Global Wood Production

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Abstract

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To meet the global demand for wood the old forest management module of the IMAGE integrated assessment model (Bouwman et al. 2006) only applied clear felling. As a consequence in whole gird cells the forest was completely harvested. In reality, however, there many different ways to produce wood, ranging from selective logging to clear felling and forestry plantations. Each of these logging systems will have different effects on the area needed for wood production and impact on remaining forest and diversity patterns. The global biodiversity model GLOBIO (Alkemade et al. 2009), which is coupled to the IMAGE model, however, needs more precise information on area needed and differentiates in impact of different forest management types. In this report an overview is given of different forest management types (clear felling, selective felling, reduced impact logging and forest plantations) and the associated wood production and harvest losses on an area base in different climate zones (boreal, temperate and tropical). The data were collected form scientific and grey literature for a sample of 20 important wood producing countries across most world regions that are distinguished within the IMAGE model. Together these example countries covered 81.5% of the global industrial round wood production in 2005.

Keywords: clear felling, felling volume, forest plantations, global, harvest volume, IMAGE model, reduced impact logging, selective logging, wood production

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1 Introduction

1.1 Background

The Integrated Model to Assess the Global Environment (IMAGE, Bouwman et al., 2006) is used to study impact of global and environmental change in an integrated way, including different anthropogenic drivers and environmental impacts. The IMAGE model is coupled with a number of models that provide input on for instance economic and population developments, energy consumption and subsequent demand, trade and production of agricultural and wood products. Combination of regional production of agricultural and wood products and climate determined growth conditions determine land use and land-use change and associated emissions of greenhouse gases and effects on hydrological and atmospheric interactions. Subsequently the effects on biodiversity of land-use change, and other anthropogenic drivers like fragmentation, climate change and N deposition can be assessed using the GLOBIO3 global biodiversity model (Alkemade et al., 2009).

Within the framework of global assessment studies like the "Global Biodiversity Outlook" (CBD 2006, CBD 2010, ten Brink et al., 2007) information is needed on changes of areas and quality of ecosystems under different land-use scenarios. With the IMAGE and GLOBIO models the global effects of future developments in land-use can be projected and estimated. Forest ecosystems play an important role in such scenario studies. In previous versions of the forest management module in the IMAGE model harvesting of wood was only represented by clear felling of grid cells. In realty, however, there are many different ways to produce wood, ranging from selective logging to clear felling and forestry plantations. Each of these logging systems will have different effects on the area needed for wood production and impact on remaining forest diversity. As the land-use compartment of the IMAGE model originally was mainly focused on green house gas emissions the application of only clear cut did give sufficiently reliable results on a global scale. The GLOBIO3 model, which is coupled to the IMAGE model, however, needs more precise information on area needed for forestry and differentiates the impact of different forest management types.

Therefore for model scenarios on forest ecosystems there is need for more and better information on:
- Wood production from various different forest management practices.
- The associated area of forest managed for timber production in a given year.

The IMAGE model will be improved to take into consideration three different forest management systems (clear felling, selective felling, and forest plantations), each yielding different volumes of industrial round wood per unit of areas and each associated with different impact on remaining forest and biodiversity.

The aim of this study is to provide information and data to improve the forestry part of the dynamic land use module of the IMAGE model. Based on these data it should be possible to determine the area of forest annually needed under different management regimes to be to be able to meet the global demand for wood.

1.2 Methods

In this report an overview is given of different forest management types (clear felling, selective felling, reduced impact logging and forest plantations) and the associated wood production and harvest losses on an area basis in different climate zones (boreal, temperate and tropical). The data were collected from scientific and grey literature for a sample of 20 important wood producing countries (Table 1) across most world regions that are distinguished within the IMAGE model (Figure 1). Together these example countries cover 81.5% of the global industrial round wood production in 2005.

Based on an analysis of wood production data from FAOstat (FAO 2009) for each of the climatic zones (boreal, temperate and tropical) from each continent, countries with highest wood production were identified. Additional criterion for the selection of countries was that they should cover most of the regions that are distinguished in the IMAGE model (Figure 1). From an initial overview, 20 countries were selected (Table 1), which in 2005 in total produced 1,392 million m^3 of industrial round wood, or 81.5% of the total global industrial round wood production.

