ultimately be stabilised at a level that would prevent dangerous anthropogenic interference with the climate system. To attain this objective the emissions of greenhouse gases should be limited considerably. Countries differ from each other in their potential for reducing emissions and in the economic consequences of emissions limitations. This is due to their different natural conditions and resource base, energy systems, and economies, including historical development and wealth.

The Intergovernmental Panel on Climate Change (IPCC 1996a, 1996b) gives the following generic technology options for the reduction of fossil fuel CO_2 emissions: 1) improvement of energy efficiency in industry, transportation, and the commercial/residential sector, 2) improvements in efficiency of fuel conversion (e.g. combined heat and power (CHP) production and more efficient generation of electricity), switching to less carbon-intensive fuels, and switching to renewable sources of energy. In addition, the IPCC lists others, e.g., increased use of nuclear energy, and capture and disposal of CO_2 emissions from fossil fuel utilisation.

The objective of the present paper is to give an outlook of bioenergy use in various countries and to assess the potentials and limitations of enhanced use of bioenergy for mitigation of greenhouse gas emissions especially in Finland. The results concerning the comparison of energy use in different OECD countries — presented in this paper — are from the study by Lehtilä et al. (1997).

Factors affecting energy use and CO_2 emissions in some countries

The structure of primary energy supply in some countries is presented in Figure 1. Certain countries, e.g. Norway or Sweden, have abundant domestic hydropower resources while some others rely to a high degree on domestic or imported fossil fuels. With respect to nuclear power the national policies differ significantly, France and Sweden utilize it very much, and some others such as Austria or Denmark not at all in domestic energy supply.

The structure of energy consumption also varies among countries (Figure 2). In some countries, as in Finland, the percentage of energy use in industry is large, due especially to energy-intensive industries such as manufacturing of pulp and paper and both ferrous and non-ferrous metals. In some other countries the relative weight in energy consumption is in the residential/commercial and transport sectors. In the case of Finland, about 90 % of the paper produced is exported, such that Finland provides paper for an average population ten times larger than its own. This is a result of economic development based on the utilisation of natural resources.

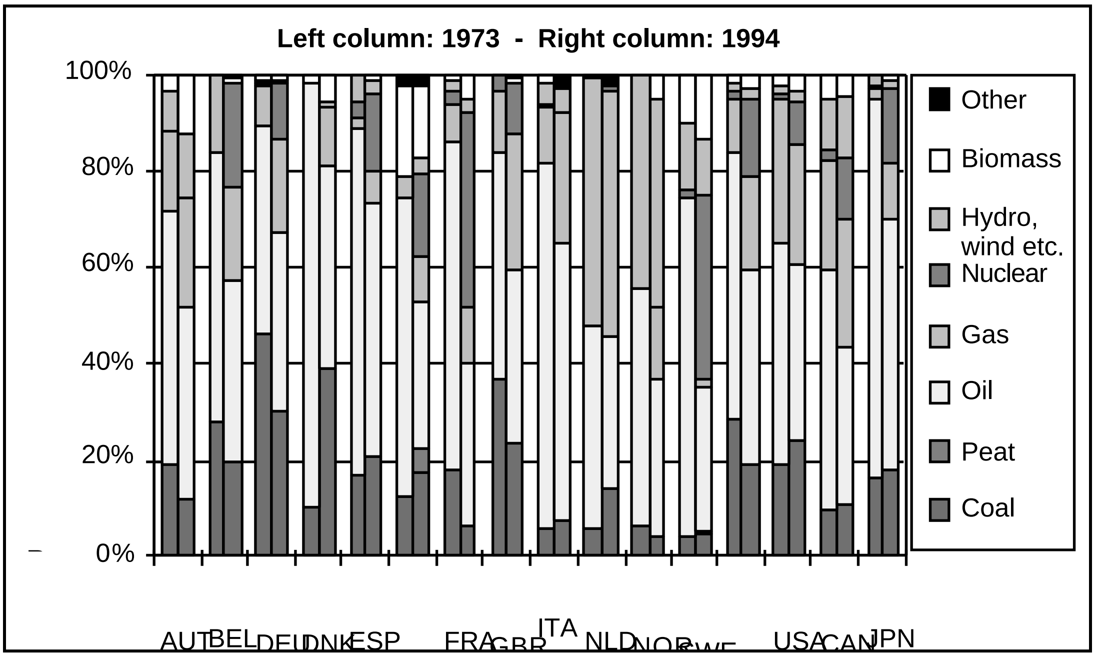

Figure 1. Structure of primary energy supply by energy source in selected OECD countries in 1973 and 1994, according to IEA methodology (Lehtilä et al. 1997).

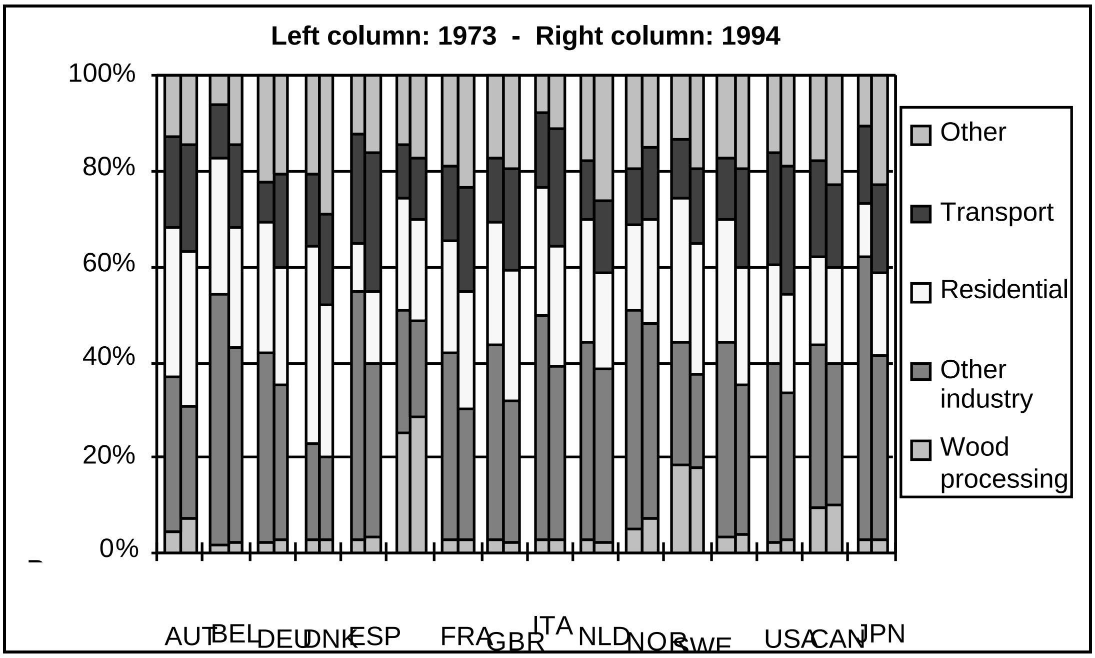

Figure 2. Structure of energy consumption by energy end-use sector in selected OECD countries in 1973 and 1994. All primary energy allocated to end-users of energy (Lehtilä et al. 1997).

With regard to the utilisation of biomass for energy, Finland has been the leading country in western Europe throughout the period studied, 1960–1995. Furthermore, while even in many developed countries a major proportion of the biomass use has been so-called traditional firewood, in Finland most of the utilisation has long occurred in state-of-the-art cogeneration plants. In 1994, biomass accounted for about 15% of the total primary energy in Finland, which was about five times as much as the average in the EU or in the USA. A comparison of the utilisation of biomass for energy is presented in Figure 3 for selected OECD countries.

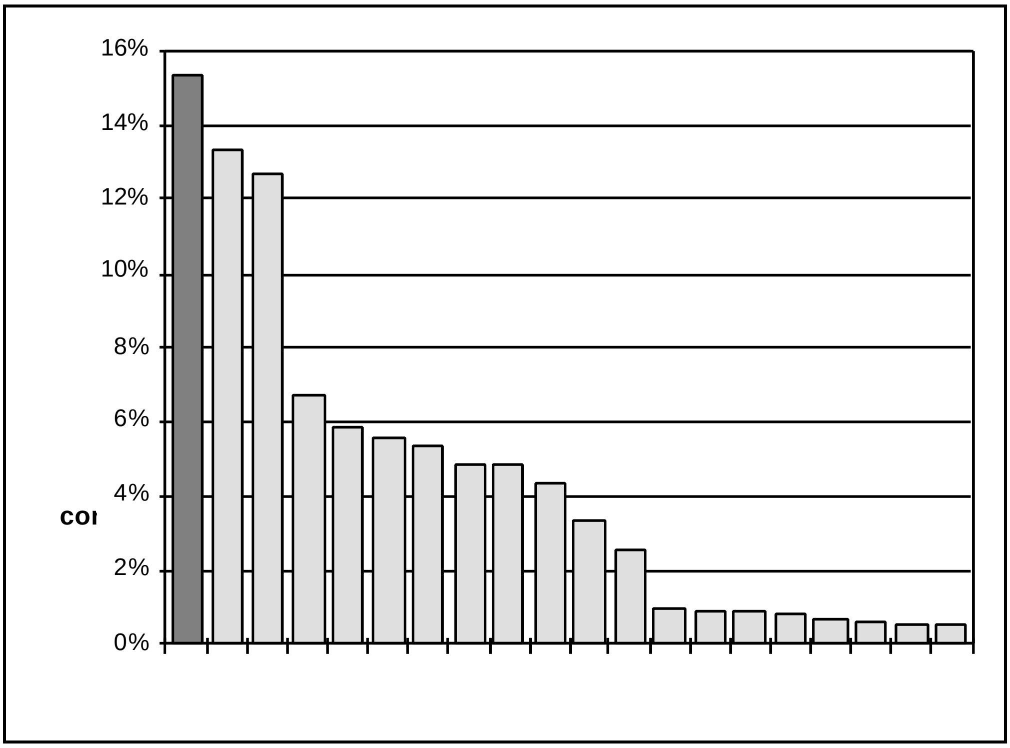

Figure 3. Share of biomass fuels of total primary energy consumption in selected countries in the year 1994 (Lehtilä et al. 1997).

Power and heat generation

The structure of electricity generation by energy source is shown in Figure 4 for selected OECD countries. Countries with a very high reliance on fossil fuels in power production include Denmark, Greece, and Ireland. Apart from the much larger use of biomass, Finland appears to have a production structure almost similar to the average over EU. However, it should be pointed out that this figure does not show anything about the technologies used for electricity generation, but only the energy sources.

Table 1 presents a summary of the estimated specific emissions in the year 1994 for Finland, EU, the USA, and the OECD as a whole. Despite the seemingly similar structure by energy source in Finland and in the EU, the Finnish electricity sector appears to be much less carbon intensive.

There are two important reasons for this difference: The very important role of combined heat and power (CHP) production, and the exceptionally large use of biomass for thermal power generation in Finland. With its high total energy efficiency (80%–90%) and low distribution losses, combined heat and power can improve the overall efficiency of the power generation sector considerably.

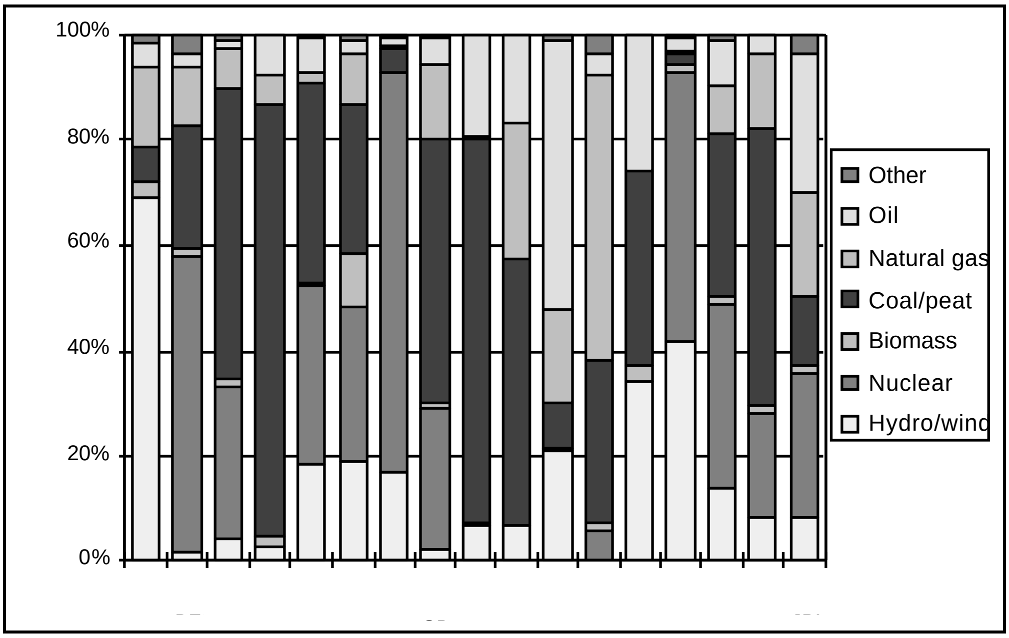

Figure 4. Electricity generation by energy source in selected countries. Per cent shares of gross electricity output (Lehtilä et al. 1997).

Table 1. Average specific CO_2 emissions from electricity generation in Finland and other OECD countries in the year 1994 (Lehtilä et al. 1997).

	Finland	**EU**	**USA**	**OECD**
g CO_2 / kWh	260	405	615	480

Reducing the CO_2 emissions from electricity generation by increasing the use of renewables is a high-priority policy target in many countries. Most of the hydro resources are already fully utilized in European countries, including Finland. Therefore, in the medium term (10–30 years), significant additional potential can mainly be identified in biomass fuels and wind energy.

In Figure 3 it was already shown that biomass fuels have in many countries an important contribution to the primary energy supply. Nevertheless, in power generation biomass has in most countries still only little role. At present, the only developed country with significant biomass-based power generation is Finland. In Finland biomass accounts for as much as 10% of the total electricity generation. The second largest shares are in Portugal and Austria, which both reach a penetration of about 3%. In all other countries, biomass accounts for 2% or less of the total electricity generation. The average in EU countries was only 1.2% in the year 1994.

With reference to the overall percentages shown in Figure 5, Finland is at present the leading country in utilisation of renewable biomass or wind energy for electricity generation. Biomass is mainly used in advanced fluidised-bed combustion (FBC) CHP plants, or in recovery boilers utilizing waste liquors from pulping.

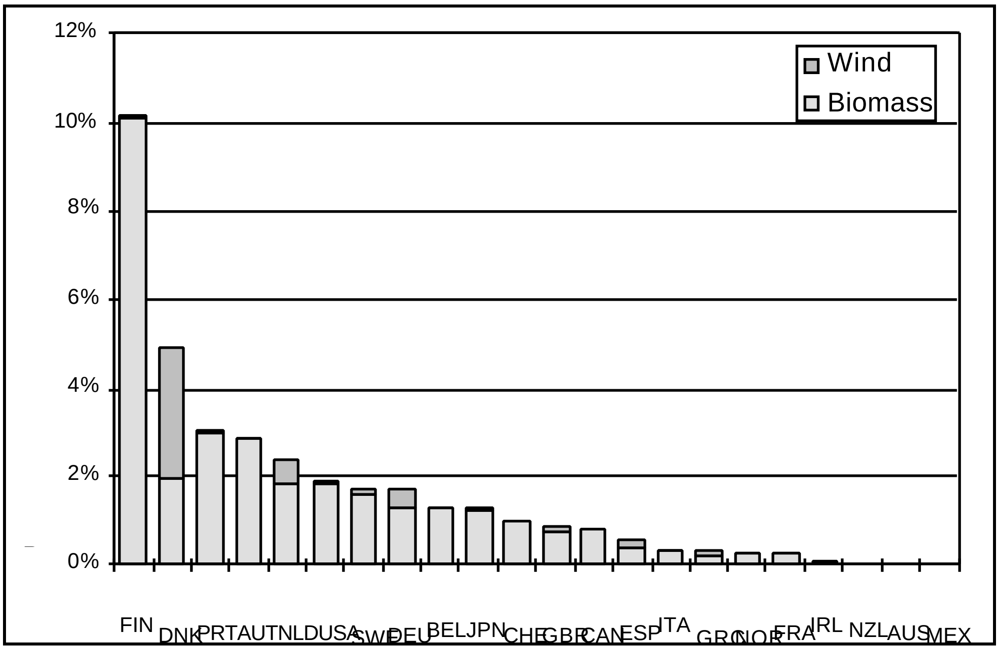

Figure 5. Share of biomass and wind based electricity production of total electricity generated in selected countries (biomass share in 1994, wind in 1995) (Lehtilä et al.1997).

The present share of cogeneration of the total electricity generation is shown in Figure 6 for all EU countries (excluding Luxembourg). The total shares of CHP are based on a comprehensive review published in 1997 (Cogen 1997). As to the estimated split of cogeneration into industrial and district/small scale generation, data from several recent sources have been used (Cogen 1997, Euroheat 1996, IEA 1996a). In terms of per capita generation of electricity in CHP systems (in full CHP mode), Finland is clearly the leading country in Europe.

With regard to the overall contribution of CHP to the total national electricity generation, the average share over all EU countries is about 10%. Denmark has achieved the highest share of 40%, while Finland is second with a share of 34%. Three other countries, Netherlands, Austria, and Germany, have also achieved a position well above the EU average. In general, industrial CHP appears to have a more prominent role than district or small-scale CHP. Industrial schemes account for about 60% of the total CHP generation within EU. The few countries where district/small scale CHP dominate, are Denmark, Finland, Austria, and Sweden.

It has been estimated that the overall share of CHP in the electricity generation of the EU countries could be increased to about 30% during the next decades (Cogen 1997). This would mean a huge potential for additional CHP generation within the EU.

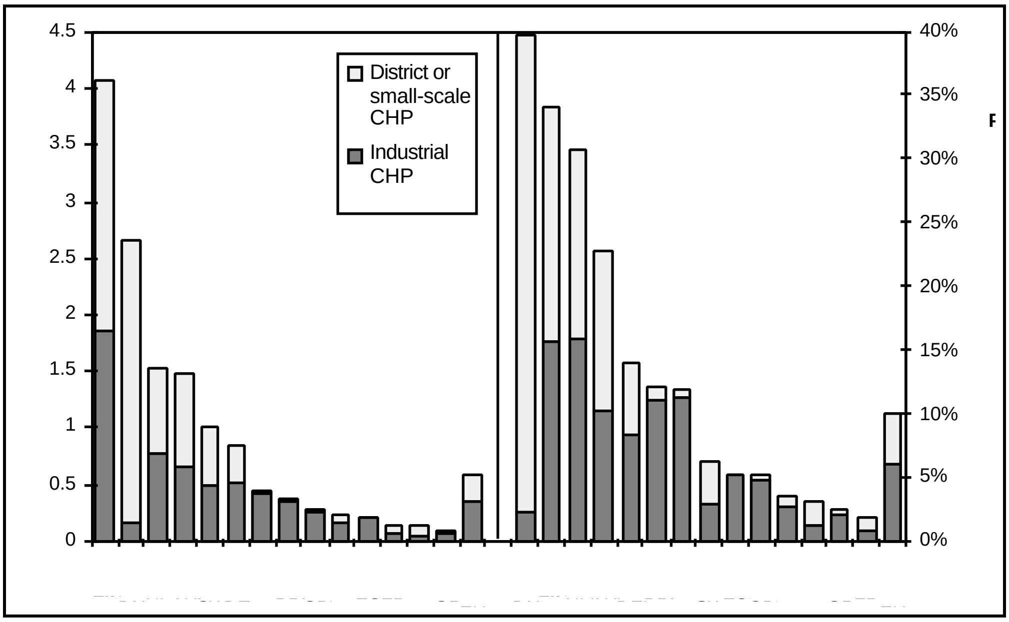

Figure 6. Share of cogeneration of total national electricity generation in EU countries (Sources: Cogen 1997, Euroheat 1996, IEA 1996a).

However, the potential can be assessed to be most significant in countries which today have a relatively low CHP share. In Finland, on the other hand, about 80% of all the heat loads served by plants of 1 MW size or above are already being utilized for CHP, and further potential is thus quite limited.

Wood processing industries and the greenhouse impacts of the forest sector in Finland

The wood processing industry uses roundwood harvested from forest ecosystems to produce sawn goods and wood-based panels in wood-products industries, and fiber products in pulp and paper industries. Wood processing industry in Finland uses more than half of the total energy consumption of the industries. As shown in Figure 2 its percentage of the total energy consumption in Finland was about 28 % in 1994 and of CO_2 emissions about 16 %.

The forest industry uses, to a large extent, wood as an energy source, not as raw material only. About half of the roundwood is used in manufacturing of sawn goods and wood-based panels, and the rest in manufacturing of pulp and paper. Pulp is produced by using mechanical or chemical processes. In mechanical pulping more of the mass of the wood raw material can be utilized for end-products than in chemical pulping, but externally produced energy is needed. In chemical pulping the lignin part of the wood can be utilized as a source of energy, and a smaller amount of end-products is obtained, but in a modern plant, energy can be generated even more than needed in the pulping process.

Figure 7 gives an overview of the Finnish forest industry energy use divided into external energy (fuels and electricity) input to the industry system and into energy generated within the system using by-product fuels like wood waste and black liquor. The numbers are for the whole wood processing industry, including the manufacturing of sawn timber and panels as well as pulp and paper. About two thirds of the fuel use within the forest industry is based on by-products and waste, and more than one third of the electricity consumed is generated within the industry, mainly using by-product and waste fuels. Energy statistics consider these almost totally as primary energy use, although they can to a large extent also be seen as internal energy flows of industrial processes. The fuels are usually efficiently utilised in cogeneration of heat and electricity for the processes.

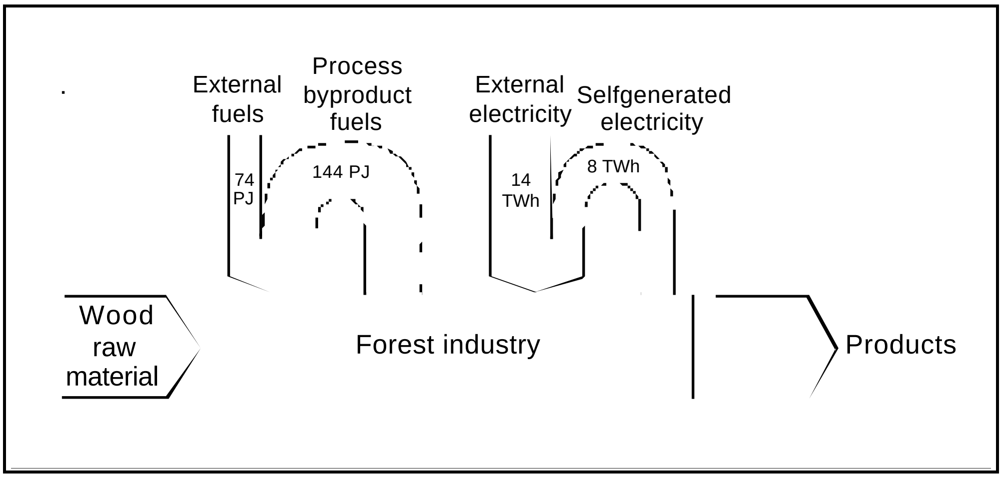

Figure 7. Flows of energy and raw material supply in the Finnish forest industries in the year 1994 (Lehtilä et al. 1997).

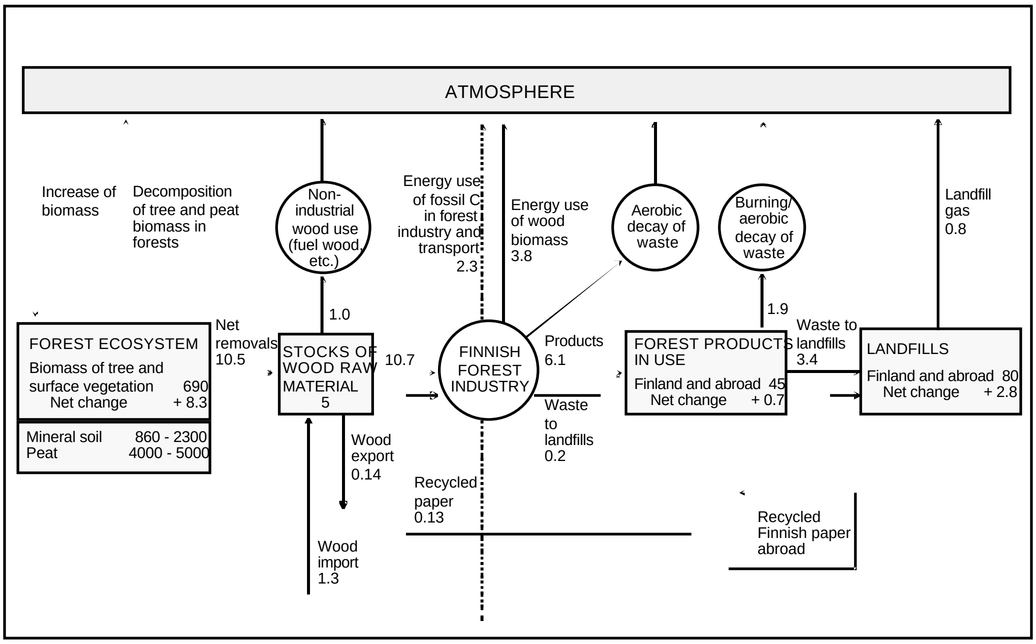

Figure 8. Carbon reservoirs (Tg C) and fluxes (Tg C a^{-1}) of the Finnish forest sector in 1990 (Pingoud et al. 1996).

Forest ecosystems exhibit significant carbon exchange with the atmosphere through photosynthesis and respiration processes. The area of forest and scrub land in Finland is about 23 million hectares.

Forest ecosystems also act as a significant storage of carbon. The carbon storage and flows of the total forest sector in 1990 are depicted in Figure 8 in the case of the Finnish forest industries. The biomass of the tree and surface vegetation of the forest ecosystems in Finland form a considerable storage of about 690 Tg C (Pingoud et al. 1996, MoE 1997). The growth of the forest exceeded the drain considerably and the carbon storage increased by about 8 Tg C in 1990. Figure 9 shows the development of the carbon balance of the biomass of the Finnish forest ecosystems; after about 1970 the forest growth has been clearly greater than the cuttings and natural drain (Kanninen et al. 1993).

