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Costs and benefits of a more sustainable production of tropical timber

WOt-technical report 10

E.J.M.M. Arets & F.R. Veeneklaas

WAGENINGEN UR
For quality of life

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Abstract

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This study is part of the TEEB (The Economics of Ecosystems and Biodiversity) study of trade chains, and assessed the impact of harvesting tropical timber on ecosystem services and the costs and benefits of more sustainable production. The costs of implementation and the benefits from increased ecosystem services levels were assessed for two alternatives to conventional selective logging (CL), sustainable forest management (SFM) and forest plantation. The SFM alternative involves certified forest management implementing reduced impact logging techniques. The forest plantation alternative involves high-yield plantations that have a larger impact on ecosystem services than CL on the actual plantation area, but require only an equivalent of 11-42% of the CL area due to the higher yields per unit of area, and thus allows a larger area of primary forest to be conserved. The majority of Dutch imports of tropical timbers are from South America and South East Asia. We conducted separate analyses for South America and South East Asia to account for regional differences in terms of logging practices, timber yields and the extent and value of ecosystem services.

The costs and benefits associated with the following ecosystem services were assessed quantitatively based on data from a large number of publications: costs of sustainable forest management and certification, and benefits from timber production, carbon sequestration and maintaining carbon stocks (REDD+), and collection of wild food and non-timber forest products (NTFPs). To include the time effects of logging, the analysis was done for a 60-year period, which includes two 30-year logging cycles with three logging events for CL and SFM and four harvests for plantations, in a 15-year rotation. Since costs and benefits are incurred and received at different moments in time, they were discounted over time at 0% (no discounting) and 4% a year, which covers the reasonable range for discounting.

The results show that in South America the higher costs of SFM over 60 years are more than offset by the higher total timber yields over three harvest events. This is not the case in South East Asia, but including the market value of higher levels of non-timber ecosystem services compensates for the lower yield at a 0% discount rate. At a 4% discount rate, the lower benefits from timber are not compensated by additional benefits from ecosystem services. The plantation alternative involves relatively high costs per unit of value of timber produced. Since plantations support relatively few other ecosystem services directly on the planted area, the advantages of plantation could arise from land sparing and the resulting provision of ecosystem services by natural forests, in particular carbon sequestration.
The insights offered by this study can be used to develop mechanisms to compensate the higher costs associated with certified sustainably produced timber with benefits by enhanced ecosystem services delivery.

Key words: costs and benefits, sustainable production, tropical timber, ecosystem services, sustainable forest management, forest plantation, conventional selective logging, South America, South East Asia

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Summary

Policy context
The Netherlands depends heavily on imports for many biotic resources and commodities like (tropical) timber, soy, palm oil, cacao and bio-energy. As a consequence, the country has a relatively large ecological footprint abroad, affecting ecosystems in the production countries. Dutch policy aims at sustainable use of these ecosystems to minimise adverse impacts on the environment and biodiversity and to maintain the productive capacity of these ecosystems. In this respect the focus of Dutch policy is on improving the sustainability of production chains rather than on reducing production.

The TEEB-NL (The Economics of Ecosystems and Biodiversity) study requires greater insight into the relation between Dutch trade chains and ecosystem services. The present study assessed the impact of tropical timber harvesting on ecosystem services, and the costs and benefits of more sustainable production. We have, where possible, quantified and assessed the effects of alternative, more sustainable, production methods on the provision of a range of ecosystem services. The resulting insights can be used to develop mechanisms to compensate the higher costs associated with certified sustainably produced timber from benefits offered by enhanced delivery of ecosystem services.

At its peak, in 2006-2007, the Netherlands imported about 1.3 million m^3 of tropical round wood, sawn wood and plywood a year. As a result of the economic crisis, imports had declined to approx. 0.9 million m^3 in 2011. About 90% of the imported wood is used within the Netherlands, while the remaining 10% is re-exported. The import share of certified timber meeting the sustainability criteria for government procurement had increased to 39% in 2011, mainly as a result of the sustainable procurement requirements by the Dutch government, the tropical timber programmes of the sustainable trade initiative (IDH) and voluntary initiatives by the wood importing and processing industry.

Tropical forest management regimes considered
Three management regimes were compared for their costs and benefits, the latter including the provision of ecosystem services:

- Conventional selective logging (CL).
  This is logging without implementation of specific actions to reduce the damage to the remaining forest. Only a limited number of tree species are being harvested. As a result, the residual forest remains at least partly intact, but damage may be considerable, affecting a number of services provided by the forest.
- Sustainable forest management (SFM) or reduced impact logging (RIL).
  This is selective logging that meets the standards of important forest certification schemes like FSC or PEFC. It implies a number of measures to minimise the damage to the residual forest, and particularly future timber trees. Negative impacts on ecosystem services like carbon sequestration, future timber and NTFPs are likely to be less than with CL. The question is how large the effects on ecosystem services are, and what costs and benefits are involved.
- Productive forest plantations.
  Timber plantations aim to increase timber production per unit of area. As a result, smaller areas are needed to produce the same amount of timber. Efficient production of timber by plantations may thus reduce the pressure on the primary forest, which is important for a wide variety of services.

Ecosystem services considered
The following ecosystem services from tropical forests were considered. Some can be quantified and expressed in monetary terms, while others cannot.

Quantifiable
1. Timber yields.
2. Carbon sequestration and maintaining a carbon stock.
3. Benefits from hunting and fishing ('wild food').
4. Benefits from gathering other NTFPs, such as nuts, rattan and the like.
5. For South East Asia only[1]: benefits from sediment load prevention at hydro-electric plants.

Only in qualitative terms
6. Water control, including watershed protection, erosion control, provision of drinking water, reduced risks of flooding and maintenance of water quality downstream.
7. Conservation of biodiversity as a goal in itself or as a means to promote eco-tourism.
8. Indigenous culture.

Some benefits of better forest management will be realised in the future, so an appropriate discount rate must be applied. To cover the range of discount rates that is usually used in this type of studies, we applied both a 0% discount rate and a rate of 4% per year. A 0% discount rate implies that the contributions of immediate and future costs and benefits are equally valued. The higher the discount rate, the lower the importance of future costs and benefits in the overall cost-benefit evaluation.

Results
Our examination of different forest management regimes and their impact on the provision of ecosystem services shows that some of the services rendered can be quantified while some cannot. We also found that prices can be attached to the quantifiable services, so that it is possible to express all of them in the same unit of measurement: money. We found differences in the costs of the three management regimes, which made it possible to confront these with the monetary benefits (of some of the ecosystem services). This enabled us to carry out a – partial – cost-benefit comparison of the different management regimes used to produce tropical timber, and identify possibilities to capture the values of these benefits, which may help stimulate sustainable production. The cost-benefit analysis is partial to the extent that benefits that can – in principle – be expressed in monetary terms were only included when reliable data was available. The analysis is also partial because no attempt was made to assess the so-called remaining value of the forest after logging (or the plantation) at the end of the 60-year period considered.

The results are expressed per ha and are based on (discounted) cumulative costs and benefits of a 60-year timespan (which covers two felling cycles of 30 years with three timber harvests for selective logging)

Quantitative assessment
a) *Timber yields and harvesting costs (see also Figures S.1-S.4 below).*
   - The present values of benefits and costs[2] are by definition always higher at a 0% discount rate than at a 4% rate.
   - Timber yields (in money terms) in South East Asia are considerably higher than in South America, by a factor of 2–2.5.
   - In **South America**, timber yields (in money terms) of **RIL** are higher than those of **CL** (while for plantation they are equal to CL by definition), but so are the costs. These higher costs, however, are more than offset by future higher yields, resulting in a positive difference in net yield for RIL of US$ 1000 per ha at a 0% discount rate and US$ 330 at a 4% discount rate (present values per ha over a 60-year period).
   - Hence, even without taken the higher level of ecosystem services into account, RIL is preferable solely from a commercial long-term business point of view.
   - This is different in **South East Asia**. Over a 60-year (three logging events) period, CL yields more than RIL, while costs are lower. The results show a net yield per ha of US$ 19,900 for CL and US$ 16,800 $ for RIL at a 0% discount rate. The corresponding figures at a 4% discount

[1] No relevant studies on the impact of forest management on watershed services has been found for Brazil.
[2] Costs and benefits are always expressed as present value (2010) per ha at 2010 price levels

rate are US$ 12,400 (CL) and US$ 9,200 (RIL). Hence, the differences in net yield (present value) are approx. US$ 3200 in favour of CL at both discount rates.

- In this region, the potential commercial advantages of RIL over CL must be sought in the market value of the non-timber ecosystem services provided.
- At **plantations**, the harvest takes place at a much later date than with selective logging, as it takes time for plantations to mature. Hence, the present value of the timber yield is greatly influenced by the discount rate applied.
- The plantation alternative shows relatively high costs per dollar of timber produced (especially in South America). Since plantations support relatively few other ecosystem services on the plantation area, its advantages could arise from land sparing and the resulting provision of ecosystem services by semi-natural forests, particularly carbon sequestration.

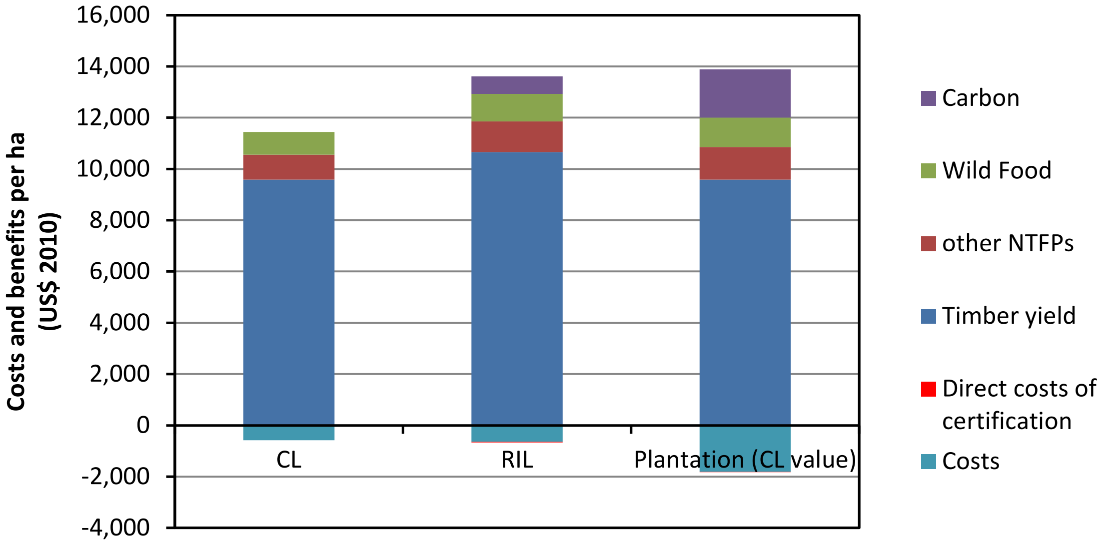

Figure S.1 *Quantifiable costs and benefits,* ***South America, 0% discount rate*** *(present value US$/ha, 2010 price level).*

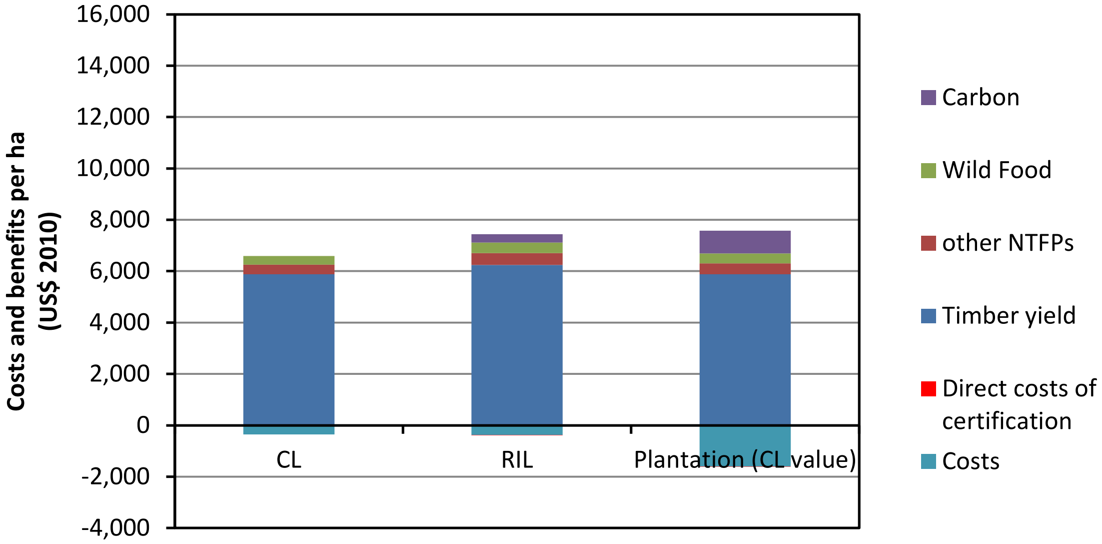

Figure S.2 *Quantifiable costs and benefits,* ***South America, 4% discount rate*** *(present value US$/ha, 2010 price level).*

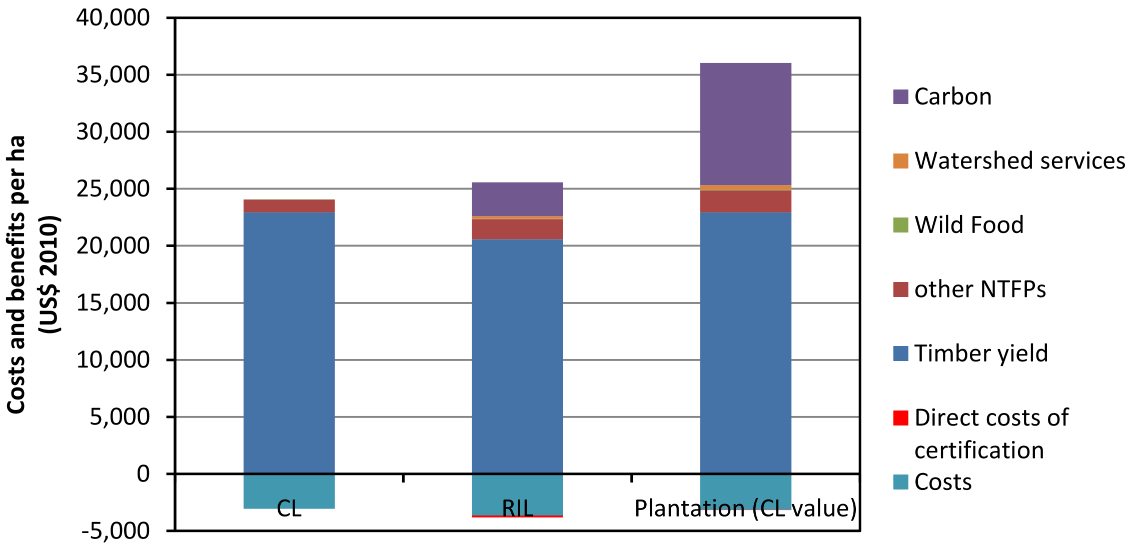

Figure S.3 *Quantifiable costs and benefits,* ***South East Asia, 0% discount rate*** *(present value US$/ha, 2010 price level).*

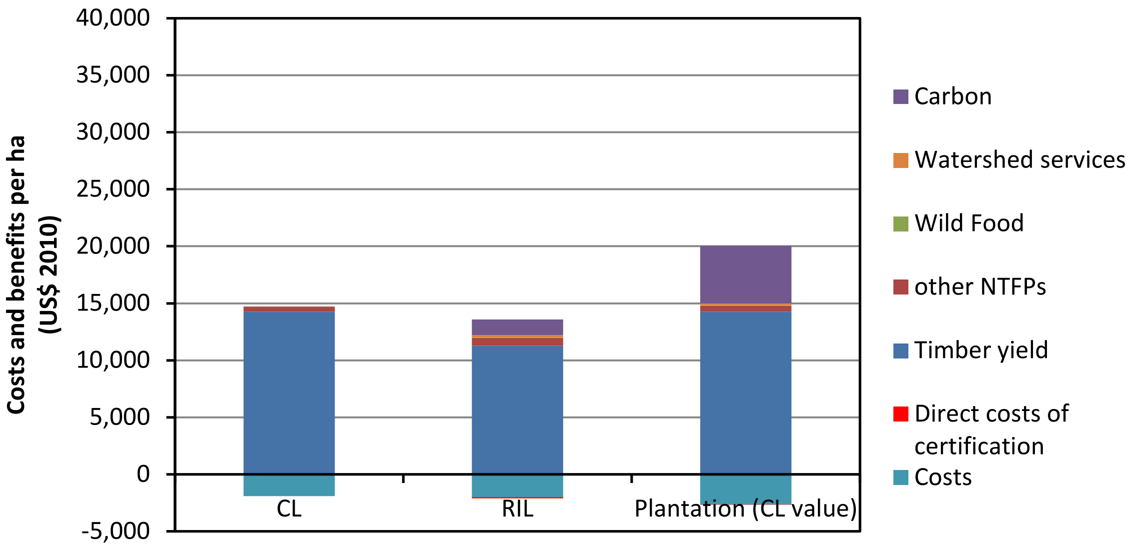

Figure S.4 *Quantifiable costs and benefits,* ***South East Asia, 4% discount rate*** *(present value US$/ha, 2010 price level).*

b) Ecosystem benefits

- Timber yields under **RIL** in South East Asia are twice those in South America. Remarkably, the *share* of quantifiable non-timber ecosystem services (carbon, wild food, other NTFPs and watershed services) in the total benefits in both world regions differs less: around one fifth (Figure S.5). The composition of this share varies greatly, however: carbon sequestration and NTFPs dominate in South East Asia, while the various components are more evenly distributed in South America (Figure S.5).
- In **South East Asia**, rattan is an important forest product, while wild food is much less important than is the case in South America. Moreover, there are some figures for Malaysia on the impact of forest management on sediment loads at hydro-electrical plants, making a modest contribution to the quantifiable benefits of ecosystem services there (see Annex 3, not represented in the figures S.1-S.4).
- On plantations in **South America**, carbon stock, wild food and other NTFPs have more or less equal shares in monetary terms. Under RIL, the relative share of carbon stock is considerably smaller than the share of the other non-timber benefits (and in CL it is by definition zero, as this management regime is taken as the baseline).