Table 1

Selected countries based on contribution to global round wood production and distribution across continents and climatic zones. For each country its annual wood production (1000 m^3) and contribution to global wood production in is given for 1990, 2000 and 2005 (source of annual wood production: FAO 2007).

Country	**Industrial round wood production (1000 m^3)**			**Contribution to global production (%)**		
	1990	**2000**	**2005**	**1990**	**2000**	**2005**
Boreal forests						
Canada	155,958	198,918	208,712	9.2	12.4	12.2
Russian Federation	-	105,800	138,000	0.0	6.6	8.1
Sweden	49,071	57,400	92,300	2.9	3.6	5.4
Temperate forests						
Australia	17,213	24,407	26,332	1.0	1.5	1.5
Chile	14,386	24,437	32,529	0.8	1.5	1.9
China	91,229	96,019	94,669	5.4	6.0	5.5
France	34,913	43,440	28,253	2.1	2.7	1.7
Germany	80,341	51,088	50,905	4.7	3.2	3.0
Japan	29,300	17,987	16,166	1.7	1.1	0.9
New Zealand	11,947	19,279	19,005	0.7	1.2	1.1
Poland	15,549	24,489	28,531	0.9	1.5	1.7
South Africa	13,008	18,616	18,214	0.8	1.2	1.1
United States of America	427,200	420,619	423,456	25.2	26.3	24.8
Tropical forests						
Brazil	74,277	102,994	118,123	4.4	6.4	6.9
Congo, DRC	3,053	3,653	3,653	0.2	0.2	0.2
India	24,407	18,761	23,192	1.4	1.2	1.4
Indonesia	38,366	33,497	30,720	2.3	2.1	1.8
Malaysia	41,260	15,095	24,483	2.4	0.9	1.4
Mexico	7,580	8,105	6,181	0.4	0.5	0.4
Nigeria	8,263	9,418	9,418	0.5	0.6	0.6
Selected countries	1,137,320	1,294,022	1,392,843	67.0	80.9	81.5
World	1,696,440	1,598,936	1,708,226			

Were relevant and possible a distinction was made between harvesting of softwood (coniferous) and hardwood (broad leaved) species and for plantation also between fast growing species (i.e. for paper and pulp) and slow growing species (i.e. for timber production). Focus of the assessment is on industrial round wood. Fuel wood is not included because this is largely produced by informal processes and not so much in forest management systems.

The forest management systems that will be included in the improved forest management module in IMAGE are clear felling, selective logging and forest plantations. Therefore data were collected for the following The management regimes that will be identified are:

- Selective logging (sub-divided in conventional (CL), without specific measures in place to reduce impact on the remaining forest and reduced impact logging (RIL) with a number of measures in place to reduce the impact of logging activities on the with re-growth to (semi-)natural forest.
- Clear-felling where a whole forest area is completely felled and harvested. Data on wood from thinnings that are part of a clear-felling system will also be included in this assessment.
- Forest plantations with exotic or native tree species growing under controlled circumstances.

For each of these example countries data on wood production systems, total annual wood production, harvest intensities per management system, remaining wood volumes and biomass production were collected and interpreted. Information and data were collected from grey literature and electronic sources (e.g. FAO and UNECE reports and databases, reports on national forest inventories) and scientific literature. Based on this for each country the average wood volume felled and produced