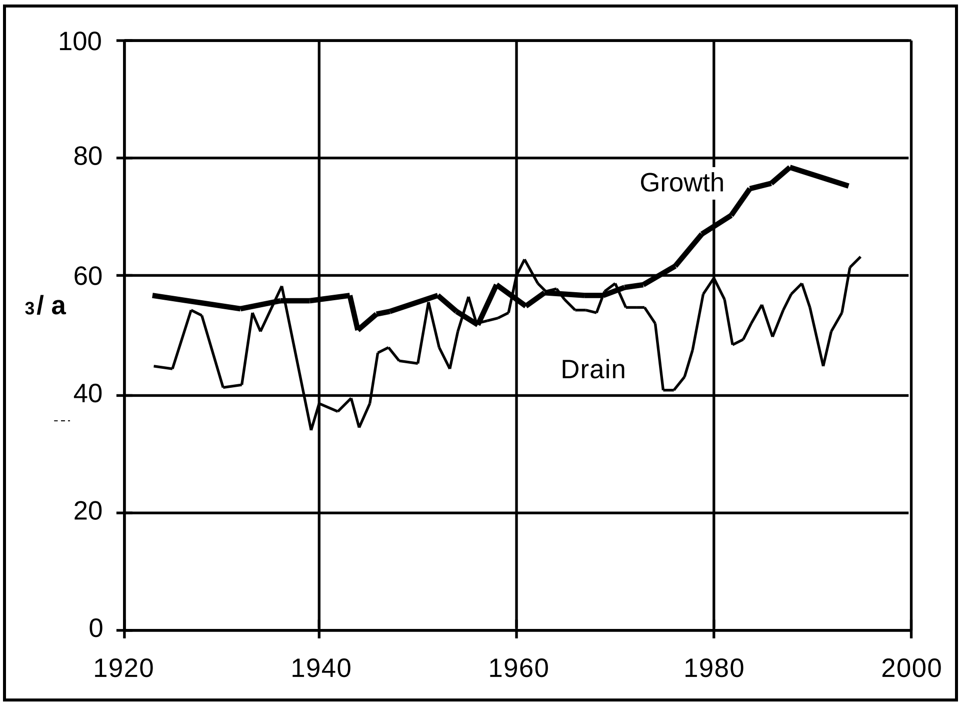

Figure 9. Annual growth of stemwood volume, and drain due to fellings, silvicultural measures and natural mortality in Finland during the years 1923–1995 (Kanninen et al. 1993 and Forest Research Institute 1996).

Potentials of decreasing the greenhouse impacts of the forest sector

The Kyoto Protocol limits the fossil CO_2 emissions and gradually also the carbon sinks of forest ecosystems will be presumably included to the greenhouse gas balance of the parties. This will also have consequences for use of bioenergy. The forest industries in Finland is considered as an example in the following.

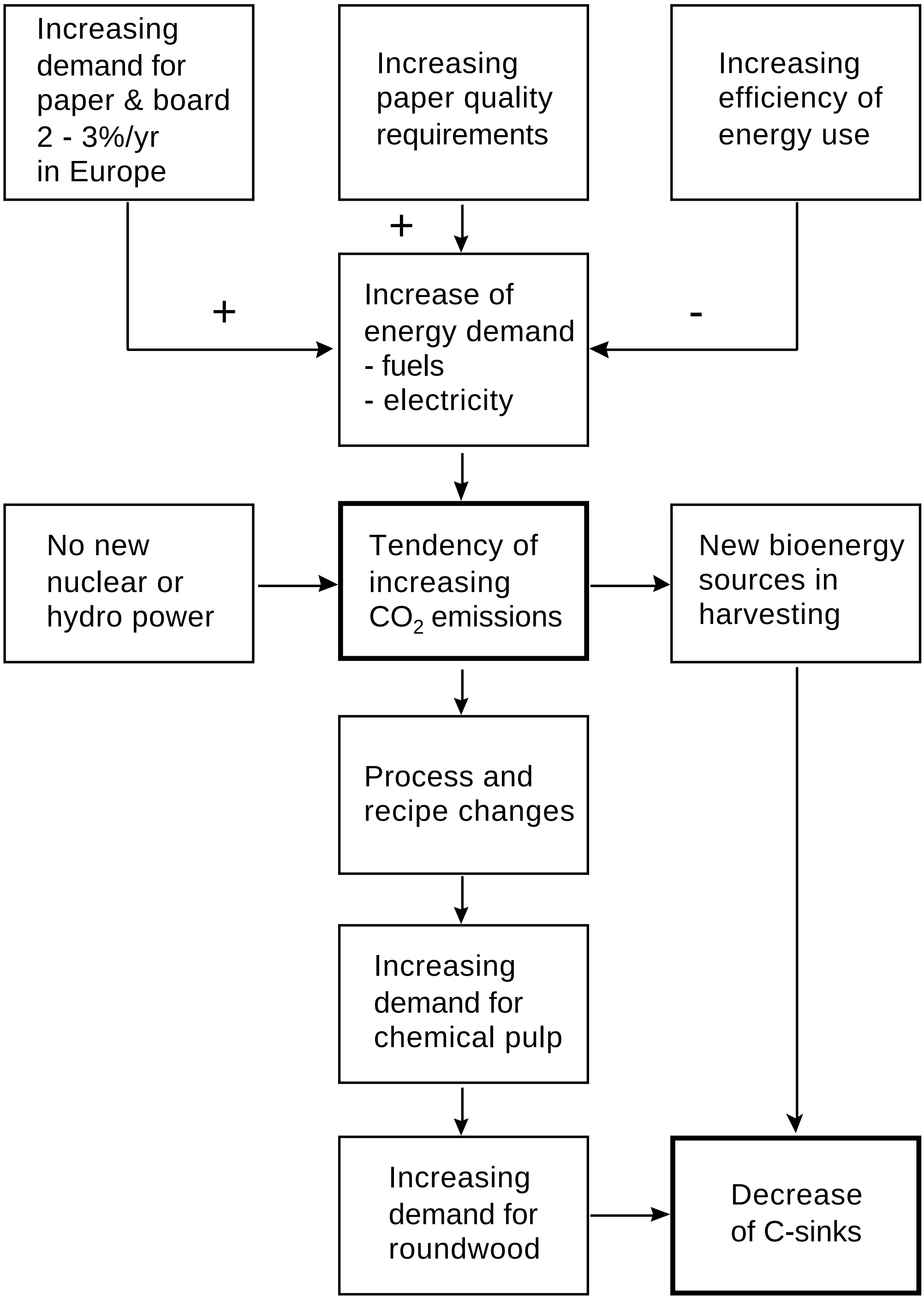

Figure 10. The dilemma of the Finnish pulp and paper industries in limiting the greenhouse impacts.

The problems of Finnish pulp and paper industries in reducing its greenhouse impacts are illustrated by Figure 10. The chemical wood processing is economically more important than the mechanical one bringing about 80 % of the export income of the whole forest industries in Finland. At present there is a 2-3 % annual increase in the demand for paper and board products in Europe, which results in a similar trend of increasing paper production in Finland, and consequently also the energy and roundwood consumption increases if no process changes take place. The continuous improvement of paper (and pulp) quality seems likewise rather increase than decrease the energy demand of pulp milling through the increase of specific energy consumption. However, there still are some potentials of increasing energy efficiency of the energy production in forest industries.

The historical development of the chemical wood processing in Finland has led to a strong position to the manufacture of mechanical pulp and high-quality paper grades based on it. The relative low price of electricity related to the price of roundwood together with a good raw material base of spruce roundwood have formed the boundary conditions for the development. Although Finnish forest stand covers only about 0.5 % of the forests in the world, the share of Finnish paper and board exports from the international imports is about 15 %. Finnish forest industries are in leading position in some paper grades based on mechanical pulp. The use of wood raw material in paper manufacture can be relatively low nowadays, taking also into account the amount filler materials which can be about 40% in some paper grades.

As mentioned earlier, in mechanical pulping the specific consumption of wood is lower but the external electricity demand is high. Chemical pulping uses much more wood raw material, but the external energy demand is low and is replaced by wood based bionergy, because the lignine part of the wood is utilised in the form of black liquor as process energy. In modern chemical pulp mills electricity can even be sold out. These differences between chemical and mechanical pulping are illustrated by the examples in Table 2.

Table 2. Raw material and net energy demand of pulp milling, some examples (Malinen et al. 1993).

	Chemical pulp		Mechanical pulp		Recycled
	Softwood[1]	Hardwood[2]	PGW[3]	TMP[3]	DIP[4]
Raw material					
- pulpwood (m^3/ADt)	6.3	4.6	2.8	2.8	
- recycled f. (t/ADt)					1.1
Fossil fuel (GJ/ADt)	1.6	1.5			5.3
Electricity (MWh/ADt)			2.2	3.1	0.25
Excess heat (GJ/ADt)				4.4	
Electricity sold out (MWh/ADt)	0.31	0.25			

ADt = air dry tonne (moisture content 10%). 1) CGF18, 2) CGF12, 3) Freeness=45, peroxide bleaching, 4) peroxide bleaching.

Table 3. Examples of specific energy consumption of some production processes in the forest industries.

	Heat to process GJ/ADt	Electricity to process MWh/ADt
Chemical wood processing		
Chemical pulp[1]		
- softwood (CGF18)	14.5	0.89
- hardwood (CGF12)	12.5	0.78
Mechanical pulp[1] (Freeness=45, peroxide bleaching)		
- PGW	0.2	2.3
- TMP	-4.4	3.2
De-inked pulp (recycled)[1] (peroxide bleaching)	4	
Paper mill[2]	4.8—7.3	0.58—0.78
Mechanical wood processing[3]		
Sawmilling (per m^3)	1.2	0.085
Plywood (per m^3)	5.7	0.3
Chip board (per m^3)	2.7	0.19
Wood fibre board (per t)	7—10	0.6—1.2

1) Malinen et al. 1993, 2) Timonen 1995, 3) Myréen, Anhava 1992

Nuclear power has been an important source in the electricity supply of mechanical pulping. The potentials for new hydropower in Finland are limited. When no new nuclear power will be built, the only realistic alternatives of escaping an increase of CO_2 emissions due to the increasing energy consumption in forest industries are 1) to increase the use of new energy sources of forest waste wood or 2) to change the processes and pulp recipes of paper grades in a way that causes less fossil CO_2 emissions. The latter alternative is possible by increasing the use of chemical pulping (and similarly increasing the use of pulpwood) .

Both cases above result in a decrease of carbon sink in the forest ecosystems. As can be seen from Figure 9 the growth may already be decreasing simultaneously with the increasing drain. The quantitative limits for sustainable forestry are quite close.

Concluding remarks

When considering the total greenhouse balance of the forest industries and forestry in Finland, including both the CO_2 emissions and the carbon sinks, we are faced with a difficult multicriteria decision and optimisation problem. The Finnish forest industry is important for the export income and employment, and it is the greatest bioenergy user in Finland. Because of the efficient harvesting and transportation logistics for roundwood, the large scale integrated plants of the forest industries seem to have the best potentials for bioenergy utilisation in Finland. The biofuels (black liquor, bark, chips etc.) are produced as a by-product of a more valued production process and no additional harvesting logistics is needed. On the other hand, chemical wood processing is very energy intensive (illustrated in Table 3) and one could always ask why the bioenergy could not be applied in a more useful way than producing such short-lived products. The trend of increasing specific energy consumptions in the manufacture may even continue, due to the maximisation of the optical, printing and other quality requirements of paper.

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The effect of land use practices on greenhouse gases

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Abstract

Data are presented for New Zealand on carbon stocks and flows for different land uses, at the single-hectare scale. Included are the carbon in vegetation and soil, and methane production from livestock. A model is described whereby the user can graph changes in carbon stocks for combinations of soil type, browsing animal, livestock carrying capacity, and site productivity. Land use options modelled are continued pasture, agroforestry, forestry and land abandonment. It is clear that there is a lack of data available on carbon sinks and sources other than carbon dioxide uptake by radiata pine plantations. Carbon uptake by afforestation of pastures since 1990, during the first reporting period defined in the Kyoto Protocol (2008-2012) could be as high as 38 million tonnes of carbon. Preliminary data on soil changes with afforestation suggests this sequestration value could decrease by 10% due to soil carbon losses over the same period. This loss is almost offset by avoided methane emissions due to the removal of livestock.

Keywords: carbon, carbon sequestration, modelling, agroforestry, methane, livestock

Introduction

The Kyoto Protocol was intended to set quantified emission limitation and reduction commitments for Annex I countries (mostly OECD). Despite some ambiguous text which requires further clarification, this objective has been largely met. The Protocol states that countries shall use the gross carbon emissions that occurred in 1990 as their emissions baseline. The first quantified emission limitation and reduction commitment period is from 2008 to 2012. The net emissions in this period will be compared with the gross baseline, and should not exceed the specified percentage of its baseline. The net emissions includes removals of carbon in ‘sinks resulting from direct human-induced land-use changes and forestry activities limited to afforestation, deforestation and reforestation since 1990, measured as verifiable changes in carbon stocks’ (IPCC, 1998).

There is some uncertainty regarding the meaning of 'reforestation' and whether it includes restocking i.e. replanting after harvesting. In this case it is assumed that restocking is not included, since the IPCC definition states it is "planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use". With this definition it could be argued that since 75% of New Zealand was once covered in indigenous forests, the afforestation currently occurring is in fact reforestation. Regardless of which term is chosen, there has been a significant area of plantations established since 1990.

Forestry in New Zealand consists of two distinct components: natural indigenous forests, covering some 6.4 million hectares (24% of land area), and a plantation estate of 1.6 million hectares (6% of land area). It is important to stress that there has been a purposeful development of these complementary forestry estates, separating commercial from non-commercial management values and objectives. The development of the production forests has enabled the preservation of the indigenous forests by providing an alternative source of wood and providing a new industry with a wide range of social, economic and environmental benefits. Planted forests now account for 99.1 % of New Zealand's annual harvest.

The plantation forest estate has been expanding over the past 5 years at an average rate of around 70,000ha each year. This new planting has been mainly carried out by farmers on abandoned agricultural land, not at the expense of the natural forests, so to evaluate stock changes since 1990 the baseline land use must be pasture. The impact of land use change on carbon emissions to the atmosphere therefore includes carbon sequestration achieved through the establishment of plantations on pastures which has occurred after 31 December 1990. It also includes carbon sequestered by scrub and native plants growing on abandoned agricultural land. However, as well as the carbon contained in the vegetation, the full impact of afforestation or scrub reversion must also take into account changes in soil carbon, and the methane emissions not released as a result of the removal of livestock. There are also reports of pastoral soils being a source of N_2O (e.g. Carran *et al*., 1995) and some forest soils being a sink for methane (Maclaren, 1996), but a lack of comparative data between land uses in New Zealand means that neither of these factors have been included in our calculations.

Pastoral farms (predominantly sheep, beef and dairy) occupy 13.6 million ha or 51% of the land in New Zealand, (Statistics New Zealand,1997). It is estimated, however, that only 32% of New Zealand can be maintained in pasture without significant erosion controls, including the use of woody vegetation to bind the soil and reduce soil moisture (Eyles, 1993). Following the removal of government subsidies for pastoral farming in the mid 1980's, large areas of marginal pasture on steep erodible slopes have been left to regenerate into scrub and native forest (Taylor *et al.*, 1997). Other areas have been planted with exotic tree species, mainly *Pinus radiata*. The area of plantation forest has increased from 1.2 Mha in 1988 (Statistics New Zealand, 1992) to 1.6 Mha in 1997 (NZFOA, 1997).

There are well developed modelling systems for plantation forestry systems in New Zealand, such as the stand model STANDPAK (West, 1993) and the FOLPI estate model (Manley *et al*., 1991). These can be used for the prediction of carbon (Maclaren and Wakelin, 1991; Ford-Robertson, 1995) as described later in this paper. There is, however, a lack of equivalent systems for other land uses, i.e. pastoral farming and scrub.

This paper collates information on carbon stocks and flows in different land uses and combines these data in a prototype model. Much of the data is derived from a large agroforestry research trial at Tikitere near Rotorua. The model has been used to give a preliminary comparison of the greenhouse gas balance of various land-uses in terms of the net cumulative impact on atmospheric carbon levels, and to identify areas where more work is required. The preliminary results are interpreted in terms of the likely impact of land use change in New Zealand, and the effect of these changes during the first commitment period as defined in the Kyoto Protocol.

The Baseline Pastoral Farming Scenario

Data on pasture biomass is usually reported as annual productivity rather than total on-site biomass, for the simple reason that the biomass levels vary throughout the year. Annual productivity rates (from 2.8 to 17.2 tonnes of dry matter per hectare per year (Langer, 1990)) are useful in carbon flux calculations, but have limited use in determining average levels of carbon stocks, which is what is required.

Tate *et al.* (1997) estimate that improved pastures contain 2.9 tC/ha, including above- and below-ground components, although it is generally agreed that this value will vary between sites and over time. The residual biomass in pasture is also affected by the type of livestock, with the above-ground carbon content estimated at 0.45 tC/ha for sheep and 0.75 tC/ha for cattle (Hawke, pers. comm.). To account for this difference in the above-ground fraction, estimates of 2.9 tC/ha have been used for total carbon in pasture grass under sheep and a higher value of 3.2 tC./ha for cattle. There are also two options for site productivity: both the high and low productivity pastures are assumed to contain the same quantity of carbon, but the more productive pasture can carry more livestock.

Methane (CH_4) emissions per animal change with the livestock type. Estimates of methane emissions for one sheep are 30 g/day and 250 g/day for a cow (Ulyatt, 1996). These have been converted to carbon dioxide equivalents (using a Global Warming Potential of 21, based on 100 year timeframe (Ministry of Commerce, 1997)) and reported in tC/animal/year; these equate to 0.06 tC/year for a sheep and 0.52 tC/year for a cow. The livestock carrying capacity and type of animal is used to calculate cumulative CH_4 emissions. Marginal pasture systems do not produce as much methane as highly productive pastoral systems because they sustain fewer animals.

Soil carbon under pasture varies with soil type between 38 and 62 tC/ha, (Scott *et al.* in press). Five soil types with default values are provided in the model, as well as a user input option if better information is available. It is assumed that no soil carbon is lost on high productivity pasture sites due to continual inputs from pasture. On low productivity or marginal pasture sites it is considered likely that erosion would cause a soil carbon decrease, but there is insufficient quantitative data to include this at this time.

Pasture productivity and animal type are used to estimate the average annual livestock carrying capacity of a site; but there is also a user input available if the livestock carrying capacity is known. The livestock carrying capacity of high productivity pasture is assumed to be 15 livestock units , based on data from Tikitere (Hawke, pers.comm.). The livestock carrying capacity of low productivity pasture (which is perhaps more likely to be afforested) is assumed to be 7 livestock units (MAF, 1993).

Figure 1 is an example of the information produced by the model for pasture. The scenario for this example is volcanic soil (as at Tikitere) and a highly productive pasture being grazed by sheep. Overall this system adds carbon to the atmosphere due to the continued annual CH_4 emissions from the livestock.

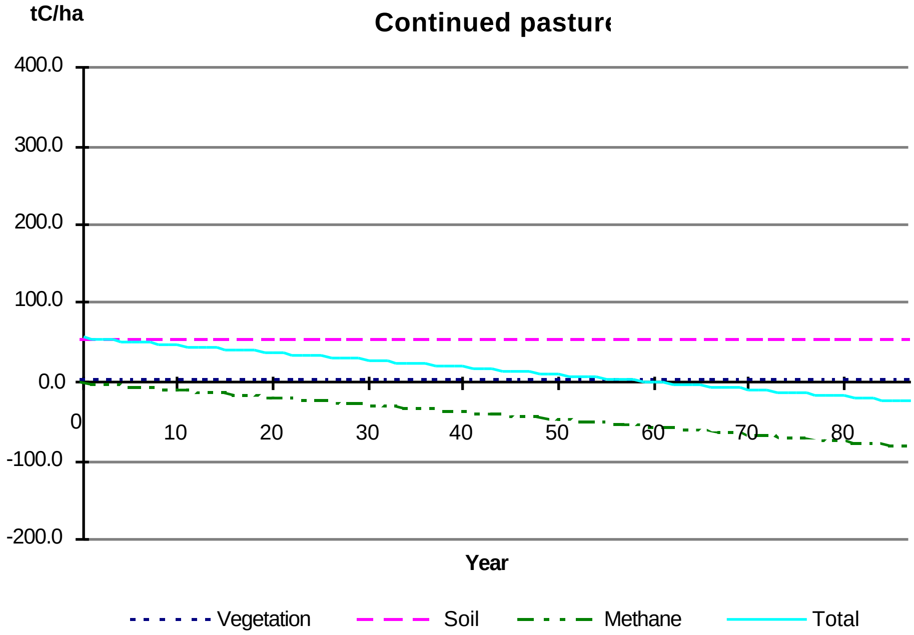

Figure 1. Pasture scenario

The Agroforestry Scenarios

The agroforestry scenarios used are some of those practised at Tikitere. These involve the establishment of a tree crop in pasture at low tree stockings, excluding livestock for the first 3 years, and then reintroducing them, but at declining numbers over the years as the pasture is shaded and covered in debris.

There are two scenarios in the model for agroforestry, as described below.

1. Plant 200 stems/ha (s/ha); prune to 6.1m; and thin (non-production, i.e. thin to waste) to 100 s/ha; harvest all stems at age 28.
2. Plant 400 s/ha; prune to 6.1m; thin to waste leaving 200 s/ha; harvest all stems at age 28.

Carbon contained in the trees is estimated using the CARBON module in STANDPAK. The STANDPAK model is a widely used stand modelling system, containing growth models derived from many years' data from tens of thousands of permanent sample plots located throughout New Zealand (Pilaar and Dunlop, 1990). The Stand Growth module of STANDPAK predicts many of the necessary input values required by the CARBON model. A key concept underlying the CARBON model is that, given current knowledge of growth partitioning, mortality, and decay of tree components, the gain in the dry matter content of the stem can be used to predict dry matter and carbon gains of the remaining components. The CARBON model estimates carbon contained in live trees, roots, litter and understorey. The measured stem growth data, together with other model inputs, are used to tailor CARBON to the site and forestry regime.

For the agroforestry scenarios, the silvopastoral regime used in the first 28 year rotation is assumed to continue in subsequent rotations, with over-sowing of pasture between rotations. Since there is pasture instead of the usual forest understorey, the predicted understorey component of the CARBON model was replaced by pasture values.

Carbon contained in the pasture is estimated by multiplying the open pasture by the % changes in livestock carrying capacity (as derived form the AGROFORESTRY module in STANDPAK). Livestock carrying capacity is directly related to pasture production. As trees increase in size, land becomes unavailable for pasture production decreasing the carbon present on site in the form of grass. Livestock carrying capacity and animal type are used to calculate cumulative methane emissions.

Initial soil carbon quantity is estimated in the same way as for pasture, based on soil type. One might assume that since the quantity of soil carbon under pasture remains constant, and it declines under forestry, then perhaps agroforestry should have an intermediate rate of decline. There was no data to support this assumption, so it is assumed to stay static during each of the agroforestry scenarios.

Figure 2 shows the results of changing from the above pasture system to an agroforestry system. Carbon contained in vegetation increases and methane emissions are reduced when compared to pastoral farming.

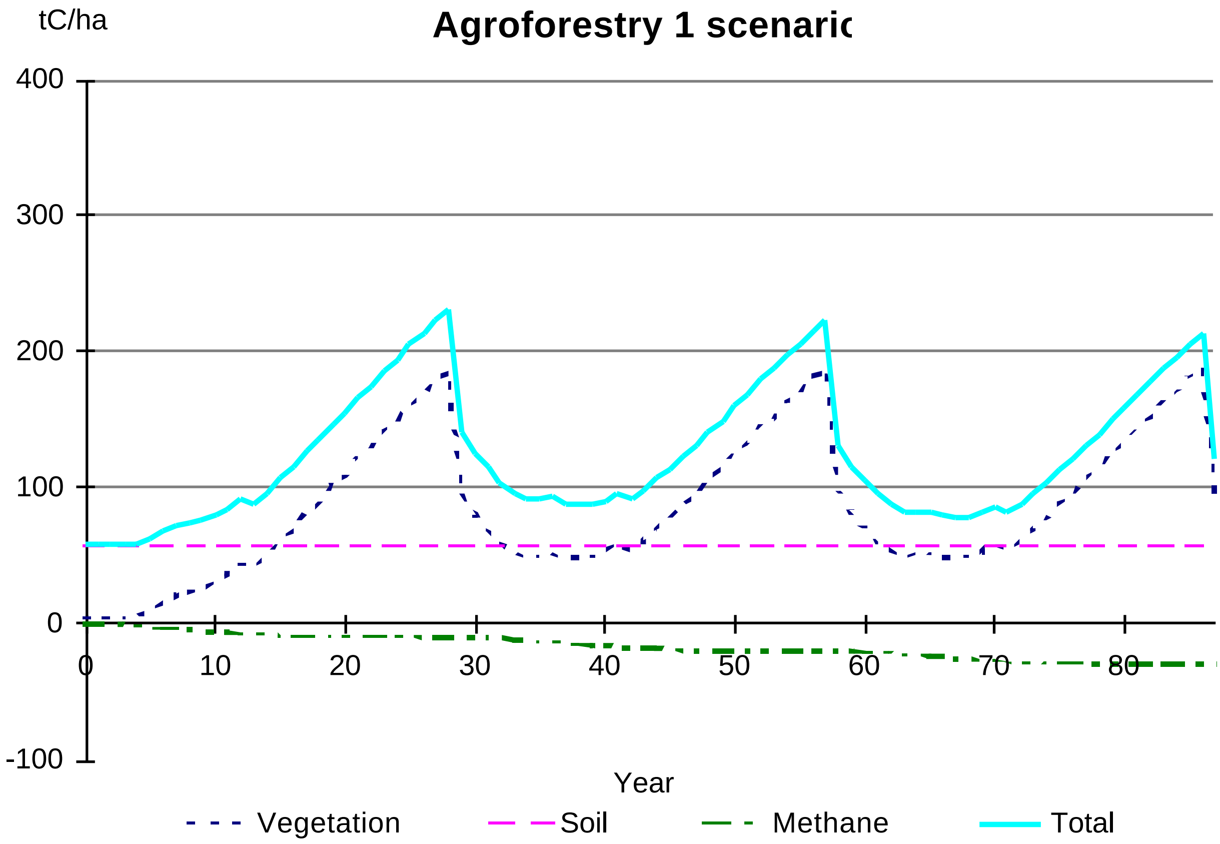

Figure 2. Agroforestry 1 scenario

The Afforestation Scenario

Carbon contained in production forestry has also been estimated using the CARBON model in STANDPAK. The afforestation output changes with site productivity. If the high productivity option is chosen the forestry output is derived from Tikitere research data, with the establishment of 800 stems per ha, pruning to 6.3m and thinning (to waste) to 400 s/ha. Plantations on fertile pastures produce significantly more biomass than those on ‘traditional’ forest sites over the same rotation. The low site productivity option is based on a similar silvicultural regime, with the forestry output derived from Central North Island models. There are 4 main categories of silvicultural regimes in New Zealand, all of which could be included in the model. However only the most common category is included in the model at present, as it is practised on almost half of the current plantation forest estate (NZFOA, 1997). This regime involves planting 1200 s/ha, pruning to 6m and thinning (to waste) down to a final crop of 250 s/ha. Harvesting occurs after 28 years in both afforestation options, and the site is replanted in the following year. CH_4 emissions are zero under forestry as there are no animals included in this option.