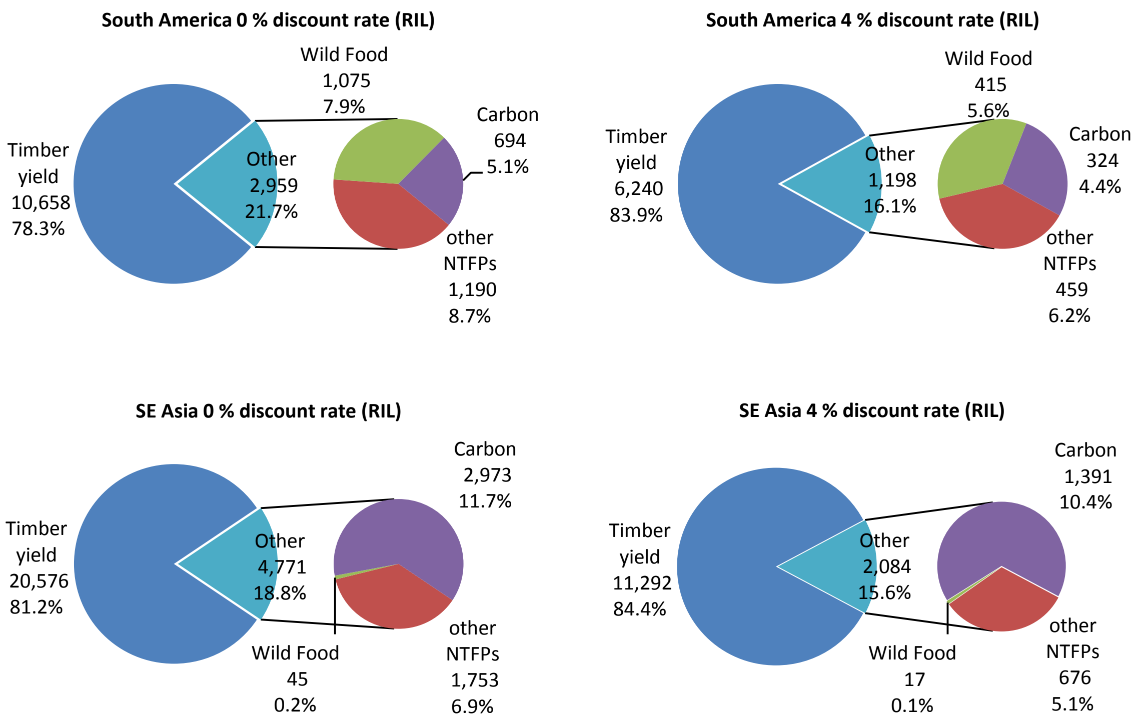

Figure S.5 *Share of the benefits from different ecosystem services for RIL in South America and Southeast Asia, at 0 and 4% discount rates. Values in 2010 US dollars and their share in percentages.*

Qualitative assessment

Not all ecosystem services could be expressed in monetary terms, either because they are difficult to quantify (e.g. hydrological effects) or because they are too much dependent on location and specific local conditions, e.g. eco-tourism potential. Generalised statements for huge regions like South America or South East Asia then become meaningless. In most cases the impossibility of putting general dollar values on these services stems from both reasons. This does not mean that the impacts of different types of forest management are of no importance: locally they can be of the utmost importance, but may differ for different stakeholders. Their value is therefore indicative of their potential, and whether the values can indeed be realised must be judged for each specific case.

Evaluating the impact of the three forest management regimes requires a broader perspective. Therefore, a qualitative assessment was carried out of a number of these impacts, both in terms of potentials and of importance to the various stakeholders. This was done by the first author in cooperation with colleagues with many years of experience of working in tropical forests, and combined with a review of the available literature.

This resulted in the following conclusions.

- The delivery potential of all ecosystem services (except timber production) is highest for natural, pristine forest and lower when timber is harvested. This drop in the provision of these services is greatest under conventional logging (CL) and less under sustainable forest management (SFM = reduced impact logging – RIL). Compare the first three columns of Table S.1.
- The effect of **plantation** very much depends on local circumstances. In general, the potential of forest plantations to deliver ecosystem services is considered to be lower than that of natural forests, but plantation development on degraded lands may be a very important source of ecosystem services like erosion prevention and carbon storage. Species selection is then very important to prevent additional negative effects.
- These observations concerning the provision of ecosystem services are of great importance to the **local communities** (with the exception of carbon sequestration), including the locally employed forest workers. For the **national governments,** it is especially the flood prevention function and

the carbon storage function that are considered highly important. For more information see the scores on the right-hand side of Table S.1.

- As expected, **timber production** (in terms of volume) is highest on plantations. This obviously matters most to the forestry sector (from the workers up to the large companies themselves) and to the local and national governments (local and export earnings).
- Future primary research should give more attention to quantifying the impact of forest management regimes on drinking **water** quality and the effects on indigenous **culture**. These impacts on the local community can be severe, but are difficult to quantify. In the case of plantations, these functions are even at risk of being degraded. The same goes, to a slightly lesser degree, for the potentials for hunting, fishing & forest products and for biodiversity.
- **International conventions** address issues such as timber production and carbon stock (which are moderately influenced by forest management regimes) and biodiversity and indigenous culture (which can be strongly influenced by management regimes).

Table S.1
Potential of management systems to provide services, and the importance of these services for different stakeholders.

Ecosystem service	**Delivery potential**				**Importance to**								
	Natural	**SFM**	**CL**	**Plantation**	**Forest workers**	**Non-forestry**	**Local government**	**Large company**	**Community forestry**	**National government**	**International community**	**Dutch consumers**	**International conventions**
Timber production	1	3	3	4	+++	+	++	+++	+++	++	0	+	X
Carbon stocks	4	3	3	2	+	+	+	0	+	+++	++	++	X
Wild food	4	3	2	0	+++	+++	+	0	0	+	0	0	0
NTFP	4	3	2	0	+++	+++	++	0	0	+	0	0	0
Quality of drinking water	4	2	2	-1	+++	+++	+++	+	+	++	0	0	0
Hydrological functions	4	3	3	1	+	+	+++	+	+	++	0	0	0
Water retention	4	3	3	2	+++	+++	++	+	+	++	0	0	0
Soil properties incl. erosion	4	3	2	1	++	++	+++	+	+	++	0	0	0
Flood prevention	4	3	3	1	++	++	+++	+	+	+++	0	0	0
Biodiversity	4	3	3	0	++	++	0	0	0	0	++	0	X
Indigenous culture	4	3	2	-1	+++	+++	++	0	0	+	0	0	X

-1 = reduced services;
0 = no potential;
1-4 = low to high potential.

Importance:
0 = unimportant,
+ to +++ = low to high importance

1 Introduction

TEEB of trade chains
The Netherlands depends heavily on imports for many biotic resources and commodities like (tropical) timber, soy, palm oil, cacao and bio-energy, . As a consequence, the Netherlands has a relatively large ecological footprint abroad, affecting ecosystems in the production countries. Dutch policy aims at sustainable use of these ecosystems to minimise adverse impacts on the environment and biodiversity and to maintain the productive capacity of these ecosystems. In this respect the focus of Dutch policy is on improving the sustainability of production chains rather than on reducing production.

The TEEB-NL (The Economics of Ecosystems and Biodiversity) study requires greater insight into the relation between Dutch trade chains and ecosystem services. The present study assessed the impact of harvesting tropical timber on ecosystem services and the costs and benefits of more sustainable production. We have, where possible, quantified and assessed the effects of alternative, more sustainable, production methods on the provision of a range of ecosystem services. The analysis carried out in this study can be characterised as a partial cost-benefit analysis plus a qualitative assessment of impacts by experts.

Dutch imports of tropical timber
At its peak, in 2006-2007, the Netherlands imported about 1.3 million m^3 of tropical round wood, sawn wood and plywood a year (Figure 1.1) As a result of the economic crisis, imports declined to approx. 0.9 million m^3 in 2011. About 90% of the imported wood is used within the Netherlands, while the remaining 10% is re-exported. The import share of certified timber meeting the sustainability criteria for government procurement had increased to 39% in 2011, mainly as a result of the sustainable procurement requirements by the Dutch government and the sustainable trade initiative (IDH). This is tropical wood from forests that are covered by the PEFC and/or FSC certification standards. Currently the Malaysian MTCS system that is covered by the PEFC system does not yet meet the sustainable procurement criteria and is therefore excluded from the certified sustainable share.

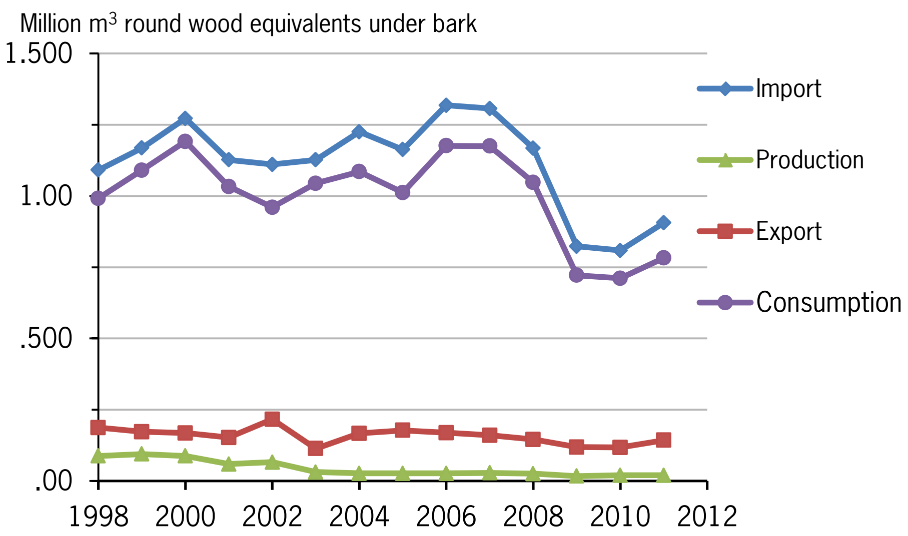

Figure 1.1 *Dutch imports, use and exports of tropical wood.*
Source: CBS et al., 2013.

Brazil, Malaysia and Indonesia are among the largest producers and exporters of tropical wood (e.g. ITTO 2012) and are also the three most important tropical countries from which the Netherlands imports tropical wood (e.g. Kamphuis *et al.*, 2011).

Forest management alternatives

Tropical timber is produced in different ways with different impacts on ecosystem services. Tropical forests are characterised by a large diversity of tree species, most of which have either unknown or undesirable wood properties, are too small or are too rare and therefore unknown (e.g. Lindenmayer and Laurance 2012). Consequently, only a small selection of the species in the forest is of actual economic importance for timber production. Selective logging, in which only a limited number of species are harvested, is therefore the most widely practiced logging method in the tropics.

Selective logging involves harvesting only individuals of the economic species that are sufficiently big, preferably trees with a diameter at breast height (DBH) of over 30 cm (e.g. Shearman *et al.,* 2012). The eventual impact of selective logging on the remaining forest depends on the abundance and size distribution of the economic species. In forests with high abundances of economic species, harvesting intensities, and therefore also the total damage to the surrounding forest, tend to be larger than in forests with low abundances of economic species. In addition to such forest-dependent characteristics, which determine the intensity of harvesting, the mode of selective logging will also determine the impact on forest structure, on biodiversity and on potential ecosystem services.

The present study examined three alternative types of wood production. Two of these types of forest management relate to selective logging, i.e. conventional and sustainable forest management, while the third alternative involves the potential of using wood plantations to reduce the overall impact per unit of timber produced. Conventional selective logging was taken as the reference situation, with which the other two alternatives were compared.

- *Conventional selective logging* (CL) was considered without the implementation of specific actions to reduce the damage to the remaining forest. In this method, only a limited number of tree species are being harvested. As a result, secondary forests remain at least partly intact, but damage may be considerable, probably affecting a number of services provided by the forest (e.g. Guariguata *et al.,* 2009).
- *Sustainable forest management* (SFM) or *reduced impact logging* (RIL). Under this heading we generally considered selective logging that meets the standards of important forest certification schemes like FSC or PEFC. This means, for instance, that RIL should be implemented. This is selective logging with implementation of a number of measures to minimise the damage to the residual forest, and particularly future timber trees. Negative impacts on ecosystem services like carbon sequestration, future timber and NTFPs are likely to be less than with CL. The question is how large the effects on ecosystem services are and what costs and benefits are involved.
- *Productive forest plantations*. Timber plantations aim to increase timber production per unit of area. As a result, smaller areas are needed to produce the same amount of timber. In some cases, production of timber from plantations may thus reduce the pressure on the primary forest. Timber plantations range from pure monocultures to plantations with a mixture of species and buffer zones with local species planted.

These alternatives are further elaborated in Chapter 2; their consequences for timber yields and other ecosystem services are discussed in Chapter 3. In Chapter 4 the results of the cost-benefit analyses are presented. Annex 1 lists abbreviations that are frequently used throughout the text.

2 Three types of forest management

2.1 Conventional selective logging (CL)

Selective logging of natural forests often implies the opening up of previously less accessible areas. Before timber harvesting can take place, a number of preparatory actions need to be taken, involving administrative and infrastructural aspects. First, an area or concession needs to be acquired, usually involving permits from local and national government agencies, i.e. forestry authorities or commissions, and fees that need to be paid. Once a concession is acquired (or sometimes beforehand), inventories of standing stocks need to be made and management plans need to be developed. The logging can be organised in many different ways. For instance, the concessionaire can implement the whole process themselves, but there are also arrangements possible, which may involve road construction during logging being subcontracted to third parties, and timber being sold to existing sawmills for processing.

Infrastructure
In any case, infrastructure is needed to extract the timber from the concession area and to process the harvested logs. This includes construction of main roads to create access to the different logging blocks, and log landings to temporarily stock logs for transport to a sawmill (e.g. close to a harbour). This can have large impacts on the forest. If no proper bridges and culverts are built, water courses and hydrology can be severely affected. Depending on the size and organisation of the operation, an on-site log yard and sawmill will be needed, including workshops for the maintenance of equipment and vehicles, although it is also possible to use existing centrally located sawmills. If the concession is located away from population centres, accommodation for forest workers will also be needed. The impact of the latter, however, will probably be restricted to a relatively small area within the concession area. The actual timber harvesting requires more detailed inventories, and feeder roads need to be constructed, with additional effects on the forest.

Felling
Probably the largest physical effects are caused by the felling itself, with falling trees damaging the surrounding forest and not seldom tearing down other trees entangled with them by vines.

Skidding
Once trees have been felled, they need to be extracted from the forest. This process, called skidding, makes use of heavy machinery to pull the felled logs from the forest to a place accessible to bigger trucks (a log landing along a main road). If logging is not well planned and mapped in advance, this involves a lot of driving around through the forest, resulting in destruction of the understorey and medium-sized trees. It may also cause soil compaction in the tire tracks, which seriously limits the regeneration of vegetation in these skid trails. Unplanned skidding wears out the machinery, resulting in high costs of repair and maintenance. Yet, this is still the predominant skidding approach. In most countries, logs and stumps need to be registered and numbered to allow forestry authorities to check the locations of origin of logs.

Sawing and transport
The logs that have been hauled to the log landings subsequently need to be transported to a log yard and/or sawmill. The usual mode of transport is by truck over the main roads, but occasionally watercourses or railway systems are also used. At the sawmills, the logs are registered again and prepared for further transport or sawn to meet the required dimensions. *Sawing efficiency varies greatly across regions and mills, and can be as low as 30% in tropical sawmills.* The waste, i.e. bark, saw dust and leftovers, is often burned in the open air, although it is occasionally used as an energy source for operating the sawmill or to heat kilns used for drying wood.

After the logs have been processed or preprocessed, the sawn wood and finished products need to be transported to the harbour and shipped for export. This involves handling of the wood and administrative procedures.

Timber benefits
The value added by timber harvesting is highest if final products are delivered, and lowest if unprocessed logs are exported. To increase the value added in the countries of origin, many countries tax exports of logs at a much higher rate than exports of sawn wood and finished wood products. The grade/quality of exported wood is usually higher than that of wood for local consumption. A side-effect of harvesting more wood for export, without proper planning and inventories before harvesting, is that more lower quality timber (e.g. hollow or split trees) becomes available. This will subsequently affect local wood prices. We therefore also needed information on wood prices (local and exported) and the distribution of local and export quantities.

Other benefits
Effects of conventional logging on other services tend to be relatively small, except probably those on wild food and other NTFPs. We need to distinguish between short-term and longer-term effects. In the short term, access to the logged area will be enhanced, allowing hunters and collectors from other regions to enter the logged areas and collect food and NTFPs (often to be traded). This may lead to overhunting and overharvesting, reducing the availability to local people.

2.2 Sustainable forest management (SFM)

The UN defines sustainable forest management (SFM) as a 'dynamic and evolving concept, which aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations.'

2.2.1 Certification

In timber certification, a distinction is made between certification of forest management and certification of the 'chain of custody' (CoC). Certified forest management guarantees that forest is managed according to the criteria and indicators of the certifying body, which should guarantee sustainable forest management. This certification is at the level of individual forest management units (FMUs). CoC certification also follows the wood through the whole chain of processing and distribution, making sure that no wood from non-certified sources is mixed into the certified end product. For instance, timber that has been harvested with a forest management certificate but sawn in a sawmill without a CoC certificate will eventually reach the customer without the certificate. There are examples of regions where some concessions have acquired a FSC forest management certificate, but since no sawmills with a CoC certificate are as yet available there, the timber cannot be exported as certified timber. Although the wood comes from a sustainable source, it cannot be identified as such in international trade (see also Simula *et al.,* 2004).

Maintaining or gaining market access has been found to be the most important reason for timber producers to seek certification. This is especially the case for producers from countries that are major exporters of tropical wood, like Brazil, Indonesia and Malaysia (Durst *et al.,* 2006). Image and credibility were also important reasons for certification, while to a lesser extent, certification in developing countries is driven by anticipated price premiums (Durst *et al.,* 2006). A reason why price premiums are not the most important driver for logging companies to certify forest management is that such price premiums are seldom reaped by the logging companies. It is mainly other actors in the supply chain that reap the economic added value of certification (Rametsteiner and Simula 2003).

Stepwise approach
Steps towards certification are smaller in areas where there is already greater attention and support for sustainable production than in those with a large gap between current management practices and certification requirements. The indirect costs of certification are higher if the initial situation does not already include more sustainable management practices. Using a phased approach, full compliance

with the certification standard can be reached in incremental steps. This allows available resources to be focused on achieving specific tasks, which is believed to make it easier to progress towards meeting SFM requirements for certification standards (Durst *et al.,* 2006; Simula *et al.,* 2004). Although the International Tropical Timber Organization (ITTO) supported such a stepwise approach, and it had some practical applications, it has not been officially recognised by certification organisations.

2.2.2 Reduced Impact Logging (RIL)

One of the aims of sustainable forest management (SFM), including RIL practices, is to reduce the impact of the selective logging activities on the remaining forest. Although the difference between CL and RIL in terms of harvested volumes is generally not large, the difference in damage to the forest is. Consequently, higher future timber yields can be sustained by RIL than by CL.