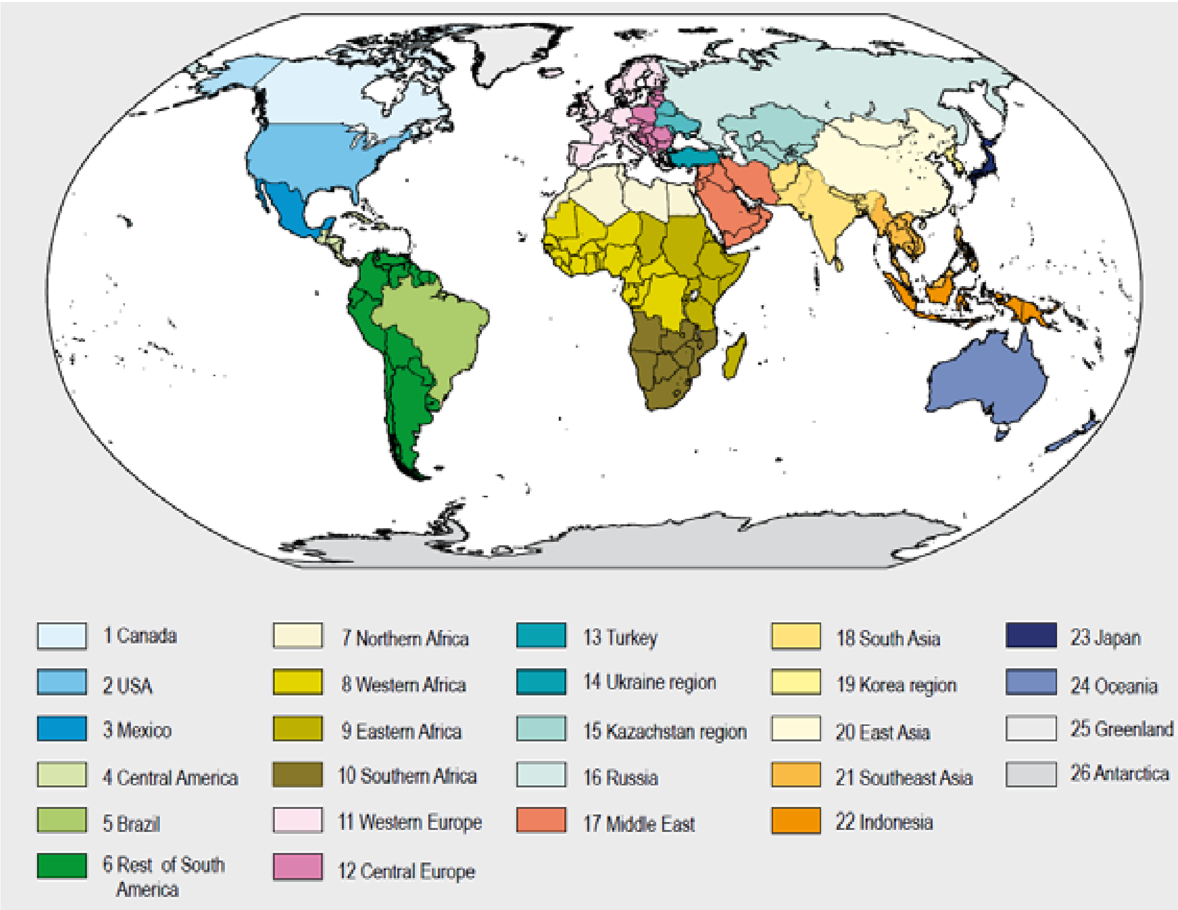


Figure 1

Classification of regions in IMAGE 2.4. Source of map: Bouwman et al., *2006. A list of all countries in each region can be found on: http://www.pbl.nl/en/themasites/fair/definitions/datasets/index.html*

It is evident that not all combinations of management system and forest type occur in all regions. Plantations with endemic species may be hard to distinguish from semi-natural mono-species forests. Additionally the classification of forest management systems appears to be a semantic issue. Some of the semi-natural production forests in Europe that are (partly) replanted after clear felling, would be classified as plantations in Canada. The differences between clear-felling, selective logging and reduced impact logging will gradually cross, depending on for instance applied harvest intensities and skills of forest workers.

If available, data for the parameters listed in Table 2 were collected in separate spread sheets for each country. Not all data are always available for all combinations of species type, forest characteristics and forest management type. Due to apparent differences in definition and representation of the data it's not always possible to directly compare or join data from different sources. Different sources use the same terms, but the actual meaning may show subtle differences.

