IEA Bioenergy

Task 25
Greenhouse Gas Balances of Bioenergy Systems

Summary of the joint Task 25 and COST E21 Workshop session

Land-Use, Land-Use Change and Forestry: the Road to COP6

28 September 2000
Joensuu, Finland

K.A. Robertson, and B. Schlamadinger (eds.)

October 2000

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Presentations

Session 2: Carbon Accounting Methodologies

The ton-year index as a basis for carbon accounting of forestation projects under the Climate Convention

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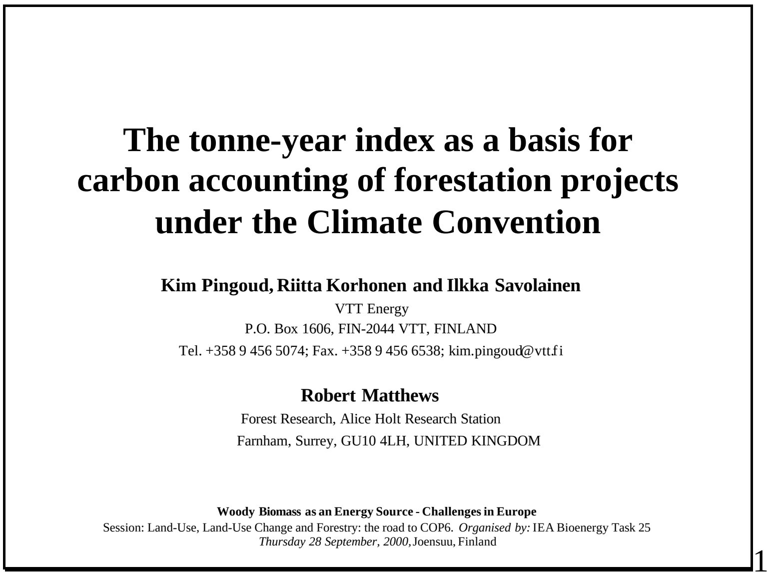
ABSTRACT

Carbon can be sequestered from the atmosphere in forests in order to lower the atmospheric carbon dioxide (CO_2) concentration. Ton-years of sequestered carbon have been suggested as a index to account for carbon sequestered in forest-based projects with finite duration. Simple case studies are presented here that illustrate how the ton-year approach can be contrary to the objective of stabilising atmospheric CO_2 concentrations as expressed in the UN Climate convention. The example cases are closely related to the IPCC estimates of global forestation potentials to the year 2050. Calculations show that a ton-year index for a forestry project can in certain circumstances indicate that carbon sequestration helps in the mitigation of climate change even when the impact of the project is an increase in the atmospheric CO_2 concentration. The use of a ton-year index is also likely to overstate and encourage projects and policy measures aimed at permanently maintaining enhanced stocks of carbon in forests, while understating and discouraging projects and measures aimed at reducing dependence on fossil energy sources through enhanced supply of bioenergy. However, model simulations demonstrate that measures involving replacement of fossil energy supplies with renewable bioenergy sources are more effective at achieving a long-term reduction in atmospheric CO_2 concentration. It is concluded that use of a ton-year index may result in inappropriate allocation of resources to meet the objective of the convention.



Carbon accounting principles for GHG sinks and sources in terrestrial ecosystems

State-of-the-art:

- human-induced activities (ARD, additional?) not clearly defined
- accounting rules have not been specified or agreed
- rules and principles are debated among scientists, governmental officials and environmentalists
- key contribution IPCC Special Report on LULUCF accepted by governments in May 2000

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In this presentation:

evaluation of the tonne-year index as a measure of cooling impact in the long-term, approximated by the impact on the atmospheric CO_2 concentration

(remembering that its stabilisation is the ultimate objective of the UNFCCC)

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The tonne-year approach

- motivation: to promote positive contribution to C sequestration made by short duration forestry projects
- particular attention in the IPCC Special Report on LULUCF
- basic idea: to give credit for each year that the sequestered C stock is maintained

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Tonne-year based index as a measure of cooling impact

Carbon-crediting index $\boldsymbol{Q_1}$ (unit = tonnes of C):

$$Q_1(t) = \frac{1}{t}\int_{t_0}^{t} C_S(t)\,dt$$

$$= \left(\int_{t_0}^{t} C_S(t)\,dt \Big/ \int_{t_0}^{t_0+t} (1\,tonne\ C)\,dt \right) \times 1\,tonne\ C$$

Above formula: tonne-yrs of the project *divided by* tonne-yrs of 1 t carbon sequestered ‘permanently’ for t years

$Q_1(t)$ = carbon sequestration tonne-year index for year t (tonnes),
t_0 = year in which project is commenced,
$C_s(i)$ = the additional carbon stock in biomass attained by the project in year t,
t = ‘equivalence time’ (years).

By convention, the indefinite accumulation of $Q_1(t)$ may be restricted by capping the value of $Q_1(t)$ at the value attained at the end of the finite time frame of t years.

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Comparison: Global warming potential (GWP) factor as a measure of cooling impact

Cumulative radiative forcing or absolute global warming potential (AGWP) of a forestation project (here actually the *cooling* impact) is proportional to the integral:

$$AGWP(t) \cong \int_{t_0}^{t} C_A(t)\,dt$$

$C_A(t)$ = carbon stock **absent from the atmosphere** due to the forestation project
Note: For calculating C_A a model describing the dynamics of carbon exchange between the atmosphere and oceans is needed

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GWP_{100} factor of a forestation project as a function of time ($t_0 \le t \le t_0 + 100$ yr) :

$$GWP_{100}(t) = AGWP(t)/AGWP_{1\ tC\ permanent}(t_0+100\ yr)$$

Above formula: tonne-yrs of carbon absent from the atmosphere due to the project *divided by* tonne-yrs of carbon absent from the atmosphere due to 1 tC sequestered at t_0 'permanently' for 100 yrs

Carbon-crediting index Q_2 on the basis of the GWP_{100} factor:

$$Q_2(t) = GWP_{100}(t) \times 1\ tonne\ C$$

Conclusion: when *t* = 100 yr the tonne-year index Q_1 is a fair approximation for the more correct GWP_{100}-based index Q_2

Neither provides incentives for sustainable solutions?

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Illustrative test example: Hypothetical global forestation and bioenergy scenarios

- loosely based on global forestation scenarios presented in the IPCC Second Assessment Report (SAR); they originate in the study of Nilsson and Schopfhauser (1995)
- bioenergy scenarios base on the mean annual increment of the potential plantations between 2030 and 2100; assumed that stemwood converted into energy replacing light fuel oil

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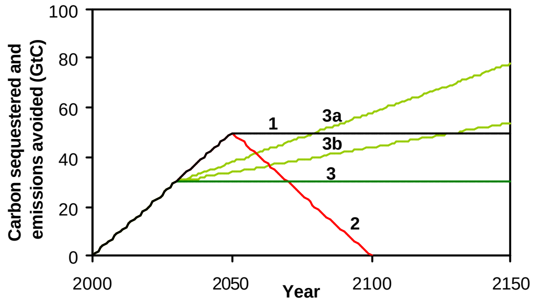
The carbon sequestration scenarios

Note: 3a and 3b include emission reductions due to bioenergy substitution for fossil fuels



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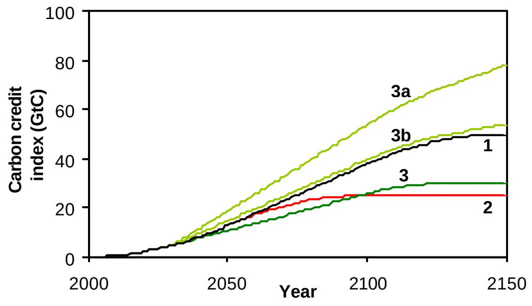
Carbon credits given by the tonne-year based index Q_1



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Impacts of the scenarios on the atmospheric CO_2 concentrations

• Simplified global-scale model of the exchange of carbon between the atmosphere and oceans, called REFUGE (Korhonen et al. 1993) used in the calculations

• REFUGE is an exponential-term approximation of a non-linear three-dimensional ocean model due to Maier-Reimer and Hasselmann (1987); assumption: initial CO_2 concentration increased by 25 % from pre-industrial levels

• Calculations based on a pulse response function* describing the impact of an emitted CO_2 pulse on the atmospheric concentration

*$F[CO_2] = 0.131 + 0.201 \exp(-t/362.9) + 0.321 \exp(-t/73.6) + 0.249 \exp(-t/17.3) + 0.098 \exp(-t/1.9)$
F = fraction of emitted CO_2 remaining in the atmosphere
t = time since emission in years