Planning and reducing damage associated with felling and skidding are key aspects of RIL. More specifically, these include (see for instance Blate *et al.,* 2002; Holmes *et al.,* 2002; Peña-Claros *et al.,* 2008; Putz *et al.,* 2001):

- Directional felling, aiming to let trees fall into existing natural gaps, or gaps created by trees felled before. This will reduce the damage to surrounding trees and canopy.
- Low stumps, to get more timber from one tree.
- Cutting vines to prevent surrounding trees that are entangled with the felled trees by vines falling together with the felled tree.
- Improved inventories (100%), mapping all trees that will be harvested, to reduce damage to the forest by skidders searching for felled trees.
- Checking potential crop trees for hollow trunks or other defects, to prevent the unnecessary felling of trees.
- Planning of roads and skid trails to minimise the extent of the road and skid-trail network.
- Reducing soil damage by skidding, including for instance restricting skidding to dry weather conditions.
- Winching of trees to limit the number of large skid trails, to reduce the extent of skidder damage.
- Marking of future crop trees and seed trees with the intention to reduce damage to the marked trees during the felling of surrounding trees. Seed trees are important for quick regeneration of the forest after logging.
- Protection of watercourses, including the construction of proper bridges and/or culverts to cross creeks and rivers.
- Logging restrictions in protected areas, allowing no hunting in the logged forest.

In general, it is especially the training of forest workers and the time needed for planning in RIL that lead to higher costs compared to CL, but the higher (sustained future) yields and reduced damage to equipment mean that net financial gains are expected to be higher in the long term (Boltz *et al*., 2003; Holmes *et al.,* 2002; Van der Hout 1999; Van Gardingen *et al.,* 2003).

2.3 Forest plantations

Non-timber ecosystem services

Forest plantations include planting of trees on areas that were previously natural forests, or on areas that had other designations, like agriculture. Ecosystem services provided by these plantations greatly depend on plantation management and the types of species planted. Moreover, it matters whether undergrowth is stimulated or controlled, and ecosystem services are also influenced by the rotation cycle chosen, as fast-growing short-rotation plantations, like Eucalyptus plantations, are likely to deliver fewer ecosystem services than long-rotation plantations with for instance Teak or Rubber. How this turns out depends on local circumstances. For example: planting Eucalyptus can reverse erosion, but at the same time, because of high evapotranspiration, dramatically reduce water availability.

The net effect of establishing a plantation will also greatly depend on the previous land use. Compared with natural forests, a number of services are likely to be reduced, while the services provided by the plantations will increase in comparison with arable land.

3 Timber yields and other ecosystem services of the forest management alternatives

3.1 Introduction

Based on a review of published data and other information, this chapter tries to quantify physical and economic effects of the different forest management alternatives on forests and ecosystem services. We have assumed that in natural forests, local communities are allowed to extract timber for their own use, and NTFPs both for subsistence use and trade and export. The alternative logging options are expected to have – apart from the yields of timber – a number of effects on ecosystem goods and services; see Sections 3.3-3.6.

Tropical forests render a number of other ecosystem services. In this report we consider four groups of them:

- NTFPs, such as game, fish and other products gathered in the forest.
- Carbon sequestration and maintaining a carbon stock.
- Water control, including watershed protection, erosion control, provision of drinking water, reduced risks of flooding and maintenance of water quality downstream;
- Conservation of biodiversity that can be exploited by means of eco-tourism.

As explained above, the provision of these ecosystem services can be threatened by harvesting or cultivating tropical timber. These effects are mainly in terms of physical availability. Tenure and access issues can also play a role, but can work both ways: sometimes improving access, sometimes blocking it. Under FSC certification, roads must be closed to motorised vehicles after harvesting, but this might still give the local community better access to the forest.

A comprehensive comparison of CL and RIL studies (FAO 2004) shows that damage to the residual forest stands under CL is in the range of 30 - 70% (this means that 30 to 70% of the remaining trees are severely damaged or dead), depending on forest structure and harvesting intensities. This damage to the residual stands can be considerably reduced by applying RIL techniques. In a case study in Indonesia (Sist *et al.,* 1998), for instance, at moderate levels of harvesting (<8 trees per ha) ~50% of the trees in the forest were found to be severely damaged by CL, compared to only 25% with RIL (Table 3.1).

We used the following estimates of damage to the residual forest. In South American tropical forests, logging damage is on average 17% for RIL and 32% for CL (averages estimated from De Graaf *et al*., 1999; FAO 1997, 2004; Sist and Ferreira 2007; Van der Hout 1999) while in South East Asia, with higher logging intensities, this is on average 54% for CL and 28% for RIL (estimated from Bertault & Sist 1997; FAO 2004; Grieser-Johns 1996; Kilkki 1992; Pinard *et al.,* 2000; Pinard *et al.,* 1995; Richter 2001; Sist *et al.,* 1998; Sist *et al.,* 2003b; Tay 1999; Van Gardingen *et al.,* 1998 (See Annex 4).

Additionally, 30 to 75% of the forest area in conventionally logged areas can be severely affected by logging roads, skid trails and landings, while careful planning and construction of these leads to an impact on only 10-25% of the forest under RIL (FAO 2004).

Table 3.1

Estimated percentage of damage in the residual and surrounding forest.

	Conventional logging	Reduced impact logging
S America	32%	17%
SE Asia	54%	28%
Affected by infrastructure (roads, skid trails, landings)	30-75%	10-25%

Source: see Annex 4

There are also potential positive effects of selective logging on the availability and use of ecosystem services. The infrastructure associated with commercial selective logging operations may, for instance, facilitate the collection of NTFPs by the local population and the transportation to markets.

3.2 Timber production

3.2.1 Conventional and reduced impact logging (CL and RIL)

Timber yields in m^3

Calculations were made on the assumption that CL and RIL have the same 30-year felling cycle. Medjibe and Putz (2012) reviewed production volumes of CL and RIL systems based on several literature sources, including a number of studies from South East Asia and South America. We selected all studies from these two regions that provided data on production levels and costs of timber, and calculated average production levels for both regions.

For South America, the average harvest levels per hectare are very similar for CL and RIL, see Table 3.2. In South East Asia, the average harvesting intensity of the first harvest is much higher than in South America, mainly due to the higher abundance of commercial tree species. The intensity of the first harvest is substantially higher for CL than for RIL.

Table 3.2

Average volume of timber extracted by conventional selective logging (CL) and reduced impact logging, first harvest (with ranges between brackets).

Region	CL (m^3 ha^{-1})	RIL (m^3 ha^{-1})
S America	27.5 (25-30)	28.6 (20-39)
SE Asia	85.7 (28-136)	62.8 (53-106)

Based on Medjibe and Putz, (2012).

Profits with CL and RIL

Based on reported logging costs and log sale prices (see Medjibe and Putz 2012), logging profits vary substantially between harvest systems and with harvesting intensities, expressed either per hectare logged or per timber volume harvested. Among the 10 studies that compared RIL and CL, 6 found CL to be more profitable if expressed on a per hectare harvested basis, but this number fell to only 3 when expressed on a volume harvested basis (Figure 2 in Medjibe and Putz 2012). This effect apparently results from the typically higher harvesting intensities in CL operations. When compared on the basis of areas allocated for harvesting rather than the portions actually harvested, RIL profits were substantially lower (data not shown in Medjibe and Putz 2012), but this effect depends substantially on whether areas to be excluded from logging due to proximity to streams or steep slopes are included within the demarcated logging blocks.

For the Brazilian Amazon region, maximum allowed harvesting intensities are 30 m^3 per hectare, in combination with a minimum of 25-35 years felling cycle (De Graaf and Van Eldik 2011; Zarin *et al.,* 2007). Both the CL and RIL volumes considered here for tropical wood from Brazil are below this maximum allowed yield.

The intensity and sustainability of the first harvest will determine the timber yields that can be sustained in the future and thus the future benefits from logging. Many studies have assessed the differences between CL and RIL in terms of future yields (see e.g. Medjibe and Putz 2012; Putz *et al.,* 2012). The trend these studies show is that timber yields after the first rotation are consistently higher under RIL than CL (Table 3.3).

Modelling studies show that under CL as well as under improved forest management, the relatively high timber yields of the first harvest decline by approx. 50% during the second and subsequent harvests (meta-analysis in Putz *et al.,* 2012; Putz *et al.,* 2013). Timber yields at second and subsequent harvests, however, can be sustained at those lower levels. Differences in consecutive timber yields between CL and RIL have been quantified based on a number of published studies presenting model projections with a cutting cycle of approximately 30 years (Table 3.3).

Table 3.3

Logging intensities at first harvest and yields as a percentage of the first harvest for second and third harvests. The cutting cycle is the time in between two logging events.

CL = conventional logging, RIL= reduced impact logging.

Country	Logging method	Cutting cycle	Yield 1st cut (m^3 ha^{-1})	Yield 2nd cut (% of 1st)	Yield 3rd cut (% of 1st)	Reference
S America						
Brazil	CL	40	30	50	55	Macpherson *et al.,* 2010
Brazil	CL	30	39	74	38	Valle *et al.,* 2007
Brazil	CL	30	30	18		Valle *et al.,* 2006
Brazil	RIL	40	30	67	73	Macpherson *et al.,* 2010
Brazil	RIL	30	75	72		Silva *et al.,* 1995
Brazil	RIL	30	36	89	56	Valle *et al.,* 2007
Brazil	RIL	30	21	36		Sist and Ferreira 2007
Brazil	RIL	30	34	56	35	Van Gardingen *et al.,* 2006
Bolivia	RIL	30	10.3	34	14	Blate 2005
Bolivia	RIL	30	14.7	47	32	Blate 2005
Guyana	RIL	25	32.5	76	71	Arets 2005
Averages applied	**CL**	**30**	**27[1]**	**12.7 m^3 (47% of 1st)**		
	RIL	**30**	**28[1]**	**15.1 m^3 (54% of 1st)**		
SE Asia						
Indonesia	CL	35	80		49	Van Gardingen *et al.,* 2003
Indonesia	CL	35	78	79	45	Sist *et al.,* 2003a
Indonesia	RIL	35	80	43	53	Van Gardingen *et al.,* 2003
Indonesia	RIL	35	60	56	59	Van Gardingen *et al.,* 2003
Indonesia	RIL	35	50	86	90	Van Gardingen *et al.,* 2003
Malaysia	RIL	30	106	70[2] (100)	70[2] (100)	Healey *et al.,* 2000
Malaysia	CL	30	136	44[2] (63)	44[2] (63)	Healey *et al.,* 2000
Averages applied	**CL**	**30**	**85[1]**	**38.3 m^3 (45 % of 1st)**		
	RIL	**30**	**63[1]**	**41.0 m^3 (65% of 1st)**		

Sources: Selection of studies by Putz *et al.,* (2012) and additions from Healey *et al.* (2000).

1) Based on data in Medjibe and Putz (2012).

2) Based on a 60-year cutting cycle (Arets (2005) and the assumption that the yield at the second cut in a 30-year cutting cycle is approximately 70% of the yield at the second cut in a 60-year cutting cycle. Value for 60-year cutting cycle between brackets.

Monetary value

To value benefits from timber, we used the export value for industrial round wood as reported for 2010 by the International Tropical Timber Organisation (ITTO) database[3]. Timber prices were assumed to be equal for CL and sustainable forest management (SFM) and were US$ 183 m^{-3} for South America (Brazil) and US$ 142 m^{-3} in South East Asia (average prices for Malaysia and Indonesia), see Table 3.4.

Table 3.4

Export price for industrial round wood, 2010 (US$ per m^3).

	Conventional logging	Sustainable forest management
S America	183	183
SE Asia	142	142

Our analysis does not consider potential effects of market failures and wood shortage. In South East Asian countries in particular there are signs of imminent shortage of wood from natural forests (Shearman *et al.,* 2012), which will most likely have strong effects on the price of round wood from natural forests.

Costs

The most important direct costs associated with certification are incurred by improving forest management practices, while the additional costs of auditing and monitoring are relatively modest for large-scale producers (Simula *et al.,* 2004).

Included in the calculation is a small amount of direct costs of certification. Based on Simula *et al.,* (2004) we used US$ 0.36 /m^3 for SFM and US$ 0.01 /m^3 for plantation. Note that these do not cover the costs of complying with the requirements, as those are partly included in the regular cost difference between RIL and CL.

Medjibe and Putz (2012) reported production volumes and costs of CL and RIL production systems based on several literature sources from South East Asia and South America. They differentiated the costs of timber production into pre-harvest, harvest planning, infrastructure and harvest operation[4]. To calculate average costs per region, we selected the studies from South America and South East Asia, which provide data on both production volume and production costs. Costs are expressed in US$, at 2010 prices (converted using the consumer price index), see Table 3.5.

Table 3.5

Average costs for timber production in conventional logging (CL) and reduced impact logging (RIL) (US$, 2010 prices).

Timber costs (US$ m^{-3})	South America		South East Asia	
	CL	RIL	CL	RIL
Pre-harvest	0.32	2.25	0.39	2.59
Harvest Planning	0.23	0.55	0.00	0.39
Infrastructure	1.68	0.63	3.34	4.29
Harvest Operation	8.83	7.65	15.15	17.90
Total	11.06	11.08	18.88	25.17

Source: Medjibe and Putz (2012)

3 http://www.itto.int/annual_review_output/

4 Sawing and processing of wood adds further value to the timber. Costs of saw mills and processing industries vary widely and are not included in this analysis as they are considered to be not directly related to costs and benefits from ecosystem services. However, to comply with Chain of Custody (CoC) certification, i.e. to ensure that timber from certified forest management remains certified sustainable, saw mills and other processing industries will incur additional costs to meet the demands for certification and the CoC certification itself.

3.2.2 Forest plantations

The plantation alternative was quantified using detailed information on costs and benefits from plantation development and harvesting in Malaysia provided by FAO (2002). Since the forest plantations had to serve as an alternative to harvesting from natural forests, we selected Acacia (*Acacia mangium)* and Teak (*Tectona grandis)*, two species that are considered general utility species with broad potential applications, as examples. The relative availabilities of plantations with these two species in Brazil (South America) and Malaysia and Indonesia (South East Asia) (FAO 2002) were used to assess the relative contributions of these two plantation species to the plantation alternative that was evaluated in this study (see Table 3.6).

Table 3.6
Assumed distribution of tree species in the plantation alternative

	Acacia	Teak
S America	76%	24%
SE Asia	62%	38%

Yields
Data on timber production in plantations is based on a case study by FAO (2002) for plantations in Malaysia. This was the only available study to quantify log and chiplog productivity in combination with the costs of plantation establishment and the maintenance and thinning and harvesting costs for different tree species, including Teak and Acacia. For the South American (i.e. Brazil) analysis, the costs and benefits were calculated using relative price differences between Malaysia and Brazil.

A scenario in which the total amount of timber produced over a 60-year period is equal to the production from CL (equivalent in volume) would show a major reduction in monetary timber yields, as prices of Acacia-Teak timber from plantations are lower than average prices from CL. This is the result of the low value of Acacia wood (US$ 75 in our calculations) compared to the value of wood from CL (see Table 3.4 of export prices for industrial round wood above) and the large contribution of Acacia to the total production from plantations. The value of wood from Teak plantations we used is much higher (US$ 300), but this tree has a smaller share in the total production from plantations.

A fairer comparison can be made by comparing CL and plantation yielding the same amount in monetary terms (equivalence in money value). This is the comparison we made in Chapter 4[5]. The consequence is that under the plantation scenario, more m^3 of timber are harvested and consequently a larger part of the area is under cultivation (and a smaller part is left for natural forest). This evidently has consequences for the provision of non-timber ecosystem services from the remaining (or 'spared') semi-natural forest (see Annex 3 for the plantation area needed compared to natural forest area, at different discount rates).

Prices of timber from plantations are differentiated into two levels, depending on the year of harvesting within the rotation cycle, as the harvesting year influences the size of the logs and the quality of the timber. The wood harvested during intermediary thinnings is of chip log quality, which is lower than that of the wood from final felling.

Costs
The estimated costs for the plantation alternative are also based on FAO (2002) and include costs of establishment, maintenance, thinning and harvesting. Establishment costs occur only once, at the start of the production. Costs of land purchase are not included, as they are property transfers and as such not part of an economic cost-benefit analysis. All costs are expressed in US$, at 2010 prices.

[5] Calculations on the basis of equal-volume CL and equal-value RIL yields were also made and are available.

3.3 Wild food and other non-timber forest products (NTFPs)

In many tropical forest regions, non-timber (or non-wood) forest products (NTFPs) are an important source of subsistence food, medicines and materials. They are also important for employment and household cash income (e.g. Arnold and Ruiz Perez 1998; Duchelle *et al.,* 2011; Guariguata *et al.,* 2009; Kaimowitz 2003; Odebode 2003; Pimentel *et al.,* 1997). In the Amazon region, Brazil nuts (*Bertholletia excelsa*) and fruits and palm hearts of the Açaí palm (*Euterpe oleracea*) are among the most important NTFPs. In Pando, Bolivia, collection and trading of Brazil nuts provides up to 43% of total household incomes (Duchelle *et al.,* 2011). In South East Asia, rattan is considered one of the more valuable NTFPs from mixed-use management (management for timber and NTFPs) and generates substantial foreign exchange for the producer countries (Panayotou and Ashton 1992; Shanley *et al.,* 2002).

Based on a questionnaire held among a large number of households in different areas in Nigeria, Awe *et al.,* (2011) concluded that the most important reason for gathering NTFPs was food security, followed by self-income and employment. In a review of valuation studies, Ferraro *et al*. (2012) concluded that NTFPs provide a major share of total household consumption and income especially in poor communities without ready access to markets. For these communities, they also provide an important safety net against economic shocks and in times of food scarcity. NTFPs seem to be less important for communities with access to commodity markets.

Net present value (NPV) of revenues from NTFPs is often assessed to be higher than the value of other more destructive land uses. A seminal paper by Peters *et al*. (1989) calculated the time-discounted NPV of present and future harvests of NTFPs at US$ 6630 for a single hectare of rain forest near Iquitos, Peru. This value, however, was based on the value of the standing inventory and not on actually extracted and marketed quantities. A number of other issues relating to the method applied also make this a very unrealistic estimate of the possible value of benefits from NTFPs. For instance, it excludes post-harvest losses and neglects market insecurities and the necessary destructive extraction of some of the products, which would reduce yields of future harvests (see Sheil and Wunder 2002 for a detailed discussion of these issues).