Table 2
List and description of collected parameters

Parameter	Value(s)	Description
Species type	Softwood Hardwood	Softwoods: coniferous tree species. Hardwoods: Broadleaved or non-coniferous tree species.
Forest characteristics	Primary, Modified natural, Semi-natural, Productive plantation	Characteristics of the harvested forest, based on the categories used in FRA 2005 (FAO 2006a), see definitions below: *Primary forest* Forest of native species, with no visible indications of human activities and with ecological processes not significantly disturbed. *Modified natural forests* Forest/Other wooded land of naturally regenerated native species where there are clearly visible indications of human activities, e.g.: Selectively logged-over areas, areas naturally regenerating following agricultural land use, etc. Also areas where it is not possible to distinguish whether the regeneration has been natural or assisted. *Semi-natural forests* Forest of native species, established through planting, seeding or assisted natural regeneration, e.g.: Areas under intensive management where native species are used and deliberate efforts are made to increase/ optimize the proportion of desirable species, thus leading to changes in the structure and composition of the forest. Areas under intensive management where thinning or fertilizing, are made to improve or optimise desirable functions of the forest. These efforts may lead to changes in the structure and composition of the forest. *Productive plantation* Forest of introduced species and in some cases native species, established through planting or seeding mainly for production of wood or non-wood goods, e.g.: stands of introduced species established for wood production. In the finally aggregated data only a distinction is made between primary or natural forests and forest plantations.

Parameter	Value(s)	Description
Management type	Clear felling, Selective logging (conventional and reduced impact logging (RIL)), Forest plantation	If not explicitly stated, in principle, the logging activities are followed by re-growth (natural or planted). Clear felling is a system of wood production in consecutive cycles of complete cutting and subsequent regrowth. The area of clear cut forest keeps a designation as forest. If forest is converted to other land uses it is considered to be deforested. Selective logging is mainly practiced in tropical forests that due to their heterogeneous nature often only have few individuals of commercial species per ha. As a consequence only usually only 4-10 trees are harvested per ha. Two sub-categories are considered. Conventional selective logging without specific measures to reduce damage to the remaining forest stand and reduced impact logging in which specific planning an techniques are applied to minimise the damage to the residual stand. Based on an estimation of the share of these two sub categories a weighted average for selective logging is calculated. In forest plantations management is optimised for efficient industrial round wood production.
Area harvested annually	Ha	Total area harvested in a given year. This area is calculated based on the wood production in the focal country or region and the produced volume of wood per hectare.
Area share in total production	Fraction	Share of a given combination of species type, forest characteristic and management type in the total industrial round wood production of the focal country or region.
Felled volume per ha	m^3 ha^{-1} over bark (o.b.)	Average stem volume felled per hectare. This includes trees that are felled, but left in the forest and other losses due to improper felling. Felling damage and trees killed in the remaining forest under selective felling are separately accounted for.
Felled volume	m^3 o.b.	Total stem volume felled to meet the wood demand in a country or region.
Conversion factor		Conversion factor giving the felling volume (over bark) per cubic metre of round wood produced (under bark). This conversion factor accounts the difference between over bark and under bark volumes and for losses due to improper felling and trees left in the forest.
Produced volume per ha	m^3 ha^{-1} under bark (u.b.)	Average wood volume produced per hectare. This is the volume that is actually being extracted from hectare of forest excluding the losses that are left in the forest. It also excluded debris that may be collected for fuel wood.
Produced volume	m^3 u.b.	Volume (under bark) of [WoodType] produced. [ProducedVol] = [FelledVol] / [ConvFact].

In chapter two the collected data are described and summarised for each country. The countries are grouped by climatic regions with forest (boreal, temperate and tropical) and ordered alphabetically.

Because besides wood production from the described forest management systems, also wood from conversion of forest to other land uses may contribute to the total industrial round wood demand, in chapter 3 an estimation is made for the potential contribution of wood from forest conversion or deforestation to the countries' total annual round wood production.

In chapter 4 the translation (aggregation and substitution) from the country derived statistics to the IMAGE regions is explained. This also includes the calibration of parameters used in the IMAGE model.