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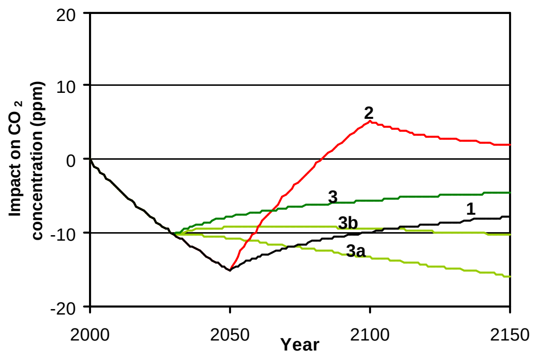
Impacts of the scenarios on the atmospheric CO_2 concentrations



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Conclusions

• **Tonne-year crediting gives permanent credit even if C stock is lost**

• **Ultimate objective of the UNFCCC to stabilise the CO_2 concentrations**

• **Temporary sequestration can even increase the CO_2 concentration in the long term and be in contradiction with the ultimate objectives of the UNFCCC**

• **Tonne-year indices may result in inappropriate allocation of resources to meet its objectives**

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An Alternative Procedure Of Accounting For Land-Use Change And Forestry Activities Under The Kyoto Protocol

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ABSTRACT

The Kyoto Protocol was adopted in order to reduce the net emission of greenhouse gases to the atmosphere. That included management of the biosphere. However, the wording that has been adopted is very difficult and costly to implement, and may ultimately make it impossible to cost-effectively include biosphere management to reduce net greenhouse gas emissions.

An alternative scheme is proposed here to more effectively deal with the anthropogenic component of carbon emissions from the biosphere. It would categorise the terrestrial biosphere into different land-use types, with each one having a characteristic average carbon density determined by environmental factors and management. Each transition from one land-use type to another, or a change in average carbon density within a specified type, due, for example, to changing management, would be defined as anthropogenic. This change would be credited or debited to the responsible nation. To calculate annual credits and/ or debits, a characteristic further time course for each possible land-use transition needs to be defined, and the annual debit/ credit is then calculated as the change in carbon density multiplied by the land area involved and divided by the relevant time constants.

We believe that this scheme would be simpler and less costly to implement than one based on the current wording of the Kyoto Protocol. It would also avoid undue credits or debits because credits and debits could only accrue due to identified anthropogenic components of biospheric carbon changes. Carbon fluxes that are due to natural variation, on the other hand, would not result in credits or debits. It would thereby only reward and encourage those land-use changes that would lead to ultimate net increases in carbon storage.

A practical procedure of accounting for LUCF activities under the Kyoto Protocol

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T.P. Singh, India
IPCC Special Report on LULUCF

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Ian Galbally, CSIRO Atmospheric Research

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Outline

- Problems with biosphere accounting
- Alternative proposal
- Examples

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Problems with definitions

accounting rules

data availability

costs

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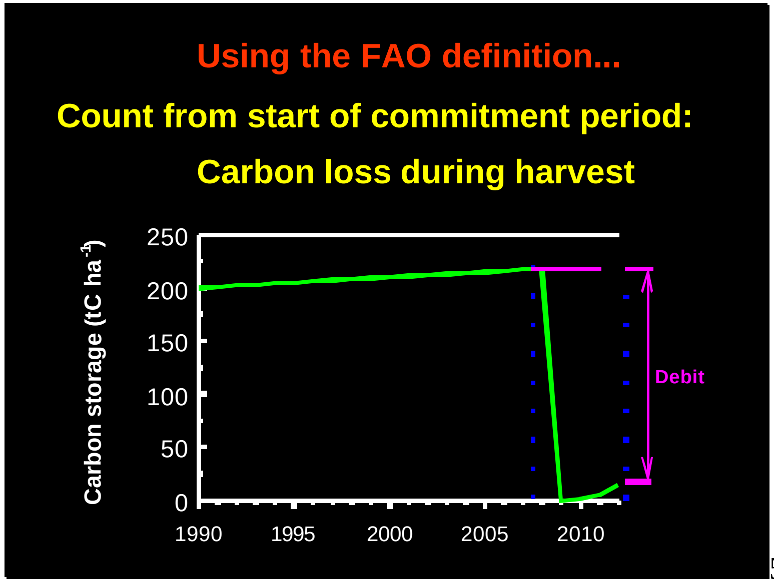
Using the FAO definition...
Count from start of commitment period:
Carbon loss during harvest
Carbon storage (tC ha-1)
250
200
150
100
50
0
1990
1995
2000
2005
2010
Debit

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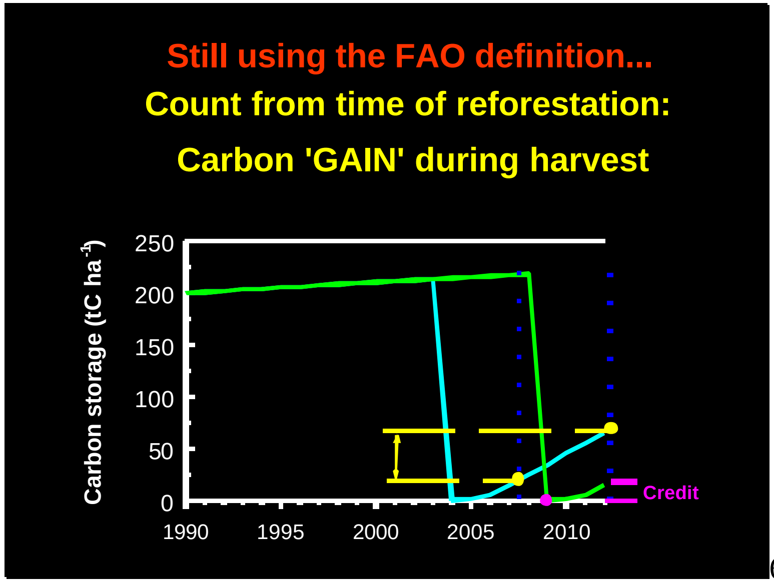
Still using the FAO definition...
Count from time of reforestation:
Carbon 'GAIN' during harvest
Carbon storage (tC ha-1)
250
200
150
100
50
0
1990
1995
2000
2005
2010
Credit

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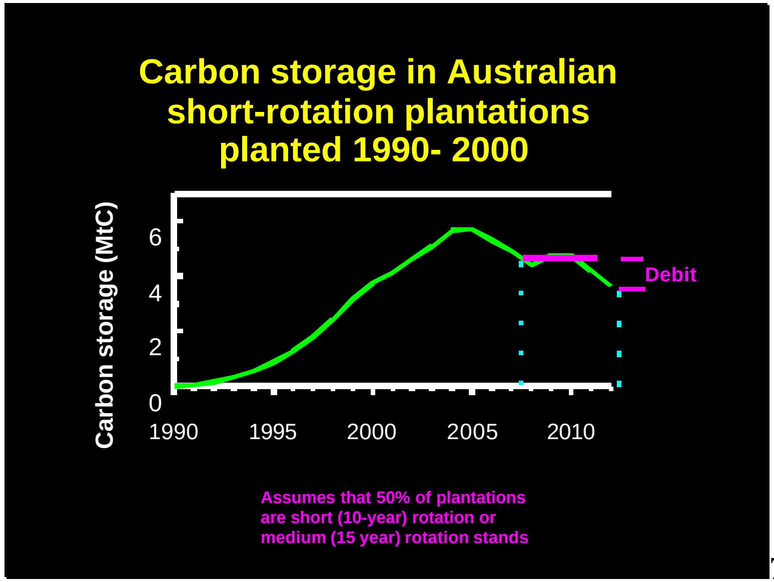
Carbon storage in Australian
short-rotation plantations
planted 1990- 2000
Carbon storage (MtC)
6
4
2
0
1990
1995
2000
2005
2010
Debit
Assumes that 50% of plantations
are short (10-year) rotation or
medium (15 year) rotation stands

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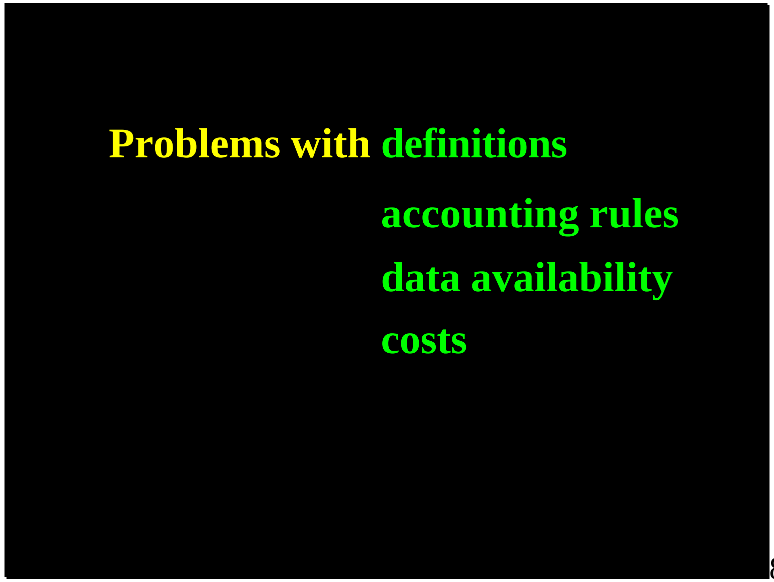
Problems with definitions
accounting rules
data availability
costs

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Can vegetation management for greenhouse abatement ever be operationalised?