Since Peters *et al*. (1989), a number of more realistic NTFP valuation studies have become available. There are many studies relating NTFP extraction to household income, but few actually provide data on a per forest area basis (Ferraro *et al*. 2012), as is required for our analysis. The valuation estimates range from US$ 6 to US$ 47 per hectare per year (Ferraro *et al.,* 2012; Godoy *et al.,* 2002; Gram 2001; Shone and Caviglia-Harris 2006). In a study of a forest-based community in Brazil, Shone and Caviglia-Harris (2006) found that the average income from NTFPs was US$ 32 (at 2010 prices) per ha per year, while the total harvest value of the NTFPs was US$ 67 (see also Godoy *et al.,* 2002.

Our focus is on NTFPs collected from natural forests. In some cases, publications provide production quantities and market prices for NTFPs that are very likely based on the production from agro-forestry systems like home gardens, small holder plantations or even large-scale plantations. Chomitz and Kumari (1998) argue that it is important for valuation to separate the purely extractive systems, in which NTFPs are harvested from natural forests, from more intensive agro-forestry systems ranging from enrichment plantings of desirable NTFP species to plantations. For instance, Van Beukering *et al.* (2003) list *Aleurites moluccana* (Candelnut / Kemiri) as the most important NTFP from the Leuser ecosystem. In North Sumatra, however, this tree is extensively cultivated in home gardens (Krisnawati *et al*.), so most of the listed productivity in the Leuser ecosystem probably stems from cultivated trees. The same probably applies to more of the listed medium- and high-value NTFPs for which cultivation is possible.

Logging and concession management is expected to impact on the availability of NTFPs (Guariguata *et al.,* 2011; Guariguata *et al.,* 2010). Most studies assessing the effect of selective logging on NTFP extraction have reported a negative impact, but few studies have actually quantified the impact (Rist *et al.,* 2012). Damage from logging activities will probably have a similar impact on the NTFP species as on other species. For instance, a study by Guariguata *et al*. (2009) in FSC-certified forests in

Bolivia with extremely low logging intensities of on average 0.5 trees per ha (4-5 m^3) found that about 0.1 Brazil nut tree per ha was severely damaged, making the risk of severe damage to the trees about 3%. These damage rates are likely to be much higher under logging with higher intensities: assuming a more 'typical' logging intensity of 30 m^3 ha^{-1}, the risk of damage could be estimated at around 17%, which is similar to the level of damage usually observed with RIL (see below). Pre-harvest marking of valuable NTFP trees like Brazil nut could reduce logging damage to these trees and would secure future harvests of these products. Brazil nut is a valuable NTFP collected mainly in Brazil and Bolivia. Estimates of the impact of CL on NTFP extraction as perceived by local forest communities in a rapid rural appraisal indicated a 86% decline in the value of fruit and nut extraction and an 68% reduction in hunting rates, see Menton (2003).

Yields of Non-Timber Forest Products

South America
We calculated the NTFP production for Brazil based on the per area information from Gram (2001). The total value of NTFPs collected from natural forests was US$ 35.5 (2010 prices) per ha per year, about 60% of which was from hunting and fishing and 40% from collecting other products. This did not include the relatively high-value Brazil nuts, which added an additional US$ 9.1 per ha per year in natural forests. This value was based on average yield estimates by Nunes *et al*. (2012), including yields derived from studies presented in that publication (i.e. Kainer *et al.,* 2007; Wadt *et al.,* 2005; Zuidema 2003; Tonini *et al.,* 2008) combined with the average profits for shelled nuts. Consequently, the total estimated value of collecting and hunting NTFPs from natural forests we used in our analysis was US$ 44.6 (Table 3.7). This value is also within estimates for NTFPs in the Brazilian Amazon by Shone and Caviglia-Harris (2006). We assumed that the loss of NTFPs in logged forests is proportional to the damage to the residual stand (CL 32%, RIL 17% in South America, see Section 3.1), and that access is not affected by its management status.

Table 3.7
Estimated value of NTFPs from natural forest, South America, (US$/ha per year, 2010 prices)

Game	Fish	Other	Total
21.3	14.2	9.1	44.6

Sources: see above

South East Asia
There are few studies from South East Asia that have quantified NTFP value and can be linked to the physical effects of selective logging (Ferraro *et al.,* 2012). An exception is the study by Healey *et al.* (2000), which was initially also used as a pilot to this study (see Annex 2). The approach in this study, however, is very different from the approach we followed for the South American case above, as they directly assessed the impact of CL and RIL on a number of services. The results, however, are all related to changes in value compared to natural forests, without providing the actual value of services in natural forest. Both CL and RIL reduce the benefits and costs of NTFP harvesting (in this case rattan and wild food). In conventionally logged forests the annual benefits from harvesting rattan (an important NTFP in South East Asia) were US$ 17.24 (2000 prices) per ha lower than in natural forests, while the annual benefits from hunting wildlife (wild food) were US$ 0.45 (2000 prices) per ha lower than in natural forests.

To allow the calculation of the plantation scenario, in which part of the natural forests is retained, we estimated the total annual rattan and wild food value for natural forests, while assuming that the loss of benefits is proportional to the logging damage to the forest.

Studying the same RIL study area as Healey *et al.* (2000), Pinard and Putz (1996) found that in CL about 44% of the residual forest is destroyed or severely damaged. About the same damage levels for the same area were reported by Tay *et al.* (2002). Based on this, the value of rattan harvesting in natural forests was estimated at US$ 30.8 (2000) per ha per year and the value for wildlife hunting at US$ 0.8 (2000) per ha per year. Using the World Bank consumer price index for Malaysia, we converted these values to 2010 US$ (see Table 3.8). Subsequently, we estimated losses of NTFP benefits for CL and RIL based on the average rates of damage to the residual forest (see Section 3.1).

Table 3.8
Estimated value of NTFPs from natural forest, conventional logging (CL) and reduced impact logging (RIL) in South East Asia, (US$ per ha per year, 2010 prices).

Forest management regime	Wild food	Rattan	Total
Natural forest	1.0	39.9	41.0
CL	0.5	18.4	18.8
RIL	0.7	28.7	29.5

Sources: see above

We have assumed that the forest plantations themselves do not provide NTFPs, although it should be noted that in certain agro-forestry systems it would be possible for plantations to provide such goods. In the case of rubber plantations for wood production, the rubber can still be tapped, which would provide an additional source of income for the plantation. The NTFPs provided in our plantation scenario are the result of 'sparing' natural forests, as a result of the higher productivity of plantations compared to selectively logged forests.

Costs of NTFP collection and harvesting
There is very limited information on the differences in costs for collecting and harvesting NTFP under the different alternatives studied. Nunes *et al*. (2012) estimated the costs of transportation using existing infrastructure networks at US$ 1.13 per 70 kg bag of shelled Brazil nuts (which would correspond to about US$ 0.24 per ha on which the nuts are collected (average 14.6 kg ha^{-1}). Transportation is facilitated in logging concessions by the availability of logging roads and skid trails. Our study did not include the costs of NTFP collection and harvesting.

Sustainability of NTFP harvesting and hunting
The mere fact that local people use the forest to collect and harvest timber and NTFPs and hunt for local game species does not necessarily mean that such uses are always sustainable. In a case study region in Northern Bolivia where Brazil nuts are collected, many vertebrate species were found to have diminished due to uncontrolled hunting, both for subsistence consumption and for international fur markets (Guillén 2002). Also, NTFP harvests can show drastic year-to-year variation due to unequal distribution of NTFP species over the forest and variation in productivity between years (e.g. Gram 2001).

3.4 Carbon stocks and carbon sequestration

Tropical forests store large quantities of carbon and therefore play an important role in regulating global climate. Although there is great uncertainty about the level of carbon emissions from tropical deforestation and forest degradation (including selective logging), recent studies estimate emissions to be between 0.81 and 1.5 gigaton carbon annually, accounting for about 10-25% of global greenhouse gas emissions (Baccini *et al.,* 2012; Gullison *et al.,* 2007; Harris *et al.,* 2012; Pan *et al.,* 2011).

Reducing deforestation and forest degradation is considered a relatively cheap option for carbon emission mitigation as compared to more advanced technological solutions to reduce emissions from fossil fuel use. As a consequence, reducing deforestation and forest degradation and promoting forest conservation and sustainable forest management have gained increased attention in international discussions on climate change.

In recent years, the UNFCCC discussed ways in which reducing emissions from deforestation and forest degradation (REDD) in developing countries could contribute to climate change mitigation. Since the 2007 Conference of the Parties (COP-13) the Bali Action Plan has set out the path for the negotiations on REDD to be included in the successor to the Kyoto Protocol. At the 2009 COP-15 in Copenhagen, parties further agreed to not only include reduced emissions from deforestation and degradation, but also conservation of forest carbon stocks, sustainable management of forests and enhancement of carbon stocks as mitigation options under a UNFCCC REDD-plus mechanism.

REDD+ should eventually result in a ***compensation mechanism*** that encourages and allows implementation of policies to effectively protect and sustainably manage tropical forests. Compensation will be offered for emission reductions that are achieved compared to a business-as-usual baseline.

There is great variation in local carbon stocks, which may range from 72 tons to 225+ tons of carbon per hectare in aboveground biomass, depending on forest type and region (e.g. Gibbs *et al.,* 2007). Moreover, it matters for the valuation of a unit of carbon dioxide whether it uses carbon market prices or the prevented (future) economic and social costs associated with the emissions of CO_2. The latter are, however, highly speculative. Avoided emissions at market prices can be used to compensate the extra costs of improved forest management. Therefore, our analyses used market prices of avoided C emissions.

To assess the carbon-related benefits of more sustainable wood production we followed the reasoning behind REDD+. We took CL as the baseline, with which other forest management types were compared.

A number of studies have assessed the effects of RIL on carbon stocks and carbon sequestration. The effect of selective logging on carbon stocks is generally negative, but its magnitude depends greatly on logging intensity and level of damage (Asner *et al.,* 2005; Kirby and Potvin 2007). As a result, RIL involves smaller carbon losses at similar timber extraction levels than CL (Healey *et al.,* 2000; Medjibe *et al.,* 2011; Pinard and Putz 1996; Putz *et al.,* 2008), see Figure 3.1.

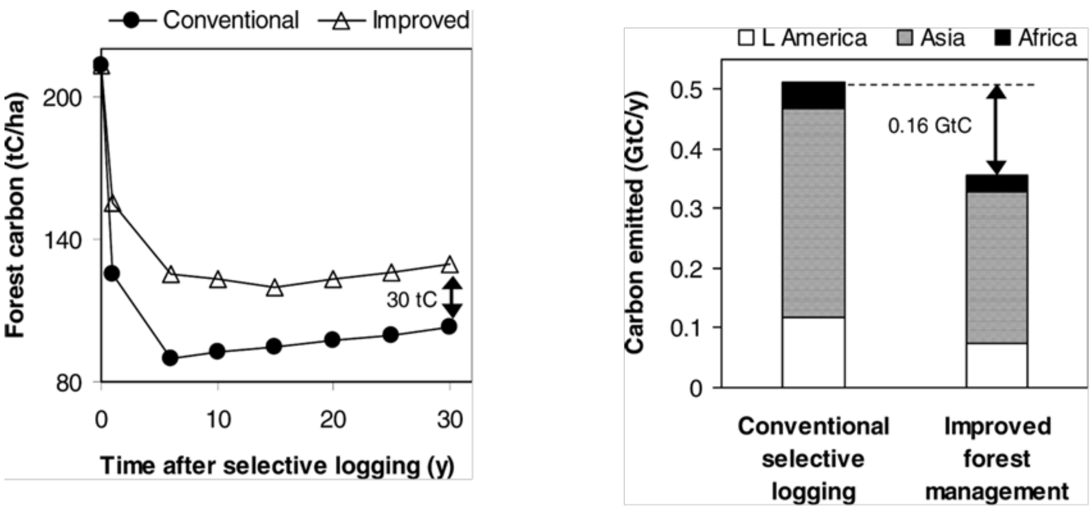

Figure 3.1 *A) Reductions in carbon losses from improved forest management per hectare of Malaysian forest, and B) Annual reductions in global carbon emissions that would result from adoption of improved tropical forest management practices.* Source: Putz *et al.* (2008)

Based on two cases in Putz *et al*. (2008), comparing CL and RIL in Brazil and Malaysia, we estimated benefits from carbon retained under RIL compared to CL (Table 3.9).

Tropical plantations generally store much lower total carbon quantities than natural forests, with differences that may be as large as 53-77% in Ghana and Brazil (Wauters *et al.,* 2008). A global meta-analysis by Liao *et al*. (2010) showed a 28% reduction in total carbon stocks in plant biomass and soil. This meta-analysis included 86 experimental comparisons between plantations and adjacent natural forests and included different forest types and biomes, not only tropical forests. The observed trend was the same in all geographic regions, but the impact on carbon in aboveground biomass was found to be especially large in tropical forests, compared to the other regions.

Table 3.9

Carbon loss and retention in harvesting with 30-year logging cycles in Brazil and Malaysia, for CL and RIL

	Original data		CO_2 eq.		Benefits at 5 US$/ton		Benefits at 10 US$/ton	
	Sabah, Malaysia	Para, Brazil	Sabah, Malaysia	Para, Brazil	Sabah, Malaysia	Para, Brazil	Sabah, Malaysia	Para, Brazil
Total carbon in unlogged forest (t ha^{-1})	213	186	782	683				
Logging intensity (m^3 ha^{-1})	125	30						
Carbon loss and retention with 30-y logging cycles								
- Loss from CL (t ha^{-1})	108	19	396	70	1,982	349	3,964	697
- Loss from RIL (t ha^{-1})	78	12	286	44				
- Carbon retained due to RIL (t ha^{-1}) = prevented emissions	30	7	110	26	551	128	1,101	257

Source: Putz et al. (2008)

Market prices for carbon offsets fluctuate greatly and vary across the types and vintage of projects and the expected permanency of the offsets (Kollmuss *et al.,* 2008). Prices on voluntary markets tend to be lower than on the compliance market. Related offsets prices for LULUCF and REDD range between 5 and 5 US$ per ton CO_2 (Kollmuss *et al.,* 2008). This will probably be closer to 5 for voluntary REDD credits, but is expected to be higher once REDD will become a mechanism under the UNFCCC. **Here we used an estimated US$ 10 per ton CO_2 as the market price for carbon offsets** (US$ 10 per CO_2 eq. of prevented emissions).

We assumed that emissions are reduced in every situation where sustainable forest management replaces conventional selective logging. Hence, these REDD+ related benefits are generated by the sustainable forest management alternative at every logging event throughout the logging cycles of one ha of forest. Transaction and implementation costs for REDD+ have been estimated at US$ 1 per ton CO_2 (Olsen and Bishop 2009), which we have already subtracted from the market price. The result thus shows the net economic benefits of reduced carbon emissions.

3.5 Soil and watershed services

Forest cover is considered beneficial for a large number of hydrological processes and services, like water infiltration, streamflow/water availability, flood mitigation, etc. In reality, the relationships are very complex (Bruijnzeel 2004; Calder 2007; Lele 2009; Lele and Srinivasan 2013) and extremely difficult to quantify and generalise. As benefits from soil and watershed services vary too much from place to place, they are not included in the quantitative assessment in Section 4.1 but are included in the qualitative assessment instead (Section 4.2). The only exception is the reduction of sediment loads at hydro-electric power stations (figures for South East Asia only).

Soil erosion is considered to be higher under CL than RIL, especially if the logging area includes steep slopes. Healey *et al.* (2000) estimated the impact of soil compaction on benefits from future timber yields. In our assessment, this effect is already discounted for in the estimated losses of future timber yields as presented in Section 3.2.

A number of studies have assessed the value of hydrological services of forests for hydro-electricity, mainly linked to the prevention of erosion and reduction of sediment loads, but also to the regulation of water supply.

Healey *et al.* (2000) estimated the impact of increased sediment loads (due to logging) on hydro-electric power stations. On an annual basis, the additional costs of removing the sediment in this case study site in Malaysia were estimated at US$ 5.21 per ha for CL, compared to natural forests (2000 prices). According the authors, this is only a rough estimate and should be treated with caution, but since it is one of the few published results quantifying the impact of logging on watershed services, we decided to use it here. The damage caused by CL to the residual forest in the Healey *et al.* (2000) study area was only 44% (see Pinard and Putz (1996) and Section 3.3), while our assessment included an estimated average damage by CL of 54% (see Section 3.1). To estimate a value for natural forests for use in our assessment we therefore corrected the original value in proportion to the differences in damage levels.

The value for watershed services under CL was subsequently assumed to be zero and that under RIL again proportional to the damage under RIL (28%, see Section 3.1). Using the World Bank consumer price index for Malaysia, these values were converted to 2010 US$.

Table 3.10
Estimated value of sediment load prevention by natural forest, conventional logging (CL) and reduced impact logging (RIL) in South East Asia (US$ per ha per year, 2010 prices).

Forest management regime	Value
Natural forest	6.40
CL	0
RIL	4.61

Sources: see above

In an extensive valuation study of forests in Aceh, Van Beukering *et al.* (2009) compared a full conservation scenario with a scenario involving an increasing deforestation rate. Their assessment of water supply under these scenarios included the importance of forests for the soil recharging capacity and peak flow, but it seemed to ignore the effect of evapotranspiration by the standing forest, which usually results in a reduction in base-flow and will thus reduce water flows (e.g. Lele 2009; Lele and Srinivasan 2013).

3.6 Eco-tourism

Depending on local conditions, eco-tourism can be a substantial source of income. We expect, however, that there will only be minor differences in the impacts of CL and SFM on eco-tourism. Plantation leaves larger shares of natural forest intact and might therefore result in a greater attraction value (outside the harvested areas) for tourists.

As benefits from eco-tourism vary too much across different locations, they are not included in the quantitative assessment in the next chapter but in the qualitative assessment instead.

4 Results

4.1 Quantitative assessment

This survey of different forest management regimes and their impact on the provision of ecosystem services shows that some of the services rendered can be quantified while some cannot. We also found that prices can be attached to the quantifiable services so that it is possible to express them in the same unit of measurement: money. We found differences in the costs of the three management regimes, which makes it possible to confront these with the monetary benefits (of some of the ecosystem services). This enabled us to carry out a – partial – cost-benefit comparison of the different management regimes to produce tropical timber. The cost-benefit analysis is partial to the extent that benefits that can – in principle – be expressed in monetary terms were only included when existing reliable data was available. The analysis is also partial because no attempt was made to assess the so-called remaining value of the forest after logging (or the plantation) at the end of the 60-year period considered.