Carbon contained in soil at the beginning of afforestation is assumed to be the same as for pasture and is dependent on the soil type chosen. Soil carbon in the top 0.1m has been assumed to decrease by 30% over the first rotation, based on data from Scott *et al.* (in press), and continues to decrease at a much slower rate over successive rotations, regardless of site productivity. This soil carbon decrease is estimated using the equation below:

$$y = S \times x^{-0107}$$

where y = the quantity of soil carbon
S = initial soil carbon quantity, and
x = year after afforestation

Figure 3 is an example of the information produced by the model for afforestation of a highly productive pasture on volcanic soil. Despite the decline in soil carbon, this system contains a lot more carbon than either the pasture or agroforestry systems shown above.

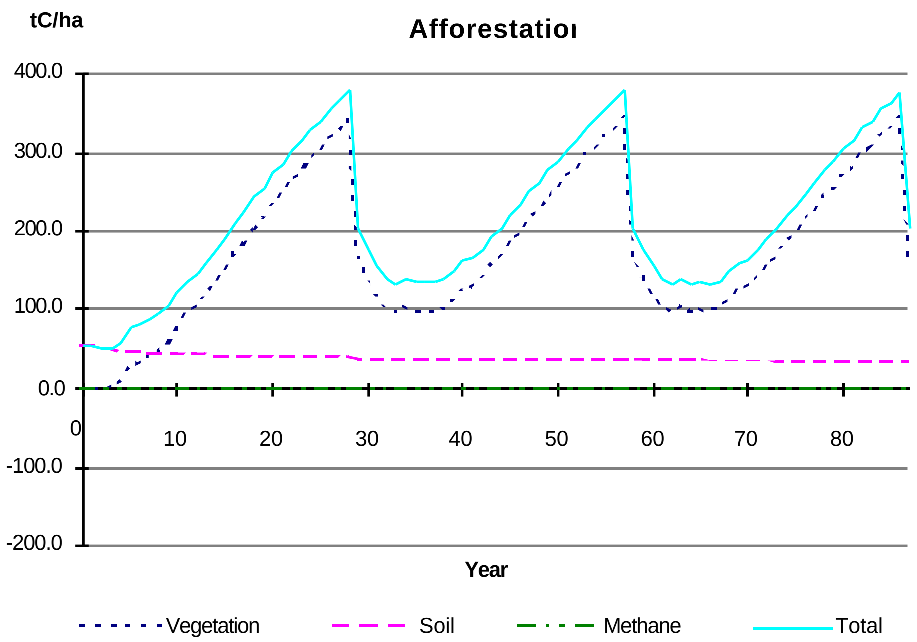

Figure 3. Afforestation scenario (high productivity pasture site)

The Abandonment Scenario

Marginal pastures, particularly on erodible slopes, are being abandoned and reverting to scrub. The successional sequence and timing will vary between sites, but for this example we have assumed immediate colonisation by indigenous manuka/kanuka (tea-tree) communities. It is likely that gorse would invade first, and be replaced over time by manuka/kanuka, but the time series biomass data for such changes are not yet available.

There is very little biomass information available on manuka/kanuka scrub and even less on gorse. Bergin *et al.* (1994) have published relationships between height and age of manuka/kanuka regeneration in the East Cape region of New Zealand, and other data has been sourced from Fogarty et al. (in manuscript) and through personal communications. Much of the information available on scrub is unpublished and shows great variability both within and between sites. This information has been used to generate the following equation which predicts carbon contained in manuka/kanuka scrub (regardless of site productivity) over time:

$$y = 42.421 \times Ln(x) - 26801$$

Where y = carbon (tC/ha), and
x = year.

Methane emissions are zero under the abandon scenario as grazing is discontinued.

Carbon contained in soil before abandonment is the same as for pasture and is dependant on the soil type chosen. There is little information available on soil carbon under scrub vegetation. Tate (1995) suggest that it is similar to pasture, therefore soil carbon is assumed to remain unchanged.

Figure 4 shows the model results from the abandonment scenario. There is very little vegetation up until about 3 years when the scrub starts invading, increasing rapidly until around 10 years, and then increasing slowly.

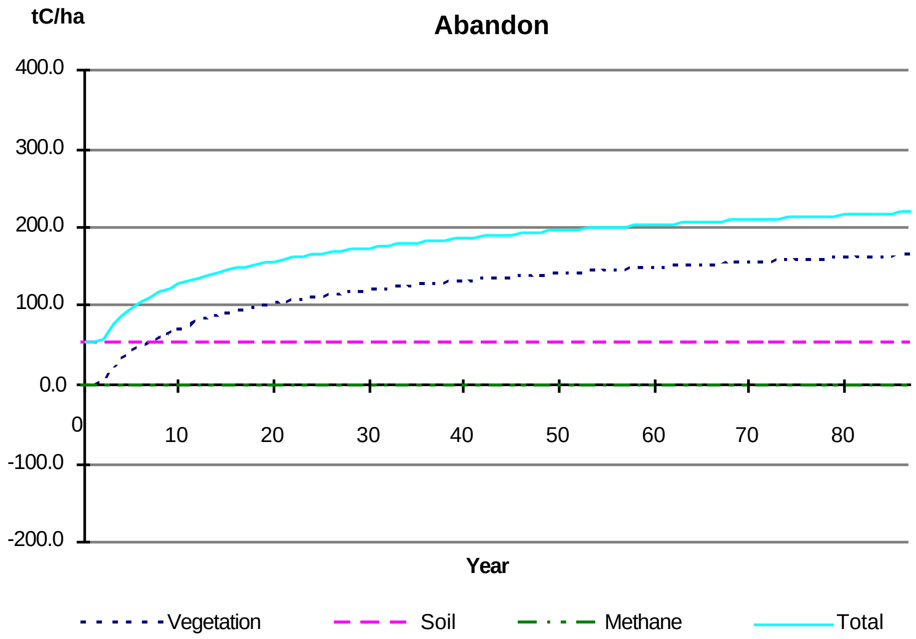

Figure 4. Abandonment scenario

Discussion and Conclusions

The total carbon in each of the scenarios is presented in Figure 5, with each scenario starting from the baseline value (year 0) of 58 tC/ha. Pasture carbon is substantially less than all other scenarios after 20 years and continues to decline, reaching a negative value after about 60 years. The Agroforestry 1 scenario also displays a slight decrease over time, after the first harvest, because of the continued methane emissions.

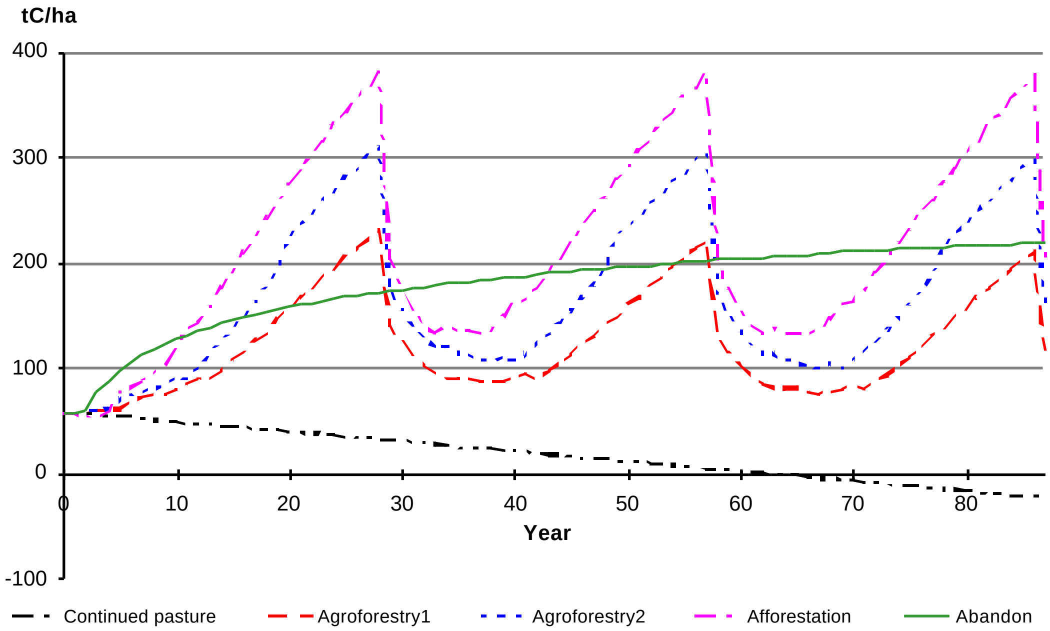

Figure 5. Total carbon for each of the scenarios.

The above Figure shows the fluctuations in carbon over successive forest rotations, and it is therefore difficult to estimate the long term averages for the agroforestry and forestry regimes. For comparative purposes it is necessary to evaluate land use options on an equitable basis. In this study, we have assumed a 29ha pasture is converted to other land uses at a rate of 1ha/yr. This accounts for a 28 year rotation and one year between harvesting and replanting. The results shown in Figure 6 are converted to values for a single hectare (i.e. the total divided by 29).

It is clear that the carbon impact of pasture is the least beneficial over the long term, and the trend is certainly downwards due to the continued methane emissions. The gradual conversion to other land uses means that there is a slight decrease initially in carbon stock, due to the continued pasture on the remaining land.

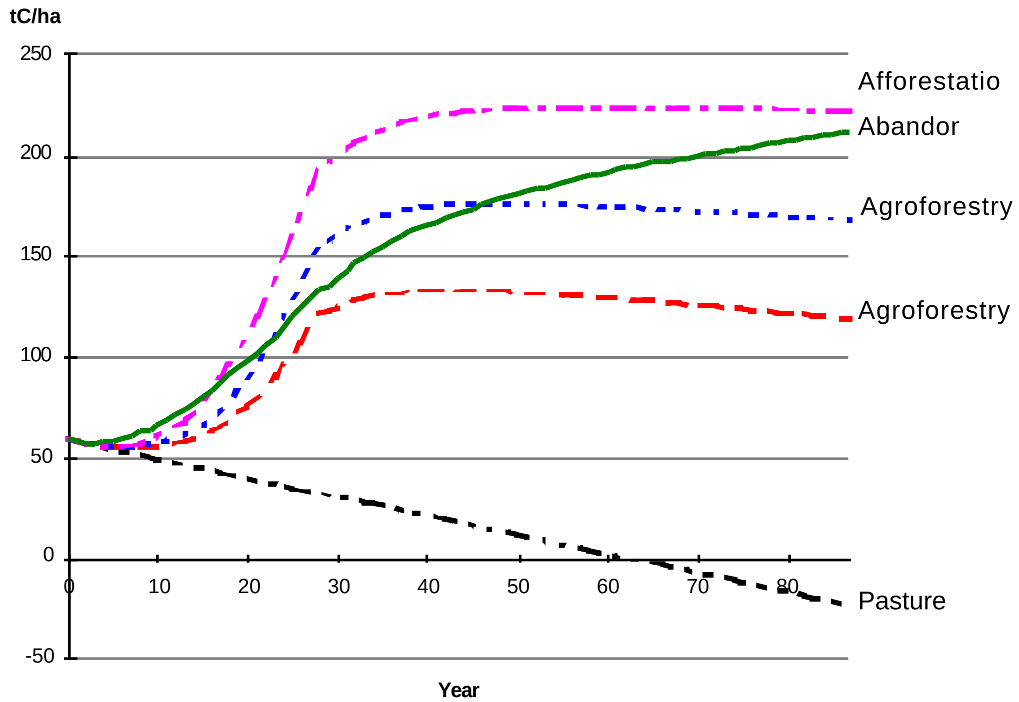

Figure 6. Impact of changing land use

This has serious implications since pasture is the predominant land use in NZ. In Figure 6, the afforestation scenario achieves a long term carbon stock of 222 tC/ha, as compared with the pasture at -23 tC/ha. Of the 5 Mha considered unsuitable for continued grazing, most is likely to be poor quality pasture. If pastoral farming practices continue on this low productivity land (with less methane emissions than for high productivity pasture), there would be only 20 tC/ha remaining at the end of the same period. If this is compared with the current pasture situation (58 tC/ha) it equates to a loss of 38 tC/ha over the 86 years; this represents a source of nearly 200 MtC. The afforestation scenario on poorer quality land would only achieve a long term average of 150 tC/ha (including 35 tC/ha soil carbon), a 92 tC/ha increase over the next 86 years, despite the decrease in soil carbon anticipated by some researchers; this would provide a carbon sink of over 450 MtC. The net result of afforestation of this 5Mha is therefore a gain of 650 MtC. It is quite possible that this could be further improved by soil carbon losses due to erosion on the poor quality pastures.

These values can be put into perspective in relation to the National reporting as required under the Kyoto Protocol (all values reported here in million tonnes of carbon, as carbon dioxide equivalents, with 100 year global warming potentials). The gross emissions of carbon dioxide in New Zealand in 1990, resulting from use of fossil fuels, has been reported to be 6.9 MtC (MfE, 1997). The latest emissions projections suggest that during the 5 years of the first reporting period, 2008-2012, total CO_2 emissions will be 49.4 MtC, which represents an increase above the baseline of 12.9 MtC (Table 1). If all six relevant greenhouse gases are included, the total emissions over the period rises to 112.7 MtC, but the increase above the baseline (20.9 MtC) is only 8.2 MtC (Table 1).

Table 1. Emissions forecasts (MtC) for first commitment period

	CO_2 only		CO_2, CH_4, N_20, SF_6, HFCs, PFCs	
Calendar year (to 31 Dec)	Total emissions	Increase since 1990	Total emissions	Increase since 1990
1990	6.9		20.9	
2008	9.3	2.4	22.3	1.4
2009	9.4	2.5	22.4	1.5
2010	9.5	2.6	22.5	1.6
2011	9.7	2.7	22.7	1.8
2012	9.8	2.9	22.9	2.0
Total	49.4	**12.9**	112.7	**8.2**

Note: all emissions quoted in carbon dioxide equivalents, with 100 year GWPs

The emissions forecasts can be compared with the gross sequestration anticipated by plantations established since 1990. Table 2 shows the results of three new planting scenarios, each based on the current 'average' forestry regime (i.e. not accounting for improved growth rates on abandoned farmland): the first assumes there is no more new planting but almost 450,000ha have already been established between 1991 and 1997 and these are anticipated to sequester 13.5 MtC during the first commitment period. The second scenario assumes planting 65,000 ha in 1998 and 1999 and 55,000 ha/yr thereafter; sequestration in this case is estimated at 37.5 MtC. The high new planting scenario assumes establishment of 90,000 ha/yr and sequesters 51.6 MtC. It must not be forgotten that some (about 16%) of the new planting is preceded by clearing/burning existing vegetation and there may be other losses through land use change and forestry activities which will reduce these gross seuqestration values. However, despite such adjustments, it is evident from these values that New Zealand can meet its net emissions obligations without any significant afforestation programme. The medium planting scenario could lead to the availability of significant quantities of tradeable carbon credits.

Table 2. Gross sequestration by plantations in first commitment period (MtC)

Calendar year (to 31 Dec)	Increase in stock in plantations established since 1990 (different planting scenarios) none	medium (55 kha/yr)	high (90 kha/yr)
2007	39.2	50.6	56.0
2008	42.2	57.5	65.1
2009	45.0	64.3	74.3
2010	47.2	71.6	84.6
2011	49.7	79.6	95.7
2012	52.7	88.2	107.6
Increase 2008-2012	13.5	**37.5**	51.6

Note also that these gross sequestration figures do not include the soil carbon losses which have been suggested. If the 30% soil carbon loss over the first rotation is included (as described previously), in the medium planting scenario there would be a soil carbon loss from the top 0.1m of 3.5 MtC. Avoided methane emissions over the same period would be 2.7 MtC.

It must be stressed that these are only preliminary results, and there is further work required to validate several of the assumptions. There is considerable work required to bring this type of comparative model up to the standard of the existing forestry modelling systems. This requires data collection and validation, particularly for gases other than carbon dioxide. There may also be a need to incorporate 'avoided' emissions, as well as fossil fuel emissions from land management and harvesting operations. However, the clear message from this preliminary exercise is that pastoral farming is a considerable source of carbon, and afforestation would rapidly reverse the situation and provide a substantial carbon sink.

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How to determine baseline scenarios for a forest sector carbon balance

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Abstract

The objective of this paper is to compare different scenarios for carbon sequestration in the forest sector in Finland. The dynamics of carbon sequestration has been simulated with a gap-type forest simulation model and a wood product model, which take into account carbon flows and storages in forests, as well as in wood products. In the baseline scenario we have applied current forest management practices. In an another scenario, current recommendations for forest management were applied, which resulted in more intensive harvesting levels than in the baseline scenario. Both scenarios have been run also under changing climatic conditions to demonstrate possible impact of climate change on carbon sequestration. This study demonstrates that carbon sequestration assessments should include not only carbon in the biomass of trees, but also carbon in the soil and in the wood products, and interactions between respective pools. Partial assessments are likely to result in missleading estimates of the actual carbon sequestration. Also possible implications of the Kyoto Protocol has been discussed.

Keywords*:* carbon sequesration, forest management, wood use, forest sector, climate change, scenario analysis

1. Introduction

The global climate is expected to change substantially in the foreseeable future due to the rapidly increasing concentration of greenhouse gases in the atmosphere, in particular that of carbon dioxide (Houghton et al. 1990, 1992, 1995). The importance of reducing carbon (C) emissions with the aim of slowing down the build-up of the atmospheric carbon dioxide is widely agreed, i.e. in the United Nations Framework Convention on Climate Change in Rio de Janeiro in 1992 and just recently in Kyoto. This implies that fossil fuels should be used less, that the use of land, forests, and their products be utilized in a sustainable manner, possibly increasing sequestration of C into the ecosystems and other stocks and replacing fossil fuel based energy and products with renewable wood based energy and products.

In the long run, the C accumulated in forests from the atmosphere will be released back to the atmosphere through respiration, decay of litter, humus and soil organic matter, oxidation of wood products, and possibly as a result of disturbances in forests. Net change in the C stocks (vegetation, soil, products) shows if these stocks are C sinks (accumulating C) or C sources (loosing C). It should be noted that the state of these stocks varies over time, i.e. a pool can be a sink one year but can be a source next year. Fluctuations are more pronounced on smaller spatial scales than on larger scales. Therefore is important to look on the dynamics of C stocks and not only on particular years. The Intergovernmental Panel on Climate Change (IPCC) have provided guidelines to calculate national greenhouse gas inventories for land-use change and forestry (IPCC 1996). These guidelines assume, however, that wood products are oxidiced immediately and that there is no accumulation of C in long lifespan products. In the Kyoto Protocol, C stock changes in land-use change and forestry are limited to afforestation, reforestation and deforestation. Both of these seem to leave part of the system out of the consideration and possibly providing biased estimates.

Impact of forest management on the structure and functioning in Finland much larger than that of natural disturbances. Moreover, forest growth is strongly limited by temperature, especially in the northern part of the country. Predicted climate change may have strong influence on forest growth and productivity, and thus on C sequestration. This should not be neglected in C sequestration scenarios. In this paper we have compared impacts of different forest management regimes and possible impacts of changing climatic conditions on C sequestration in the forest sector in Finland. Also some implications of the Kyoto Protocol are discussed.

2. Method and data

Method

The dynamics of C sequestration for the forest sector in Finland has been simulated using dynamic forest (Kellomaki et al. 1992, Karjalainen 1996a) and wood product models (Karjalainen et al. 1994), which take into account C transfers between forests, wood products and the atmosphere (**Figure 1**), allowing calculation of the net changes in each of the C stocks and in the whole system. This procedure has been applied earlier both on stand level assessments (Karjalainen & Kellomäki 1995, Karjalainen 1996b,c) and national level assessments (Karjalainen et al. 1997, Pussinen et al. 1998).

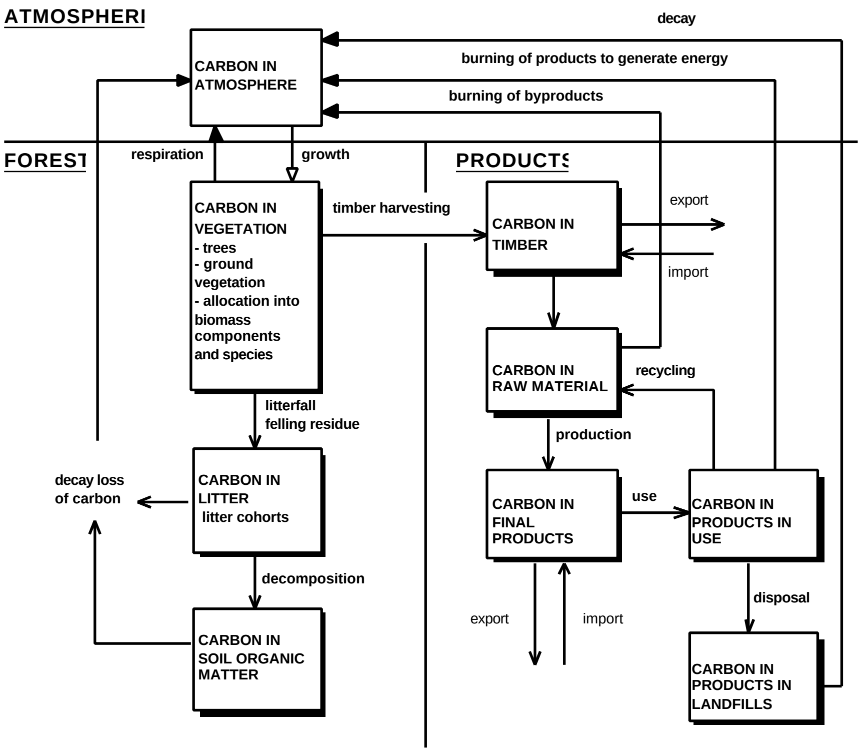


Figure 1. Outlines of the Atmosphere–Forest–Wood-based Products C interactions in this study (C flows and stocks).

Forest simulation model

Carbon flows and stocks in forests have been simulated with a gap-type model (Kellomäki et al. 1992, Karjalainen 1996a,b, Talkkari & Hypén 1996) in which site conditions are described in terms of availability of light, growing season degree days, available soil moisture, and available nitrogen. These environmental conditions scale tree growth from the optimum level to actual level. Also, the establishment and death of trees, as well as the establishment, growth and death of ground vegetation, are influenced by these environmental constraints. Forest management comprises stand establishment, thinning, and clear felling. Removals through felling of trees are converted into timber assortments (logs, pulpwood, and residue wood) in accordance with the specific dimensions for each assortment. This model has been widely used to assess the effects of the changing climate on boreal forests in Finland (Kellomäki & Kolström 1992a, 1992b, 1993, Kellomäki 1995, Karjalainen 1996a,b,c, Talkkari 1996, Talkkari & Hypén 1996), also on regional and country levels (Talkkari 1996, Pussinen et al. 1998).

Wood-product model

Timber harvest, divided into timber assortments by tree species, is used as the input to the wood-product model. Harvested timber is processed into products and the carbon is followed until the products are removed from use and the carbon is released back into the atmosphere. The conversion of timber into wood products (fuelwood, chemical pulp and paper, mechanical pulp and paper, plywood and saw timber) is based on product/timber units typical for the wood-processing industry in Finland. The final products are divided into four lifespan categories to describe the use of raw material in production, and the use of products. These lifespan categories are short (fuelwood, newsprint, some of packing paper, paperboard, and printing and writing paper), medium-short (the rest of the packing paper, paperboard, and printing and writing paper), medium-long (part of saw timber and plywood) and long (rest of the saw timber and plywood). It should be noted that the wood-product model does not consider the use of primary energy in processing wood into products, except for the use of wood mainly in the form of by-products. For further details of the product model see Karjalainen *et al.* 1994 and 1995.

Carbon budget

Carbon flows and storages can be calculated for each component (see **Figure 1**), but particular interest is focused on the net carbon sequestration of forest ecosystem (net change in forest ecosystem), forest carbon storage, net carbon sequestration of wood products (net change in wood products), wood-product carbon storage, and total net carbon sequestration and storage of the entire forest and wood-product system (total net change).

Input data

The calculations have been done only for the productive forest land on mineral soils (average annual growth at least 1 m^3/ha), representing approximately 66% of the forestry land area, i.e. 15.2 Mha. Data collected from 1256 permanent plots within the national forest inventory by the Finnish Forest Research Institute provided the basis for constructing the initial forest carbon storage for the year 1990. The tree characteristics used as input were tree species and diameter at breast height, and the site characteristics comprised coordinates, altitude, site type, depth of the humus layer, soil fertility and type. Climatic conditions (temperature, precipitation, heat sum, evapotranspiration) were simulated based on coordinates and altitude.

Scenarios

In the current climate scenario, the temperature and precipitation values are from the period 1961–1990. For the changing climate, the increases in temperature and precipitation (**Table 1**) are from three scenarios applying low, central and high emission estimates of the IPCC (IS92c, a, f in Houghton *et al.* 1992).

Currently forests are not managed as intensively as the recommendations would allow (Tapio 1994). Current harvesting levels were achieved when each year 7% of the stands that have exceeded thinning and clearfelling limits were harvested. This meant that propability of harvest in these stands was 50% in 10 years. This is later called as Current Management. In another scenario, forest management was intensified to the level recommendations allow. This level was achieved during a 46 year period. This is later called as Intensive Management.

Table 1. The scenarios of seasonal temperature and precipitation change over Finland for 1990–2100 (Carter *et al.* 1995). Rates of change are assumed to be linear.