Management of the biosphere can only have lasting impact by replacing **low** carbon-storage potential land-use types with types with **higher** carbon-storage potential.

Actual carbon storage in the biosphere is affected by anthropogenic and natural factors. In assigning credits/ debits, **only the anthropogenic** factors should be considered.

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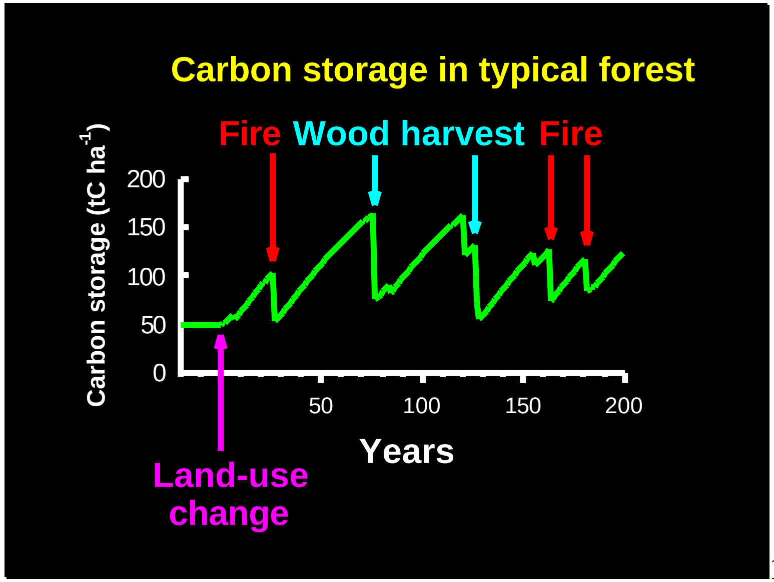

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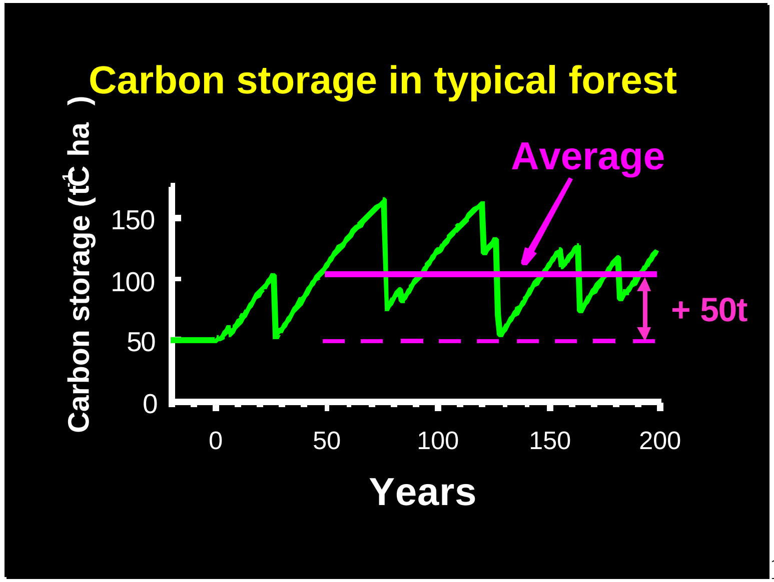

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The proposal:

- Sub-divide biosphere into different land-use types.
- Establish characteristic carbon storage potential for each land-use type.
- Give credits/ debits for conversion between land-use types with different carbon storage potential.
- Give credits/ debits for human-induced change of carbon storage within land-use types.

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Calculating potential C storage

Potential C density =
Equilibrium C density x Land use factor

Potential C density is long term average carbon density
Equilibrium C density is natural carbon density (constant)
Land use factor is C density relative to equilibrium, for each land use

Potential C stock = Area x Potential C density

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Expressed as equations:

$$C_{pot} = C_{eq} \cdot f_{lu}$$

C_{pot} = potential average carbon density
C_{eq} = equilibrium carbon density
f_{lu} = land-use factor

Carbon stock = å $A_i \cdot C_{pot(i)}$

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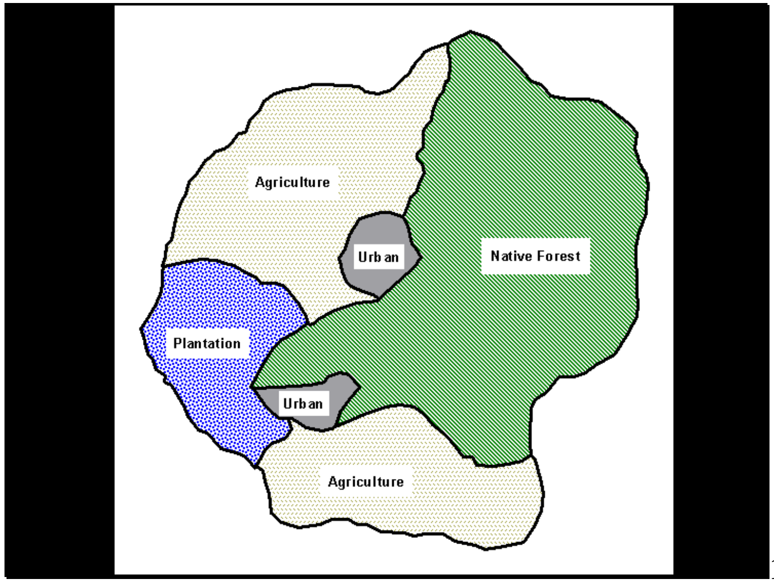

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Type	Area (ha)	Equ C density (tC ha^{-1})	Land use factor	Total C (MtC)
Forest	500,000	500	1.0	250.0
Plantation	100,000	500	0.75	37.5
Agriculture	350,000	500	0.4	70.0
Urban	50,000	500	0.1	2.5
Total	1,000,000			360.0

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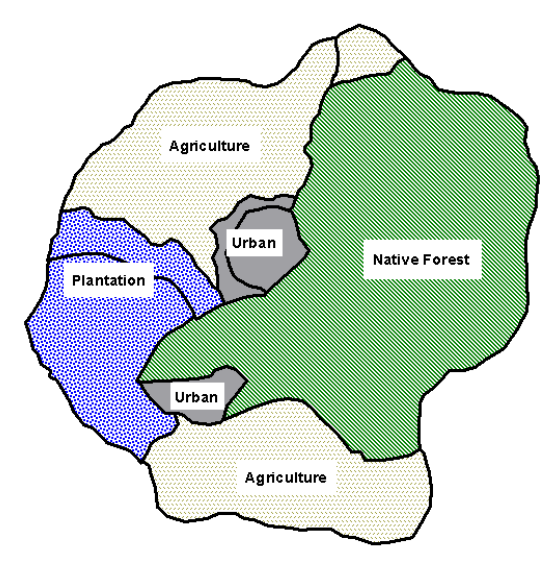

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Example I: Area changes

Type	New area	Area change	Equ C density (tC ha^{-1})	Land use factor	New C (MtC)	C change (MtC)
Forest	495,000	-5,000	500	1.0	247.5	-2.5
Plantation	110,000	+10,000	500	0.75	41.25	+3.75
Agriculture	340,000	-10,000	500	0.4	68.0	-2.0
Urban	55,000	+5,000	500	0.1	2.75	+0.25
Total	1,000,000				359.5	-0.5

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Example II: Carbon density changes due to direct human action

Forest: More access roads (-0.5%)

Plantation: Shorter rotation (-1.0%)

Agriculture: Minimum tillage (+1.0%)

Urban: More trees (+0.1%)

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Example II: Carbon density changes

Type	Area	C_{eq} (tC ha^{-1})	new factor	change in factor	New C (MtC)	C change (MtC)
Forest	500,000	500	0.995	-0.005	248.75	-1.25
Plantation	100,000	500	0.74	-0.01	37.0	-0.5
Agriculture	350,000	500	0.41	+0.01	71.75	+1.75
Urban	50,000	500	0.101	+0.001	2.525	+0.025
Total	1,000,000				360.025	0.025

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Example III: Change in equilibrium carbon density

Suppose climate change reduces soil carbon so that total carbon storage potential diminishes by 1% every five years.