In this section we present the costs and benefits of the following ecosystem services.
1. Timber yields.
2. Cost of forest management.
3. Cost of certification.
4. Carbon sequestration and maintaining a carbon stock.
5. Benefits from hunting and fishing ('wild food').
6. Benefits from gathering other non-timber forest products, such as nuts, rattan etc.
7. For South East Asia only: benefits from sediment load prevention at hydro-electrical plants.

Not included in this quantitative assessment are:
- Water control, including watershed protection, erosion control, provision of drinking water, reduced risks of flooding and maintenance of water quality downstream.
- Conservation of biodiversity as a goal in itself or as a means to promote eco-tourism.
- Indigenous culture.

These ecosystem services are discussed in Section 4.2.

The forest management regimes considered are:
- Conventional selective logging (CL).
- Sustainable forest management (SFM) or reduced impact logging (RIL).
- Productive forest plantations (plantation for short).

A more comprehensive description is provided in Chapter 1.

Discounting costs and benefits
Costs and benefits are incurred and received at different moments in time. This poses a problem for a fair comparison, as future costs and benefits are appreciated differently from present costs. The usual way to tackle this problem is to recalculate costs and benefits to the so-called present value (or net present value) by discounting: future costs and benefits are weighed in such a way that the further these are in the future the lower their weight. This yearly 'depreciation' is called the discount rate.

Discount rates reflect people's time preference. In the economy, discount rates are normally positive. In other words: people appreciate gains now more highly than gains later, and they regret present costs more than future costs. This is why people are willing to pay positive real interest on borrowed money (real interest = the nominal interest rate minus the rate of inflation) and lenders, like banks, demand interest on their loans[6].

[6] Discount rates and (net) present value have nothing to do with inflation, as they are always expressed in real (i.e. corrected for inflation) terms.

The next issue is to select an appropriate discount rate for the costs and benefits found in the preceding chapters. For years it used to be common practice, especially for infrastructure projects, to apply a 4% discount rate. Up until recently, this was more or less in line with the long-term real interest rate. In recent years, however, long-term interest rates seem to have become permanently lower, sparking a debate (also in the Netherlands) about the discount rate to apply for long-running projects. Moreover, and more importantly in this context, there is the criticism that discounting on future benefits from ecosystem services does not consider the specific, non-renewable and irreversible aspects of ecosystems and their services. Some, therefore, advocate a 0% discount rate when these ecosystem services are involved.

We do not take a stand in this debate, but calculated present value both with a discount rate of 0% and one of 4%. The latter implies that costs made and benefits received over 17.5 years are weighed at only 50%, those over 35 years at 25%, those over 53 years at 12.5%, etc. The half-life is 17.5 years, so to say. In our view, the 0-4% range covers the reasonably acceptable range for discounting.

From Figures 4.2- 4.9 we can draw the following conclusions (for numerical results see Annex 3).

a) Timber yields and harvesting cost

- The present values of benefits and costs[7] are by definition always higher at a 0% discount rate than at a 4% rate.
- Timber yields (in money terms) in South East Asia are considerably higher than in South America, by a factor of 2–2.5.
- In **South America**, timber yields (in money terms) of **RIL** are higher than those of **CL** (while for plantation they are equal to CL by definition), but so are the costs. These higher costs, however, are more than offset by future higher yield, resulting in a positive difference in net yield for RIL of US$ 1000 per ha at a 0% discount rate and US$ 330 at a 4% discount rate (present values per ha over a 60-year period).
- Hence, even without taking the higher level of ecosystem services into account, RIL is preferable solely from a commercial long-term business point of view.
- This is different in **South East Asia**. Over a 60-year (three logging events) period, CL yields more than RIL, while costs are lower. The results show a net yield per ha of US$ 19,900 for CL and US$ 16,800 for RIL at a 0% discount rate. The corresponding figures at a 4% discount rate are US$ 12,400 (CL) and US$ 9,200 (RIL). Hence, the differences in net yield (present value) are approx. US$ 3200, in favour of CL, at both discount rates.
- In this region, the potential commercial advantages of RIL over CL must be sought in the market value of non-timber ecosystem services provided.
- At **plantations**, the harvest takes place at a much later date than with CL, as it takes time for plantations to mature after planting. Hence, the present value of the timber yield is greatly influenced by the discount rate applied.
- The plantation alternative shows relatively high costs per $ of timber produced (especially in South America). Since plantations support relatively few other ecosystem services directly on the plantation area, their advantages could arise from land sparing and the resulting provision of ecosystem services by these natural forests, particularly carbon sequestration.

b) Ecosystem services benefits

- Timber yields under **RIL** in South East Asia are twice those in South America. Remarkably, the *share* of quantifiable non-timber ecosystem services (carbon, wild food, other NTFPs and watershed services) in the total benefits in both world regions differs less: around one fifth (Figure 4.1). The composition of this share varies greatly, however: carbon sequestration and NTFPs dominate in South East Asia, while the various components are more evenly distributed in South America.

[7] Cost and benefits are always expressed as Present value (2010) per ha at 2010 price level

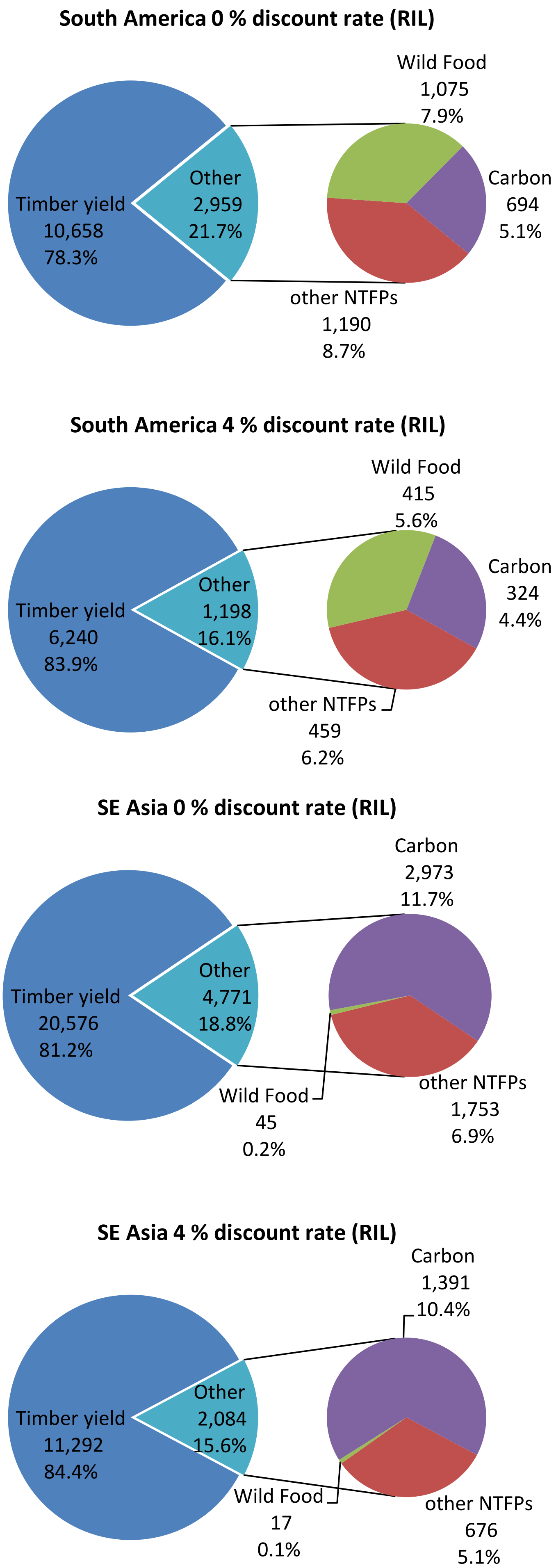

Figure 4.1 *Share of the benefits from different ecosystem services for South America and Southeast Asia, at 0 and 4% discount rates. Values in 2010 US dollars and their share in percentages.*

- In South East Asia, rattan is an important forest product, while wild food is much less important than is the case in South America. Moreover, there are some figures for Malaysia on the impact of forest management on sediment loads at hydro-electrical plants, making a modest contribution to the quantifiable benefits of ecosystem services there (see Annex 3, not represented in the figures above).
- On plantations in South America, carbon stock, wild food and other NTFPs take a more or less equal share in monetary terms. Under RIL, the relative share of carbon storage is considerably smaller than the share of the other NTFPs (and in CL it is by definition zero, as this management regime is taken as the baseline). For further details see Annex 3.

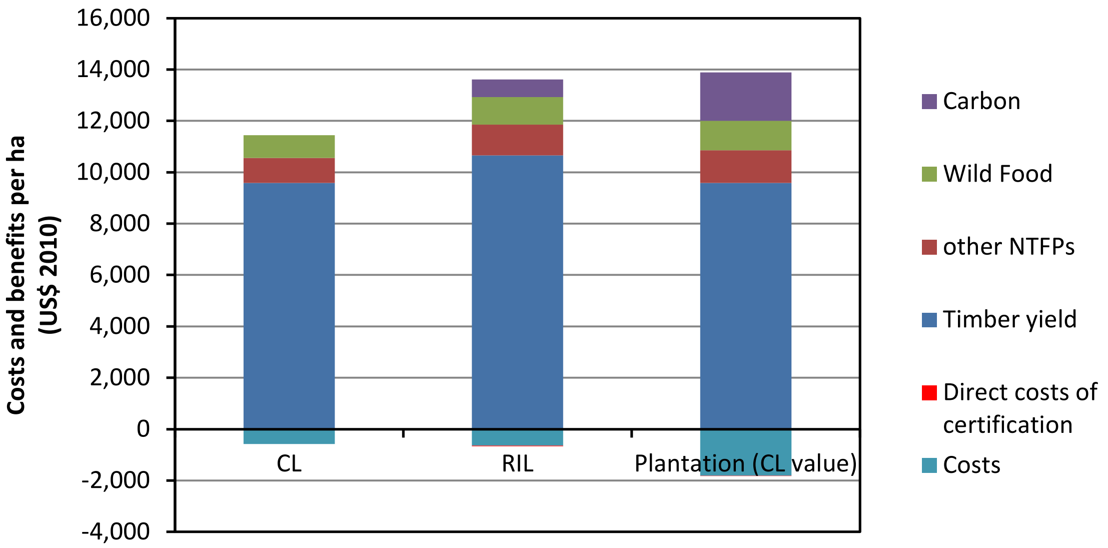

Figure 4.2 *Quantifiable costs and benefits,* ***South America, 0% discount rate*** *(present value US$/ha, 2010 price level).*

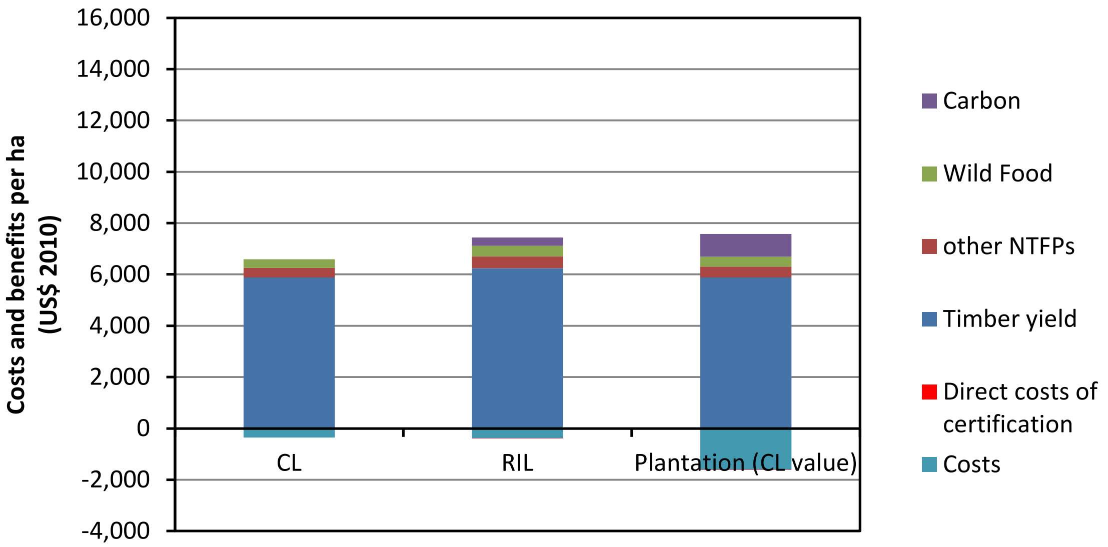

Figure 4.3 *Quantifiable costs and benefits,* ***South America, 4% discount rate*** *(present value US$/ha, 2010 price level).*

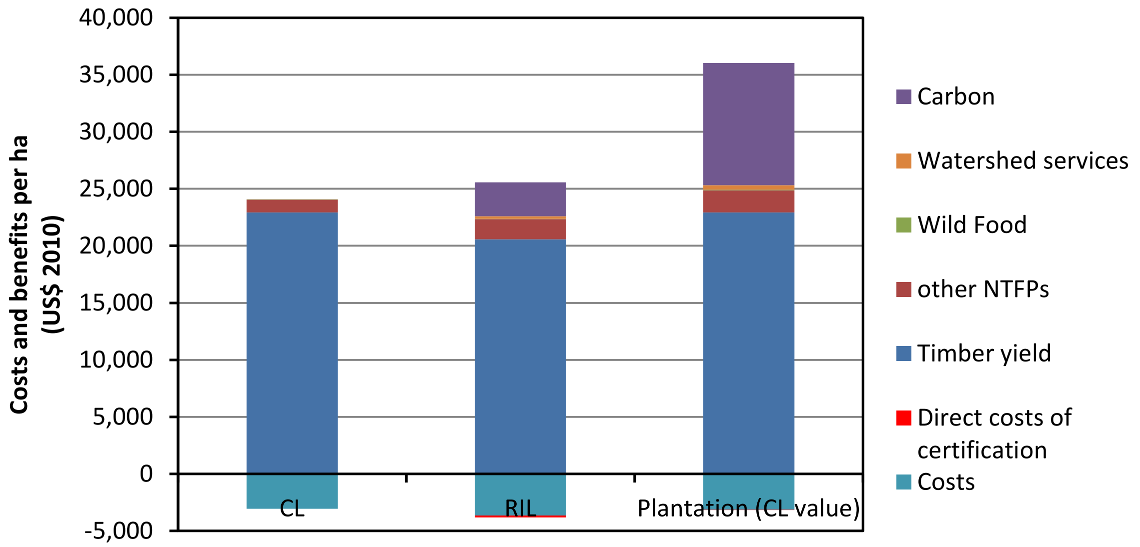

Figure 4.4 *Quantifiable costs and benefits, **South Eeast Asia, 0% discount rate** (present value US$/ha, 2010 price level).*

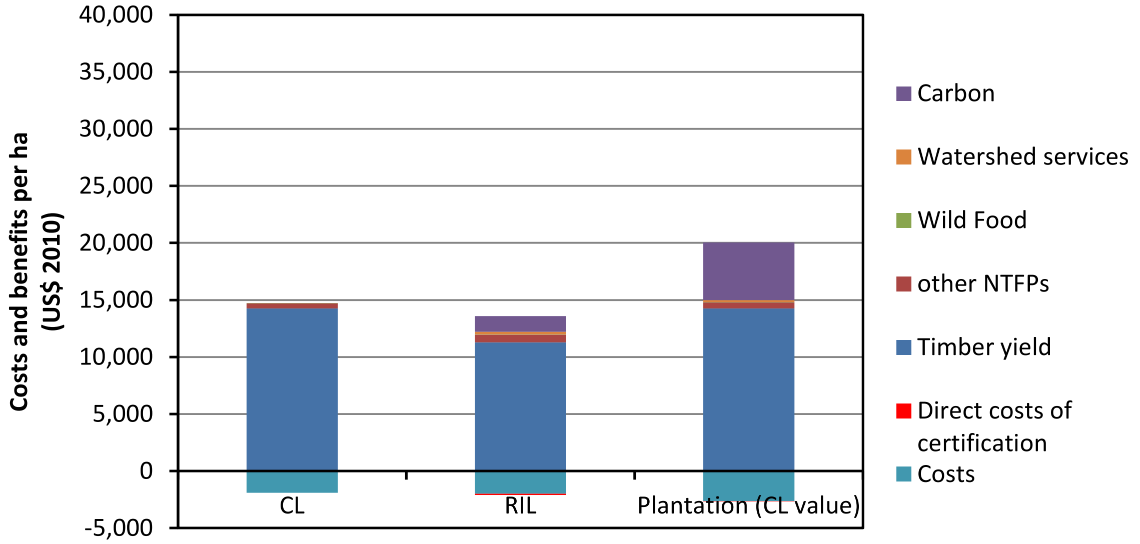

Figure 4.5 *Quantifiable costs and benefits, **South East Asia, 4% discount rate** (present value US$/ha, 2010 price level).*

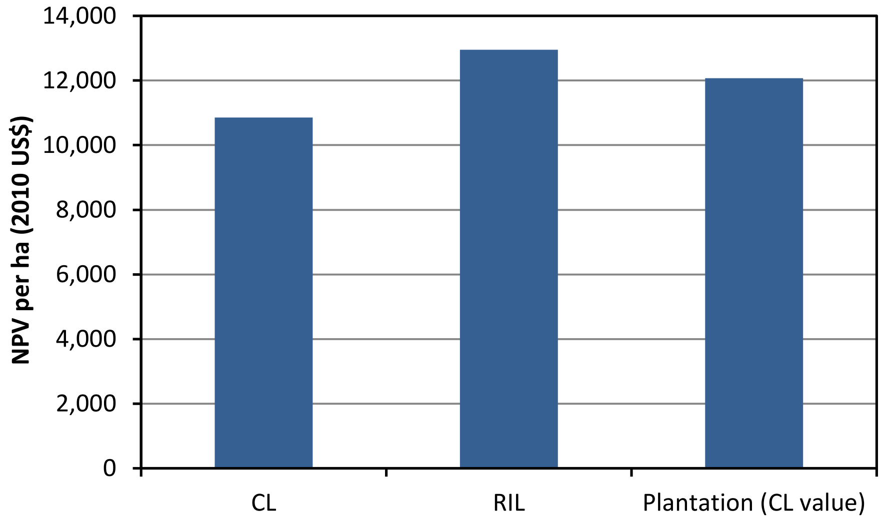

Figure 4.6 *All quantifiable benefits from ecosystem services minus costs, **South America, 0% discount rate** (present value US$/ha, 2010 price level).*