Season	**Temperature change, °C/decade**			**Precipitation change, %/decade**		
	Moderate	Intermediate	Greatest	Moderate	Intermediate	Greatest
Spring, MAM	0.1	0.4	0.6	0.125	0.5	0.75
Summer, JJA	0.075	0.3	0.45	0.25	1	1.5
Autumn, SON	0.1	0.4	0.6	0.25	1	1.5
Winter, DJF	0.125	0.6	0.75	0.42	2	2.5
Annual	0.1	0.4	0.6	0.25	1	1.5

The current wood-product storages were calculated by running the wood-use data for the period 1860–1990 in the wood product model (Kunnas 1973, Tapion taskukirja 1956, 1975, Yearbook of Forest Statistics 1990–1991, 1992). Exports and imports of timber and wood products were excluded from the calculations, since the aim was to assess the contribution of wood grown and processed in Finland to carbon sequestration regardless of the end-use location of the final products.

3. Results

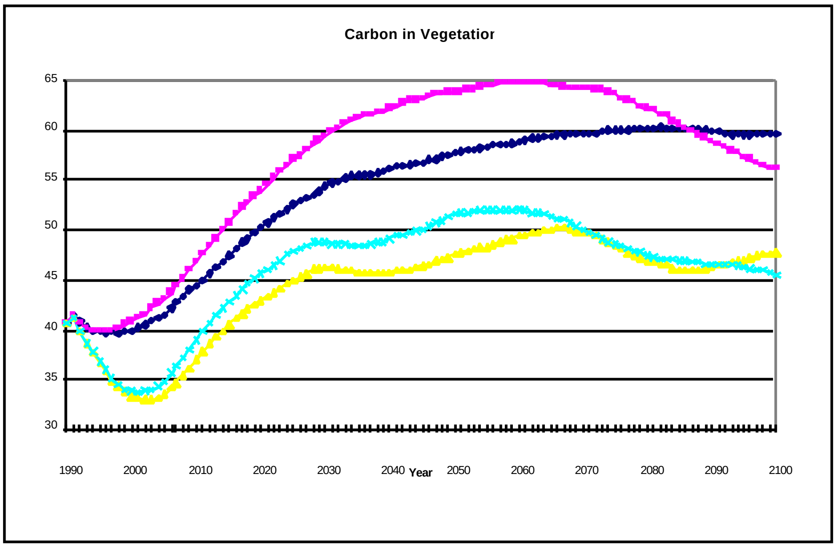
All the C stock were higher in 2100 than in 1990 (**Table 2**). This indicates that forest stocks are not yet at the maximum levels. Current age class structure of forests is fairly even and allows therefore accumulation of C in forests. Largest changes took place in products stocks as a result of continuous production and use of products. Also litter and soil organic matter stocks increased more than that of vegetation. Impact of intensified management on C stocks was larger than that of intermediate climate change, except in case of soil organic matter. Intensified forest management decreased forest stocks, since more C from vegetation was transferred in products. Intensified management decreased also litter and soil organic matter stocks since the input to these stocks decreased. Under current climatic conditions forest stocks decreased by 14-20% and product stocks increased by 14-20%. Since forest stocks are larger, change in the forest sector stock was -5%. Under intermediate climate change, forest stocks decreased by 14-19%, product stocks increased by 9-18%, but the forest sector stock decreased by 10%. Intermediate climate change decreased forest stocks, that of vegetation by 5-6%, that of soil organic matter by 22%, while litter stocks increased by 24-27%. Product stocks increased by 13-14%, but the total forest sector stock decreased by 5-10%. It should be noted that under moderate climate change all the forest stocks were higher than under current climate over the whole simulation preriod (1990-2100). Under intermediated climate change, however, vegetation and soil organic matter stocks started to decrease (became C sources) after year 2070 (**Figure 2**). This was a result of increased natural mortality and faster decomposition of soil organic matter. Litter stock increased, since input in that stock increased more than decomposition of litter (larger input of stemwood which do not decompose as quickly as other litter cohorts). Under greatest climate change vegetation and soil organic matter stocks became C sources earlier, after 2050. These changes turned the whole forest sector to a slight C source under intermediate climate change after 2075, but to a much larger C source under greatest climate change after 2060.

Table 2. Size of the C stocks in 1990 and in 2100 when applying current management and intensive management under current climate and under intermediate climate change.

C stock	**1990 stock, Mg C/ha**	**Current climate, stock in 2100**		**Intermediate climate change, stock in 2100**	
		Current management	Intensive management	Current management	Intensive management
Vegetation	42.1	59.6	47.7	56.0	45.4
Litter	6.4	13.9	11.8	17.3	15.0
SOM	20.5	49.8	42.9	38.8	33.4
Forest	69.0	123.3	102.2	112.2	93.8
Products in use	7.3	15.0	17.4	17.2	18.7
Products in landfills	3.3	12.3	14.7	13.8	16.3
Products total	10.6	27.3	31.0	31.0	35.0
Forest sector	85.1	150.7	143.2	143.2	128.7

It is worth to emphasise that each C stock has its own dynamics (**Figure 2**) and that they are connected to each other (output from one is input to another), and therefore changes as a result of changed forest management or changing climatic conditions will affect all of them either directly (in case of forest stocks) or indirectly (in case of product stocks).

Average net C sequestration over the whole simulation period (1990-2100) was higher in forests than in products (**Figure 3**). Under current climatic conditions, 77% of the net C sequestration took place in forests and 33% in products when applying current management. When intensive management was applied, 66% of the net sequestration was in forests and 44% in products. As a consequence of climate change share of forests of the net C sequestration decreased. Gross fluxes in forests are much higher than those in products (**Figure 4**). Approximately 10% of the gross production was actually sequestered in the forest sector.


Carbon in Vegetatior
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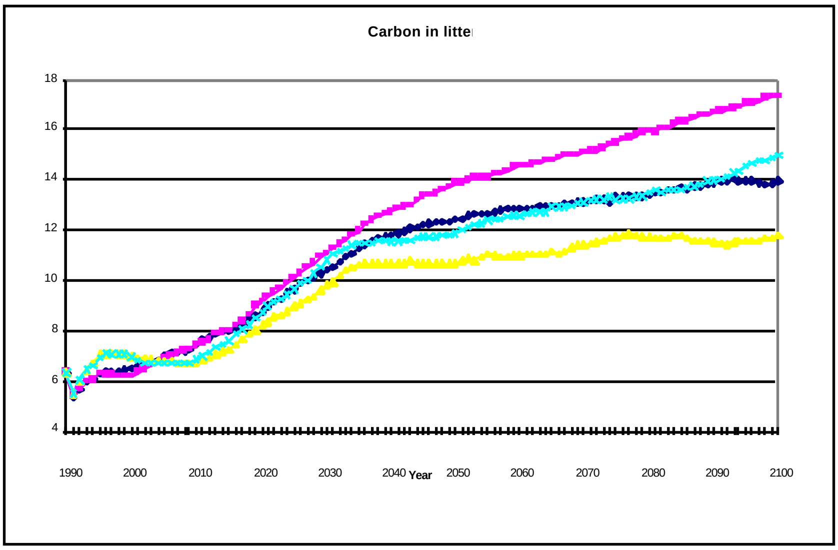
Carbon in litte
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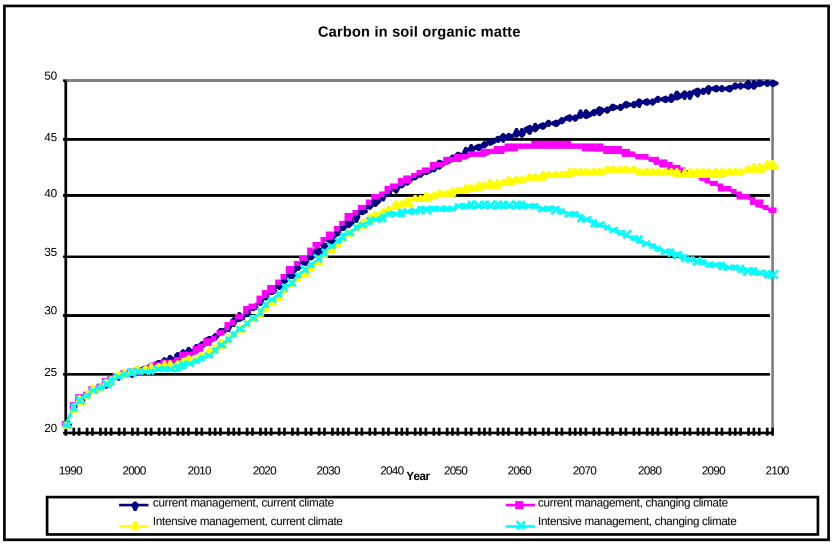
Carbon in soil organic matte
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current management, current climate
current management, changing climate
Intensive management, current climate
Intensive management, changing climate

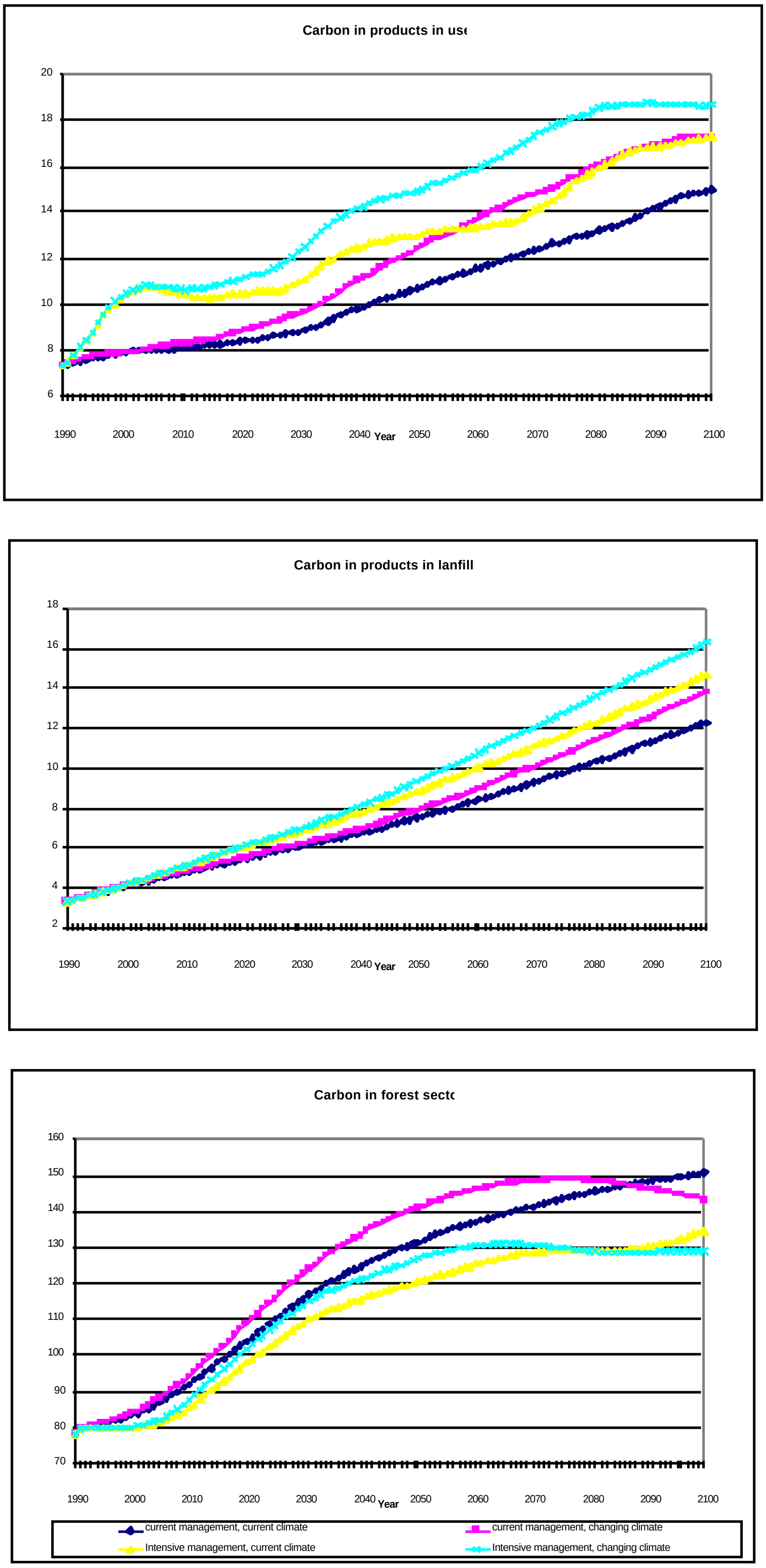

Figure 2. Development of C stocks in different scenarios.

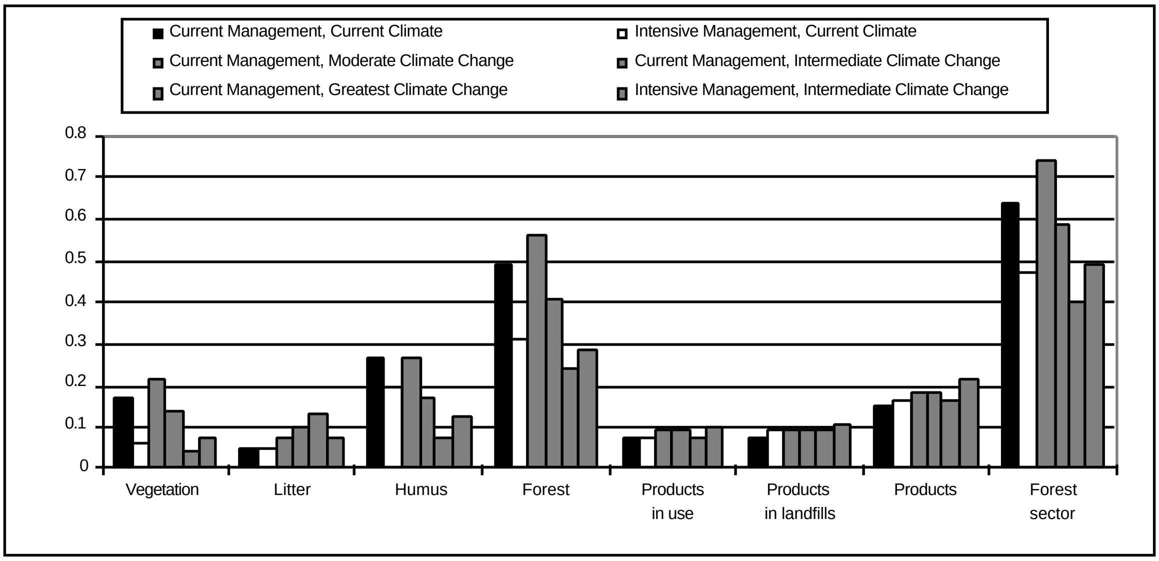

Figure 3. Average net C sequestration over the simulation period (1990-2100) in different scenarios.

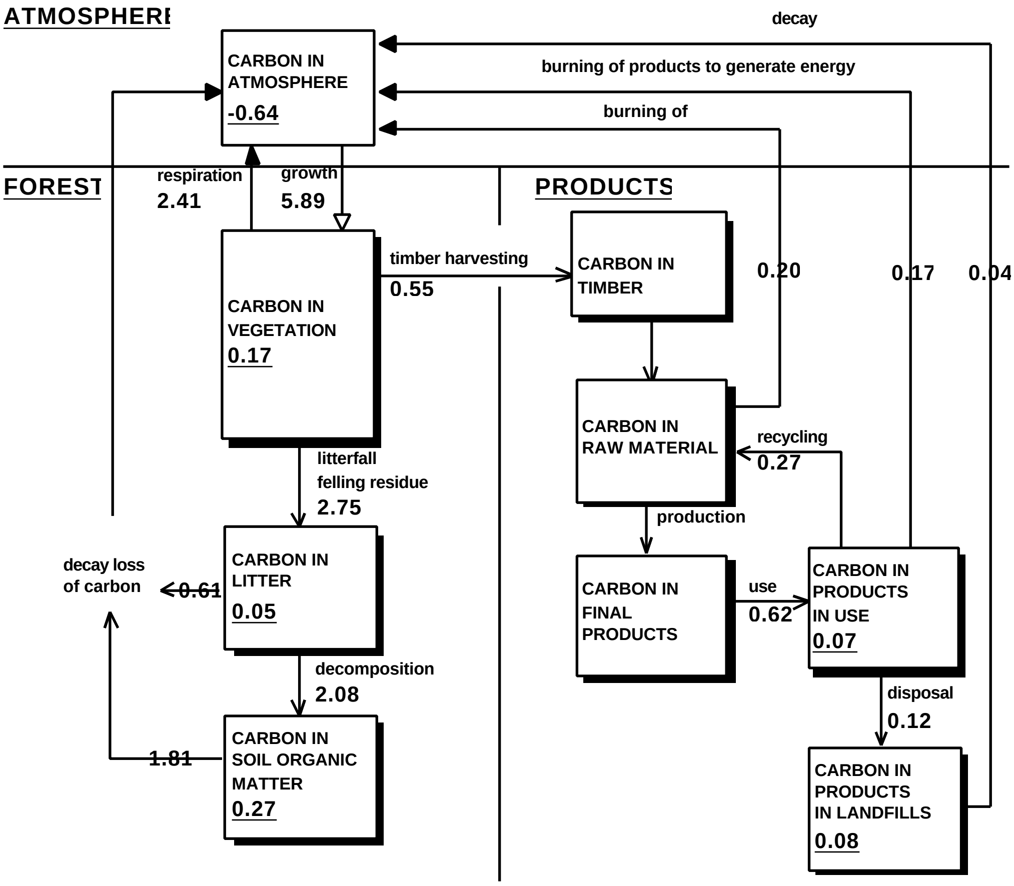

Figure 4. Average C fluxes over the whole simulation period under current climatic conditions when current management was applied.

4. Discussion

We have demonstrated how forest sector C stocks could develop when forest management practices are changed. Our computations show that it is not enough to look on one stock, for e.g. on vegetation, since the forest sector have also other components. Also dynamics of the system should be followed, since C sequestration is not static. Climatic conditions are likely to change as a consequence of human influence and this should be taken into account in C sequestration assessments, since also changing climatic conditions can influence on forest sector C sequestration.

We applied two forest management scenarios. These scenarios resulted in different C distribution in the forest sector, but also resulted in differences in net C sequestration. Both of the applied management scenarios may be argued to be possible ones for baselines. Current forest management practices (applied current management) follows the actual thinning and clearfelling practices, and could therefore be basis for a baseline. Forest management guidelines (applied intensive management) provides the earliest possible timing for thinning and clearfelling. If this is thought to be a kind of recommendation, then also forest management guidelines could be regarded as baseline. Another possibility could be that forest sector is though to be neither sink nor source in the baseline, i.e. zero for the initial year. Then changes from the zero line would be credited or debited.

Kyoto Protocol limits land-use and forestry activities to afforestation, reforestation, and deforestation since 1990. Protocol does not give definitions to these activities. The IPCC guidelines to calculate national greenhouse gas inventories for land-use change and forestry (IPCC 1996) define reforestation as *planting of forests on lands which have previously contained forests but which have been converted to some other use*, while FAO defines reforestation as *artificial or natural re-establishment of forest on previously forest or other wooded land. Artificial reforestation may be planting or seeding*. If we had applied in our simulations the Kyoto protocol and IPCC definitions, net impact of forestry would have been zero, since we did not assume any changes in forest land area. If we had applied FAO definition, then regeneration of clearfelled areas could have been taken into account and forest sector would have showed a C sink. In this case one important part of the ”equation” would have been neglected - what has preceeded reforestation - harvesting. Inclusion of harvesting would have resulted in substantial source, since clearfelling takes place in high C density stands and buildup of C stocks takes fairly long time. Therefore we suggest that the whole system should be described and taken into account, but system should be described correctly as has been discussed in Apps et al. (1997).

If only the activites mentioned in the Kyoto Protocol as defined in the IPCC guidelines for national greenhouse gas inventories for land-use change and forestry would be taken into account, impact of forestry in Finland on the national greenhouse gas balance would differ from the reality. Afforestation and reforestation area in Finland has been and is likely to be small and would provide a small C sink. Total forest area, however, has been decreasing slightly according to forest statistics and if similar trend is to continue, would provide a source for Finland. Actually area of productive forest land and also growing stock has increased fairly long time and forests in Finland can be claimed to have been a C sink in the recent past (see e.g. Karjalainen et al. 1997). Also this shows that inclusion of only some activities and parts in the system would not tell the status of the whole system, which should be in the focus.

Acknowledgements

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Establishing a basis for the assessment of greenhouse gas and other impacts from combustion of biomass compared with coal

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Abstract

An overview is given of the importance of coal utilisation to the New Zealand economy and the possibilities for replacement by biomass. Life cycle analysis issues are discussed in establishing a basis for the assessment of greenhouse gas and other impacts from combustion of biomass compared with coal as a reference combustion system. Preliminary experimental results are presented for combustion gases from an underfeed stoking combustor burning various forms of wood waste and compared with coal combustion measurements. Factors impacting on combustion performance (moisture, ash, particle size, combustion regime and environmental) are assessed for their relative importance in demonstrating biomass combustion technology. These results are discussed in relation to further research required to identify the range of greenhouse gas emission factors for both biomass and coal under different combustion systems.

Workshop Summary

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I have met many of the participants of this workshop at various conferences in the Northern Hemisphere. It is a great delight to see you here in New Zealand, because this small country is quite isolated and is difficult to visit. I hope you will take the opportunity to see some more of New Zealand before returning home.

From my perspective, this has been an excellent workshop, with very clear presentations of papers that contain considerable substance. Keith Mackie provided the welcome on behalf of Forest Research, and he correctly stated that key outcomes of the Kyoto Protocol were the inclusions of forest sinks and emissions trading. Joseph Spitzer welcomed us on behalf of the IEA Task XV/25, and then made the understatement of the day by saying that the Protocol produced more questions than answers.

The first speaker was Murray Ward, from the New Zealand Ministry for the Environment, who gave a fascinating first-hand account of Kyoto. As an active and influential participant in the negotiations, Murray summed up the feeling of that conference with the expression: “for now, let’s allow the minimum amount of sinks possible”. Sinks were seen as a cop-out by many delegates. For others, they involved the “fear of the unknown”. There was also a lot of ignorance, for example in the confusion of sinks and reservoirs. The words of the Protocol could not be taken at face value, because there was a political background behind each one. It will be evident to workshop participants that Murray has an excellent grasp of the scientific concepts behind carbon sequestration. This gives me great satisfaction to observe. When I see a government official with this advanced level of understanding, I feel that¾as a scientist whose job is to advise such people¾I have done my job.

Bernhard Schlamadinger followed closely on from Murray, detailing some of the confusions and perversities evident in the existing protocol. He mentioned, for example, that if ‘harvesting’ is to distinguished from ‘deforestation’ then the minimum or maximum time-interval between periods of forest cover should be clearly specified. Allowing Land Use Change and Forestry (LUCF) sinks to be excluded from the 1990 baseline and LUCF sources to be included would result in great distortions for those countries that possess both. If the Clean Development Mechanism (CDM) allows, say, the US to gain credits from tree-planting in Costa Rica, what happens when those sinks become a steady-state reservoir, or¾worse¾a source? Bernhard thought that, for forestry, a longer time span for reporting was necessary than the 5 years implicit in the Protocol. Despite its failings, Bernhard thought the Protocol was “a good beginning”. I agree with him, but think that the Protocol has already achieved some of its goals. It has brought the Greenhouse Effect to the attention of many people who had previously ignored it. The presence of so many representatives of industry in this workshop is evidence that it is being taken seriously, and that decisions are being taken today on the basis that future supplies of cheap fossil fuel may be restricted.

Doug Bradley brought a Canadian perspective to bear on the Protocol, pointing out that the current provisions do not really apply to Canada, in view of the small area of afforestation that is taking place in that country. The Protocol ignored the huge carbon reservoir in Canada's existing forests, natural or managed. His interpretation of the word 'reforestation' differed from that of Murray Ward. He thought it included replanting (restocking), whereas Murray was convinced that it applied only to land that was being planted in trees having spent a long period in another (low carbon density) land use. Doug thought that forest management that includes fire control, silviculture and disease prevention has a great impact on carbon sequestration, and is cost-effective. He argued, like Bernhard, that a longer time horizon is required to do justice to various management interventions. My view is that increasing the MAI of a forest, by various management techniques, does not necessarily increase its long-term carbon-density. If trees grow faster, they may merely be harvested at a younger age. The advantage in increasing MAI lies in the fact that, because of substitution effects, this would result in decreased use of fossil fuels. This would be accounted for in the "emissions" side of the ledger, and no credit needs to be provided in the columns relating to LUCF.

Murray Parrish spoke on behalf of the Forest Industries of New Zealand. Most people would expect such a person to be enthusiastically in favour of carbon credits from forestry, and no doubt many were surprised at the vehemence with which he opposed such a scheme. He had several objections to carbon credits, including the increase in land prices that is expected to result. He argued that carbon credits would provide a windfall gain to current owners of bare (ie low carbon-density) land, but would provide no lasting benefit to future forest owners who would have to pay more dearly for their most important raw material. Continuing the theme of the previous two speakers, Murray pointed out some perverse consequences of the Protocol. Anthropogenic deforestation, for example, is an expensive debit, but natural deforestation is not counted. This provides a strong incentive for a human who wishes to clear an area of forest to create a "natural" fire. Murray argued that even a modest value placed on carbon credits would soon distort the forestry sector to the stage where it was farming for carbon, with wood as a by-product. Weeds could be more valuable than timber trees. He stated that the global warming was caused by fossil fuels, and should be solved through fossil fuels, without involving the forestry industry. I disagree with him here. Enhanced atmospheric CO2 is in part (perhaps one-third) the result of global deforestation, and reforestation is merely the reverse of the process. Secondly, study after study has shown that afforestation is the most cost-effective mitigation solution, albeit a partial and temporary one.

Gregg Marland from Oak Ridge gave a very lucid exposition of GORCAM results. He came up with a whole new list of perverse outcomes from Kyoto, as it currently stands. His central theme was that you don't optimise a system by optimising components of that system, in a piecemeal way. If only post-1990 plantings are to be considered, then we must distinguish the harvested wood from these plantings, and track this right through the economy. It might pay to leave the post-1990 plantings for on-site carbon sequestration, and to obtain wood only from plantings that were established prior to 1990. It might pay Annex I countries to plant their trees in non-Annex I countries, because then they could benefit from the different carbon accounting practices that are outlined in the Protocol.

Alice LeBlanc, from the USA, provided a new perspective on carbon credits, when she described her activities at the project, rather than the national scale. At first glance, project analysis seems premature. How can we make rules for individual industries before we have national rules? For that matter, how can we make national rules before the international agenda has been finalised? But this misses the point. Sure, if legalistic solutions are favoured, where individuals and nations are expected to try to minimise their obligations to the rest of the human race, then Alice's work is misguided. But if there are people out there with goodwill, who genuinely want to take responsibility for their actions, then she is ahead of her time. Alice has brought together more than 160 companies who are prepared to operate on a voluntary, self-regulatory basis. While the international community dithers, people like Alice are actually doing things.