2 Country data and description

2.1 Boreal Forests

The forests of Canada, the Russian Federation and Sweden were selected as examples of boreal forests for data collection. The Swedish National Forest Inventory (NFI) provides the most complete and coherent dataset from which it was possible to determine both the volumes and areas harvested per species type per forest management type. From these figures the average felled volumes per hectare could be calculated with small uncertainties. In Sweden there is, however, a long-time observed difference between the figures provided in the National Forest Inventories (based on stumps >5 cm) and the National Forest Agency's calculated annual gross fellings. In accordance with figures given by the NFI 5% was added to their volume estimates.

The official Canadian forestry statistics provide either areas harvested per management type or volumes harvest per species type. It's impossible to combine these statistics directly, like could be done for Sweden. Hence the total volumes harvested per species type and the areas harvested per management type are relatively reliable. The combinations of these two, however, were based on data from Sweden for the volumes felled per ha for clear felling and thinning, while the remainders were assigned to selection felling. Therefore these data should be regarded as an educated guess.

For Russia no official forestry statistics were available. Therefore the FRA 2005 data (FAO 2005h), which are compiled by Russian forestry officials were used as a basis. A major uncertainty in the Russian data is caused by the widespread illegal logging, which is sometimes estimated to be as much as the official figures. No data were available for Siberia, the major forest area of the Russian Federation. Therefore data on volumes felled per hectare were based on volumes of standing stock in mature forests (the forests that will be logged) in the North of the European part of the Russian federation, which is most similar to the Siberian forest.

In Canadian and Swedish forestry statistics, no plantations are mentioned. Most logging occurs in natural and semi-natural forests. These semi-natural forests in both countries are established through planting, seeding and assisted natural regeneration. The difference with plantations is that native species are used. Although Russia has a large area of productive plantation forests, this is only 1.5% of the total productive forest area. No data were available on their contribution to round wood production. In the Russian Federation mainly primary forests are harvested, without emphasis on silvicultural improvements of regeneration.

From the data it can be concluded that the production per ha is highest in Sweden and Canada, although the information from Canada is partly based on data from Sweden. The production per ha in the Russian Federation is partly impeded by the lower standing volumes in mature forests, but also by the relatively big losses after felling. Lower standing volumes in Russian forests are probably the result of lacking silvicultural treatments to enhance growing stock of desirable species.

2.1.1 Canada

Canada's total land area covers 922 million ha of which 310 million ha is categorised as forest and 91.9 million as other wooded land (total of 402 million ha) in the Global Forest Resource Assessment 2005 (FRA-2005) (FAO 2006a). However, according UNECE/FAO (2000)'s TBFRA-2000, 244.5 million ha is categorised as forest and 173 million as other wooded land (total of 417.5 million ha). Approximately 83% of the total forest area was estimated to be Boreal forest and only 17% was estimated to be temperate forest (Lee et al., 2003). The absolute forest area reported by this latter study, however, differed again from the numbers presented in the two studies mentioned before.

Until 2001 the national forest data were based on Canada's forest inventory of 1991 (CanFI 1991), that was updated in 1994. Most data from 2001 onwards are based on a new forest inventory in 2001 (CanFI 2001). Because CanFI 2001 differs from CanFI 1991 in a number of ways, the data from both inventories cannot be compared meaningfully (see FAO 2006a for more details). In the UNECE/FAO (2000) study, the reported area of forest corresponded to the area of 'timber-productive" forest in CanFI 1991, while the area of other wooded land corresponded to the area of "timber-unproductive" forest in CanFI 1991. In CanFI 2001 the classification more closely followed the classification used in the Global Forest Resources Assessment (FAO 2006a). For the analyses and reporting of Canadian wood production these differences are likely to have no effect.

According UNECE/FAO (2000) 62.8% of the forest is coniferous forest (softwoods), 15.5% is broadleaved (hardwoods) and 21.7% is mixed forest. Of the land that is available for wood supply, 82.9% is in public ownership, 0.5% is owned by indigenous or tribal peoples and 16.6% is in private ownership (UNECE/FAO 2000).