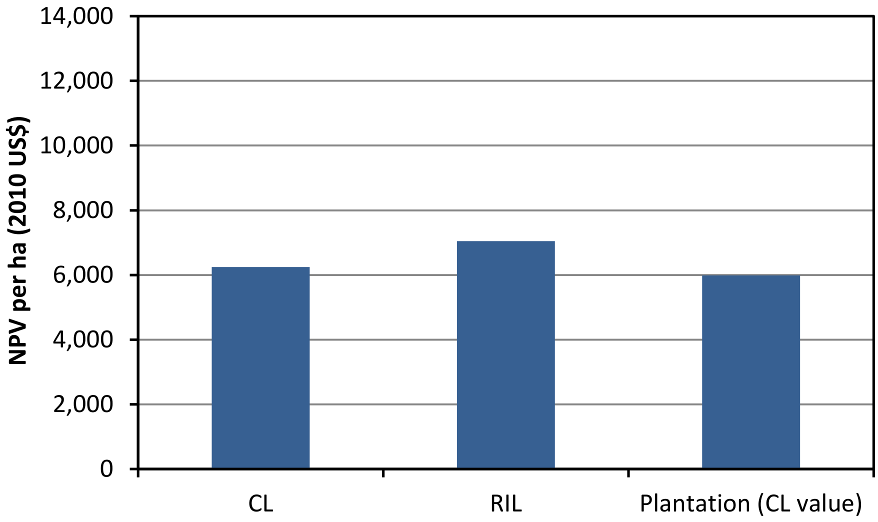

Figure 4.7 *All quantifiable benefits from ecosystem services minus costs,* ***South America, 4% discount rate*** *(present value US$/ha, 2010 price level).*

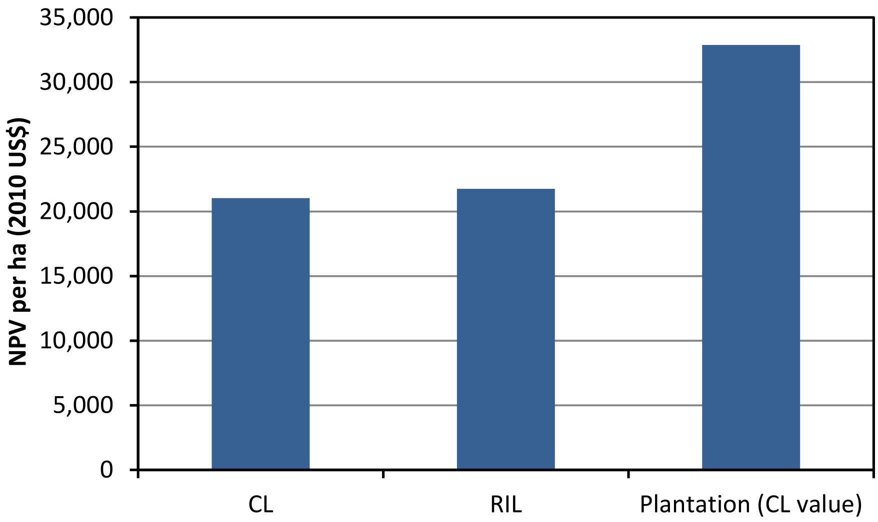

Figure 4.8 *All quantifiable benefits from ecosystem services minus costs,* ***South East Asia, 0% discount rate*** *(present value US$/ha, 2010 price level).*

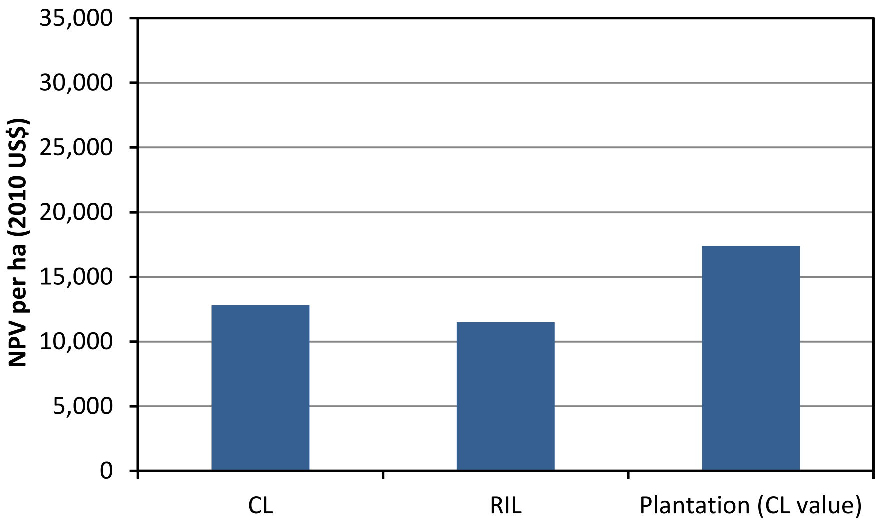

Figure 4.9 *All quantifiable benefits from ecosystem services minus costs,* ***South East Asia, 4% discount rate*** *(present value US$/ha, 2010 price level).*

4.2 Qualitative assessment

As explained in the previous chapter, not all of the (potential) benefits of ecosystem services could be expressed in monetary terms, either because they are difficult to quantify (e.g. hydrological effects) or because they are too much dependent on location and specific local conditions (e.g. eco-tourism potential). Generalised statements for huge regions like South America or South East Asia then become meaningless. In most cases, the impossibility of putting a general dollar value on these services stems from both reasons. This does not mean that the impacts of different types of forest management are of no importance: locally, they can be of the utmost importance, but they may differ for different stakeholders. Their value is therefore indicative of their potential, and whether the values can indeed be realised must be judged for each specific case.

Evaluating the impact of the three forest management regimes therefore requires a broader perspective. Hence, a qualitative assessment was carried out of a number of these impacts, in terms of both potentials and the importance to the various stakeholders. This was done by the first author in cooperation with colleagues with many years of experience of working in tropical forests, and combined with a review of the available literature.

Table 4.1 should be read as follows.
Delivery potentials (first four columns):
-1 = reduced services;
0 = no potential and;
1-4 = low to high potential.

Importance:
0 = unimportant,
+ to +++ = low to high importance

Table 4.1
Potential of management systems to provide services, and importance of these services for different stakeholders.

Ecosystem service	Delivery potential				Local communities								
	Natural	SFM	CL	Plantation	Forest workers	Non forestry	Local government	Large company	Community forestry	National government	International community	Dutch consumers	International
Timber production	1	3	3	4	+++	+	++	+++	+++	++	0	+	X
Carbon stocks	4	3	3	2	+	+	+	0	+	+++	++	++	X
Wild food	4	3	2	0	+++	+++	+	0	0	+	0	0	0
NTFP	4	3	2	0	+++	+++	++	0	0	+	0	0	0
Quality of drinking water	4	2	2	-1	+++	+++	+++	+	+	++	0	0	0
Hydrological functions	4	3	3	1	+	+	+++	+	+	++	0	0	0
Water retention	4	3	3	2	+++	+++	++	+	+	++	0	0	0
Soil properties incl. erosion	4	3	2	1	++	++	+++	+	+	++	0	0	0
Flood prevention	4	3	3	1	++	++	+++	+	+	+++	0	0	0
Biodiversity	4	3	3	0	++	++	0	0	0	0	++	0	X
Indigenous culture	4	3	2	-1	+++	+++	++	0	0	+	0	0	X

This allows the following conclusions.

- The delivery potential of all ecosystem services (except timber production) is highest for natural, pristine forest and lower when timber is harvested. This drop in the provision of these services is greatest under plantation, less under CL and least under SFM (= RIL). Compare the first three columns of Table 4.1.
- The effect of **plantation** very much depends on local circumstances. In general, the potential of forest plantations to deliver ecosystem services is considered to be lower than for natural forests, but plantation development on degraded lands may be a very important source of ecosystem services like erosion prevention and carbon storage. Species selection is then very important to prevent additional negative effects.
- These observations concerning the provision of ecosystem services are of great importance to the **local community** (with the exception of carbon sequestration), including the locally employed forest workers. For the **national government**, it is especially the flood prevention function and the carbon storage function that are highly important. For more information see the scores on the left-hand side of Table 4.1.
- As expected, **timber production** (in terms of volume) is highest on plantations. This obviously matters most to the forestry sector (from the workers up to the large companies themselves) and to the local and national governments (local and export earnings).
- Future primary research should give more attention to the impact of forest management regimes on drinking **water** quality and the effects on indigenous **culture**. These impacts on the local community can be severe, but are difficult to quantify. In the case of plantations, these functions are even at risk of being degraded. The same goes, to a slightly lesser degree, for the potentials for hunting, fishing & forest products and for biodiversity.
- **International conventions** address issues such as timber production and carbon stock (which are moderately influenced by forest management regimes) and biodiversity and indigenous culture (which can be greatly influenced by management regimes).

References

Arets, E. J.M.M. (2005). *Long-term responses of populations and communities of trees to selective logging in tropical rain forests in Guyana*. PhD thesis, Utrecht University, Utrecht, The Netherlands, Tropenbos-Guyana Programme, Tropenbos International, The Netherlands.

Arnold, J.E.M. and M. Ruiz Perez. (1998). *The role of non-timber forest products in conservation and development*. Pages 17-41 in E. Wollenberg and A. Ingles, editors. Incomes from the forest: methods for the development and conservation of forest products for local communitiesCIFOR, Bogor, Indonesia. http:/www.cifor.org/online-library/browse/view-publication/publication/483.html.

Asner, G.P., D.E. Knapp, E.N. Broadbent, P.J.C. Oliveira, M. Keller and J.N. Silva. (2005). *Selective Logging in the Brazilian Amazon*. Science 310 (5747):480-482.

Awe, F., C.O. Osadebe, E. Imoagene, F.A.Y., T.S. Eniola and E.O. Adeleke. (2011). *Assessment of rural households' objectives for gathering non-timber forest products (NTFPs) in Kogi State, Nigeria*. African Journal of Environmental Science & Technology 5 (2):143-148.

Baccini, A.,S.J. Goetz, W.S. Walker, N.T. Laporte, M. Sun, D. Sulla-Menashe, J. Hackler, P.S.A. Beck, R. Dubayah, M.A. Friedl, S. Samanta and R.A. Houghton. (2012). *Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps*. Nature Clim. Change 2 (3):182-185.

Bertault, J.G. and P. Sist. (1997). *An experimental comparison of different harvesting intensities with reduced-impact and conventional logging in East Kalimantan, Indonesia*. Forest Ecology and Management 94 (1-3):209-218.

Blate, G.M. (2005). *Modest trade-offs between timber management and fire susceptibility of a Bolivian semi-deciduous forest*. Ecological Applications 15 (5):1649-1663.

Blate, G.M., F.E. Putz and J.C. Zweede. (2002). *Progress towards RIL adoption in Brazil and Bolivia: driving forces and implementation successes*. in T. Enters, P. Durst, P. C. S. Kho, and G. Man, editors. Applying reduced impact logging to advance sustainable forest management. FAO - Regional office for Asia and the Pacific, Bangkok, Thailand.

Boltz, F.,T.P. Holmes and D.R. Carter. (2003). *Economic and environmental impacts of conventional and reduced-impact logging in Tropical South America: a comparative review*. Forest Policy and Economics 5 (1):69-81.

Bruijnzeel, L.A. (2004). *Hydrological functions of tropical forests: not seeing the soil for the trees?* Agriculture, Ecosystems & Environment 104 (1):185-228.

Calder, I.R. (2007). *Forests and water—Ensuring forest benefits outweigh water costs*. Forest Ecology and Management 251 (1–2):110-120.

CBS, PBL and Wageningen UR. (2013). *Balans van tropisch hout en houtproducten voor Nederland, 1988 - 2011 (indicator 0071, version 12, 6 February 2013)*. www.compendiumvoordeleefomgeving.nl. CBS, Den Haag; Planbureau voor de Leefomgeving, Den Haag/Bilthoven and Wageningen UR, Wageningen, The Netherlands.

Chomitz, K. M. and K. Kumari. (1998). *The Domestic Benefits of Tropical Forests: A Critical Review*. The World Bank Research Observer 13 (1):13-35.

de Graaf, N.R., R.L.H. Poels and R.S.A.R. Van Rompaey. (1999). *Effect of silvicultural treatment on growth and mortality of rainforest in Surinam over long periods*. Forest Ecology and Management 124 (2-3):123-135.

de Graaf, N.R. and T. van Eldik. (2011). *Precious Woods, Brazil*. in M. Werger, editor. Sustainable management of tropical rainforests: The CELOS Management SystemTropenbos International, Paramaribo, Suriname.

Duchelle, A.E., P. Cronkleton, K.A. Kainer, G. Guanacoma and S. Gezan. (2011). *Resource Theft in Tropical Forest Communities: Implications for Non-timber Management, Livelihoods, and Conservation*. Ecology and Society 16 (1).

Durst, P., P.J. McKenzie, C.L. Brown and S. Appanah. (2006). *Challenges facing certification and eco-labelling of forest products in developing countries*. International Forestry Review 8 (2):193-200.

FAO. (1997). *Environmentally sound forest harvesting: Testing the applicability of the FAO Model Code in the Amazon in Brazil*. Forest Harvesting Case Study No. 8. Rome.

FAO. (2002). *Case study of tropical forest plantations in Malaysia by D.B.A Krishnapillay. Forest Plantations Working Paper 23*. Forest Resources Development Service, Forest Resources Division. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2004). *Reduced impact logging in tropical forests. Literature synthesis, analysis and prototype statistical framework*. Forest Harvesting and Engineering Working Paper No.1. Food and Agriculture Organization of the United Nations, Rome, Italy.

Ferraro, P. ., K. Lawlor, K.L. Mullan and S.K. Pattanayak. (2012). *Forest Figures: Ecosystem Services Valuation and Policy Evaluation in Developing Countries*. Review of Environmental Economics and Policy 6 (1):20-44.

Gibbs, H.K., S. Brown, J.O. Niles and J.A. Foley. (2007). *Monitoring and estimating tropical forest carbon stocks: making REDD a reality*. Environmental Research Letters 2 (4):045023.

Godoy, R., H. Overman, J. Demmer, L. Apaza, E. Byron, T. Huanca, W. Leonard, E. Pérez, V. Reyes-Garcı́a, V. Vadez, D. Wilkie, A. Cubas, K.McSweeney and N. Brokaw. (2002). *Local financial benefits of rain forests: comparative evidence from Amerindian societies in Bolivia and Honduras*. Ecological Economics 40 (3):397-409.

Gram, S. (2001). *Economic valuation of special forest products: an assessment of methodological shortcomings*. Ecological Economics 36 (1):109-117.

Grieser-Johns, A. (1996). *Bird population persistence in Sabahan logging concessions*. Biological Conservation 75 (1):3-10.

Guariguata, M.R., C. García-Fernández, R. Nasi, D. Sheil, C. Herrero-Jáuregui, P. Cronkleton, O. Ndoye and V. Ingram. (2011). *Timber and Non-timber Forest Product Extraction and Management in the Tropics: Towards Compatibility?* Pages 171-188 in S. Shackleton, C. Shackleton, and P. Shanley, editors. Non-Timber Forest Products in the Global ContextSpringer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-642-17983-9_8.

Guariguata, M.R., C. García-Fernández, D. Sheil, R. Nasi, C. Herrero-Jáuregui, P. Cronkleton and V. Ingram. (2010). *Compatibility of timber and non-timber forest product management in natural tropical forests: Perspectives, challenges, and opportunities*. Forest Ecology and Management 259 (3):237-245.

Guariguata, M.R., J.C. Licona, B. Mostacedo and P. Cronkleton. (2009). *Damage to Brazil nut trees (Bertholletia excelsa) during selective timber harvesting in Northern Bolivia*. Forest Ecology and Management 258 (5):788-793.

Guillén, A. (2002). *Summaries of the field-testing results in Mexico, Bolivia and Brazil*. Pages 28-44 in P. Shanley, A.R. Pierce, S.A. Laird, and A. Guillen, editors. Tapping the green market: certification and management of non-timber forest productsEarthscan Publications, London, UK. http:/www.cifor.org/online-library/browse/view-publication/publication/1125.html.

Gullison, R.E., P.C. Frumhoff, J.G. Canadell, C.B. Field, D.C. Nepstad, K. Hayhoe, R. Avissar, L.M. Curran, P. Friedlingstein, C. D. Jones and C. Nobre. (2007). *Tropical forests and climate policy*. Science 316 (5827):985-986.

Harris, N.L., S. Brown, S.C. Hagen, S.S. Saatchi, S. Petrova, W. Salas, M.C. Hansen, P.V. Potapov and A. Lotsch. (2012). *Baseline Map of Carbon Emissions from Deforestation in Tropical Regions*. Science 336 (6088):1573-1576.

Healey, J.R., C. Price and J. Tay. (2000). *The cost of carbon retention by reduced impact logging*. Forest Ecology and Management 139 (1-3):237-255.

Holmes, T.P., G.M. Blate, J.C. Zweede, Pereira, Jr., P. Barreto, F. Boltz and R. Bauch. (2002). *Financial and ecological indicators of reduced impact logging performance in the eastern Amazon*. Forest Ecology and Management 163 (1-3):93-110.

ITTO. (2012). *Annual review and assessment of the world timber situation 2012*. International Tropical Timber Organization, Yokohama, Japan.

Kaimowitz, D. (2003). *Not by bread alone. Forests and rural livelihoods in Sub-Saharan Africa*. Pages 45-62 in T. Oksanen, B. Pajari, and T. Tuomasjukka, editors. Forests in poverty reduction strategies: Capturing the potentialEuropean Forest Institute, Joensuu, Finland.

Kainer, K.A., L.H.O. Wadt and C.L. Staudhammer. (2007). *Explaining variation in Brazil nut fruit production*. Forest Ecology and Management 250 (3):244-255.

Kamphuis, B., E.J.M.M. Arets, C. Verwer, J. van den Berg, S. van Berkum and B. Harms. (2011). *Dutch trade and biodiversity. The biodiversity and socio-economic impacts of Dutch trade in soya, palm oil and timber*. LEI report 2011-013 and Alterra report 2155. LEI, Wageningen UR, The Hague, The Netherlands.

Kilkki, R. (1992). *Reduction of wood waste by small-scale log production and conversion in tropical high*. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/docrep/u7890E/u7890E00.htm

Kirby, K.R. and C. Potvin. (2007). *Variation in carbon storage among tree species: Implications for the management of a small-scale carbon sink project*. Forest Ecology and Management 246 (2-3): 208-221.

Kollmuss, A., H. Zink and C. Polycarp. (2008). *Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards*. WWF Germany, Berlin, Germany.

Krisnawati, H., M.H. Kallio and M. Kanninen. (2011). *Aleurites moluccana (L.) Willd.: Ecology, silviculture and productivity*. Center for International Forestry Research (CIFOR), Bogor, Indonesia. http:/www.cifor.org/online-library/browse/view-publication/publication/3393.html.

Lele, S. (2009). *Watershed services of tropical forests: from hydrology to economic valuation to integrated analysis*. Current Opinion in Environmental Sustainability 1 (2):148-155.