No credits or debits to be given.

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Delayed crediting/ debiting

3 Options

1. Detailed change matrix
2. 50-year linear delay
3. 50-year linear delay for increase;
   10-year linear delay for decrease

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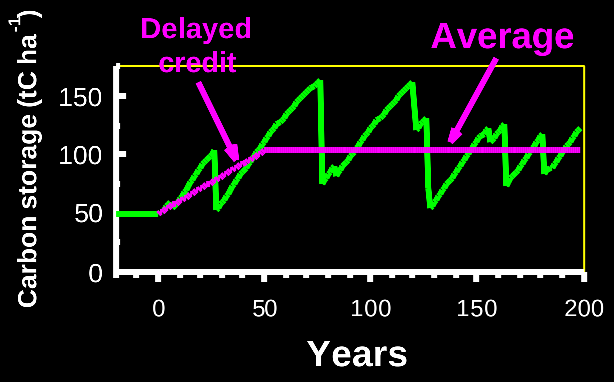
Carbon storage in typical forest



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Verification

Data requirements

- **Area estimates**
  - remote sensing
  - planning information
  - spot checks
- **Potential average carbon density**
  - stratified sampling
  - general scientific understanding
  - statistics
  - spot checks

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Conclusions (1)

- Biosphere carbon management difficult and costly to implement
- Alternative scheme is simpler and more directly in keeping with the aim of accounting for anthropogenic effects on the biosphere.

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Conclusions (2)

- Credits/ debits mainly related to change in area under different land-use types.
- Human-induced changes in carbon density within land-use types should also lead to credits/ debits.
- Carbon fluxes from natural causes, either short-term or long-term, should not generate credits/ debits.

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Full paper available at:

http://www.ffp.csiro.au/publicat/pdfs/alternative_kyoto.pdf

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Carbon accounting methodologies — a comparison of real-time, tonne-years, and one-off stock change approaches

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ABSTRACT

Trading in carbon credits from afforestation and reforestation is foreshadowed by the Kyoto Protocol. Human-induced sinks can compensate for human-induced emissions, but given ongoing combustion of fossil fuels, there needs to be an ongoing contribution from sinks. Because forests are sinks only when they are expanding in area or carbon density, and because there is a limit to the quantity of growing stock per unit area, afforestation must be continuous. Given a limited global area of plantable land, this cannot continue in perpetuity. Even if 500 million hectares of land were afforested worldwide, and resulted in a one-off increase in carbon-density of 100 tonnes/ha, this amounts to only 50 Gt C removed from the atmosphere. The IPCC Second Assessment Report examined scenarios of carbon accumulation from 1991-2100 of 630-1410 Gt C, so it can be seen that the potential contribution of afforestation is very small. Forest sinks are a popular topic in the current decade because they are seen as being a relatively low-cost first step to reduction of net greenhouse gas emissions.

Before trading in carbon sinks can eventuate, however, numerous technical difficulties have to be resolved including the acceptance of a standard method of carbon accounting. The concept of “tonne-years”, whereby the quantity of carbon sequestered is multiplied by the time it is out of atmospheric circulation, appears to be gaining credence in international fora. This concept is flawed and threatens to undermine the “stocks” based accounting approach that is built into the Kyoto Protocol. A preferable approach is to accept that afforestation is merely the reverse of deforestation, and is a one-off movement of carbon from the atmosphere to the earth’s surface. Carbon credits could be a one-off payment made to a land owner who undertakes to change the long-term carbon density of a piece of land and to retain that increased carbon density in perpetuity.

New Zealand Forest Research Institute Limited

Carbon Accounting Methodologies

Piers Maclaren and
Justin Ford-Robertson

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Introduction

- Fundamentals of C sequestration
- Carbon credits
  - Real-time accounting
  - Tonne-year accounting
  - Carbon density accounting
- Summary

2

Sink/source definitions

- Sink - any process, activity or mechanism which removes a GHG, an aerosol or a precursor of a GHG from the atmosphere.
- Source - any process or activity which releases a greenhouse gas (GHG) or a precursor of a GHG into the atmosphere.

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Carbon Source

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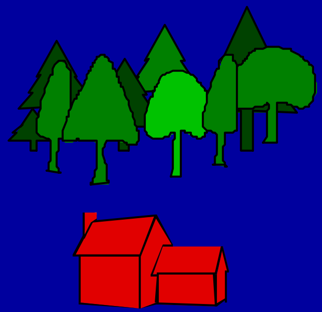
Carbon reservoir

- A component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored



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Carbon reservoir

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Carbon reservoir

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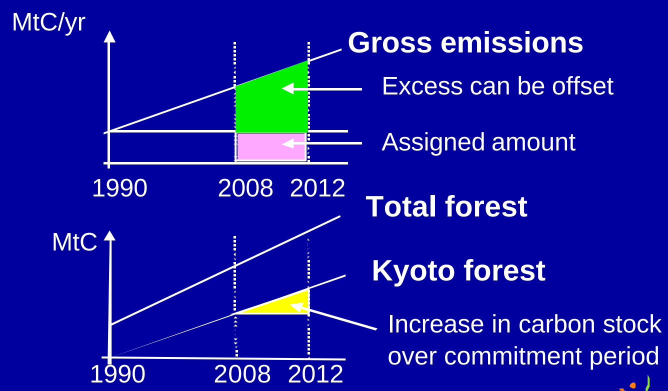
Kyoto Protocol: Gross Emission/Net Sequestration



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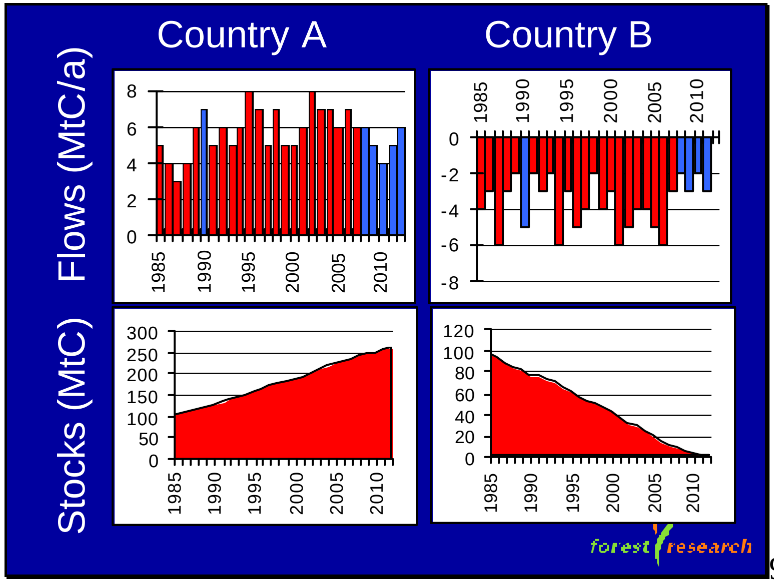

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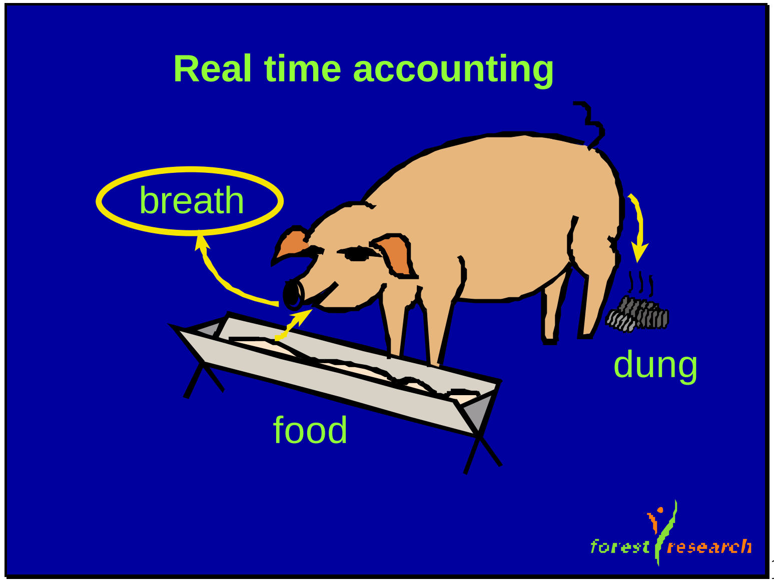