At the same time approximately 50% of the forest in Canada is undisturbed primary forest (53.3% in 2000 (FAO 2006a), 50.7% in 1994 (UNECE/FAO 2000). FAO (2006a) classifies the other 46.7% as modified natural forest, while UNECE/FAO (2000) classified the other 49.3% as semi-natural forest. There are no productive plantations in Canada.

The Compendium of Canadian forestry statistics (CCFM 2006) provides information on areas harvested by ownership, harvesting method and province or territory from 1975 to 2002 and merchantable volumes of round wood harvested by category, species group and province or territory from 1970 to 2002. However, the areas harvested are not sub-divided by species group, which makes it impossible to combine the areas harvested by harvesting method and the volumes harvested by species type and forest type.

For instance in 2000 in Canada a total forest area of 1,046,812 ha was harvested (CCFM 2006). Of this total area 90.3% (945,092 ha) was harvested using clear felling, 7.7% (80,683 ha) using selection felling and 2.0% as part of a commercial thinning (CCFM 2006). This latter area, however, will be still available for clear felling later. From this total area 198,916,000 m^3 industrial round wood (of which 163,471,000 m^3 softwood and 35,445,000 m^3 hardwood) and 2,927,000 m^3 fuelwood (of which 528,000 m^3 softwood and 2,399,000 m^3 hardwood) was harvested.

On forest available for wood supply, 76.4% of the total growing stock were softwoods (12,772,573 m^3 o.b.) and 26.4% were hardwoods (4,581,987 m^3 o.b.) (UNECE/FAO 2000).

Both UNECE/FAO (2000) and FAO (2006a) show zero changes of forest area over time. In the UNECE/FAO (2000) the area of forest available for wood supply was the same in 1980 and 1991 (125,863,000 ha) and according the data in FAO (2006a), total forest area (310,134,000 ha), primary forest area (165,424,000 ha) and modified natural forest area (144,710,000) remained the same in 1990, 2000 and 2005. From this it could be concluded that only forests identified as modified natural were harvested during 1990-2005, i.e. only forests that were harvested before are harvested.

Description of data

An overview and compilation of the most relevant data is given in Appendix 2. The official Canadian forestry statistics provide either areas harvested per management type or volumes harvest per species type. It is not possible to combine these statistics directly. For clear felling and commercial thinning in Canada, therefore the average volumes harvested per hectare for Sweden were used, which is a best guess. This estimate (195 m^3 ha^{-1}) is similar to an estimate based on NAI (1.81 m^3 ha^{-1} yr^{-1}) as calculated from data in TBFRA 2000 (UNECE/FAO 2000) in combination with 100 years growth to reach maturity.

Because the same volumes harvested per hectare were used for soft- and hardwoods, it was assumed that the shares of areas harvested per species type for clear felling and commercial thinning were relative to their shares in total volumes harvested (82% softwoods, 18% hardwoods). Then for clear felling and thinning the felled volumes could be calculated based on the areas harvested and the felled volumes per ha. For the calculation of harvested areas and volumes with selection felling (i.e. specific implementation of clear felling) another strategy was necessary. The CCFM (2006) data showed that in the provinces with relatively high percentages of selection felling relatively more hardwoods were harvested. The volume felled with selection felling was calculated as the total volume harvested, minus the volumes harvested with clear felling and thinning. Subsequently the volume felled per hectare was calculated by dividing this total volume harvested by selection felling by its area. This was again assumed to be similar for both soft- and hardwoods. Finally the area harvested by selection felling per species type was calculated by dividing the felled volumes by the felled volume per hectare. Finally to assess an average value of wood production per ha for all clear felling in Canada the total wood production was divided by the total area of both types of clear felling.

Conversion factors of felling volume per cubic metre of round wood production were not available. Based on the average factor for Scandinavian countries (UNECE/FAO 2005) with Boreal forest, here a conversion factor of 1.25 was used, i.e. for each cubic metre under bark of round wood produced, 1.25 m^3 over bark is felled. The bark percentage on removals was 12%, both for softwood and hardwood species. Softwood saw logs and veneer are converted to lumber with an assumed efficiency of 45% (Kurz et al., 1992). From hardwood logs 30% is used for non-construction lumber, 35% is used for pulp chips and 35% is residue (Kurz et al., 1992). Soft- and hardwood pulp logs are converted to chips with an assumed efficiency of 85% (Kurz et al., 1992).