Lele, S. and V. Srinivasan. (2013). *Disaggregated economic impact analysis incorporating ecological and social trade-offs and techno-institutional context: A case from the Western Ghats of India*. Ecological Economics 91 (0):98-112.

Liao, C., Y. Luo, C. Fang and B. Li. (2010). *Ecosystem Carbon Stock Influenced by Plantation Practice: Implications for Planting Forests as a Measure of Climate Change Mitigation*. PLoS ONE 5 (5):e10867.

Lindenmayer, D.B. and W.F. Laurance. (2012). *A history of hubris – Cautionary lessons in ecologically sustainable forest management*. Biological Conservation 151 (1):11-16.

Macpherson, A.J., M.D. Schulze, D.R. Carter and E. Vidal. (2010). *A Model for comparing reduced impact logging with conventional logging for an Eastern Amazonian Forest*. Forest Ecology and Management 260 (11):2002-2011.

Medjibe, V. P. and F. E. Putz. (2012). *Cost comparisons of reduced-impact and conventional logging in the tropics*. Journal of Forest Economics 18 (3):242-256.

Medjibe, V.P., F.E. Putz, M.P. Starkey, A.A. Ndouna and H.R. Memiaghe. (2011). *Impacts of selective logging on above-ground forest biomass in the Monts de Cristal in Gabon*. Forest Ecology and Management 262 (9):1799-1806.

Menton, M.C. (2003). *Effects of logging on non-timber forest product extraction in the Brazilian Amazon: community perceptions of change*. International Forestry Review 5 (2):97-105.

Nunes, F., B. Soares-Filho, R. Giudice, H. Rodrigues, M. Bowman, R. Silvestrini and E. Mendoza. (2012). *Economic benefits of forest conservation: assessing the potential rents from Brazil nut concessions in Madre de Dios, Peru, to channel REDD+ investments*. Environmental Conservation 39 (02):132-143.

Odebode, S. O. (2003) *Contributions of Selected Non-Timber Forest Products to Household Food Security in Osun State, Nigeria*.Conference proceedings 12th World Forestry Congress, Quebec, Canada. Vol. A. Forest for People.

Olsen, N. and J. Bishop. (2009). *The Financial Costs of REDD: Evidence from Brazil and Indonesia*. IUCN, Gland, Switzerland.

Pan, Y., R.A. Birdsey, J. Fang, R. Houghton, P.E. Kauppi, W.A. Kurz, O.L. Phillips, A. Shvidenko, S. L. Lewis, J. G. Canadell, P. Ciais, R. B. Jackson, S. Pacala, A. D. McGuire, S. Piao, A. Rautiainen, S. Sitch and D. Hayes. (2011). *A Large and Persistent Carbon Sink in the World's Forests*. Science.

Panayotou, T. and P. S. Ashton. (1992). *Not by Timber Alone: Economics and Ecology for Sustaining Tropical Forests*. Island Press, Washington D.C., USA.

Peña-Claros, M., T.S. Fredericksen, A. Alarcon, G.M. Blate, U. Choque, C. Leano, J. C. Licona, B. Mostacedo, W. Pariona, Z. Villegas and F. E. Putz. (2008). *Beyond reduced-impact logging: Silvicultural treatments to increase growth rates of tropical trees*. Forest Ecology and Management 256 (7):1458-1467.

Peters, C.M., A.H. Gentry and R.O. Mendelsohn. (1989). *Valuation of an Amazonian rainforest*. Nature 339 (6227):655-656.

Pimentel, D., M. McNair, L. Buck, M. Pimentel and J. Kamil. (1997). *The Value of Forests to World Food Security*. Human Ecology 25 (1):91-120.

Pinard, M.A., M.G. Barker and J. Tay. (2000). *Soil disturbance and post-logging forest recovery on buldozer paths in Sabah, Malaysia*. Forest Ecology and Management 130:213-225.

Pinard, M.A. and F.E. Putz. (1996). *Retaining forest biomass by reducing logging damage*. Biotropica 28 (3):278-295.

Pinard, M.A., F.E. Putz, J. Tay and T.E. Sullivan. (1995). *Creating Timber Harvest Guidelines for a Reduced-Impact Logging Project in Malaysia*. Journal of Forestry 93 (10):41-45.

Putz, F.E., G.M. Blate, K.H. Redford, R. Fimbel and J. Robinson. (2001). *Tropical forest management and conservation of biodiversity: an overview*. Conservation Biology 15 (1):7-20.

Putz, F.E., P.A. Zuidema, M.A. Pinard, R.G. A. Boot, J.A. Sayer, D. Sheil, P. Sist and J. K. Vanclay. (2008). *Improved tropical forest management for carbon retention*. PLoS Biology 6 (7):e166.

Putz, F.E., P.A. Zuidema, T. Synnott, M. Peña-Claros, M.A. Pinard, D. Sheil, J.K. Vanclay, P. Sist, S. Gourlet-Fleury, B. Griscom, J. Palmer and R. Zagt. (2012). *Sustaining conservation values in selectively logged tropical forests: the attained and the attainable*. Conservation Letters 5 (4):296-303.

Putz, F.E., P.A. Zuidema, T. Synnott, M. Peña-Claros, M.A. Pinard, D. Sheil, J.K. Vanclay, P. Sist, S. Gourlet-Fleury, J. Palmer, R. Zagt and B. Griscom. (2013). *A more realistic portrayal of tropical forestry: response to Kormos and Zimmerman*. Conservation Letters:n/a-n/a.

Rametsteiner, E. and M. Simula. (2003). *Forest certification--an instrument to promote sustainable forest management?* Journal of Environmental Management 67 (1):87-98.

Richter, F. (2001). *Financial and economic assessment of timber harvesting operations in Sarawak, Malaysia*. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/docrep/004/Y2699E/y2699e00.htm.

Rist, L., P. Shanley, T. Sunderland, D. Sheil, O. Ndoye, N. Liswanti and J. Tieguhong. (2012). *The impacts of selective logging on non-timber forest products of livelihood importance*. Forest Ecology and Management 268 (0):57-69.

Shanley, P., A.R. Pierce, S.A. Laird and A. Guillen. (2002). *Tapping the green market: certification and management of non-timber forest products*. Earthscan Publications, London, UK. http:/www.cifor.org/online-library/browse/view-publication/publication/1125.html.

Shearman, P., J. Bryan and W.F. Laurance. (2012). *Are we approaching 'peak timber' in the tropics?* Biological Conservation 151 (1):17-21.

Sheil, D. and S. Wunder. (2002). *The value of tropical forest to local communities: complications, caveats, and cautions*. Conservation Ecology 6 (2, art. 9. [online]).

Shone, B.M. and J.L. Caviglia-Harris. (2006). *Quantifying and comparing the value of non-timber forest products in the Amazon*. Ecological Economics 58 (2):249-267.

Silva, J.N.M., J.O.P. d. Carvalho, J. d. Lopes, B.F. de Almeida, D.H.M. Costa, L.C. de Oliveira, J. K. Vanclay and J. P. Skovsgaard. (1995). *Growth and yield of a tropical rain forest in the Brazilian Amazon 13 years after logging*. Forest Ecology and Management 71 (3):267-274.

Simula, M., S. Astana, R. Ishmael, E.J. Santana and M. Schmidt. (2004). *Report on financial cost-benefit analysis of forest certification and implementation of phased approaches*. ITTO Thirty-seventh Session of the International Tropical Timber Council. ITTC(XXXVII)/13. ITTO, Yokohoma, Japan.

Sist, P. and F.N. Ferreira. (2007). *Sustainability of reduced-impact logging in the Eastern Amazon*. Forest Ecology and Management 243 (2-3):199-209.

Sist, P., T. Nolan, J.G. Bertault and D. Dykstra. (1998). *Harvesting intensity versus sustainability in Indonesia*. Forest Ecology and Management 108 (3):251-260.

Sist, P., N. Picard and S. Gourlet-Fleury. (2003a). *Sustainable cutting cycle and yield in a lowland mixed dipterocarp forest of Borneo*. Annals of Forest Science 60:803-814.

Sist, P., D. Sheil, K. Kartawinata and H. Priyadi. (2003b). *Reduced-impact logging in Indonesian Borneo: some results confirming the need for new silvicultural prescriptions*. Forest Ecology and Management 179 (1-3):415-427.

Tay, J. (1999). *Economic Assessment of Reduced Impact Logging in Saba, Malaysia*. PhD Thesis, University of Wales.

Tay, J., J. Healey and C. Price. (2002). *Financial assessment of reduced impact logging techniques in Sabah, Malaysia*. in T. Enters, P. Durst, P.C.S. Kho, and G. Man, editors. Applying reduced impact logging to advance sustainable forest managementFAO - Regional office for Asia and the Pacific, Bangkok, Thailand. http://www.fao.org/docrep/005/ac805e/ac805e0g.htm.

Valle, D., P. Phillips, E. Vidal, M. Schulze, J. Grogan, M. Sales and P. van Gardingen. (2007). *Adaptation of a spatially explicit individual tree-based growth and yield model and long-term comparison between reduced-impact and conventional logging in eastern Amazonia, Brazil*. Forest Ecology and Management 243 (2-3):187-198.

Valle, D., M. Schulze, E. Vidal, J. Grogan and M. Sales. (2006). *Identifying bias in stand-level growth and yield estimations: A case study in eastern Brazilian Amazonia*. Forest Ecology and Management 236 (2–3):127-135.

van Beukering, P., K. Grogan, S.L. Hansfort and D. Seager. (2009). *An economic valuation of Aceh's forests: The road towards sustainable development.* Institute of Environmental Studies, VU University, Amsterdam, The Netherlands.

van Beukering, P.J.H., H.S.J. Cesar and M.A. Janssen. (2003). *Economic valuation of the Leuser National Park on Sumatra, Indonesia*. Ecological Economics 44 (1):43-62.

van der Hout, P. (1999). *Reduced impact logging in the tropical rain forest of Guyana - ecological, economic and silvicultural consequences*. Ph.D. Utrecht University, Tropenbos-Guyana Programme, Georgetown, Guyana.

van Gardingen, P.R., M.J. Clearwater, T. Nifinluri, R. Effendi, W. Rusmantoro, M. Noor, P. A. Mason, K. Ingleby, R.C. Munro, P.R. Van Gardingen, M.J. Clearwater, T. Nifinluri, R. Effendi, W. Rusmantoro, M. Noor, P.A. Mason, K. Ingleby and R.C. Munro. (1998). *Impacts of logging on the regeneration of lowland dipterocarp forest in Indonesia*. Commonwealth Forestry Review (249):71-82.

van Gardingen, P.R., M.J. McLeish, P.D. Phillips, D. Fadilah, G. Tyrie and I. Yasman. (2003). *Financial and ecological analysis of management options for logged-over Dipterocarp forests in Indonesian Borneo*. Forest Ecology and Management 183 (1-3):1-29.

van Gardingen, P. R., D. Valle and I. Thompson. (2006). *Evaluation of yield regulation options for primary forest in Tapajos National Forest, Brazil*. Forest Ecology and Management 231 (1-3): 184-195.

Wadt, L.H.O., K.A. Kainer and D.A.P. Gomes-Silva. (2005). *Population structure and nut yield of a Bertholletia excelsa stand in Southwestern Amazonia*. Forest Ecology and Management 211 (3):371-384.

Wauters, J.B., S. Coudert, E. Grallien, M. Jonard and Q. Ponette. (2008). *Carbon stock in rubber tree plantations in Western Ghana and Mato Grosso (Brazil)*. Forest Ecology and Management 255 (7):2347-2361.

Zarin, D.J., M.D. Schulze, E. Vidal and M. Lentini. (2007). *Beyond Reaping the First Harvest: Management Objectives for Timber Production in the Brazilian Amazon*. Conservation Biology 21 (4):916-925.

Zuidema, P.A. (2003). *Demography and management of the Brazil nut tree (Bertholletia excelsa)*. PROMAB Scientific Series 6. PROMAB, Riberalta, Bolivia.

Justification

This study was commissioned and supervised by Mark van Oorschot of PBL Netherlands Environmental Assessment Agency. The results from this report will be used as input for the TEEB (The Economics of Ecosystems and Biodiversity) Netherlands report on product chains, which will be prepared by PBL Netherlands Environmental Assessment Agency. This TEEB NL report will focus on ecosystem services and biodiversity aspects of Dutch import of tropical timber, soy, palm oil and cacao.

The approach and results have been discussed in a number of meetings with PBL, meetings with policy advisors of the Ministries of Economic Affairs and Foreign Affairs and researchers working on similar analyses of the other product chains (soy, palm oil and cacao). Mark van Oorschot and a number of his colleagues of PBL have provided feedback on earlier drafts of this report. Their comments have been considered and incorporated as much as possible in this final report.

The authors wish to thank everyone for their constructive contribution to this report.

Annex 1 List of acronyms

AAC	=	Annual Allowable Cut
CL	=	Conventional (selective) Logging
CoC	=	Chain of Custody
COP	=	Conference Of the Parties
DBH	=	Diameter at Breast Height
ES	=	Ecosystem Services
FLEGT	=	Forest Law Enforcement Governance and Trade
FMU	=	Forest Management Unit
FSC	=	Forest Stewardship Council
IDH	=	Initiatief Duurzame Handel – The Sustainable Trade Initiative
ITTO	=	International Tropical Timber Organisation
LULUCF	=	Land Use, Land-Use Change and Forestry
MTCS	=	Malaysian Timber Certification Scheme
NTPFs	=	Non-Timber Forest Products
NPV	=	Net Present Value
PEFC	=	Programme for the Endorsement of Forest Certification
REDD	=	Reducing Emissions from Deforestation and forest Degradation
REDD+	=	Reducing Emissions from Deforestation and forest Degradation and conservation, sustainable management of forests, and enhancement of forest carbon stocks
RIL	=	Reduced Impact Logging
SCBA	=	Social Cost Benefit Analysis
SFM	=	Sustainable Forest Management
TEEB	=	The Economics of Ecosystems and Biodiversity
UNFCCC	=	United Nations Framework Convention on Climate Change

Annex 2 Pilot Social Cost-Benefit Analysis (SCBA)

We implemented a pilot SCBA based on Healey *et al*. (2000). They assessed the price that should be paid to make benefits from RIL comparable to CL (Table A.2.1). Based on field data from forests logged with CL and RIL and modelled future yields they compared the cost and benefits of timber production, non-timber forest products (rattan and wildlife for meat), loss of forest productivity due to soil damage and loss in net revenue from hydroelectricity resulting from increased sediment concentrations in water.

Healey *et al.* (2000) assessed the cost and benefits on three different bases; 1) per representative hectare, 2) per logged hectare, and 3) per m^3 of timber. As a consequence of the restrictions that RIL puts on the terrain where logging is allowed (like steep slopes cannot be harvested) and other specific effectively only 52% of the total management unit area was actually affected by logging using RIL. In the area logged according CL 99.4% of the area was logged. The representative ha would be made up for 56% of forest that is affected, while 44% is not affected. The logged ha would represent an area that is completely affected.

To be able to include and also compare the cost and benefits for the other services in our SCBA, we used the data calculated per logged ha. Because the timber yields (m^3 ha^{-1}) were not the same between the two logging types it will be more difficult to translate the result per m^3 timber.

Timber
The restrictions set by RIL also resulted in lower timber yields during the first harvest. Because RIL results in less damage to the residual forest stand, after one felling cycle (60 years in this forest) the commercial volume of the stand was projected to be at the same level again as before logging, while the commercial volume in the forest logged with CL was still much lower. As a result the harvested volume at the second harvest was higher for RIL than CL. Revenues during the first harvest were calculated from measured timber yields and current prices, while revenues for the second harvest at t=60 was based on projected volumes and a 2% real price increase per annum (Healey *et al.,* 2000).

Cost of the two logging types were based on Tay (1999). See Table A2.1 for results. This includes different cost that are associated with use of heavy machinery, maintenance, fuel, tires, but also concession fees, log royalties, and timber right. The cost, however, also include the cost of labour. These are cost for the logging company, but it at the same time generates income to local people working for the logging company, i.e. indirect benefits, that now not has been considered in the cost-benefit analysis. Eventually this could be taken into consideration using data on labour time and cost involved in the different stages of logging from other sources (e.g. Van der Hout (1999) has detailed information on labour costing in RIL and CL).

Non-timber forest products
Rattan was used as example of a high value NTFP that is harvested in the logged forest. Based on post-logging inventories and published data on rattan growth rates Healey *et al.,* 2000) found that CL resulted in a greater reduction in rattan abundance compared to natural forests than RIL on a representative ha, which was especially the case for the more valuable large-cane species. The net difference per logged ha was, however much lower (see Table A2.1).

Carbon
Healey *et al*. (2000) found significant positive effects of RIL and CL on carbon sequestration rates. The carbon fixation rate under CL was estimated to be slightly but consistently higher by 0.1 t ha^{-1} than under RIL. However, because of the smaller initial impact of logging, by the time of the second harvest (after 60 years) the standing stocks under RIL had completely recovered, while that of CL was only at 82% of natural forests (Healey *et al.,* 2000).

Healey *et al*. (2000), however did not calculate the value of carbon stocks, as at the time of the study the carbon market was still developing (and still is). The estimated that the price per ton of carbon should be around 10 US$ per ha to bridge the gap between cost and benefits of RIL compared to CL.

Table A2.1

SCBA results for the comparison of conventional selective logging (CL), with reduced impact logging (RIL); (based on Healey et al. (2000), per logged hectare. Undiscounted economic benefits and cost (US$); over two cutting cycles (60 years)).