For the second part of the talk, she presented a paper by Neil Bird. This was a clever piece of work that described the effects of fire on the carbon stocks of a forest, with and without human intervention. Neil, from Canada, echoed Doug Bradley's point that for some countries fire prevention can be many times more important than afforestation programs. My attitude is that Neil has usefully contributed to scientific knowledge by providing one piece of the global climate change jigsaw puzzle. However, if he thinks his work can be used in the legalistic framework of international carbon trading, then he is living in cloud cuckoo land. As a questioner pointed out, the error limits are higher than the sequestrations estimates. Emissions trading will involve billions of dollars, so precision is vital. I doubt that science has the ability to simulate fluctuations in "natural" forests, in view of the high incidence of natural perturbations that occur (such as El Nino), and the chaotic flow-on effects that result from those. Lastly, I question the wisdom of interfering with a regularly burnt, low carbon-density ecosystem. The Australian flora and fauna, for example, is the result of 50,000 years of almost continuous burning by aborigines. Excessive fire prevention has changed the composition of plants and animals, and produced cataclysms like Ash Wednesday.

Leif Gustavsson provided an engineer's perspective from Sweden. For a long time I have greatly respected the achievements of the Swedish people. Back in 1980, they introduced measures to reduce energy consumption, which created a particularly difficult 1990 baseline to overcome. Are they dismayed? Not a bit of it. They are now attempting to eliminate *both* nuclear energy and fossil fuels! And how will they do this? Through bioenergy! I am not an engineer and I became confused with all the comparisons of heat pumps and pellet boilers, cogeneration plants and combined cycle technology, but I do know one thing: if there is any one country that can succeed in developing an economy based on bio-fuels, then that country must be Sweden.

Trevor Matheson, from Coal Research Limited New Zealand, described a trial comparing coal with bio-fuel. The latter had low levels of pollutants, except for particulates, CO and CH_4. Questioners pointed out that the pollution was because the fuel was too moist. The researchers had not used standard technology, and the IEA combustion task group could have provided useful advice. Trevor argued that bio-fuels could not totally replace coal as this was necessary for cement and steel manufacture (most of the workshop participants appeared to disagree). Transport fuels were critically important in the New Zealand scene, and¾at least with current price structures¾neither coal nor bio-fuels were suitable.

Justin Ford-Robertson gave a very clear explanation of some of the carbon modelling concepts used in New Zealand. A feature of his talk was the inclusion of methane, which, as a product of livestock, is a major component of New Zealand's greenhouse balances. Conversion of pasture to forestry displaces livestock, and therefore provides benefits additional to those involving CO_2. Justin said there may be a loss of carbon in mineral soil, as a result of afforestation, but this is minor compared to the total positive effects. New Zealand will have an almost embarrassing surplus of carbon credits in the reporting period of 2008-2012, but¾as Murray Ward pointed out¾this does not mean that New Zealand's fossil fuel users can expect a "free ride". New Zealand's carbon credits will be available for sale to the highest bidder, overseas or domestic. Domestic fossil fuel emitters will therefore not be insulated from international pressure to reduce emissions. I have been involved in the science of carbon sequestration for almost 9 years, and I sometimes find it embarrassing to stand at conferences alongside large countries like the U.S. and Russia, given New Zealand's insignificance in the global greenhouse gas picture. On the other hand, our small size and intense focus (one major plantation species) enables us to clarify the concepts and models. This is New Zealand's major contribution to the debate. From our simple situation, we can easily progress to more complicated, interesting forestry questions.

Timo Karjalainen, from the European Forest Institute, demonstrated once again the superb understanding that Fins have of their forests. Their models are sensitive to environmental factors, such as temperature, and include soil carbon and wood products. They have been tested by a series of eight national forest inventories. To New Zealanders, it may seem strange to develop such a high level of expertise for forests that have an MAI one-twentieth that of this country. But, on the other hand, their managed forests are twenty times the area of those in New Zealand. Despite being on the opposite sides of the world, and originating from quite different cultures, Finland and New Zealand appear to have a lot in common. We have similar sized countries and similar people. For both of us, forestry is a business, not just a hobby. Ian Hunter, who worked for years in New Zealand's Forest Research Institute, became head of EFI. Timo's major conclusion was that global warming would result in a turnaround from the Finland forests being a sink to being a source. This was no surprise to me. Indeed, there is no forest anywhere that can be a carbon sink in perpetuity. Even without global warming, they must all eventually become steady-state reservoirs, or¾more likely¾fluctuate between being sinks and sources. When the "missing sink" becomes a "missing source", the global scientific community will develop a greater interest in this problem.

Kim Pingoud, also from Finland, has accumulated an impressive amount of comparative data on bioenergy. The expertise of the Fins is demonstrated by the fact that they are building pulpmills in other European countries, who are themselves at the forefront of industrial development. As this is not my speciality, I could not follow much of Kim's points, but I did observe the importance he places on biomass fuels, as a step towards self-sufficiency in energy production. This applies particularly to industries included in the forestry sector. Lastly, I have great admiration for people like Kim who have the ability to present papers in other languages¾English is the *fourth* language that Kim learned! I could not give a paper in any language other than English.

David Whitehead, from New Zealand, described his elevated CO_2 project using waste gas from municipal effluent ponds. Two species of trees had been used, and after three years he can report that a high CO_2 environment appears to result in a continued increase in uptake. This is not, however, reflected in continued growth. David used the expression "diameter growth", which puzzled me, because diameter growth in radiata pine climaxes at a very early age, even without enhanced CO_2. It would be more relevant to use basal area or total biomass growth relative to ambient CO_2. Nevertheless, some factor other than CO_2 is probably limiting growth. Even if David is able to demonstrate that future trees will have higher rates of growth than present, this tells us nothing about the carbon density of future forests. Carbon stocks may not increase, because trees are merely harvested (or die naturally) at a younger age. David also consistently used the word "forest" when he meant "stand". This is a common fault throughout the literature: there are huge problems involved in "scaling up" an experiment from a leaf to a tree to a stand to a forest to the biosphere, and we cannot assume that this involves only simple multiplication. Having said this, David must be congratulated on satisfactorily completing an experiment of international importance with a shoestring budget.

Joseph Spitzer ended the formal talks with a short plea to concentrate on the bioenergy aspects of carbon sequestration, rather than being diverted into the issue of changes in standing carbon stocks, which he sees as a minor consideration.

One final comment: during the Kyoto meeting, our local environmentalists (Greenpeace New Zealand) made a characteristic protest. They scaled our parliament buildings, with a solar panel, to make the point that the future lies in solar energy. I think they have got it half right. They are quite correct in observing that the income of the world is the sunlight that falls on the planet every day, and that fossil fuels represent our capital. As any businessman knows, it is unsustainable to go on living off your capital. What Greenpeace have failed to appreciate is that a solar panel does not have to be an artificial construct of plastic, glass and aluminium. This device takes energy to manufacture, and in any case does not store the electricity that it captures. To do that, we need backup systems of hydroelectric dams. I don't know why some environmentalists are so opposed to most forestry practices, especially plantation forestry, because a tree is just a natural, biological, solar panel and fuel storage unit. Bioenergy is the sustainable, green solution for the twenty-first century. Thank you.

Energy, Bioenergy and the Carbon Budget of the Canadian Forest Product Sector

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Abstract

Forest ecosystems hold approximately 75% of the Earth's organic carbon (C), with Canada possessing one-tenth of this reserve. Canadian boreal forests have experienced changes in productivity and organic matter decomposition during last 20 years. The net result of these changes, together with changes in the disturbance regime, has been a shift in these systems changing from a net sink of atmospheric C to a small net source. Although many factors that influence the forest C-cycle are beyond direct human control, management of short-term forest product sector activities can either mitigate or aggravate the net C-balance. The Forest Product Sector (FPS) model, designed to work with the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS), accounts for harvested forest biomass C from the time it leaves the forest until it is released into the atmosphere, use and production of energy by the FPS, and emission of CO_2 during FPS processing. The FPS accounting framework uses the characteristics of different forest product types to estimate the storage of C in forest products; it tracks C through all processing steps from the transportation of the raw harvested material through various processing steps in sawmills or pulp mills, to its final destination (product, pulp, landfill, atmosphere, or recycled). Since not all the C harvested is released into the atmosphere the year it is harvested, the model tracks C in various short- and long-lived products, and in landfills. Model results are in general agreement with available data from 1929-1989.

Key words: carbon, carbon budget, carbon balance, forestry, forest products, model.

1. Introduction

Over the next 50 years, carbon (C) emissions resulting from anthropogenic activities, along with other greenhouse gases (GHGs), are projected to lead to global increases in mean surface temperature of 1.5°-4.5°C, sea level between 13 to 94 cm, global precipitation by 3-15%, global evapotranspiration by 5-10% and an average decrease in summer soil moisture (Manabe and Wetherald 1986; Schneider et al, 1992; IPCC 1995). The primary anthropogenic sources of GHGs, of which CO_2 is the most important, are associated with the burning of fossil fuels, land use change, and cement production (IPCC 1992). The most important contribution of land-use change to the GHG balance is deforestation, which presently accounts for ca. 20% of the net annual anthropogenic CO_2 emissions to the atmosphere (Anonymous 1992; Houghton et al 1992). Land-use practices, such as forestry operations, may also contribute to the net exchange of GHG with the atmosphere. It is generally assumed that under sustainable forest management practices, in which logging withdrawals balance net forest biomass increment, the net exchange of CO_2 with the atmosphere is negligible (Houghton et al 1992). Apps and Price (1996) pointed out, however, that changes in other system components' C-stores (viz. litter, soil, forest products, and energy use) must also be taken into account (Fig. 1). This paper examines the role of forest products in the C balance of Canadian forests and forest sector activities.

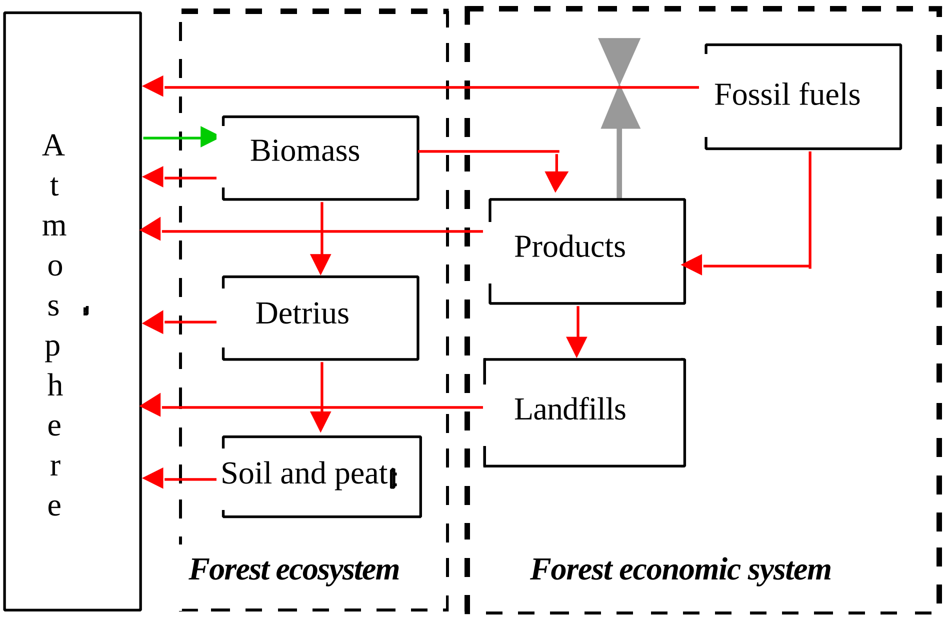

Figure 1. Forest system carbon (C) cycle. The main C reservoirs are in the atmosphere and forest ecosystem (left side) and in the forest sector (right side).

Forests and forest sector activities play an integral role in the dynamics of the global C-cycle. Forests cover ca. 30% of the global land surface but hold about 75% of the Earth's organic C (Houghton and Skole 1990). Globally, the forest biomass C reserve has decreased by 50% in the last 150 years (Houghton and Skole 1990). This loss has been associated with population growth and deforestation, primarily in the third world (IPCC 1995; Grainger 1996). Forestry practices – especially logging – clearly also influence forest ecosystem carbon stocks, but the resultant effect on the global carbon cycle – specifically the net exchange with the atmosphere –

includes more than change in forest biomass. A proper assessment of the net exchange of CO_2 between managed forest ecosystems and the atmosphere, requires that changes in all carbon pools influenced by forestry activities be estimated. Forest C pools can be divided into two major classes (Fig. 1). In the forest ecosystem (left side of Fig.1), C is exchanged between (i) tree biomass; (ii) detritus; and (iii) soils/peat and the atmosphere. Forestry operations remove carbon from the forest ecosystems, store it in different products, and influence the global C cycle in other ways (right side of Fig.1). Harvesting transfers C from the forest ecosystem to the FPS where it is converted into different products (e.g., energy, pulp, paper, lumber). The C releases and emissions from forest products include (i) decomposition and combustion of harvested tree biomass (including use of biomass for energy production, and the substitution for fossil fuels); (ii) decomposition of residues and waste from forest products in landfills; and (iii) C-emissions from the use of fossil fuels and cement in the forest sector. The net flux between C in the FPS and the atmosphere affects the status of Canada's forests as C-sinks or C-sources.

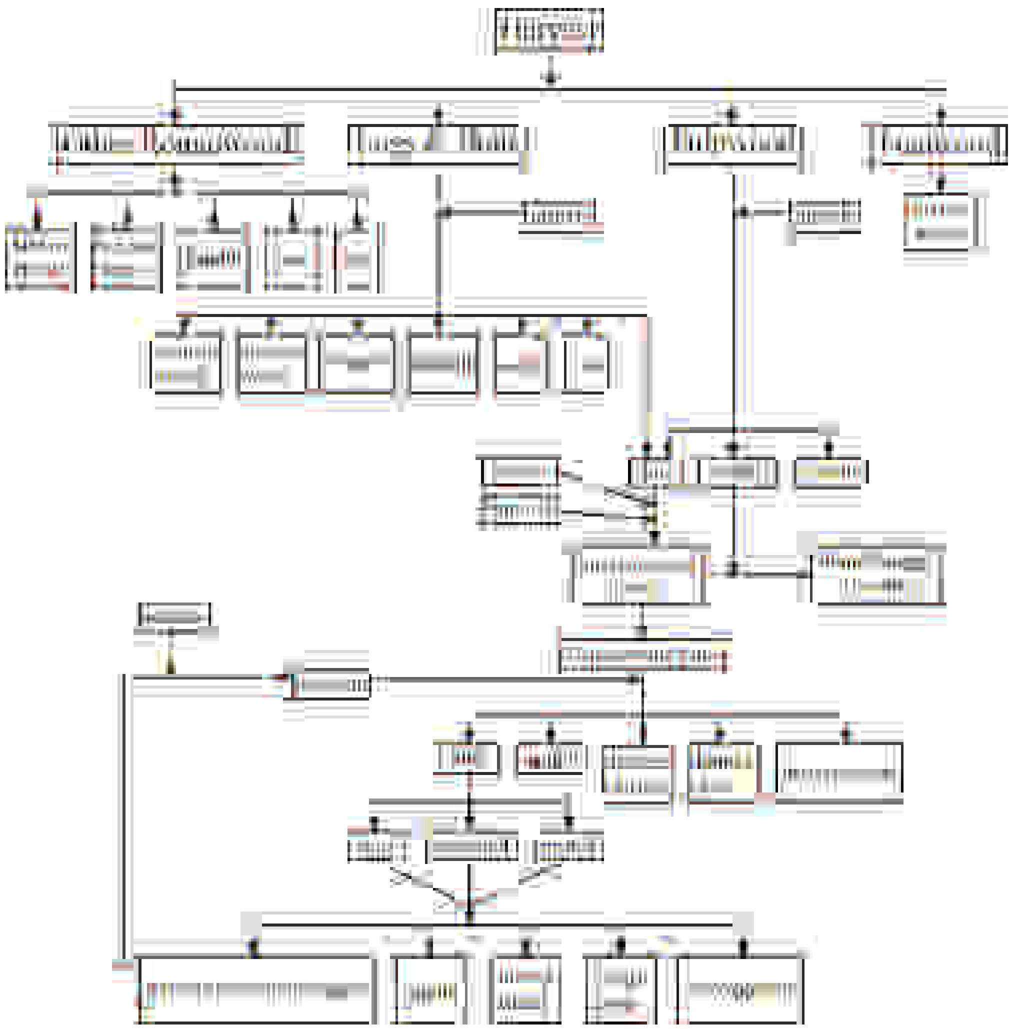

Figure 2. Flow diagram of the fate of various carbon pools in CBM-FPS

As Canadian forests account for 10% of the world's forested area, the net budget of C-fluxes between the Canadian forest sector and the atmosphere can have a significant impact on the global C-cycle. During the last 20 years, Canadian forests have experienced decreases in net ecosystem productivity and increases in the pools of decomposing organic matter. An increase in natural and anthropogenic disturbances has been reported (Kurz et al 1995), causing the Canadian boreal forest to become a small net C-source rather than a C-sink. While many factors controlling the C-cycle can not be directly influenced by national policy (e.g., global population growth rates, natural disturbances), short-term FPS activities are a significant and potentially manageable variable which can mitigate or aggravate the forest's C-source status. Forest and bioenergy strategies offer the prospect of reduced net C-emissions to the atmosphere through four mechanisms: (1) C-storage in the biosphere; (2) C-storage in forest products; (3) biofuel use to displace fossil-fuel use; and (4) use of wood products rather than products that require more fossil fuel for their manufacture (Schlamadinger and Marland, 1996).

The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2) is a dynamic C accounting simulation model that accounts for the main C pools and fluxes in the forest ecosystems of Canada (Kurz et al 1992; Apps and Kurz 1993; Kurz and Apps 1994; Kurz et al 1995; Kurz and Apps 1996). It uses empirical equations to simulate annual forest growth and soil decomposition for the different forest ecosystem types and observed disturbance history to estimate changes in net carbon exchange between the forests and the atmosphere (forest net ecosystem productivity, NEP) at regional (Kurz and Apps 1996), provincial (Kurz et al 1997), biome (Price et al 1996, Kurz et al 1996) and national (Apps and Kurz 1993, Kurz et al 1992) scales. The CBM-CFS has also been used to examine the sensitivity of national scale NEP to prescribed changes in growth, disturbance and decomposition rates under different climate change scenarios (Kurz et al 1994).

The CBM-CFS is fully described in the cited references and only its use with the forest product sector model (CBM-FPS) will be discussed in the present work. Here, CBM-FPS is described, and the contribution of the Canadian FPS to the national C budget is assessed. The CBM-FPS has been changed in numerous ways from an earlier version of the model described in Kurz et al (1992), and makes use of a larger and more complete database. The FPS model is designed to work with data from the CBM-CFS2, to provide estimates of C-stock changes in both forest ecosystem and forest product sectors (Fig. 1). Together the CBM-CFS and CBM-FPS provide a dynamic assessment of the influences of forest practices on the contribution of forests and forestry to the global carbon cycle, including forest NEP, and FPS production, energy use, energy production, emissions, and C-pool dynamics. To support both assessment and planning objectives the CBM-CFS and CBM-FPS can use observed data (for retrospective analysis) or scenario data (for projective analysis) as input.

2. The Canadian Carbon Budget-Forest Product Sector Model (CBM-CPS)

The CBM-CPS follows the transfer of C between different FPS pools (stocks) derived from harvested forest biomass from the time it is removed from the forest until it is released into the atmosphere (Fig. 2). It also accounts for the production and use of energy from harvested biomass and estimates the emission of C-based GHGs in all stages of the product production and utilization. The model simulates changes in the C-stocks of different pools during all processing steps from the transportation of the raw harvested material, through the various processing steps in sawmills or pulp mills, to its final destination (product, pulp, landfill, or atmosphere). These stocks are associated with various short- and long-lived products, their re-use through recycling, and their disposal in landfills. Export and import activities are accounted by keeping track of product C in three categories: (1) C still in Canada; (2) C that was exported; and (3) C imported into Canada.

Canadian ecosystem C inputs to the forest product sector (expressed in units of Mg C or Mg C yr^{-1}) are obtained from independent data (Canadian Forest Service 1988; Canadian Council of Forest Ministers 1992) or from CBM-CFS2 estimates. The flows of carbon represented in the CBM-FPS (Fig. 2) and the assignment of the input stream into four general product classes characterized by the half-life of the C associated with them and their expected use or subsequent fate.

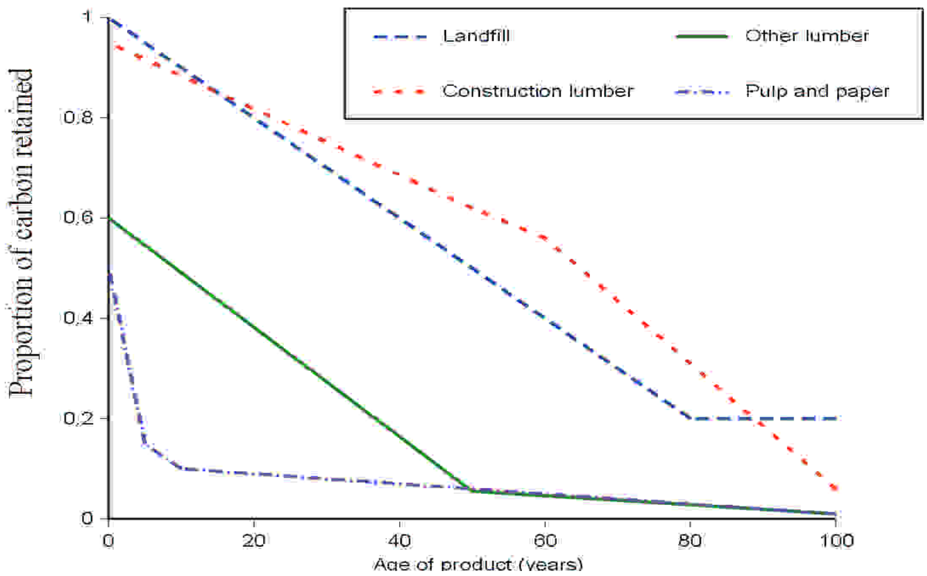

Figure 3. Carbon retention curves for three different categories product and for forest products discarded in landfills

The C-pools shown in Fig. 2 account for product C in different age cohorts, i.e., those which were created in each simulation time step. At each time step, the model ages each pool using its characteristic ‘retention curve’ (Kurz et al 1992) which describes how much of the product in that age cohort remains in the pool (Fig. 3). As the pools age, losses of C occur due to decomposition, burning, recycling, or transfer of that material to the landfill pool. It is assumed that material entering the landfill remains there until it has decomposed.

2.1. SOLID WOOD PRODUCT C POOLS AND FUELWOOD

The processing of roundwood (the upper two streams in Fig. 2) produces short and long-lived products and residues that decompose or are recycled, transferred to landfills, burned as waste, and burned to provide energy (Fig. 2). The "slow" pool represents C in lumber and forest products that remain in use for long time periods (such as that used in buildings and other structures). The "fast" pool represents non-pulp products used for a shorter period of time (e.g., packaging or lumber scraps). The processing of logs and bolts also produces chip residues which are added to the pulpwood stream.

‘Fuelwood’ in the CBM-CFS is wood that has been harvested for industrial use only and does not include domestic use. Fuelwood is assumed to be completely burned for energy. Thus, no energy besides the initial transportation energy is used, and no part of this wood is accounted in of the product pools.

2.2. PULPWOOD AND FUELWOOD C POOLS

The processing of harvested forest biomass destined for pulp and paper production is shown in the third stream of Fig. 2. The 'pulp and paper' pool contains all C in products associated with pulp and paper production. The accounting of C and energy use in the processing of pulpwood is more complex than for solid wood products. Pulpwood is first converted into chips, with some assumed loss for the debarking process, assumed to be completely burnt for energy as hogfuel. In the primary processing stage, the chips are divided into ten different processing types, including both chemical and mechanical types (Table 1), with each having a different production efficiency (pulp product output/chip input). Residues at each stage are either burned (as spent liquor for energy or as waste), sent to landfills, or assumed to decompose immediately.

Table 1: Types of processes used in the model. Recycling is a separate type.

Chemical	Mechanical	Other
Bleached Kraft	Refiner	Recycled
Unbleached Kraft	Thermo-mechanical	
Bleached Sulphite	Chemi-mechanical	
Unbleached Sulphite	Stone Groundwood	
Semi-chemical		
Dissolving and Special Alpha		

In the secondary processing, the pulp undergoes further processing to produce final products. The end-product C is represented in three end-use categories: market pulp, newsprint pulp, and other pulp (that destined for other paper products including groundwood and printing, writing, wrapping, tissue and sanitary, linerboard, corrugating, box board, and building papers). Production losses are accounted through decomposition during production, combustion as waste or for energy and transfers to landfills.

2.3. LANDFILL C POOL AND RECYCLING

The landfill pool contains all discarded biomass C resulting from various production steps or from the disposal of forest products. The landfill pool has the same structure as the slow and fast product pools, except that the landfill pool has higher retention, and all losses are assumed to be releases to the atmosphere through combustion or decomposition, either aerobic (CO_2) or anaerobic (CH_4). Recycling of lumber products is accounted for by taking a proportion of each age class in the pool and transferring this to the youngest age class of the same pool (avoiding the lumber processing losses that harvested biomass undergoes). Recycling of pulp and paper products is more complex because both imported and recycled materials are added at the primary processing stage in each time step, but data is only available for the sum of the two sources. Imports and exports of the newly produced pulp and paper products occur before the products are added to the product pools. Newly produced pulp and paper products are added to the pulp and paper pool. The model first makes the assumption that all material that is imported for recycling comes from Canadian paper products outside the country (i.e., products in the pool of C that was exported in previous years). If the imported material is insufficient to account for the

C needed for recycling, the model then removes C from the paper products pool, starting with the youngest ages (i.e., the most recently created products). Once this process has generates enough recycled C, the accounting follows the processing steps shown in Fig. 2.

2.4. ENERGY ACCOUNTING

The processing of harvested biomass in the forest product sector uses a range of different forms and amounts of energy, each of which have different C emissions associated with them. The CBM-FPS accounts for energy used in all processing steps (including transportation) from the time of harvest until the final product is produced. It does not, at the present time, include energy expended in silviculture, transportation of the final product to its place of use, or transportation of recycle materials outside the forest sector (e.g., from municipal newsprint waste collection sites). Five types of energy use are recognized in the model: (1) fossil energy; (2) purchased electrical energy; (3) self-generated hydro-electrical energy; (4) energy from fuelwoods and wood waste, including hogfuel; and (5) energy from pulp-processing residues (spent liquor).