Area harvested by harvesting method
Data of harvested areas per management type are taken from the Compendium of Canadian Forestry Statistics (CCFM 2006). In the original data no distinction was made between species types or wood types (industrial round wood, fuel wood, and total round wood). Because harvested volumes of firewood (see volumes harvested by species and wood type, below) were relatively low when compared with harvested volumes industrial round wood it was assumed that the listed areas refer to industrial round wood.

2.1.2 Russian Federation

Generally in Russia the industrial round wood is produced from a final (or principal) cut (clear felling) of mature and over mature stands or from an intermediate cut (mainly thinnings but also other fellings like sanitary and reconstruction fellings) (Gerasimov and Karjalainen 2006,UNECE/FAO 2001). The final fellings contribute 85% to 90% to the total wood production from forests (Pisarenko et al., 2001,UNECE/FAO 2001). The category wood from other fellings in these two sources is likely from non-forest areas. Because most thinnings are more like strip clear cuts (Nabuurs, expert knowledge) and also because there are no data for this category these were not included separately. Although the Russian Federation has a large area of productive plantation forests (9.2 million ha in 1990 – 11.9 million ha in 2005), this is only 1.5% of the total productive forest area of the Russian Federation. Because the contribution of plantations to wood production is not known and it is likely that production per hectare is similar to that of mature and over mature primary and modified forests this was neither separately taken into consideration. Hence the whole production from forests was attributed to clear felling of (mature and over mature) primary and modified natural stands.

Reported losses (e.g. trees cut but left on the site because areas become inaccessible after the soil thaws in spring) are between 15% and 30%. Since a loss of 30% was considered to be a lower estimate by some experts (Nabuurs, Pussinen, personal communication), this value was used for losses. Pisarenko et al (2001) reported a bark percentage of trees 15% for both softwoods and hardwoods. The conversion factor (felled volume m^3 o.b. for each cubic meter u.b. produced) then becomes 1.45, which is the same as reported in the EFSOS (UNECE/FAO 2005, Table 20).

The felled volumes per hectare for clear felling were determined based on published information on growing stock in mature stands of the North of the European part of the Russian Federation (data from Pisarenko et al., 2001) as these forests are most similar to the Siberian forests, the largest forest area in Russia. It was assumed that total growing stock would be felled (156 m^3 ha^{-1} for softwoods and 152 m^3 ha^{-1} for hardwoods). The produced volume subsequently was determined using the conversion factor felled/produced (see Appendix 2).

Additional information about forests and forest management in the Russian Federation can be found in Arets et al., 2009, FAO 2005h, Gerasimov and Karjalainen 2006, Pisarenko et al., 2001, and UNECE/FAO 2001.

2.1.3 Sweden

In Sweden forest land covers 22,886,000 ha (1999-2003), which is 56% of the total land area (SKS 2005). According the TBFRA 2000 (UNECE/FAO 2000), 16.1% of the forest was undisturbed by man (4,384,000 ha), 81.8% of the forest was semi-natural (22,311,000 ha) and 2.1% was productive plantation (569,000 ha) during the period 1992-1996. The forest characteristics reported in the FRA 2005 (FAO 2006a) did not differ very much from these numbers (2000: 16.7% undisturbed, 81% semi-natural, 2.3% plantation; 2005: 17.2% undisturbed, 80.4% semi-natural, 2.2% plantation).

Logged forest must be re-planted or naturally regenerated within three years after felling (SKS 2006). Also agricultural land without cultural heritage values has to be reforested within three years after falling in disuse (SKS 2006). During the period 2003-2005 62% of the logged area was planted, 34% was naturally regenerated, 1% was seeded and 3% received no measures (SKS 2005).