Effect	RIL Physical	 Financial US$ ha^{-1}	CL Physical	 Financial US$ ha^{-1}
Benefits				
Direct effects				
Timber	Timber yield per logged ha was 106 m^3 at 1st (real) harvest and 111 m^3 at 2nd (projected) harvest after 60 years resulting in a total yield of 217 m^3 ha^{-1}, but value per m^3 in 60 years is much higher than current value which relatively stronger increases the benefits of higher yields after 60 years.	18,315	Timber yield per logged ha was 136 m^3 at 1st (real) harvest and 85 m^3 at 2nd (projected) harvest after 60 years resulting in a total yield of 221 m^3 ha^{-1}.	13,783
NTFP's (rattan)	The abundance of rattan after RIL was reduced compared to natural forest. This is mainly the result of logging damage. The net benefits of rattan harvesting was 1,027 US$ per ha lower compared to natural forest. The abundance of rattan after RIL was reduced compared to natural forest. This is mainly the result of logging damage. Rattan prices and harvesting cost were based on local data.	-1,027	The abundance of rattan after RIL was reduced compared to natural forest. This is mainly the result of logging damage. The net benefits of rattan harvesting was 1,034.5 US$ per ha lower compared to natural forest (therefore using a negative value).	-1,034.5
Wild Food (meat from wildlife)	Value for meat from wildlife was based on density of ungulate species in the forest in combination with value of ungulate species as a source of local meat. For natural forests the net revenues were estimated at 211 US$ ha^{-1}. Because logging of tropical forest does not dramatically reduce ungulate densities this value for RIL was only 17 US$ ha^{-1} lower than in natural forest, while and 26 US$ ha^{-1} lower for CL	-17.25		-26.75
Other final products	-	-	-	-
Carbon	Estimated to compensate difference between RIL and CL	No value		No value
Fuel wood	-	-	-	-
Cost				
Direct effects				
Timber	The operational cost of planning,	12,139		7,641

Effect	RIL Physical	Financial US$ ha^{-1}	CL Physical	Financial US$ ha^{-1}
	logging and log royalties. These cost are greater for RIL than CL due to greater cost in planning and forest operations.			
NTFP's (rattan)	Cost for harvesting rattan. Not included in these cost is the fact that accessibility of forest under CL is probably better, which will reduce cost of collection.	445.25		448.50
Wild food (meat from wildlife)	Cost for hunting.	15.5		13.5
Carbon Stocks				
Carbon Sequestration				
Hydrological functions	For this aspect the study calculated the impact of eroded soil from logged forest on downstream sediment concentrations. The cost as a result of this sedimentation were cost involved with the removal of sediment from sediment ponds used to protect hydroelectricity generating stations. Greatest part of the cost is caused by loss of electricity when water diverted to drain the ponds and remove the sediment. Soil erosion and subsequent sediment yields as a result of CL and RIL were estimated based on other studies. RIL was estimated to produce 57% lower mass of sediment than CL, resulting in smaller loss of revenues.	127.75		312.75
Indirect Effects				
Soil properties incl. Erosion	Loss of forest productivity resulting from soil damage and compaction was estimated as a separate erosion effect. Soil damage and compaction are strongly concentrated in the skid trails, landing sites and roads and prevents trees reaching harvestable size by the 2nd harvest. The cost value was estimated as the loss of timber at the next harvest in these areas that are 'permanently' removed from production. RIL converted 8% of the soil to bare area while for CL this was twice as high (17%) .	445		1,024

In this analysis the total net benefit of CL is slightly higher than for RIL. However, still a number of services are missing from this overview. Also, like already mentioned before, some of the cost now incurred by the logging company (like labour cost) are in reality again benefits (generates income/employment) for other stakeholders in the chain. These effects are not yet considered and will be incorporated in the next steps of this research.

Annex 3 Numerical results

Table A3.1

*Costs and Benefits, South America, Present Value (US$/ha, 2010 prices), **0**% discount rate.*

Discount rate	0.00%		NOTE: The relative area of plantation needed to match timber value with the timber value of CL increases with increasing discount rate.		
Region	South America		This is because future benefits from timber are higher in plantations, but these are discounted more strongly		
Time horizon	60				
	Alternatives				
Benefits	**CL**	**RIL**	**Plantation (CL value)**	**Plantation (volume)**	**Plantation (SFM value)**
Percentage plantation			11.2%	8.7%	12.4%
Timber	9,586	10,658	8,734	6,759	9,711
Chiplogs	-	-	852	659	947
Timber yield	9,586	10,658	9,586	7,418	10,658
Other NTFPs	974	1,190	1,270	1,306	1,252
Wild Food	879	1,075	1,147	1,180	1,131
Carbon	-	694	1,883	1,883	1,883
Watershed services					
Total benefits ESS	1,853	2,959	4,300	4,369	4,266
Total benefits timber	9,586	10,658	9,586	7,418	10,658
Total benefits	**11,438**	**13,617**	**13,885**	**11,787**	**14,924**
Costs					
Timber	579	645	1,809	1,400	2,012
Pre harvest	17	131			
Harvest planning	12	32			
Infrastructure	88	37			
Harvest operation	463	446			
Direct costs certification		21	1	1	1
Total benefits ESS - costs	**10,859**	**12,951**	**12,075**	**10,386**	**12,911**
Timber benefits - costs	9,006	9,992	7,775	6,018	8,645
Benefit - cost ratio					
Timber	17	16	5	5	5
Carbon	-	1	1	1	1
Other ESS	3	3	1	2	1
Total	20	20	8	8	7

Table A3.2

*Costs and Benefits, South America, Present Value (US$/ha, 2010 prices), **4**% discount rate.*

Discount rate	4.00%	NOTE: The relative area of plantation needed to match timber value with the timber value of CL increases with

			increasing discount rate.		
Region	South America		This is because future benefits from timber are higher in plantations, but these are discounted more strongly		
Time horizon	60				
	Alternatives				
Benefits	**CL**	**RIL**	**Plantation (CL value)**	**Plantation (volume)**	**Plantation (SFM value)**
Percentage plantation			22.38%	8.7%	23.76%
Timber	5,878	6,240	5,337	2,064	5,666
Chiplogs	-	-	541	209	574
Timber yield	5,578	6,240	5,878	2,273	6,240
Other NTFPs	377	459	428	504	420
Wild Food	340	415	386	455	380
Carbon	-	324	891	891	891
Watershed services					
Total benefits ESS	718	1,198	1,705	1,849	1,691
Total benefits timber	5,878	6,240	5,878	2,273	6,240
Total benefits	**6,595**	**7,438**	**7,583**	**4,122**	**7,931**
Costs					
Timber	355	378	1,600	619	1,698
Pre harvest	10	77			
Harvest planning	7	19			
Infrastructure	54	21			
Harvest operation	284	261			
Direct costs certification		12	0	0	0
Total benefits ESS - costs	**6,240**	**7,048**	**5,983**	**3,504**	**6,232**
Timber benefits - costs	5,523	5,850	4,278	1,654	4,541
Benefit - cost ratio					
Timber	17	16	4	4	4
Carbon	-	1	1	1	1
Other ESS	2	2	1	2	0
Total	19	19	5	7	5

Table A3.3

*Costs and Benefits, SE Asia, Present Value (US$/ha, 2010 prices), **0**% discount rate*

Discount rate	0.00%		NOTE: The relative area of plantation needed to match timber value with the timber value of CL increases with increasing discount rate.		
Region	SE Asia		This is because future benefits from timber are higher in plantations, but these are discounted more strongly		
Time Horizon	60				
	Alternatives				
Benefits	**CL**	**RIL**	**Plantation (CL value)**	**Plantation (volume)**	**Plantation (SFM value)**
Percentage plantation			20.82%	24.5%	18.68%
Timber	22,933	20,576	21,634	25,429	19,410
Chiplogs	-	-	1,299	1,527	1,166
Timber yield	22,933	20,576	22,933	26,956	20,576
Other NTFPs	1,120	1,753	1,928	1,839	1,980
Wild Food	29	45	48	46	50
Carbon	-	2,973	10,702	10,702	10,702
Watershed services	-	214	415	313	337
Total benefits ESS	1,149	4,985	13,093	12,900	13,069
Total benefits Timber	22,933	20,576	22,933	26,956	20,576
Total benefits	**24,082**	**25,560**	**36,026**	**39,856**	**33,645**
Costs					
Timber	3,049	3,647	3,143	3,695	2,820
Pre harvest	63	375			
Harvest planning	-	57			
Infrastructure	539	622			
Harvest operation	2,447	2,594			
Direct costs certification		159	2	2	2
Total benefits ESS - costs	**21,033**	**21,754**	**32,880**	**36,159**	**30,823**
Timber benefits - costs	19,884		19,787	23,259	17,754
Benefit - cost ratio					
Timber	8	5	7	7	7
Carbon	-	1	3	3	4
Other ESS	0	1	1	1	1
Total	8	7	11	11	12

Table A3.4

*Costs and Benefits, SE Asia, Present Value (US$/ha, 2010 prices), **4**% discount rate*

Discount rate	4.00%		NOTE: The relative area of plantation needed to match timber value with the timber value of CL increases with increasing discount rate.		
Region	SE Asia		This is because future benefits from timber are higher in plantations, but these are discounted more strongly		
Time horizon	60				
	Alternatives				
Benefits	**CL**	**RIL**	**Plantation (CL value)**	**Plantation (volume)**	**Plantation (SFM value)**
Percentage plantation			42.34%	24.5%	33.52%
Timber	14,261	11,292	13,423	7,758	10,628
Chiplogs	-	-	838	484	663
Timber yield	14,261	11,292	14,261	8,242	11,292
Other NTFPs	434	676	541	709	624
Wild Food	11	17	14	18	16
Carbon	-	1,391	5,064	5,064	5,064
Watershed services	-	222	160	121	106
Total benefits ESS	445	2,306	5,778	5,911	5,810
Total benefits timber	14,261	11,292	14,261	8,242	11,292
Total benefits	**14,706**	**13,598**	**20,039**	**14,153**	**17,101**
Costs					
Timber	1,896	2,001	2,639	1,525	2,089
Pre harvest	39	206			
Harvest planning	-	31			
Infrastructure	335	341			
Harvest operation	1,522	1,423			
Direct costs certification	-	87	1	1	1
Total benefits ESS - costs	**12,810**	**11,509**	**17,400**	**12,628**	**15,011**
Timber benefits - costs	12,365	9,203	11,621	6,716	9,201
Benefit - cost ratio					
Timber	8	5	5	5	5
Carbon	-	1	2	3	2
Other ESS	0	0	0	1	0
Total	8	7	8	9	8

Annex 4 Data base logging-related damage to the remaining forest (RIL and CL)

Location	Logging method	Region	Harvest intensity	Harvest intensity extent	Damage	Damage extent	Reference
Malaysia	CL	SEA			40	% of total volume	Ahmad *et al.*, 1999 in FAO 2004 FAO 2004
Malaysia	RIL	SEA			30	% of total volume	Ahmad *et al.*, 1999 in FAO 2004
Indonesia	CL	SEA	107.2	m^3/ha (10.1 trees/ha) or 17.7m^2/ha BA	48.4	% of residual stand (23.2% dead and 25.2% injured)	Bertault & Sist 1997
Indonesia	RIL	SEA	96.8	m^3/ha (10.7 trees/ha or 17.5m^2/ha BA)	30.5	% of residual stand (17.6 dead and 19.2 injured)	Bertault & Sist 1997
Malaysia	CL	SEA	40-60	m^3/ha	75	% of residual stand	Bruenig 1996 in FAO 2004
Papua New Guinea	CL	SEA	23	m^3/ha	67	% of residual stand	Buenaflor 1989 in FAO 2004
Papua New Guinea	RIL	SEA	32	m^3/ha	22	% of residual stand	Buenaflor 1989 in FAO 2004
Suriname	CL	Br	30	m^3/ha	26.4	% of residual stand	De Graaf *et al.*, 1999
Suriname	RIL	Br	9	m^3/ha (5-8 trees/ha)	7.3	% of residual stand	De Graaf *et al.*, 1999
Papua New Guinea	CL	SEA	64-67	trees/ha	60	% of residual stand	Enright 1978 in FAO 2004
Indonesia	CL	SEA			45	% of residual stand	FAO 1997
Indonesia	RIL	SEA			25	% of residual stand	FAO 1997
Brazil	CL	Br	73	% of original stand	51.5	% of FCTs	FAO 1997
Brazil	RIL	Br	33	% of original stand	22.2	% of FCTs	FAO 1997
Malaysia	CL	SEA	89	m^3/ha	66.4	% of residual population (28.2FCTs/42.5FCTs)	Fox 1968 in FAO 2004
Malaysia	CL	SEA	52-120	m^3/ha	62	% of original stand	Grieser-Johns 1996
Malaysia	CL	SEA	20	% of original stand	66	% of all stems >10cm dbh	Hutchison, 1987 in FAO 2004
Guyana	RIL	Br	15	m^3/ha (5 trees/ha)	19.4	% of original stand (3.5 trees/tree felled)	Inglis *et al.*, 1997 in FAO 2004
Malaysia	CL	SEA	18	trees/ha (24m^2/ha BA)	47.6	% of original stand destroyed	Johns, 1988 in FAO 2004
Papua New Guinea	CL	SEA	30	m^3/ha (5-8 trees/ha)	34	% of residual stand (229 out of 673 trees or 17% of total volume)	Kilkki, 1992 in FAO 2004
Malaysia	CL	SEA	120	m^3/ha	56	% of residual stand	Moura-Costa, 1997 in FAO 2004
Malaysia	RIL	SEA	120	m^3/ha	29	% of residual stand	Moura-Costa, 1997 in FAO 2004
Malaysia	CL	SEA	116.5	m^3/ha (11.6 trees/ha)	53	% of residual stand	Nicholson, 1958 in FAO 2004

Location	Logging method	Region	Harvest intensity	Harvest intensity extent	Damage	Damage extent	Reference
Malaysia	CL	SEA	154	m^3/ha	70	% of residual stand. RIL: 50% less damage compared to CL	Pinard *et al.,* 1995
Malaysia	RIL	SEA	104	m^3/ha	40	% of residual stand. RIL: 50% less damage compared to CL	Pinard *et al.,* 1995
Malaysia	CL	SEA	90-173	m^3/ha	59	% of residual trees >60cm dbh	Pinard *et al.,* 2000[1]
Malaysia	RIL	SEA	87-175	m^3/ha	29	% of residual trees >60cm dbh	Pinard *et al.,* 2000[1]
Malaysia	CL	SEA	44.5	m^3/ha	54	% of residual stand	Richter 2001
Malaysia	RIL	SEA	27.8	m^3/ha	28	% of residual stand	Richter 2001
Indonesia	CL	SEA	80	m^3/ha	48.8	% of residual stand	Sist & Bertault 1998 in FAO 2004
Indonesia	RIL	SEA	80	m^3/ha	30.5	% of residual stand	Sist & Bertault 1998 in FAO 2004
Brazil	RIL	Br	21.3	m^3/ha (6.3 trees/ha) (3.4m^3/tree)	20.6	% of original stand (16.1% destroyed)	Sist & Ferreira 2007
Indonesia	CL	SEA	107.2	m^3/ha (10.1 trees/ha) or 17.7m^2/ha BA	48.5	% of original stand	Sist *et al.,* 1998
Indonesia	RIL	SEA	56.6	m^3/ha (7 trees/ha) or 11.4m^2/ha BA	26.9	% of original stand	Sist *et al.,* 1998
Indonesia	RIL	SEA	60	m^3/ha (7.5 trees/ha) (3.8 m^2/ha)	14.5	% of original stand (36 trees/ha)	Sist *et al.,* 2003
Indonesia	CL	SEA	83	m^3/ha (7.6 trees/ha) (5.4 m^2/ha)	24.7	% of original stand (60 trees/ha)	Sist *et al.,* 2003
SEAsia	CL	SEA	80-100	m^3/ha (8 trees/ha)	50	% of original stand	Sist, 2000 in FAO 2004
South America	CL	Br	30-50	m^3/ha (5-6 trees/ha)	35	% of original stand	Sist, 2000 in FAO 2004
Malaysia	CL	SEA	136	m^3/ha	60	% of residual stand	Tay 1999
Malaysia	RIL	SEA	106	m^3/ha	30	% of residual stand	Tay 1999
Guyana	CL	Br	8	trees/ha	15	% of residual stand	Van der Hout 1999
Guyana	CL	Br	16	trees/ha	33	% of residual stand	Van der Hout 1999
Guyana	RIL	Br	8	trees/ha	11	% of residual stand	Van der Hout 1999
Guyana	RIL	Br	16	trees/ha	22	% of residual stand	Van der Hout 1999
Indonesia	CL	SEA	10	trees/ha	38	% of canopy removed	Van Gardingen *et al.,* 1998 in FAO 2004
Malaysia	CL	SEA	90	m^3/ha	66	% of residual stand	Yeom, 1984 in FAO 2004

1): Calculated based on information in the paper and assuming 1m^2 BA = 5 m^3 (initial stand: 125 m^3/ha) and lower limits used.

SEA: South East Asia; Br: Brazil

BA: Basal Area

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1 Arets, E.J.M.M., K.W. van der Hoek, H. Kramer, P.J. Kuikman & J.-P. Lesschen (2013). *Greenhouse gas reporting of the LULUCF sector for the UNFCCC and Kyoto Protocol. Background to the Dutch NIR 2013.*

2 Kleunen, A. van, M. van Roomen, L. van den Bremer, A.J.J. Lemaire, J-W. Vergeer & E. van Winden (2014). *Ecologische gegevens van vogels voor Standaard Gegevensformulieren Vogelrichtlijngebieden.*

3 Bruggen, C. van, A. Bannink, C.M. Groenestein, B.J. de Haan, J.F.M. Huijsmans, H.H. Luesink, S.M. van der Sluis, G.L. Velthof & J. Vonk (2014). *Emissies naar lucht uit de landbouw in 2012. Berekeningen van ammoniak, stikstofoxide, lachgas, methaan en fijn stof met het model NEMA*

4 Verburg, R.W., T. Selnes & M.J. Bogaardt (2014). *Van denken naar doen; ecosysteemdiensten in de praktijk. Case studies uit Nederland, Vlaanderen en het Verenigd Koninkrijk.*

5 Velthof, G.L. & O. Oenema (2014). *Commissie van Deskundigen Meststoffenwet. Taken en werkwijze; versie 2014*

6 Berg, J. van den, V.J. Ingram, L.O. Judge & E.J.M.M. Arets (2014). Integrating ecosystem services into tropical commodity chains- Cocoa, Soy and Palm Oil: Dutch policy options from an innovation system approach

7 Knegt de, B., T. van der Meij, S. Hennekens, J.A.M. Janssen & W. Wamelink (2014). *Status en trend van structuur- en functiekenmerken van Natura 2000- habitattypen op basis van het Landelijke Meetnet Flora (LMF) en de Landelijke Vegetatie Databank (LVD). Achtergronddocument voor de Artikel 17-rapportage.*

8 Janssen, J.A.M., E.J. Weeda, P. Schippers, R.J. Bijlsma, J.H.J. Schaminée, G.H.P. Arts, C.M. Deerenberg, O.G. Bos & R.G. Jak (2014). *Habitattypen in Natura 2000-gebieden. Beoordeling van oppervlakte representativiteit en behoudsstatus in de Standard Data Forms (SDFs).*

9 Ottburg, F.G.W.A., J.A.M. Janssen (2014).*Habitatrichtlijnsoorten in Natura 2000-gebieden. Beoordeling van populatie, leefgebied en isolatie in de Standard Data Forms (SDFs)*

10 Arets, E.J.M.M. & F.R. Veeneklaas (2014). *Costs and benefits of a more sustainable production of tropical timber.*

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