Energy produced as products or byproducts of biomass processing play an important part in the energy budgets (and economics) of the FPS (Fig. 2). The model currently makes independent estimates of bioenergy used and bioenergy produced in each time step – there is no constraint to force the amount of bioenergy used in the pulp sector to be comparable to the amount of energy produced in that sector. Estimates of bioenergy use in each pulp processing type (Table 1) are based on empirical ratios of energy production to pulp production. Energy produced through burning hog fuel or spent liquor is calculated from the proportion of residue allocated to these categories and their calorific values.

2.5. ACCOUNTING OF EMISSIONS

The model calculates the GHG emissions (CO_2, CH_4, or CO) associated with each stage of processing and use of harvested biomass, including the loss of biomass through combustion or decomposition in product manufacture, as a product and in landfill. It also accounts for emissions through use of different energy forms during the processing. The model tracks whether these emissions are from biomass (burning as waste, burning for energy or decomposition) or fossil energy (fossil fuel), and the processes that generated the emissions (i.e., transportation, processing, or the aging of pools). Emissions from fossil fuels are calculated from the amount of fossil fuel or externally produced electric energy used during processing of forest products – these emissions are a direct estimate of the emissions from actual energy use in the forest product sector. Bioemissions (those directly associated with loss of biomass) are calculated from the amount of C allocated in the model to combustion (as waste or for energy) and decomposition. In the model the emissions associated with bioenergy are based on energy production, not energy use in the forest product sector.

2.6. IMPORTS AND EXPORTS

With the exceptions of pulp and paper recycling, imports and exports, the model works with proportions, i.e., the apportioning of harvested C into product streams (Fig. 2) uses multipliers which always add to one. In a given time step, the amount of C to be recycled from pulp and paper products is expressed as a multiplier on the amount of C harvested (i.e., increasing the amount of C entering the processing stream). Imports and exports are specified as absolute amounts as it is not possible to relate these amounts to harvested C. The model does, however, ensure that it does not export more C than is available for export. If no imports occur, the model will conserve C. The model accounts for C harvested in the spatial unit in which it was produced no matter where it may subsequently be transported. This includes the C that is exported – this C is accounted for in the budget of the spatial unit in which it was harvested.

3. Input data and simulations

The CBM-FPS uses annual harvest biomass (converted to C units) as its input driving data (Fig. 2). The source of these data can be historical records of feedstock received by mills and processing plants, simulated output records from the forest ecosystem model CBM-CFS, or prescribed scenarios to examine the consequence of FPS alternatives on future C stocks and flows. This paper focuses on results obtained using historical data. As shown in Fig. 1, however, to assess the implications of FPS practices on the global C-cycle requires estimates of changes in both FPS C-stocks (CBM-FPS) and forest ecosystem C-stocks (CBM-CFS2).

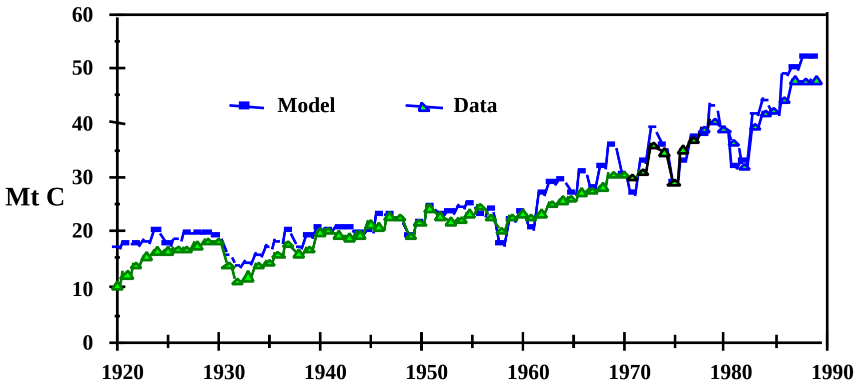

Figure 4. The total harvest predicted by the CBM-compared with historic data.CFS2

It is possible to run the CBM-FPS model interactively with the CBM-CFS2 model to provide a complete forest sector analysis, or to run them separately. Fig. 4 shows the CBM-CFS2-predicted harvest, obtained by simulation of harvesting operations in Canada's forests, together with the historic data independently reported by the forest product sector.

Table 2: Regions used in the model.

Region	**BC**	**Prairies**	**ONT**	**QUE**	**Atlantic**
Province(s)	BC	Alberta Saskatchewan Manitoba	Ontario	Quebec	New Brunswick Prince Edward Island Nova Scotia Newfoundland

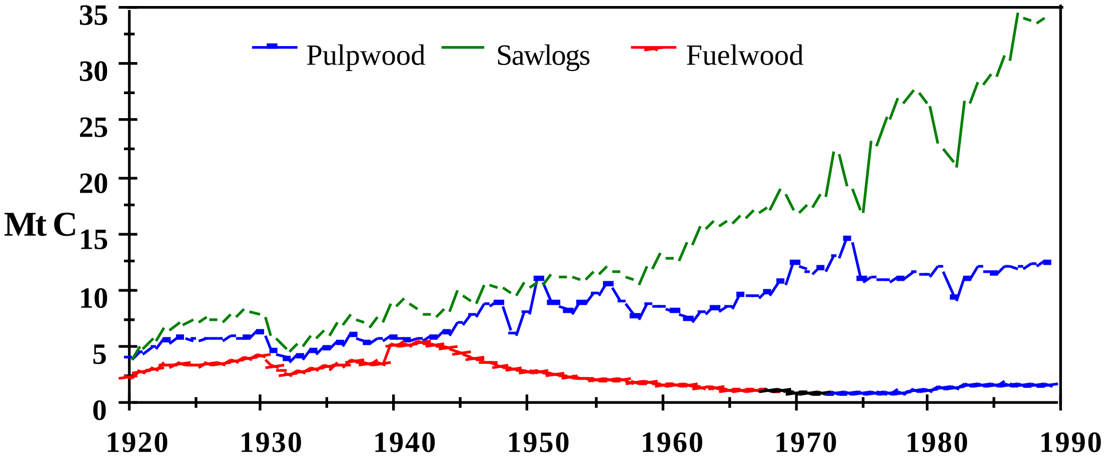

Figure 5. Allocation of harvest by wood type.

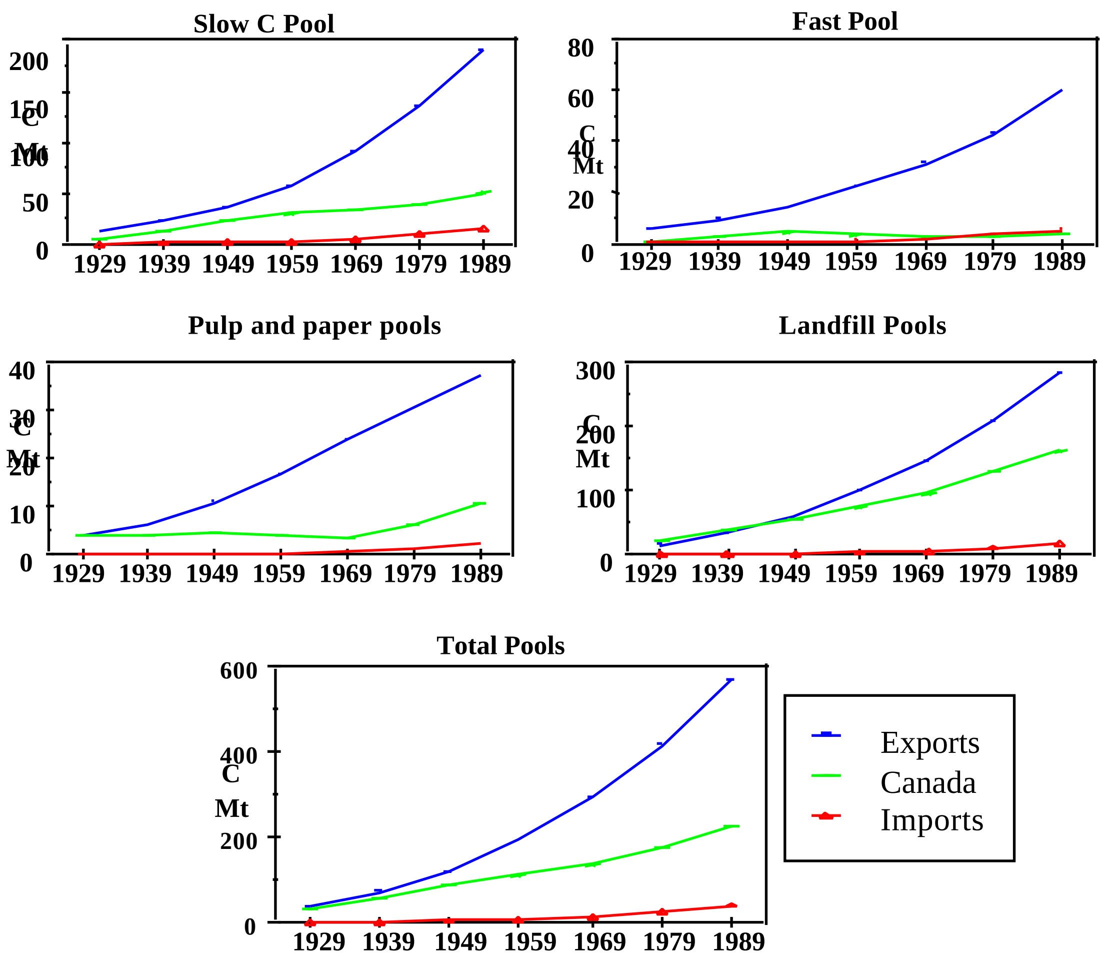

Figure 6: Product, landfill, and total pools in three categories: exported C, imported C and Canadian C that stayed in Canada. Canadian C is the sum of the bottom two segments in each case (exports plus Canada) and C in Canada is the sum of the top two segments (imports plus Canada).

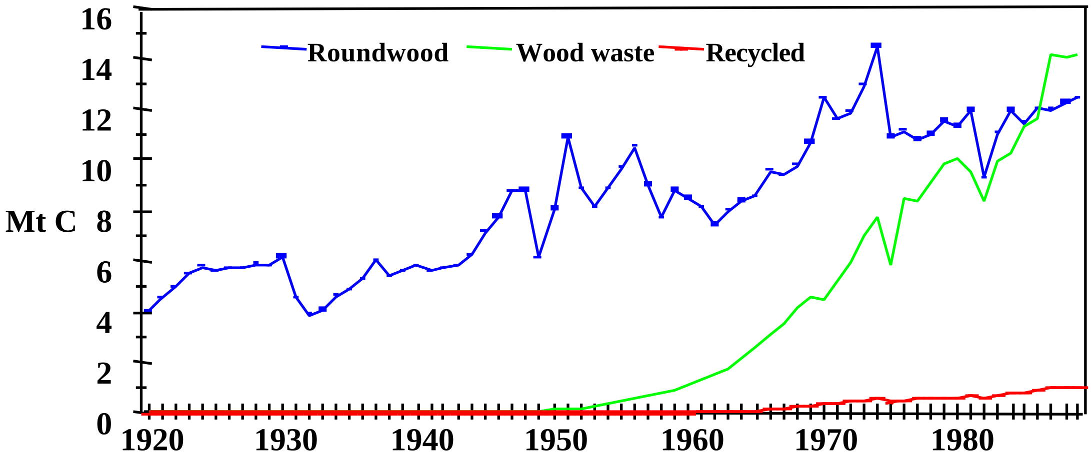

Figure 7. Sources of C entering the pulping process.

Historical data were compiled from a wide variety of federal (Canadian Forest Service 1988) and provincial sources as reported in Kurz et al (1992). Where necessary, gaps in FPS data have been augmented by extrapolating available data using data from adjacent spatial units or temporal averages. Parameters in the model are defined at different spatial scales. These scales include: the entire country (i.e., the same value is used throughout the country), a province (i.e., each province has a different value), or a region (Table 2). The CBM-FPS simulates at annual time-steps. The analysis is restricted to the period 1929-1989.

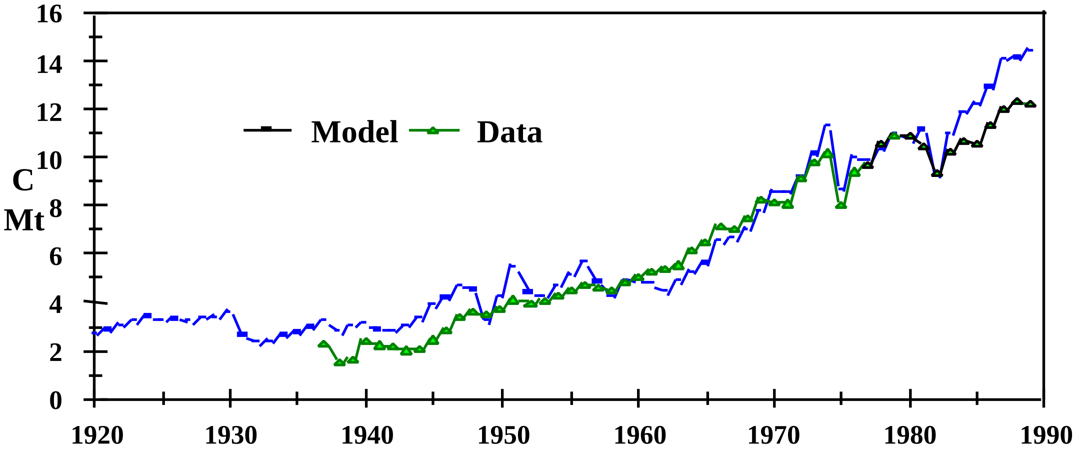

Figure 8. Comparison of the total pulp produced in the model and the actual data. Data on pulp production are only available back to 1937.

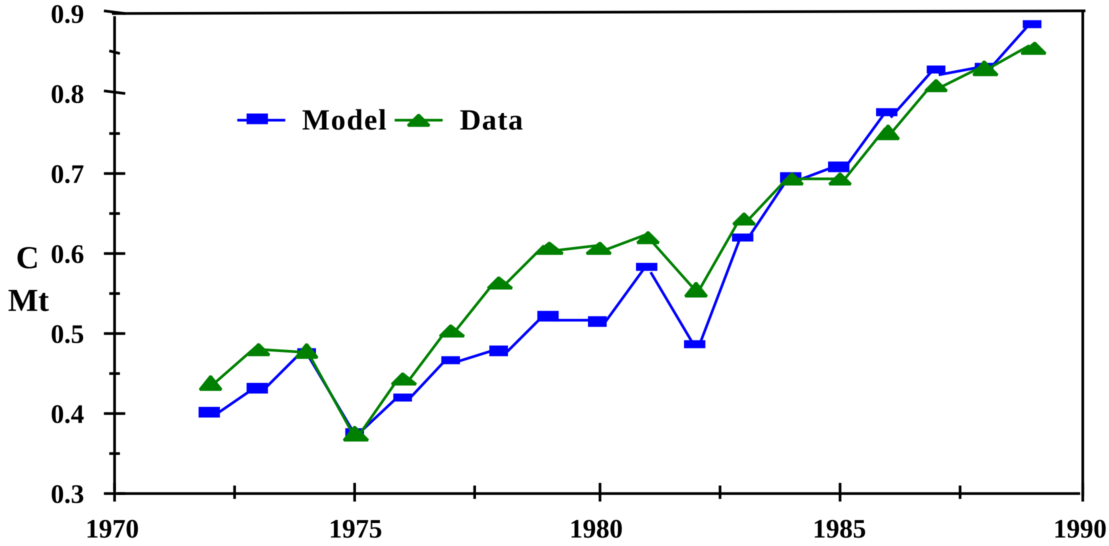

Figure 9. Comparison of the pulp produced from recycled material in the model and the actual data. No data are available before 1972.

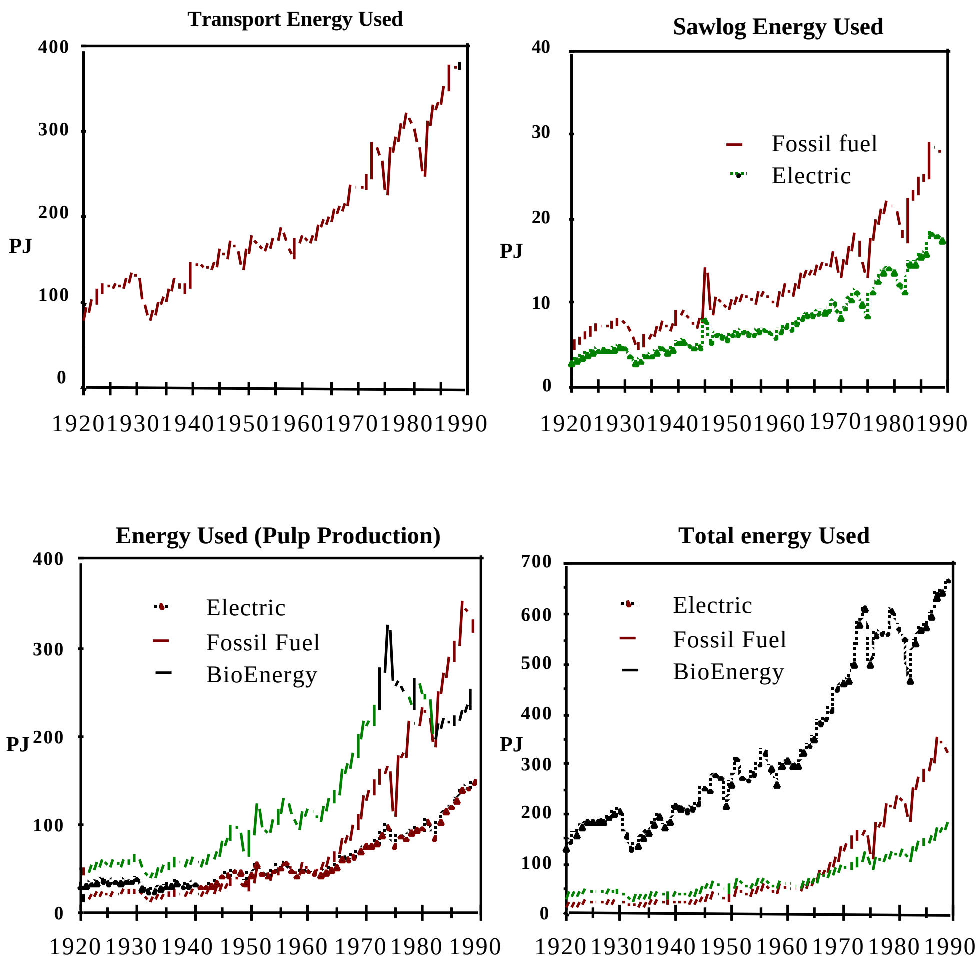

Figure 10. Energy use by sector and type of energy. Transportation includes the transportation of all types of harvest, including fuelwood. Sawlog and pulp energy used is the energy used in the processing of the roundwood into the product and does not include the energy used in the initial transportation of the harvested

4. Results

The FPS produces large quantities of output allowing a detailed analysis of the various processes and pools accounted for in the model. Here only the highlights of the model results, using the historical harvest input data for the period 1920-1989, are shown and discussed

4.1. Changes in FPS C-stocks

In addition to the increases in harvest over time (Fig. 4), the allocation of harvested biomass to different product streams has also changed significantly over the period of record, with sawlog production becoming increasingly important after 1950 (Fig. 5). As a result of both these factors, C-stocks in the forest product pools have grown over the period of record, reaching an estimated total of 850 Mt C by 1989 (Fig. 6). Pools having a long turnover time (slow pool and landfill) are, not surprisingly, the largest storage pools.

Exports play an important role in the C balance of the Canadian FPS (Fig 6) – large quantities of C are exported every year, ending up as product (Fig. 6a, b, & c) or landfill pools (Fig. 6d) outside the country. About 50% of the C exported from Canada is estimated to enter landfills outside the country.

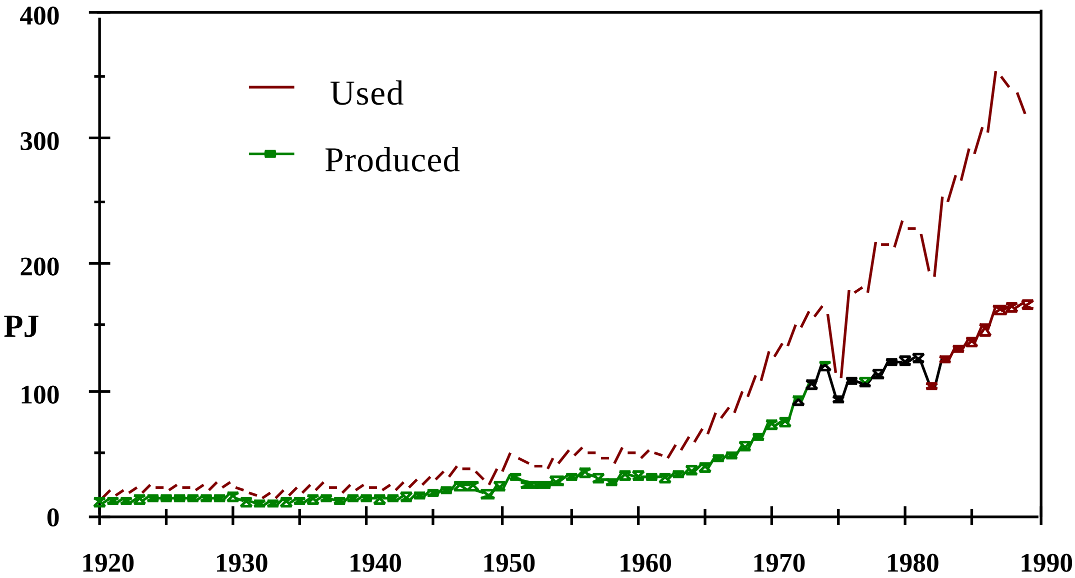

Figure 11. Bioenergy produced and used in the model in the pulp sector. Bioenergy is the sum of hogfuel and spent liquor energy

The increased proportion of sawlogs in the harvest stream appears also in the fast and slow lumber production (Fig. 6). Increases in harvested wood resulted in an increase in the amount of harvested sawlogs with a small change in the amount of harvested pulpwood (Fig. 5). Sawchip production has also risen strongly, providing material for the pulp processing stream. The increase in sawchip production is related to efficiency changes in the industry, with more of the 'waste' material being sent to pulp mills for use as chips or hogfuel. The amount of C entering the pulping process from pulpwood remains relatively constant while the use of C from other sources (wood waste and recycled material) for pulp production increased considerably (Fig. 7).

The model's predicted and actual total pulp produce are close, especially from 1950 to the early 1980s (Fig.8). The residual errors in the pulp production estimates can likely be explained by a more detailed analysis of the pulp production in each of the ten processing types. Recycled materials were handled differently amongst the ten pulp processing types but predicted and actual pulp produced from recycling material also match reasonably well (Fig. 9). The increase in the production of recycled material is independent of the increasing use of saw chips or pulpwood from harvested wood. Newsprint and other pulp production is predicted reasonably well (at least within 10% of the data). The model also makes a good prediction of the proportion of the pulp that is processed by mechanical pulping versus chemical pulping.

4.2. ENERGY

Energy use varies between different components in the sector. Transportation of the wood from the harvest site to the mill is the biggest use of fossil fuel energy (Fig. 10) while the processing of sawlogs uses a relatively small amount of energy. In the model, bioenergy is used exclusively in the pulp sector, which also uses fossil fuel and electricity. With increased use of bioenergy in pulp production, there was corresponding decrease in the use of fossil fuel. Bioenergy produced and used in the model during the pulping process show the same general trends (Fig. 11), but, especially in more recent years, bioenergy used is higher (50%) than the bioenergy produced, however the trend is the same. These differences between bioenergy used and produced might be due to errors in FPS model estimates of hogfuel and spent liquor produced during the pulping process. Data on bioenergy use in wood processing are not available. Thus, although it is known that steam operated sawmills were in use early in the 20th century, numerical data for the historic use of bioenergy for this purpose does not exist.

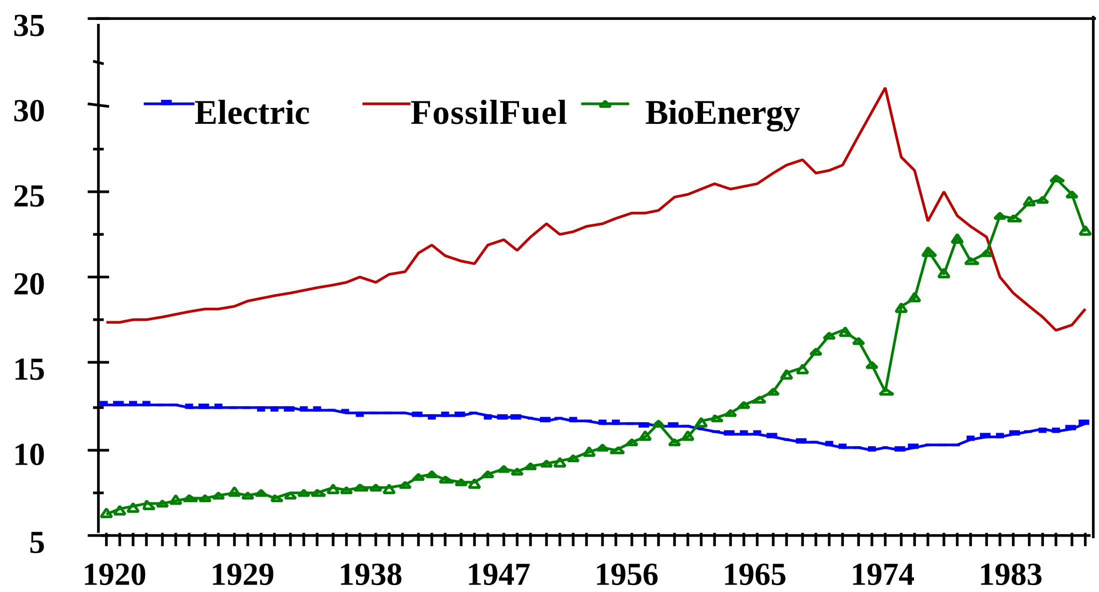

Figure 12. Energy used in processing pulp per ton of pulp produced for each of the general energy categories.