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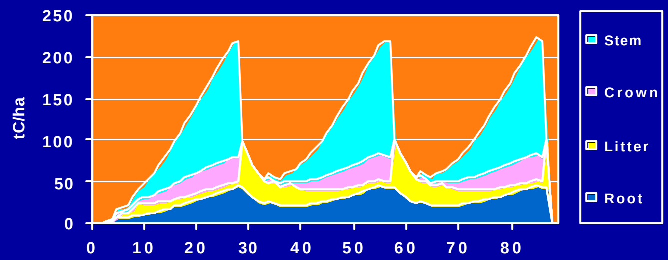
Real-time accounting



- Reflects reality
- Frequent measurements
- High transaction costs

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Tonne-year accounting

- Carbon stocks AND time value
- Relates sinks to sources
- Equivalence factors 42 - 150

- Reservoir to counteract source
- Disincentive to afforestation
- Incompatible with Kyoto Protocol

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Tonne-year accounting

- Assume 50 year equivalence
- Sequestration to offset 1 tC emissions
  - 50 tC for 1 year = 1 tC for 50 years
- No penalty for biomass removal
- Continued use of same land/crop
- Potentially includes agricultural crops

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Carbon density accounting

- Afforestation mirrors deforestation and fossil fuel use
- Simple measurement and auditing
- Limited transactions
- Credits in arrears up to long-term average
- No transactions at harvest
- Debits for deforestation (equal credits)

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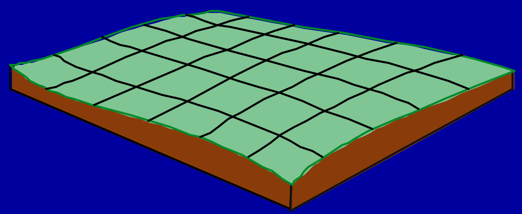
Year 0



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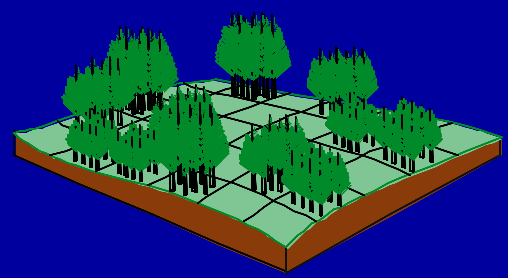
Year 10



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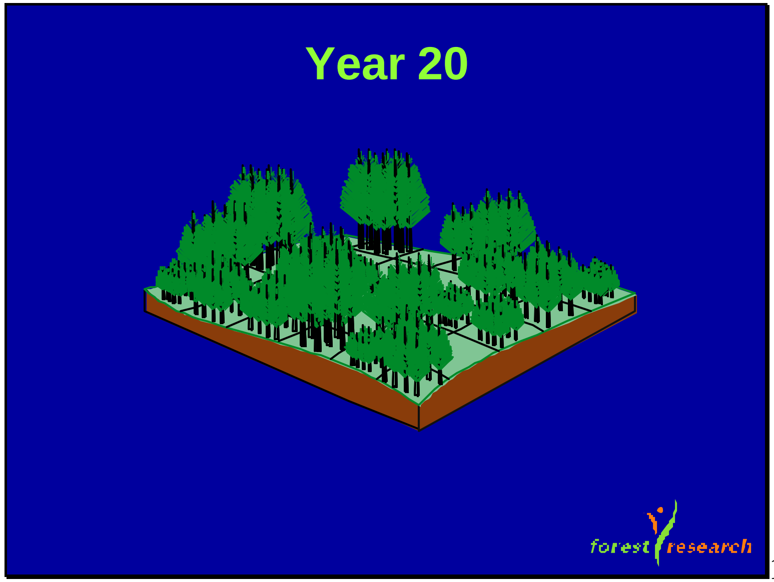
Year 20
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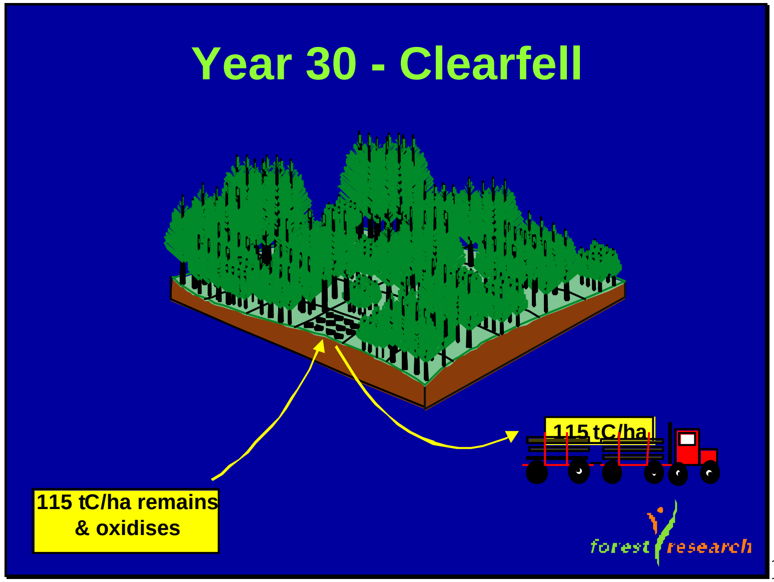
Year 30 - Clearfell
115 tC/ha
115 tC/ha remains & oxidises
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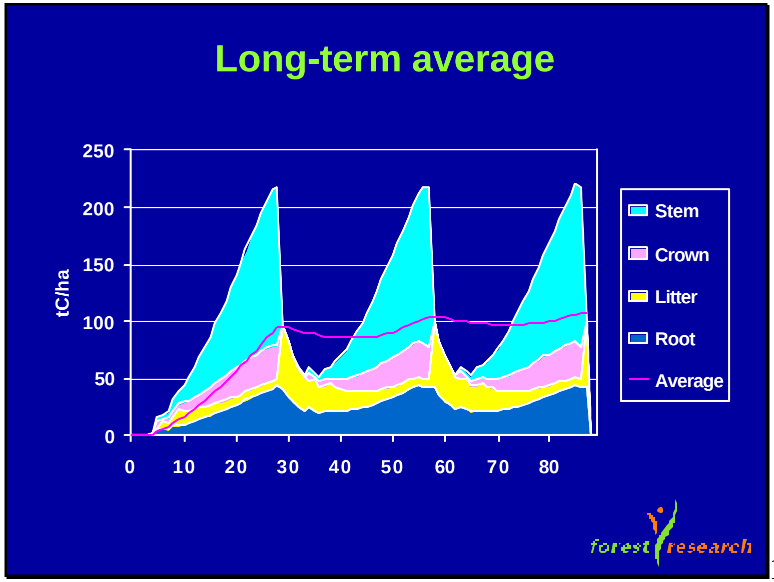
Long-term average
tC/ha
250
200
150
100
50
0
0 10 20 30 40 50 60 70 80
Stem
Crown
Litter
Root
Average
forest research

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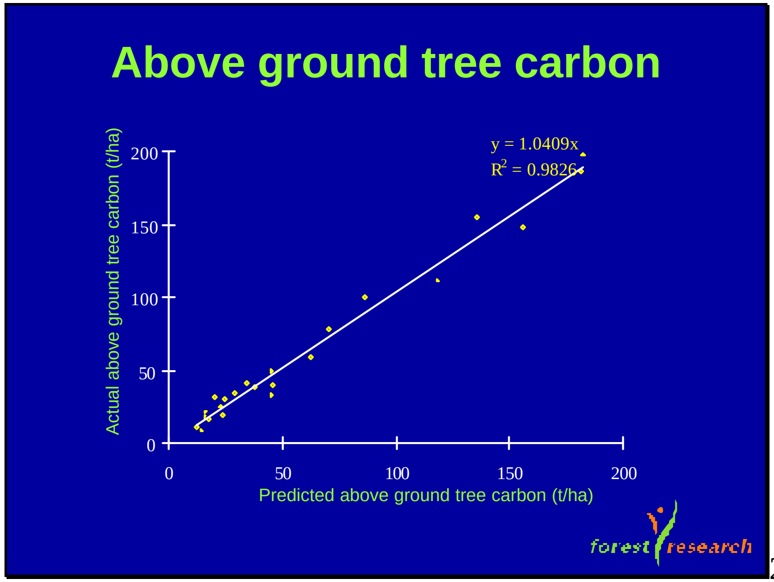
Above ground tree carbon
y = 1.0409x
R2 = 0.9826
Actual above ground tree carbon (t/ha)
Predicted above ground tree carbon (t/ha)
0 50 100 150 200
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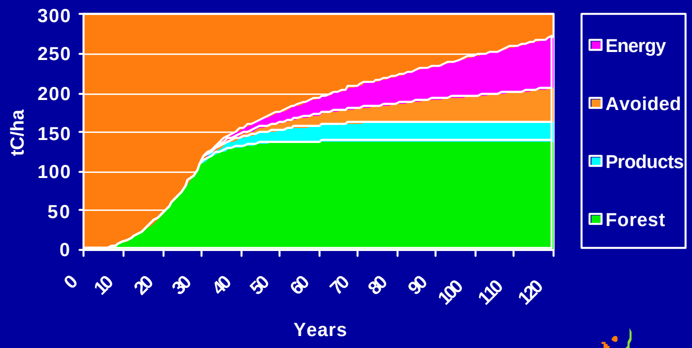
Long term benefits of sinks