Since the model predictions of total pulp production are generally in agreement with the actual data, the total energy used in each case can be compared directly. If the energy use data from the model are transformed to be the energy used per ton of pulp produced (Fig. 12), the results are in qualitative agreement with the actual energy use as estimated by the Canadian Pulp and Paper Association (1994). The use of fossil fuel for pulp production has decreased since 1974 and it appears that this decrease has been due to increased use of bioenergy.

4.3. Emissions

Bioemissions vary greatly between the different sectors. Sawlog processing produces bioemissions only during the combustion of waste while fuelwood produces emissions only from burning for energy production. Processing of pulpwood generates bioemissions from all three release mechanisms: burning for energy, burning for waste, and decomposition. There were high levels of emissions from fuelwood in the early years when other energy sources were less used (Fig. 13c). In the pulp sector, increases in emissions from burned energy accompanied the increased use of waste for energy production (Fig. 13b) while emission from burned waste stayed relatively constant. The increasing emissions from decomposition are the result of an increasing landfill C pool over the years.

Comparison of emissions and harvest inputs are a measure of the carbon storage efficiency of the FPS (Fig. 2). Within Canada, during the last 45 years of the model simulation, the proportion of C that has entered the FPS and that left as emissions has declined (Fig. 14). This decline occurs for many reasons, including the reduction in the use of fuelwood (Fig. 13c), the large portion of C in different pools was exported from Canada (Fig. 6), and the steady increase in harvest levels (Fig. 4). Even assuming sustainable forest harvests, in the long-term it must be expected that the ratio of C entering and leaving the FPS will approach 1 as the sum of the inputs into the FPS is equal to the sum of the losses from processing and decomposition. The approach to this saturation of the FPS sink is determined by the time constants of the decomposing pools and the proportion of the harvested material ending up in them. Pools that have a long turnover time, or permanently store C without further decomposition, contribute most to the long term FPS sink. For example, some landfill C that is protected from decomposition represents very long term C storage. Efforts aimed at increasing the amount of C stored in the FPS will lower the proportion of C leaving the system. CBM-FPS simulations thus provide an indication that over the past 70 years, C retention of harvested material has increased.

5. Discussion and Conclusions

The CBM-FPS represents the first attempt to account for the C-fluxes in the entire Canadian FPS. The model includes all main components of the FPS system, including production, energy use, energy production, emissions and storage pool dynamics. It also accounts for imports and exports of forest products and can be linked to a forest ecosystem production model (CBM-CFS). These analyses indicate that management of forest resources has a substantial effect of the Canadian C balance. At present a large amount of C is being stored as forest product. This steady increase in storage of C in the FPS is primarily due to a steady increase in wood harvesting (Fig. 4) and a decrease in bioemissions (Fig. 13). Although all products release C back to the atmosphere on decomposition, pools that delay this release through further decomposition or combustion act as storage pools, reducing the proportion of C leaving the system. For a given production rate, the amount of C stored in wood product is mainly influenced by the lifespan of these products. The products in the slow turnover pools store the C for long period of time in comparison to the product in the short lifespan pools e.g. ‘Fast’ pool and pulp and paper product pool, which store C for short period of time. To delay the emissions of C back to atmosphere from shorter lifespan pools, the product’s turnover time may be extended or the end-fate of the product changed. Increased recycling of forest products acts to increase the residence of C storage in these products, especially the product with shorter lifespan. The model results indicate a substantial increase in Canadian use of recycled material in pulp production since 1970.

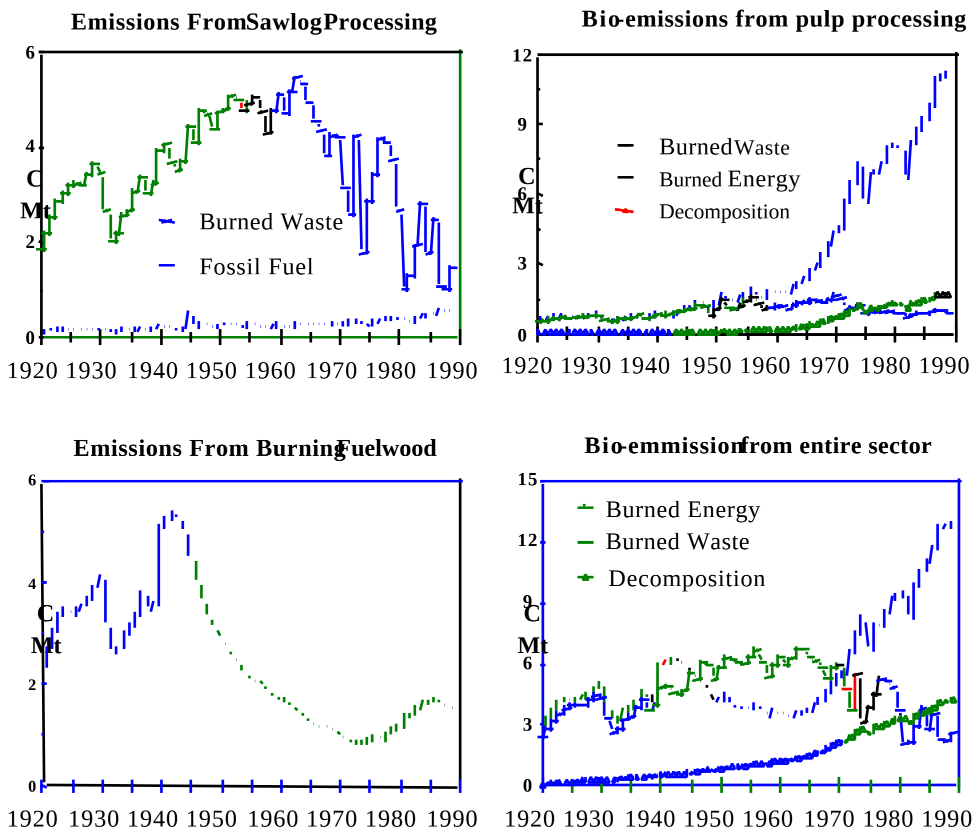

Figure 13. Bio-emissions from different parts of the forest products sector. The emissions from the entire sector include the losses from pools and landfills, while the other graphs portray only the emissions from processing.

Landfills appear to have accumulated large pools of C. About 70% of the C derived from forest harvest, both within Canada and exported from Canada, is estimated to end up in the landfills (Fig. 6). The model results are sensitive to the rate of decay used for decomposition of product in the landfills and these rates are not well established. Direct measurements of landfill C storage – and the attribution of its origin – is however problematic and impractical. Despite these sources of numerical uncertainty it is clear, however, that landfills may provide an important long-term storage for C, especially in Canada (Price et al 1996) due to cool and wet environment.

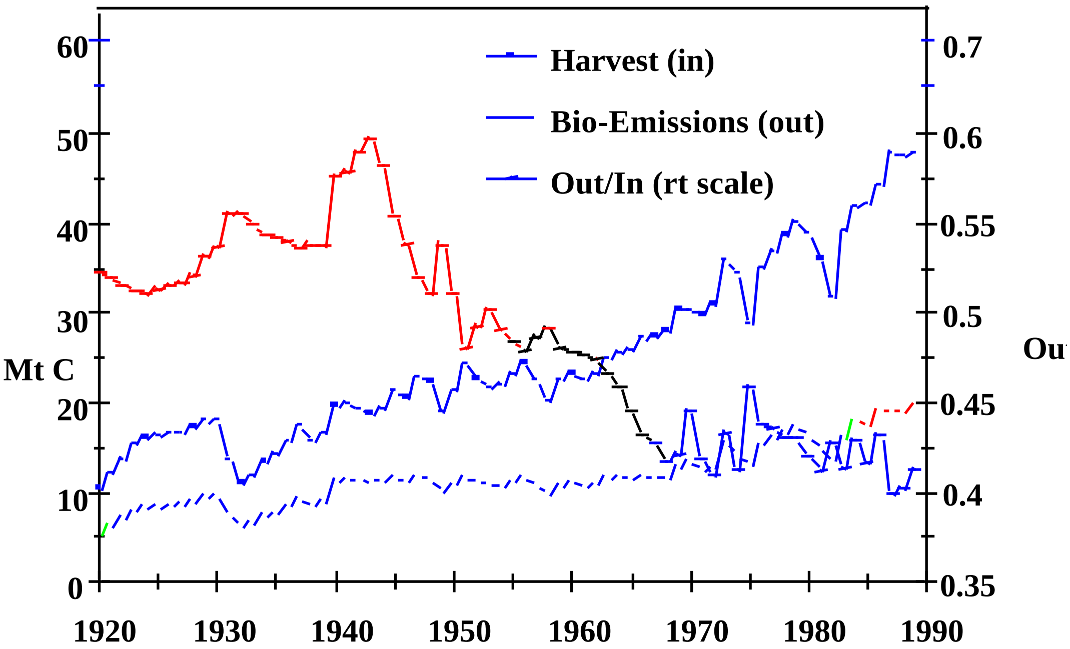

Figure 14. The C which enters and is emitted from the FPS within Canada. The C leaving Canada is through. bioemissions only and does not include the C that is exported.

Most of the FPS energy use (~90%) is used by the pulp and paper sector (Fig. 10). There has been an overall increase in C entering the pulping process since 1970 and a marked increase in the use of wood waste for bioenergy production by the paper and pulp sector. The increased production of energy from forest waste material has reduced the C storage in forest products (including land-fill) from what it would have been. The net effect of this change has, however, been a net reduction of C-emissions to the atmosphere as the bioenergy use has replaced the burning of fossil fuels (Schlamadinger and Marland 1996). In Canada, most of the C-emissions within FPS are from the pulping process and the emissions from fuelwood, sawlog processing and fossil fuel are decreasing. Further reductions in emission require changes in energy production and consumption within the FPS. The potential to further reduce the emission is found mainly in increasing the use of forest waste products for energy production.

In general, model results correspond reasonably well with available data from 1929-1989. Some of the simulated model results, however, deviate from the observed or reported data. Calculated values for newsprint and pulp production were within 10% of the reported data. At present, the model calculates energy use and production independently from one another and these estimates do not agree with each other. In addition, in the absence of historical data, the energy use coefficients in the model are assumed to be static from 1921 to 1971. There is every possible reason to speculate that energy use efficiency has changed considerably over period of time.

The model simulations appear to provide a reasonably accurate tool for retrodiction of energy/bioenergy use and the C budget of the Canadian FPS and the historical trends in these variables. Used in a projective mode, the model should provide a useful tool for both scientific advancement and sound policy decisions. The model is holistic, in that it looks at all C-pools in the FPS as a system rather than as independent, uncorrelated components. A change in an individual variable can alter the dynamics of interconnected variables and ultimately the estimated indicator for the entire system.

For scientific studies, FPS scenarios can serve as hypotheses that can be tested, rejected or improved on. The model also facilitates the synthesis of inter- and multidisciplinary data sets. Synthesis results in the generation of new data, which can result in additional and potentially avenues of scientific exploration. As the FPS simulates the probable outcomes of different policy options at different spatial and temporal scales, it can provide policy makers with well-informed option scenarios. Well-informed options will reduce the strength of partisan political agendas and assist policy makers in making the sound policy decisions.

Acknowledgments

This research has been funded, in part, through the Energy from the Forest program managed by the Department of Natural Resources Canada, Canadian Forest Service. We thank Ivor Simonson and the Canadian Pulp and Paper Association for providing summary statistics on the Canadian pulp and paper industry, Dave Luck and Statistics Canada for other industry data, and many representatives of Federal and Provincial Agencies, Universities, and Industry Organizations who provided data and information over the past years. The assistance of Tamara Lekstrum in compiling data during the early parts of this project is greatly appreciated. The authors are grateful to Dr Celina Campbell for contributions to an earlier draft of this manuscript.

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Appendix A

Workshop programm

List of participants

Task XV/25 Workshop Program

MONDAY, 9 MARCH 1998

9⁰⁰

9:00 ***Welcome and Introduction***

(Justin Ford-Robertson - Forest Research/NZ; Josef Spitzer - Joanneum Research/AUT and Operating Agent Task XV/25)

9:15 ***IEA Bioenergy Task XV/25 administrative matters - Part I***

1. From Task XV to Task 25
2. Nomination/confirmation of the National Team Leaders
3. Final Report Task XV
4. Task XV/25 Folder
5. Standard methodology for GHG balances of bioenergy systems: computer tool
6. National projects/research programmes (AUT, CAN, FIN, NZ, SWE, USA)

12:30 Lunch

14:00 ***IEA Bioenergy Task XV/25 administrative matters - Part II***

7. Task XV/25 WWW homepage
8. Work Programme 1998-2000 (basis: Task Proposal)
9. Work Programme 1998, to be approved at ExCo 41 (13-14 May, Sweden)
10. Next workshop (September 1998, Finland), other future workshops
11. IPCC collaboration
12. Miscellaneous items

18:30 Dinner (at expense of Task XV/25)

FRIDAY, 13 MARCH 1998

9:00 ***Welcome and introduction***
(Keith Mackie - Chief Science Adviser, Forest Research; Josef Spitzer - Joanneum Research/AUT and Operating Agent Task XV/25)

Part I: POLICY ANALYSIS AND TECHNICAL ISSUES (chair: J. Spitzer)

9:15 ***Sinks and the Kyoto Protocol - Interpretations, Implications and Unfinished Business***
(Murray Ward - Ministry for the Environment/NZ)

9:45 ***Technical issues regarding forestry and land-use change in the Kyoto Protocol***
(Bernhard Schlamadinger - Joanneum Research/AUT, currently at ORNL/USA and Gregg Marland - ORNL/USA)

10:15 ***Silvicultural carbon sequestration options under the Kyoto Protocol***
(Doug Bradley - E. B. Eddy Ltd./CAN; Canadian Pulp and Paper Association)

10:45 Coffee Break

11:00 ***Implications for forestry of government commitments under the FCCC***
(Murray Parrish - Forest Industries Council/NZ)

11:30 ***Does the Kyoto Protocol make a difference for the optimal carbon mitigation strategy? Some GORCAM results***
(Gregg Marland - ORNL/USA and Bernhard Schlamadinger - Joanneum Research/AUT, currently at ORNL/USA)

12:00 ***Discussion paper for the Australian Greenhouse Challenge Office's Carbon Sinks Workbook Carbon emissions avoidance through fire management. Theory and proposed methodology for estimation***
(Alice LeBlanc/USA; Neil Bird - Woodrising Consulting Inc./CAN)

12:40 Lunch

Part II: NATIONAL STUDIES, BASELINES, AND OTHER SCIENTIFIC ASPECTS **(chair: J. Spitzer)**

14:00 ***Replacing fossil fuels with forest fuels - baselines, CO_2 reduction and mitigation cost***
(Leif Gustavsson - EESS, Lund University/SWE)

14:30 ***Bioenergy and forest industry after the adoption of the Kyoto Protocol***
(Kim Pingoud, Antti Lehtilä, and Ilkka Savolainen - VTT Energy/FIN)

15:00 ***The effect of land use practices on greenhouse gases***
(Justin Ford-Robertson, Kimberly Robertson, and Piers MacLaren - Forest Research/NZ)

15:30 Coffee Break

15:45 ***How to determine baseline scenarios for a forest sector carbon balance***
(Timo Karjalainen, Seppo Kellomäki, Ari Pussinen, and Raisa Mäkipää - European Forest Institute/FIN)

16:15 ***Establishing a basis for the assessment of greenhouse gas and other impacts from combustion of biomass compared with coal***
(A. H. Clemens, W. W. Hennessy, T. W. Matheson, and R. S. Whitney - Coal Research Ltd./NZ)

16:45 ***Forest Ecosystems Elevated CO_2 Project***
(David Whitehead - Forest Research and Landcare/NZ)

17:00 Workshop summary, followed by final discussion

17:45 End of the Workshop

18:30 Dinner (at participants' expense)

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* Participation cancelled

Appendix B

List of key reports IEA Bioenergy Task XV

Final report IEA Bioenergy Task XV

IEA Bioenergy Task XV
List of key reports
(excluding those contained in this volume)

All reports are available from the Operating Agent at the following address
(except for copyrighted journal articles, or unless stated otherwise):

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Analytical Framework for Greenhouse Gas Balances of Bioenergy Systems.
Proceedings of a Workshop within Task XV of IEA Bioenergy in Graz/Austria, 20-22 September, 1995.
Includes 9 scientific papers and minutes of the workshop discussions.

- *Matthews, R..*
  Research on Energy Costs and Carbon Sequestration Value of Timber and Wood Fuel Production in Britain
- *Ford-Robertson, J. B.*
  Methods Used to Calculate the Carbon Balance of the Forest Industry in New Zealand
- *Schopfhauser, W.*
  A Global Afforestation Program for Carbon Sequestration - Conclusion and Further Research Implications
- *Freund, P.*
  IEA Greenhouse Gas R&D Program: Work on Full Fuel Cycle Analysis of Fossil Fuel Power Generation
- *Gustavsson, L., Börjesson, P., Johansson, B., and Svenningson P.*
  Reducing CO_2 Emissions by Substituting Biomass for Fossil Fuels
- *Sinisalo, J. and Savolainen, I.*
  Greenhouse Impact Expressed as Radiative Forcing Due to Bioenergy Fuel Chains
- *Marland, G.*
  Work in the U.S. on Biomass Fuels and Greenhouse Gas Emissions: Some Notes
- *Schlamadinger, B.*
  GORCAM - a Model to Calculate the Carbon Balance of Land Use and Bioenergy Strategies
- *Hektor, B.*
  Global Change and Boreal Forests: the Role of Forests in the Carbon Cycle - a Systems Approach with Special Focus on Nordic Countries

Schlamadinger, B. and Spitzer, J. (editors)
Greenhouse Gas Balances of Bioenergy from Forestry and Wood Industry.
Collection of papers published after the Task XV Workshop, Stockholm, Sweden, 29-31 May 1996.
Special Issue of *Biomass & Bioenergy* (Vol. 13, No. 6, 1997).

- *Schlamadinger, B., Apps, M., Bohlin, F., Gustavsson, L., Jungmeier, G., Marland, G., Pingoud, K., and Savolainen, I.*
  Towards a Standard Methodology for Greenhouse Gas Balances of Bioenergy Systems in Comparison with Fossil Energy Systems.
- *Marland, G. and Schlamadinger, B.*
  Forests for Carbon Sequestration or Fossil Fuel Substitution? A Sensitivity Analysis.

  Nabuurs, G. J., Päivinen, R., Sikkema, R., and Mohren, G. M. J.
  The Role of European Forests in the Global Carbon Cycle - a Review.
- *Boman, U. R. and Turnbull, J. H.*
  Integrated Biomass Energy Systems and Emissions of Carbon Dioxide.
- *Börjesson, P., Gustavsson, L., Christersson, L., and Linder, S.*
  Future Production and Utilisation of Biomass in Sweden: Potentials and CO_2 Mitigation (an update).
- *Pussinen, A., Karjalainen, T., Kellomäki, S., and Mäkipää, R.*
  Contribution of the Forest Sector in Carbon Sequestration in Finland.
- *Pingoud, K. and Lehtilä, A.*
  Role of Forest Sector and Bioenergy in Limiting the Carbon Emissions in Finland.

Papers presented by Task XV researchers at the Workshop "Implementation of Solid Biofuels for Carbon Dioxide Mitigation", 29-30 September 1997, Uppsala/Sweden (organised within the EU-funded ALTENER project "Evaluating Biofuels as a Means of Atmospheric Carbon Dioxide Mitigation" and Task XV; abstracts can be found on the Task XV homepage).
The workshop proceedings will be published as a 1998 Special Issue of *Biomass & Bioenergy*.

- *Bohlin, F.*
  Greenhouse economics and biofuels.
  Available from: Folke Bohlin, Department of Forest-Industry-Market Studies,
  Swedish University of Agricultural Sciences (SLU), Box 7054, 750 07 Uppsala, Sweden. Fax +46 18 67 35 22, e-mail: folke.bohlin@sims.slu.se

- *Christersson, L.*
  Energy forestry and its environmental consequences.
  Available from: Lars Christersson, Department of Short Rotation Forestry, SLU,
  Box 7016, 750 07 Uppsala, Sweden. Fax +46 18 67 34 40, e-mail: lars.christersson@lto.slu.se

- *Schwaiger, H. and Schlamadinger, B.*
  GHG mitigation potential of increased fuelwood use in Europe in 2020.
  Available from: Hannes Schwaiger, JOANNEUM RESEARCH, Elisabethstrasse 5,
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Schlamadinger, B. and Waupotitsch, M. (compilers)
Greenhouse Gas Balances of Bioenergy Systems: A Bibliography including Greenhouse Gas Implications of Wood Products, Forestry and Land-Use Change, compiled for IEA Bioenergy Task XV.
February 1996. 350 entries. 290 pp.
(N.B.: An update of the bibliography is scheduled for the end of 1998.)

Apps, M., Karjalainen, T., Marland, G., and Schlamadinger, B.
Accounting System Considerations: CO_2 Emissions from Forests, Forest Products, and Land-Use change - a Statement from Edmonton. July 1997.
(this paper can also be found on the Task XV homepage!)

IEA Bioenergy

Task XV:

"Greenhouse Gas Balances of Bioenergy Systems"

Final Report

(Document prepared for the 41st meeting of the
Executive Committee of IEA Bioenergy,
Vår Gård, Saltsjöbaden, Sweden, 13-14 May 1998)

1 Task Presentation

1.1 Goal

The goal of Task XV was to investigate all processes involved in the use of bioenergy systems, on a full fuel-cycle basis, with the aim of establishing overall greenhouse gas (GHG) balances. In particular, this meant to

- collect and compare existing data of net GHG emissions from various biomass production processes in agriculture and forestry and from biomass conversion;
- establish a common analytical framework for the assessment of GHG balances;
- quantify net GHG emissions associated with biomass production, processing, transportation and storage, and biomass conversion into heat, electricity or liquid fuels;
- use the common analytical framework to compare different bioenergy options and assist in the selection of appropriate national strategies for GHG mitigation;
- identify missing data and R&D requirements.

The analysis of bioenergy systems has been based on a comparison with conventional fossil fuel and other energy systems used as a reference. Apart from the scientific value of the results gained through this project, recommendations made are considered to be useful especially for decision-makers wishing to determine the maximum net GHG emission reductions achievable from bioenergy projects. This was reflected, for instance, in the Task effort to contribute to the work of IPCC and the negotiations surrounding the Kyoto Protocol.

1.2 Participants, Operating Agent and National Team Leaders

Participating countries in Task XV were:

- Austria
- Canada
- Finland
- Sweden
- United States

The Operating Agent was the Republic of Austria, represented by Dr Josef Spitzer of Joanneum Research, Graz/Austria (contact details to be found in the Appendix).

Each participating country nominated a "National Team Leader" (cf. Table 1), responsible for the coordination of the national participation in the Task.

Table 1: *National Team Leaders Task XV*

Participant	National Team Leader	Institution
Austria	Bernhard Schlamadinger	Joanneum Research
Canada	Mike Apps	Natural Resources Canada
Finland	Ilkka Savolainen	VTT Energy
Sweden	Bengt Boström	Swedish National Energy Administration (formerly NUTEK)
USA	Gregg Marland	Oak Ridge National Laboratory (ORNL)

(contact details can be found in the Appendix)

1.3 Duration and Budget

Task XV started on 1 April 1995, later than the other Tasks within IEA Bioenergy, and ended, like all other Tasks, on 30 April 1998.

In each year the Task XV budget was contributed in equal shares by the five participants. The budget in 1995 was ATS 412,500 (where ATS is the Austrian Schilling, equivalent to about US$ 40,000 in that year), while in 1996 and 1997 it was ATS 550,000 p.a. (equivalent to about US$ 47,500 on average in those two years).

The annual budgets were approximately spent as follows:

Table 2: *Cost splitting of the annual budgets*

cost factor	1995	1996	1997
Workshop organisation	25%	30%	35%
Bibliography	40%		
Work related to the IPCC Guidelines for National GHG Inventories		15%	20%
Development of a standard methodology for GHG balances	5%	15%	15%
Task XV homepage	5%	20%	5%
Presentation of Task XV work at other meetings	5%	5%	5%
Travel and consumables	10%	10%	10%
Administration	10%	5%	10%

2 Work programme

The work programme for Task XV was drafted at a meeting held 6-7 February 1995 in Graz/Austria, in which representatives from countries interested in the proposed Task participated. A final positive decision on Task XV was made at the Executive Committee meeting in Espoo/Finland (ExCo35, 29-30 March 1995), and the official start was on 1 April 1995. The work programme was subject to further refinement by the National Teams and then approved at ExCo36 in Paris/France, 14-15 November 1995. The Task XV work programme can be found on the Task XV homepage (http://www.joanneum.ac.at/IEA-Bioenergy-TaskXV)

(what follows in this section is an excerpt of the original document)

The following "table of contents" gives an overview of expected areas of interest. Depending on which bioenergy systems are finally chosen by the participants to be examined in detail, some items might be of more and some of less importance. However, the basic idea of how the fuel cycle of bioenergy systems should be split up in several steps and how the results of these steps should be aggregated, is shown by this overview. The basis of the analysis of bioenergy systems shall be a comparison with conventional or traditional fossil fuel and other energy systems as a reference.

2.1 Existing work (1995)

In order to properly base the work within the new Task on results and conclusions that have already been achieved, the first steps are to

a) prepare a directory of researchers and research groups active in the field, including short descriptions of past, ongoing or future projects.

b) prepare a bibliography of existing publications, unpublished reports, databases and other written or electronically available information.

2.2 Analytical framework (1995, 1996)

A common analytical framework for the assessment of GHG balances will be established with reference to ongoing and published work. This includes a list of the components and of the gases/substances that should be considered, the process steps where the various gases are produced and some guidelines on how to deal with things like by-products and opportunity costs and which components are likely to be large and which less important. For this purpose a workshop with experts from the participating countries was held on 20-22 September 1995 in Graz/Austria. National Teams presented the work going on in their respective countries and in a working session an analytical framework for GHG balances of bioenergy systems was discussed. Based on the minutes of this workshop a joint paper will be written that describes an agreed upon analytical framework for GHG balances of bioenergy systems and can serve as a guideline or vision for the further work in this Task. Review by other experts and a possible subsequent publication of this paper will help to assure that the analytical framework is broadly accepted. In addition, workshop proceedings with the presentations of the National Teams will be generated and distributed.

2.3 GHG balance of biomass production (1996, 1997)

This part includes detailed analyses of GHG balances of land management on a unit area (e.g. hectare) basis, i.e. changes of carbon pool sizes of vegetation, litter/debris and soil, fossil fuels used in biomass production (e.g. for harvesting, fertilizers, ...); other GHG emissions than CO_2; comparison of different options, e.g. production of timber, pulp and paper, energy feedstocks. For this comparison the effects of carbon storage in biomass products and of indirect fossil fuel substitution will be taken into account. The following land management regimes are of interest:

a) Conventional forestry
- Forestry on previously unmanaged land, land already in use or newly afforested; evaluation of current forestry practices
    - Clear cutting
    - Selective logging
    - Thinning
    - Using logging residues
    - Using residues from timber industry, pulp and paper industry

b) Short-rotation forestry
- Fast growing species on former agricultural or forest land, pasture land or fallow

c) Agriculture
- Biomass from herbaceous crops currently used for food production or from new plants like Miscanthus
- Agricultural residues from food and feed production

d) Biomass waste and recycling
- Municipal solid waste
- Paper and waste wood

2.4 GHG emissions from biomass transportation and storage (1996, 1997)

This part includes the analysis of transportation processes with respect to the use of auxiliary fossil fuels and to decay processes during storage.

a) Transportation of harvested or collected biomass

b) Biomass storage

c) Transportation of end-use fuels

2.5 GHG emissions from biomass conversion (1996, 1997)

This part of the analysis includes the efficiency of bioenergy conversion, auxiliary fossil fuels used in biomass conversion and corresponding CO_2 emissions, non-CO_2 GHG emissions, emission credits for by-products, etc.

a) Conversion of biomass feedstock into end-use biofuels
   - Solid biofuels
   - Liquid biofuels
   - Gaseous biofuels

b) End use conversion processes
   - Combustion of biofuels to produce heat and/or electricity
   - Transmission of heat, electricity to the user
   - Use of biofuels for transportation

2.6 Assessment of full fuel cycles of bioenergy systems (1997)

Items 2 through 5 will be combined to assess the GHG implications of bioenergy systems in comparison to maintaining fossil and other fuel systems. Although the format may change as work on items 2 through 5 progresses, it is expected that each National Team will produce results of the form outlined below. These analyses are expected to assist national decisionmakers in the definition of their bioenergy strategies while fulfilling the common goal within the Bioenergy Agreement.

a) Overview of GHG emissions for all important processes of the bioenergy fuel cycle. The result will be a summary of GHG emissions for various bioenergy systems including and accounting of:

   - Energy flows
   - CO_2 emissions
   - CH_4 emissions
   - N_2O emissions
   - Other greenhouse-relevant substances like ozone precursors or aerosols

This accounting system shall allow a comparison between bioenergy systems and traditional fossil fuel and other energy systems as a reference basis. This is necessary because a GHG balance of bioenergy systems needs to take into account the energy system that it would replace (e.g. type of energy carrier used, efficiency of energy conversion, ...). It should also include the fossil fuel and GHG emission offsets associated with the substitution of by-products or co-products of bioenergy systems for other products having GHG implications, e.g. wood products replacing plastic or metal ones.

b) Sensitivity and scenario analyses: Error propagation and sensitivity of results to assumed data and parameters will be examined to identify weaknesses in data bases and the need for further R&D. Scenario analyses will include the examination of different mixes of bioenergy systems. The results of the scenarios can be used to guide the selection of appropriate bioenergy strategies to meet GHG objectives.

The detailed plan of the work in item 6 will depend on the outcome of previous workshops and the needs of the National Teams.

2.7 Accompanying activities

- Organize workshops on a regular basis (one or two per year)
- Establish and maintain an electronic discussion forum on "GHG and bioenergy" (to be discussed)
- Facilitate exchange of scientists (e.g. sabbaticals), models, databases, literature and other information
- Produce semi-annual summaries of the work performed in the Task and, upon completion of the Task, a final report

(end of excerpt)

In addition to the original set of objectives (see Section 1.1), the items *contributions to the development of the "land-use change and forestry" chapter of the IPCC Guidelines* and *consultancy to the negotiations related to the Kyoto Protocol* were later on adopted as new goals (cf. Section 3.3), reflecting the high degree of flexibility with which Task XV reacted to two recent and very far-reaching international developments with respect to the combat against human-induced climate change.

3 Task XV Achievements

3.1 Workshops

Within Task XV, altogether five international workshops took place, a brief summary of each is given below. Please visit the Task XV WWW homepage at http://www.joanneum.ac.at/IEA-Bioenergy-TaskXV for more detailed information on these events (e.g. workshop programs, lists of abstracts, lists of participants, etc.).

3.1.1 1995: Graz/Austria

The first workshop within Task XV took place 20-22 September 1995, in Graz/Austria, with participants from seven countries. The first day was devoted to scientific presentations by researchers from the participating countries and presentations by invited guests. Topics addressed included:

- Carbon balance of forestry and wood industry, with special emphasis on bioenergy
- Carbon sequestration vs. fossil fuel substitution
- Afforestation scenarios in conjunction with enhanced bioenergy use
- Radiative forcing due to bioenergy fuel chains
- Greenhouse gas emissions from auxiliary energy input for biomass production, transport and conversion
- Fossil fuel chains as reference cases for bioenergy chains

On the basis of these topics the elaboration of a common analytical framework (later called "standard methodology") for greenhouse gas balances of bioenergy systems was initiated on the second day of the workshop (see Section 3.2 below). The proceedings of the Graz workshop are available from the Operating Agent.

3.1.2 1996: Stockholm/Sweden

In 1996 a workshop was held on 29-31 May in Stockholm/Sweden, jointly organized by the Swedish National Board for Industrial and Technical Development (NUTEK) and the Operating Agent, with participants from seven countries. The first day of the workshop included an excursion to the Vattenfall Drefvikens Värme AB (a heating plant near Stockholm fuelled with pulverized wood).

On the second and third day of the workshop, respectively, presentations were given on the following topics:

- Assessing the Contribution of Forest Bioenergy to the Carbon Budget of Canada's Forests: a Scaling Problem
- Effects of Land-Use Competition and Carbon-Cycle Feedbacks in Projections of Biomass Energy
- Using a Large Scale Forestry Scenario Model for a European Forests Carbon Balance
- Forestry and Biomass Options in the Economics of Carbon Dioxide Mitigation
- Contribution of the Forest Sector in Carbon Sequestration in Finland
- Forests for Carbon Sequestration or Fossil Fuel Substitution? A Sensitivity Analysis
- Carbon Dioxide Emissions from Recovery and Transportation of Logging Residues
- Role of Forest Sector and Bioenergy in Limiting the Carbon Emissions of Finland

- Agreements to Increase the Role of the Forest and Bioenergy Sectors for CO_2 Mitigation and Implications for the IPCC GHG Inventory
- Carbon Flows and Mitigation Options in the Forestry Sector: Common Methodology and Results from Eight Developing Countries
- Carbon Dioxide from Integrated Biomass Energy Systems - Examples from Case Studies in the USA

The afternoon of the third day was used for further developing a working group paper entitled "Standard Methodology for Greenhouse Gas Balances of Bioenergy Systems", a paper co-authored by workshop participants. In addition, the IPCC Draft Guidelines for National GHG Inventories, chapter "land-use change and forestry", were discussed (see Section 3.3 below).

The proceedings of this workshop were published as a 1997 Special Issue of the international journal *Biomass & Bioenergy* (see Section 4 for details).

3.1.3 1997: Vancouver/Canada and Uppsala/Sweden

In 1997 two workshops took place, the first in Vancouver/Canada (30-31 May) and the second in Uppsala/Sweden (29-30 September).

The workshop in Vancouver "Forestry, Forest Products and Energy: Greening the Greenhouse" concentrated on GHG balances related to fully integrated forest operations with bioenergy as the end point and co-product, and included one day of discussions, chaired by Bo Lim of the IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories, regarding the IPCC Guidelines (see Section 3.3 below). Papers presented included

- Recent Developments in the Forest Carbon Balance in Finland
- Putting Local Carbon Offset Projects in the Global Context
- Forest and Bioenergy Mitigation Options: the Issue of Credits and Debits
- GHG Emissions and Biomass in the Brazilian Energy System
- Using the Model GORCAM for Sensitivity Analyses of Carbon Sequestration in Forestry Projects
- Wood Construction Alternatives in Finland: Carbon Sink and Substitution for Energy Intensive Materials

Abstracts can be found on the Task XV homepage.

The workshop in Uppsala (organized within the ALTENER project "Evaluating Biofuels as a Means of Atmospheric Carbon Dioxide Mitigation" of the European Union and within Task XV by the Department of Forestry-Industry-Market Studies at the Swedish University of Agricultural Sciences, the Belgian Biomass Association, and the Task XV Operating Agent) focused on the implementation of solid biofuels for CO_2 mitigation and was divided into three main parts: (i) systems' perspectives on biofuels, (ii) economics of biofuels, and (iii) carbon dioxide and other environmental impacts of biofuels.

The Proceedings will be published in 1998 as a Special Issue of *Biomass & Bioenergy* (see Section 4 for details).

3.1.4 1998: Rotorua/New Zealand

The final Task XV workshop took place in Rotorua/New Zealand, 9 and 13 March 1998 (jointly organized by Forest Research and the Task XV Operating Agent) and constituted the End-of-Task Meeting for Task XV and at the same time the starting point for the continuation project, Task 25 (1998-2000). The first day of the workshop was dedicated to administrative matters. The presentations given by international experts on the second workshop day dealt with the effects on carbon mitigation in forestry and bioenergy of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), and with "baselines" (a topic that becomes increasingly important, especially with respect to "land-use change and forestry").

Some of the workshop participants took up the opportunity to (a) attend the seminar "Bioenergy in the Environment: International Lessons Learned" on 10 March 1998 (organized by the New Zealand Energy Efficiency and Conservation Authority - EECA), and (b) join a 2-days field study tour organized by Forest Research on behalf of Task XII (Biomass Production, Harvesting and Supply), which preceded the Task XII End-of-Task Meeting in Canberra/Australia (17-20 March 1998).

Altogether 13 presentations were given, including the papers:

- Some technical issues regarding land-use change and forestry in the Kyoto Protocol
- Implications for forestry of government commitments under the FCCC
- Does the Kyoto Protocol make a difference for the optimal forest-based C mitigation strategy? Some results from GORCAM
- Some issues related to including biotic carbon offsets in a GHG emissions trading system
- Carbon emissions avoidance through fire management. Theory and proposed methodology
- The effect of land use practices on greenhouse gases
- Bioenergy and forest industry in Finland after the adoption of the Kyoto Protocol
- How to determine baseline scenarios for a forest sector carbon balance

The workshop proceedings, covering papers presented on March 13 with respect to "Kyoto Protocol" - "forestry and bioenergy", will be published as an IEA Bioenergy Report by the end of April 1998. This shall enable a maximum impact of the workshop outcome on the upcoming discussions at the IPCC expert meeting on "land-use change and forestry: harvested wood products", in Dakar/Senegal (5-7 May 1998), the meeting of the Subsidiary Body of Scientific and Technical Advice (SBSTA) to the UNFCCC (2-12 June 1998), and the 4th Conference of the Parties (COP4) to the UNFCCC in Buenos Aires/Argentina (scheduled for 2-13 November 1998).

3.2 Standard methodology for greenhouse gas balances of bioenergy systems

This methodology, or common analytical framework, includes - among other topics - the selection of appropriate system boundaries, the question how to deal with reference scenarios for the energy system and for land use, and how non-energy by-products should be accounted for. The minutes of the discussion at the Graz workshop (1995) served as a basis for a joint paper entitled "Towards a standard methodology for greenhouse gas balances of bioenergy systems in comparison with fossil energy systems" that includes the views and opinions of researchers in the participating countries. This paper, with co-authors from each of the participating countries in Task XV, has been published in a 1997 Special Issue of *Biomass & Bioenergy* (see Section 4 for details).

The bioenergy fuel cycle is subdivided into four major steps:

- biomass production
- biomass processing
- biomass transportation and storage, and
- biomass conversion

The analytical framework considers changes of carbon storage on the site in vegetation, plant litter and soil, as well as non-CO_2 emissions from the biosphere, GHG emissions from auxiliary fossil fuels for producing, processing and transporting fuels, conversion efficiencies, and emission credits for by-products. Emphasis is on careful definition of system boundaries. The accounting system allows a comparison between bioenergy systems and traditional fossil fuel and other energy systems as a reference basis. This is necessary because a GHG balance of bioenergy systems needs to take into account the energy system that it would replace (e.g. type of energy carrier used, efficiency of energy conversion, etc.). It also includes the fossil fuel and GHG emission offsets associated with the substitution of by-products or co-products of bioenergy systems for other products having GHG implications, e.g. wood products replacing plastic or metal products. Several methods for dealing with GHG implications of cogeneration systems, both for biomass as well as fossil fuels, are suggested and discussed. The proposed framework accounts for reference land-uses, i.e., the path of carbon uptake or release that would most likely have been followed in absence of a bioenergy project, for example if the land were afforested for carbon sequestration without harvest for biomass fuel.

The standard methodology has also been presented at various occasions, for example by Leif Gustavsson at the Task XII workshop (Activities 3.1 "Liquid Biofuels" and 3.2 "Lignocellulosic Solid Fuels") on "Environmental Aspects of Energy Crop Production", 9-10 October 1997, Brasimone/Italy, and by Gerfried Jungmeier at the International Atomic Energy Agency (IAEA) Advisory Group Meeting on the “Assessment of Greenhouse Gas Emission factors from the Full Energy Chain of Biomass Based Electricity Generation Systems”, 16-19 December 1997, Vienna/Austria.

3.3 Contributions to the development of the IPCC Guidelines and the negotiations surrounding the Kyoto Protocol

In May 1996 Task XV participants evaluated the new (1996) draft of the IPCC/OECD/IEA Guidelines for National Greenhouse Gas Inventories, chapter 5 and module 5: "Land-Use Change and Forestry" ("Harvested Wood Products Module"). This section of the Guidelines includes rules how carbon emissions or carbon uptake due to activities related to forestry, bioenergy and the wood industry should be accounted for and assigned to national entities. The main concern of the Task XV participants was the fact that in the new draft Guidelines imported biofuels were not distinguishable from imported fossil fuels in terms of CO_2 emissions. I.e., 1 kWh of heat or electricity produced from imported biomass would yield approximately the same amount of CO_2 emissions, showing up in the national emissions inventory, as if it were produced using coal. The country exporting the biomass would experience a carbon sink.

During and following the workshop in Stockholm/Sweden, 29-31 May 1996, Task XV prepared the paper "Comments by participants of IEA Bioenergy Task XV on the new (1996) draft for the IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 5 and Module 5: Land-use change and forestry" (the comments are available on request from the Operating Agent), especially addressing the part that deals with the carbon accounting for harvested wood. It was suggested by the Task XV experts that wood products and fuelwood should be included in national GHG inventories in a way that encourages their use for CO_2 mitigation, which was not the case in the 1996 Draft Guidelines. These comments were then submitted to IPCC/OECD in June 1996. At the subsequent IPCC meeting in Mexico City in September 1996 the Module of the 1996 Draft Guidelines dealing with harvested wood products was not adopted and further work by the IPCC expert group on harvested wood products requested. Task XV recommendations regarding harvested wood products were also presented at the IPCC/OECD Liaison Group (IOLG) Meeting, 6 February 1997, Paris/France.

At a meeting in Edmonton, Alberta/Canada, 28-30 July 1997, a group of Task XV researchers came together on invitation of the Canadian National Team Leader and agreed on a statement of principles for reporting emissions of GHG gases from forestry, forest products, and land-use change (Apps, M., Karjalainen, T., Marland, G., and Schlamadinger, B., 1997, “Accounting System Considerations: CO_2 Emissions from Forests, Forest Products, and Land-Use Change - a Statement from Edmonton”). This document is available from the Operating Agent, and can also be downloaded from the Task XV WWW homepage (http://www.joanneum.ac.at/IEA-Bioenergy-TaskXV).

Subsequently, Task XV has been contributing to a draft IPCC special report prepared for the IPCC Expert Group on Harvested Wood Products. This report will form the basis for discussions at the IPCC Expert Group meeting in Dakar/Senegal, scheduled for 5-7 May 1998, at which several of the Task XV National Team Leaders will participate.

Finally, the technical paper "Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide", co-authored by Jack Winjum, Sandra Brown and Bernhard Schlamadinger, contrasts two carbon accounting approaches for the consideration of wood products in the IPCC Guidelines (the so-called "atmospheric-flow assessment", initially proposed in the Draft 1996 IPCC Guidelines - see above - and the "stock-change assessment") and reports on estimated national carbon source-sink balances for selected countries, regions, and the world by using the global forest database of the FAO. It has been accepted for publication in *Forest Science*.

Apparently, work done within Task XV also had an impact on the outcome of the Third Conference of the Parties (COP3) in Kyoto/Japan: The Kyoto Protocol to the United Nations Framework Convention on Climate Change, as adopted on 10 December 1997 by delegates from 150 nations, states:

> *"The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable* ***changes in carbon stocks*** *in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. [...].*
> *[...] each party included in Annex I shall provide [...] data to [...] enable an estimate to be made of its* ***changes in carbon stocks*** *in subsequent years."*
>
> (Article 3, paragraphs 3 and 4; emphasis by the authors;
> for the full text of the Protocol see http://www.unfccc.de)

In other words, sources and sinks of carbon resulting from selected human-induced land use change and forestry activities form part of future GHG emission reduction objectives. Also, this text calls for an accounting method as recommended by Task XV during the last two years (sometimes referred to as the "stock-change assessment"), which is essential for encouraging the use of fuelwood for CO_2 mitigation.

The impact of the Kyoto Protocol on forestry and bioenergy projects for mitigation of carbon emissions was subject of a workshop that Task XV organized in Rotorua/New Zealand, 9 and 13 March 1998.

The workshop participants discussed some of the principles that guided the negotiators in Kyoto with respect to forests, like: (a) to provide credits against emissions commitments only for activities that could be reliably measured and verified; (b) to provide credits against emissions commitments only for direct human-induced activities, and not for advantageous circumstances; and (c) to treat the various Parties to the Protocol in an equitable way. It was obviously inevitable that the Kyoto Protocol currently considers only a small part of the forests in the industrialized world, namely those affected by a change in land-use category. The workshop participants agreed that there is now a great need to sort out some of the questions left behind regarding forestry in the Protocol, and to develop rules and guidelines as to how the carbon accounting in each country should be carried out. Among other things, there is a need for clear definitions of terms such as "forest", "afforestation", "reforestation", or "deforestation". The workshop also addressed potential effects of the forestry accounting under the Kyoto Protocol on forest management and land prices. The Protocol leaves open the possibility of adding other forestry measures for carbon mitigation later on, and the workshop discussed possibilities how that could be done.

Most importantly, there was agreement among the workshop participants that the Kyoto Protocol includes the necessary incentives for further deployment of bioenergy as a means of climate change mitigation.

The Proceedings of the Rotorua Workshop are published as an IEA Bioenergy report (see Section 4 for details).

3.4 World-Wide-Web site

A WWW homepage for Task XV (http://www.joanneum.ac.at/IEA-Bioenergy-TaskXV) was created in 1996. It has been updated and extended continuously since then, based on information and feedback provided by researchers in the field of 'bioenergy and greenhouse gases'. The homepage offers information on the Task XV work programme, previous and upcoming workshops, a list of experts and projects in the participating countries, links to related sites (like the other IEA Bioenergy homepages), important documents and other useful information. It will continue to exist as the Task 25 homepage (http://www.joanneum.ac.at/IEA-Bioenergy-Task25). Since its introduction in October 1996, the homepage has been visited more than 900 times (as of end of March 1998).

3.5 Bibliography

In order to properly base the work within the new Task on results and conclusions that had already been achieved, the first steps in 1995 were to prepare

- a bibliography of existing publications, unpublished reports, databases and other written or electronically available information;
- a directory of researchers and research groups active in the field, including short descriptions of past, ongoing or future projects.

A draft version of this bibliography and directory was made available to the National Teams in September 1995. Their feedback and input from other experts was collected and the final version of the bibliography was completed in February 1996. The bibliography, of which more than 100 copies have been requested and sent out so far, will be updated on a regular basis, the next edition being planned to become available in late 1998 or early 1999.

3.6 Miscellaneous activities

In autumn 1996 the planning process for a possible follow-up Task was initiated. At the 38th Executive Committee Meeting (ExCo38) in Vienna, which took place 12-13 November 1996, the topic "Greenhouse Gas Balances of Bioenergy Systems" was selected as a new Task within IEA Bioenergy in the period 1998-2000. A Task Proposal, submitted to ExCo39 in Brussels/Belgium, 22-23 May 1997, was supported by seven countries. The final decision with respect to participating countries was made at ExCo40 in Rome/Italy, 20-21 November 1997, with Austria, Canada, Finland, New Zealand, Sweden and the USA being the participating countries.

The work of Task XV has been presented at the following conventions:

- IEA Bioenergy Task XIII, Activity 6 ("Integrated Bioenergy Systems") Workshop, Graz/Austria, 17-20 September 1995
- IEA Bioenergy Task XII Joint Conference "Environmental Issues for Short Rotation Bioenergy Production" in Velje/Denmark, 29 June to 3 July 1996 (presentation on carbon balances of short-rotation forestry)
- IEA Conference "Biomass Energy - Key Issues and Priority Needs", held in Paris/ France, 3-5 February 1997, a meeting that concentrated on the use of biomass for energy purposes in non-OECD countries
- Task XII workshop (Activities 3.1 "Liquid Biofuels" and 3.2 "Lignocellulosic Solid Fuels") on "Environmental Aspects of Energy Crop Production", 9-10 October 1997, Brasimone/Italy
- International Atomic Energy Agency (IAEA) Advisory Group Meeting on the "Assessment of Greenhouse Gas Emission factors from the Full Energy Chain of Biomass Based Electricity Generation Systems", 16-19 December 1997, Vienna/Austria
- "Highlights aus der Biomasseforschung" (Highlights of Biomass Research), meeting organized by the Austrian energy agency EVA and the Austrian Biomass Association on behalf of the Austrian Federal Ministry of Science and Transport, Vienna/Austria, 27 November 1997 and 31 March 1998
- IEA Bioenergy Task XII Workshop (End-of-Task Meeting) "Accomplishments in Bioenergy Production Research 1995-1997", Canberra/Australia, 17-20 March 1998

Selected activities of and results from Task XV have been presented / published on the "bioenergy" and "forest" electronic mailing lists, respectively (bioenergy@crest.org, forest@listserv.funet.fi).

Articles describing the work of IEA Bioenergy Task XV have also been written for "IEA Bioenergy News" (Vol. 7, No. 2, 1995), the Newsletter "Greenhouse Issues" (No. 22, January 1996) of the IEA Greenhouse Gas R&D Programme, and for the quarterly newsletter "GreenTimes" of IEA GREENTIE (Greenhouse Gas Technology Information Exchange) (in press).

4 List of reports from Task XV

All reports are available from the Operating Agent at the following address (except for copyrighted journal articles, or unless stated otherwise):

Reinhard Madlener
Joanneum Research
Elisabethstrasse 5
A-8010 Graz, Austria.
Phone +43 316 876 1340
Fax +43 316 876 1320.
E-mail: reinhard.madlener@joanneum.ac.at

Analytical Framework for Greenhouse Gas Balances of Bioenergy Systems.
Proceedings of a Workshop within Task XV of IEA Bioenergy in Graz/Austria, 20-22 September 1995.
Includes 9 scientific papers and minutes of the workshop discussions.

Matthews, R.
Research on Energy Costs and Carbon Sequestration Value of Timber and Wood Fuel Production in Britain

Ford-Robertson, J. B.
Methods Used to Calculate the Carbon Balance of the Forest Industry in New Zealand

Schopfhauser, W.
A Global Afforestation Program for Carbon Sequestration - Conclusion and Further Research Implications

Freund, P.
IEA Greenhouse Gas R&D Program: Work on Full Fuel Cycle Analysis of Fossil Fuel Power Generation

Gustavsson, L., Börjesson, P., Johansson, B., and Svenningson P.
Reducing CO_2 Emissions by Substituting Biomass for Fossil Fuels

Sinisalo, J. and Savolainen, I.
Greenhouse Impact Expressed as Radiative Forcing Due to Bioenergy Fuel Chains

Marland, G.
Work in the U.S. on Biomass Fuels and Greenhouse Gas Emissions: Some Notes

Schlamadinger, B.
GORCAM - a Model to Calculate the Carbon Balance of Land Use and Bioenergy Strategies

Hektor, B.
Global Change and Boreal Forests: the Role of Forests in the Carbon Cycle - a Systems Approach with Special Focus on Nordic Countries

Schlamadinger, B. and Spitzer, J. (editors)
Greenhouse Gas Balances of Bioenergy from Forestry and Wood Industry.
Collection of papers published after the Task XV Workshop, Stockholm/Sweden, 29-31 May 1996.
1997 Special Issue of *Biomass & Bioenergy* (Vol. 13, No. 6).

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Bohlin, F.
Greenhouse economics and biofuels.
Available from: Folke Bohlin, Department of Forest-Industry-Market Studies, Swedish University of Agricultural Sciences (SLU), Box 7054, 750 07 Uppsala, Sweden. Fax +46 18 67 35 22.
E-mail: folke.bohlin@sims.slu.se

Christersson, L.
Energy forestry and its environmental consequences.
Available from: Lars Christersson, Department of Short Rotation Forestry, SLU, Box 7016, 750 07 Uppsala, Sweden. Fax +46 18 67 34 40.
E-mail: lars.christersson@lto.slu.se

Schwaiger, H. and Schlamadinger, B.
GHG mitigation potential of increased fuelwood use in Europe in 2020.
Available from: Hannes Schwaiger, Joanneum Research, Elisabethstrasse 5,
A-8010 Graz, Austria. Fax +43 316 876 1320.
E-mail: hannes.schwaiger@joanneum.ac.at

Schlamadinger, B. and Madlener, R. (editors)
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Contributions include:

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(N.B.: An update of the bibliography is scheduled for the end of 1998.)

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Proceedings of the IEA Conference "Biomass Energy: Key Issues and Priority Needs", Paris/France, 3-5 February 1997, OECD/IEA, Paris, 1997, pp. 335-340.

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Winjum, J. K., Brown, S., and Schlamadinger, B.
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(forthcoming in *Forest Science*)

Furthermore, reports on the progress of Task XV were given on a semi-annual basis to the Executive Committee (i.e., a total of five progress reports).

Finally, a section in the IEA Bioenergy Annual Reports 1995, 1996, and 1997 was dedicated to Task XV. The Annual Report 1998 (forthcoming in early 1999) will include a synopsis on the achievements of Task XV/25.

Appendix: Operating Agent and National Team Leaders

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