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Summary

- Stock-based accounting preferred
- Real-time accounting impractical
- Tonne-year accounting flawed
- Carbon density accounting simple
- Sinks merely a step towards sustainable bioenergy

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Effectiveness of LULUCF carbon accounting methodologies in supportingclimate-conscious policy measures

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ABSTRACT

Any methodology accounting for sinks and sources of carbon arising from land use, land use change and forestry activities needs to reconcile and address a number of scientific and political aspirations. Apart from a basic need for physical and logical consistency, the accounting system needs to directly support the ultimate policy goal of stabilising atmospheric greenhouse gas emissions, as well as ensuring equitable treatment of participating nations that have very different levels of vegetation cover and fossil fuel consumption. In addition, potential for conflict with international conventions on protection of forests and biodiversity must be avoided. There may also be a need to provide a system that can deliver consistent results and statistics at project level and national level.

A number of carbon accounting methods, with special reference to forestry systems, have been developed and articulated in the scientific literature including so-called ‘one-off’ accounting, annual or periodic accounting and the ‘tonne-year approach’. Variants of these methodologies that are very different from each other may be specified, depending on the definition of system boundaries, so-called ‘baselines’ and the treatment of ‘additionality’. The different methods may also use changes in vegetation-based carbon stocks or modelled impact on atmospheric carbon dioxide concentration as the fundamental unit of measurement.

This paper presents an analysis and evaluation of different accounting methodologies for the forestry sector, with particular focus on their likely impact at national and international level. The analysis is based on simplified ‘thought experiments’ using a hypothetical world comprised of four ‘model’ countries that vary in land area, percentage forest cover and consumption of fossil fuels. The relative impact of alternative methodologies on the potential carbon credits or debits accrued by the four model countries is assessed and compared with the actual impact on atmospheric carbon dioxide emissions over 100 years. An assessment is made of the effectiveness of different methodologies in underpinning alternative policy measures to stabilise greenhouse emissions at the national and international level. Policy measures considered include forest protection, expansion of forest cover and increased use of renewable bioenergy. Results suggest that simple accounting systems can be just as effective as elaborate accounting systems in supporting national efforts to meet emissions targets and equitable treatment of participants. The principle of this simple analysis of a model system is transferable to the real world and to a more detailed level of geographical and ecological definition.

EFFECTIVENESS OF LULUCF CARBON ACCOUNTING METHODOLOGIES IN SUPPORTING CLIMATE-CONSCIOUS POLICY MEASURES

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THE KYOTO PROTOCOL

- Aims to meet the UNFCCC objective to reduce concentrations of greenhouse gases in the atmosphere.
- Specifically includes vegetation-based sinks and sources, caused by Land Use, Land Use Change and Forestry (LULUCF).
- Commits ‘Annex I’ (generally industrialised) nations to specified, percentage-based reductions in anthropogenic greenhouse gas emissions.
- Tries to develop a role for non-Annex I (generally developing and transitional) countries (Clean Development Mechanism).

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THE KYOTO PROTOCOL

This requires:
- Value of emissions for a reference year (1990) on which to base the percentage reductions (Article 3.7).
- Reliable annual estimates of fossil fuel emissions in years after 1990.
- Reliable annual estimates of LULUCF sinks/sources in years after 1990.
- Rules for deciding which LULUCF sinks/sources to include (Articles 3.3 & 3.4).

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THE KYOTO PROTOCOL

- Estimation of fossil fuel emissions is relatively easy to define and agree.
- Estimation of LULUCF emissions is very complicated.
- IPCC Special Report on LULUCF has been commissioned to give advice.
- Stops short of a practical evaluation of the consequences for participating countries of different accounting methodologies.
- Opportunity needs to be seized.

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OBJECTIVES OF THE STUDY

- To evaluate the impact of different LULUCF accounting methods on the reduction estimates reported by participating countries.
- To evaluate the effectiveness of different methods in achieving the UNFCCC and Kyoto objectives.
- To evaluate the impact of inclusion of LULUCF projects under the CDM.

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METHODS

- Definition of model countries with different fossil fuel emissions and LULUCF sinks/sources.
- Limit analysis to emissions, sinks and sources of carbon.
- Limit LULUCF to forestry - define land in terms of
  - unexploited forest areas
  - exploited forest areas
  - non- forest areas.

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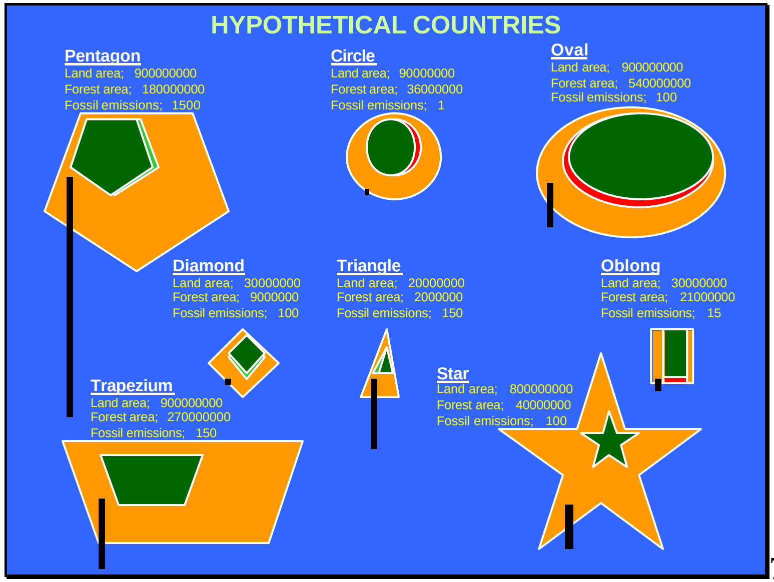

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METHODS

Initial position in 1990

- Assume all unexploited forest is ‘old growth’.
- Define age class structure for exploited forests.
- Use CARBINE for estimation of 1990 forest carbon stocks and projections for future years.
- Limit representation of forests to one species and one growth rate each for unexploited and exploited areas - same for all countries.

8 .

METHODS

Business As Usual (BAU) projection

- Projection period from 1990-2150.
- For 1990 define rates of change between land classes.
- Assume 1990 rates apply for projection period.
- Constrain:
  - forest area to minimum and maximum percentages of national land area
  - unexploited forest area to minimum percentage of national land area

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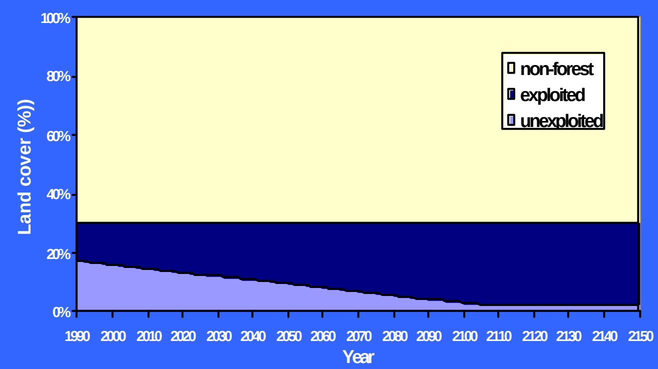
Projected land cover in country Trapezium, BUSINESS AS USUAL



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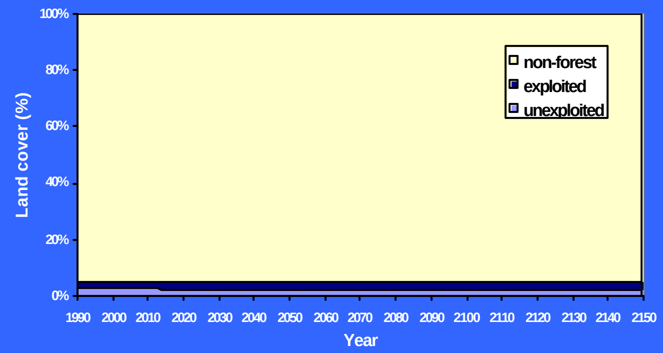
Projected land cover in country Star, BUSINESS AS USUAL



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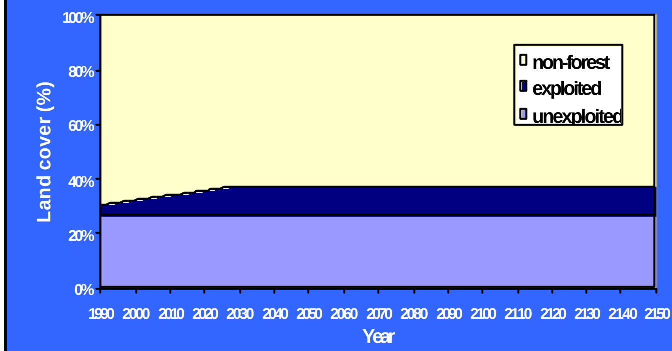
Projected land cover in country Diamond, BUSINESS AS USUAL



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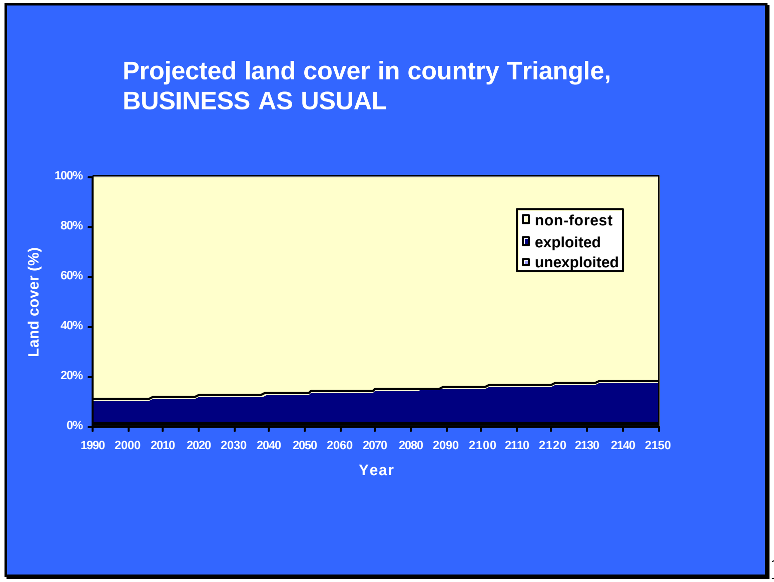
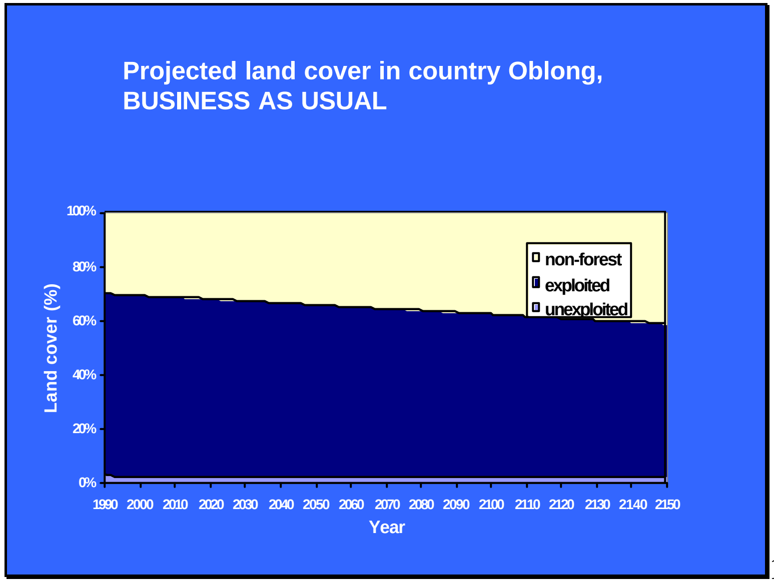

Projected land cover in country Triangle,
BUSINESS AS USUAL
Land cover (%)
100%
80%
60%
40%
20%
0%
non-forest
exploited
unexploited
1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150
Year

13


Projected land cover in country Oblong,
BUSINESS AS USUAL
Land cover (%)
100%
80%
60%
40%
20%
0%
non-forest
exploited
unexploited
1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150
Year

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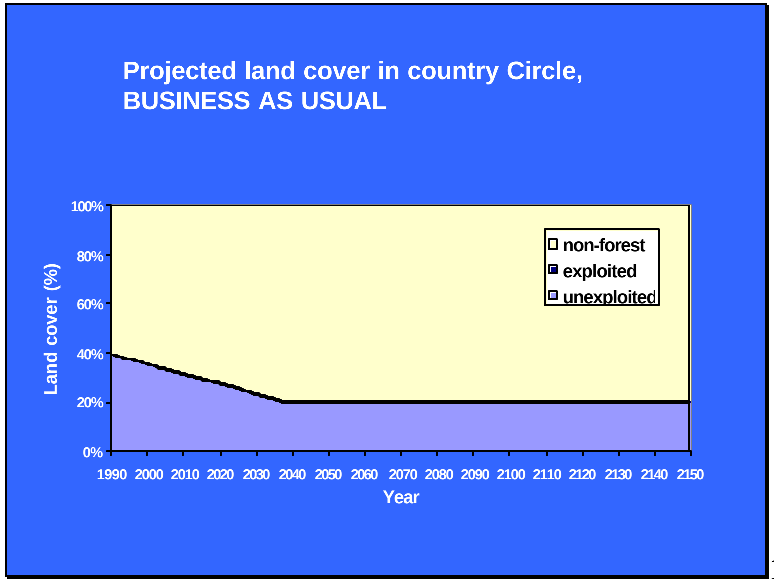
Projected land cover in country Circle,
BUSINESS AS USUAL
Land cover (%)
100%
80%
60%
40%
20%
0%
non-forest
exploited
unexploited
1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150
Year

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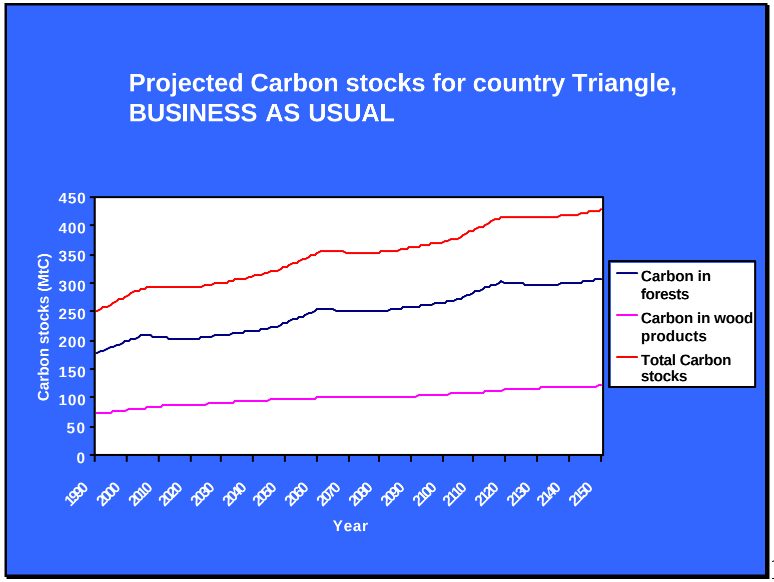
Projected Carbon stocks for country Triangle,
BUSINESS AS USUAL
Carbon stocks (MtC)
450
400
350
300
250
200
150
100
50
0
Carbon in forests
Carbon in wood products
Total Carbon stocks
1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100 2110 2120 2130 2140 2150
Year

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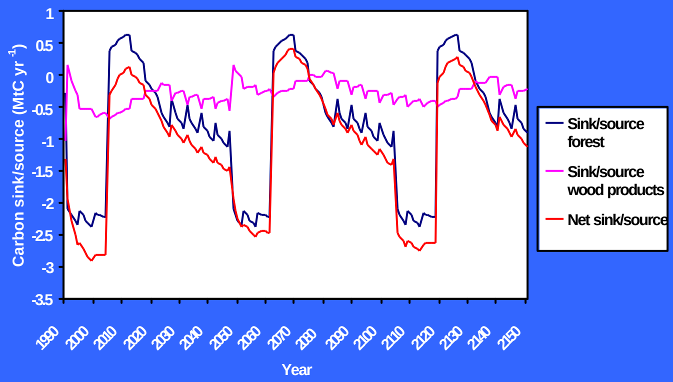
Projected Carbon sink/source for country Triangle, BUSINESS AS USUAL



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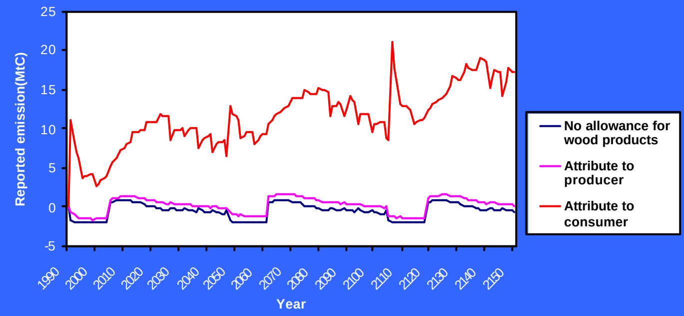
Projected Carbon sink/source for country Triangle, BUSINESS AS USUAL



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METHODS

Accounting Rules

- Wood products:
  - don't include
  - attribute to consumer
  - attribute to producer
- Baselines:
  - zero
  - reference emission for 1990
  - CARBINE projection for 1990
  - CARBINE projection for BAU

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METHODS

Accounting Rules and periods

- 1990 reference value
  - Net-net
  - Gross net
  - Article 3.7
- Accounting periods:
  - 2008-2012
  - 2013-2017
  - 2028-2032
  - 2058-2062
  - 2108-2112
  - 1990-2150

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METHODS

LULUCF accounting indices

- Real time
- One-off
- Simple Kirschbaum *et al.*
- Kirschbaum *et al.*
- Tonne-year
- Jackson

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METHODS

Scenarios (fossil fuel)

- BAU
- increase
- decrease
- increase then decrease
- decrease then increase

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METHODS

Scenarios (LULUCF)

- BAU
- Increased deforestation
- Afforestation for sequestration
- Afforestation for substitution
- Increased deforestation, later reversed
    - by afforestation for sequestration
    - by afforestation for substitution
- Afforestation for sequestration, later reversed
- Conservation of exploited forests
- Exploitatation of unexploited forests

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RESULTS

- Output is comprehensive and massive.
- Case for meta-analysis?
- Here are some examples …

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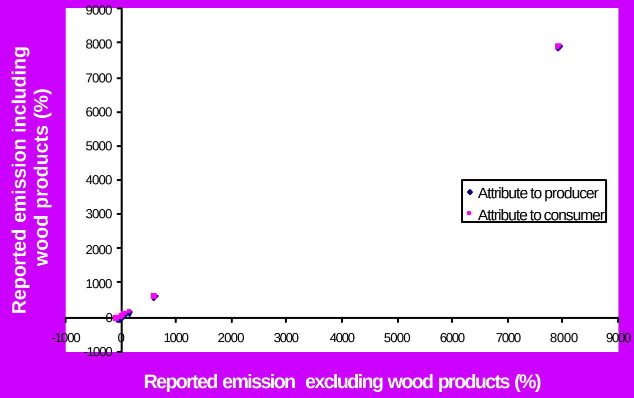
Accounting for wood products (BAU, real time index, all countries,base lines and reference values, first commitment period).



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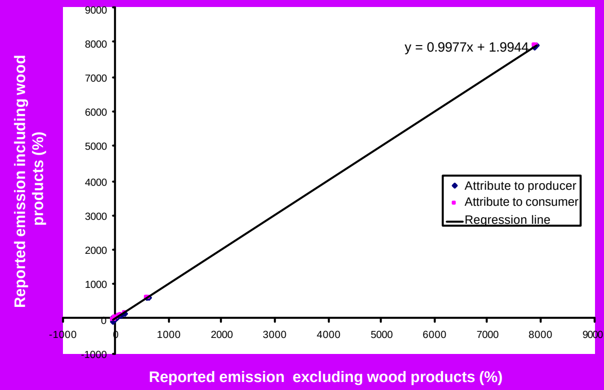
Accounting for wood products (BAU, real time index, all countries,base lines and reference values, first commitment period).



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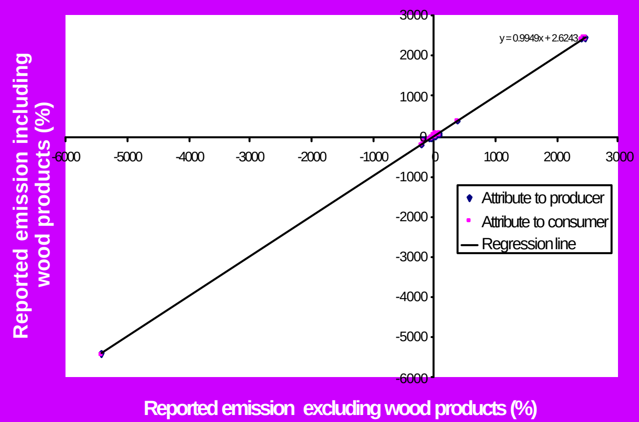
Accounting for wood products (BAU, real time index, all countries,base lines and reference values, period 1990-2150).



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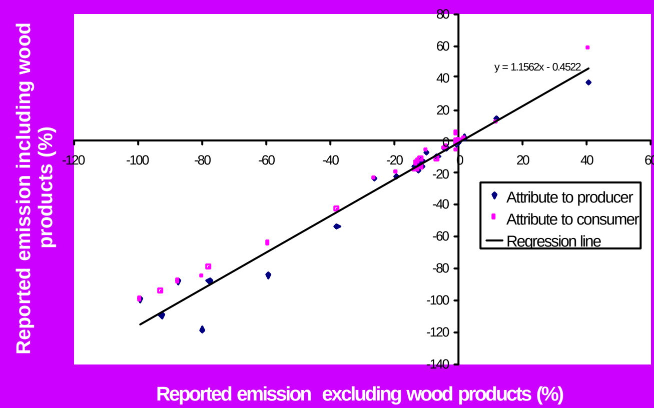
Accounting for wood products (BAU, Jackson index, all countries, base lines and reference values, first commitment period).



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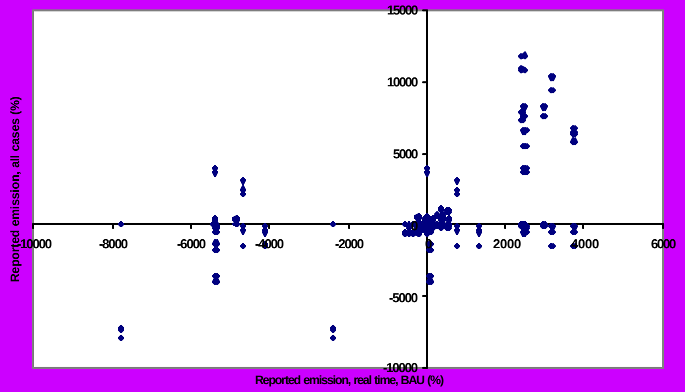
Comparison of reported emission reductions for different accounting indices against reference index (BAU, real time, all countries, base lines and reference values, first commitment period).



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CONCLUSIONS

- If LULUCF is to be included in the Kyoto Protocol, the accounting procedures can, indeed must, be kept as simple as possible, otherwise anomalous results and perverse incentives will arise.
- The potential role of bioenergy also needs to be safeguarded.
- Carbon sequestration in wood products not important at global level, of marginal importance for some countries.

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LIMITATIONS AND WEAKNESSES OF ANALYSIS

- Simplified forest structure underestimates differences between one-off and Kirschbaum *et al.* - scope for improvement.
- Trading in wood products over simplified - probably not important for sequestration, but needs improvement for substitution.
- Countries and scenarios artificial.
- Easy to get lost in detail - need to remember why we're doing this!

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STRENGTHS AND POTENTIAL OF ANALYSIS

- Analysis comprehensive and flexible.
- Analysis could be applied to real countries.
- Could combine with a model like REFUGE to estimate actual impact on CO_2 concentration.
- Results could be used to inform directly the deliberations and negotiations of the COP.

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