Generally stands are cleaned when the young trees have reached a height of 2-4 metres (between 0 and 10 years, Figure 2). About 200,000 hectares are cleaned annually (SKS 2006).

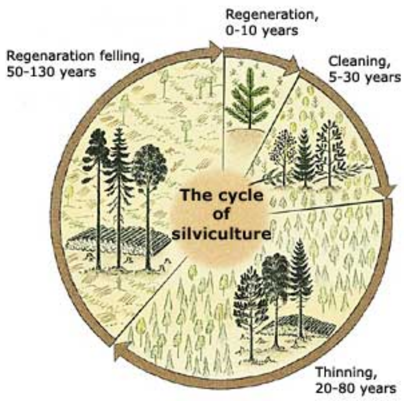


Figure 2
The cycle of silviculture in Sweden. Source: SKS (2006).

Between 5 and 30 years after regeneration started the stand is thinned 2 to 4 times. This is done for two reasons, firstly it generates income and secondly it favours the development to the remaining trees in the stand by improving growth condition. Based on data from SLU (2006) it could be calculated that during the felling season 1999/2000, 256,548 ha were thinned during which 19 million m^3 o.b. were felled, yielding 15.5 million m^3 industrial round wood (90% softwood and 10% hardwood). This is 31% of the total gross felling volume in the same period. Approximately 48% of the thinnings are first thinnings (Bäcke 1998 in Yrjölä 2002)

It is not allowed to fell the (predominately softwood) forest before it reaches an age between approximately 50 and 100 years (SKS 2006), depending on growth conditions. Normal rotation times range from approximately 90 years in Götaland, the most southern region, to 130 years in Norra Norrland, the most northern region of Sweden (SKS 2005).

In the season 1999/2000, final regeneration felling (which can be characterised as clear-cut felling with re-growth) was carried out on about 176,340 ha, which is less than 1% of the total forest area. From this area 41 million m^3 o.b. were felled, which gave a timber yield of about 33.3 million m^3 u.b. (90% softwood, 10% hardwood) (SLU 2006).

Of the total of 22,886,000 ha forest land area during the period 1999-2003 21.9% (5,018,356 ha) was sufficient mature for final felling and 36.4% (8,327,346 ha) was in the thinning age, while 4.6% (1,055,398) was still bare forest land (SKS 2005).

In 1999-2003 the standing tree volume of softwoods on all forest land was 2,393,646,915 m^3 over bark from stump to tip (81.6%), while that of hardwoods was 471,341,871 m^3 over bark from stump to tip (16.1%) (SLU 2006). Dead and wind thrown trees formed 69,300,000 m^3 over bark from stump to tip (2.4%) of the standing volume (SLU 2006).

There is a long-time observed difference between the National Forest Inventory's (NFI) figures (estimated from inventories of stumps > 5 cm) and the National Forest Agency's (Skogsstyrelsen, presented in SKS 2005) calculated annual gross fellings (based on a combination of retrieved industry data, the NFI stump inventory, and other sources of information (UNECE/FAO 2000, Yrjölä 2002). Also, according to investigations by the NFI they assumed that their stump inventory data are systematically under-estimated. Therefore for the TBFRA-2000 a calibration of the NFI data has been carried out with 1.06 (6%) (UNECE/FAO 2000). On the NFI data sheets it was estimated that the felling estimates are uncertain and probably underestimated by 5% (SLU 2006).

For this assessment the felling data based on a 5% correction of the NFI data (SLU 2006) were used in favour of the SKS 2005 data. Reason for this is that the NFI data for both volume and area are presented in a consistent manner. However in each felling season the sum of felled volume by species type was on average about 1.2 million m3 higher than the sum of felled volume by felling type. Therefore the felled volumes by felling type (clear felling, subdivided in final felling, thinning and cleaning) were used as a basis and it was assumed that the ratio between felled softwood and hardwood volumes were similar for all felling types. The NFI data also included felled volumes for felling type "other". The area from which this volume was harvested, however, was not specified. Therefore this volume was added to the volume of final felling and the area for final felling was increased relative to the increase of volume for calculation and for data from other years than those presented. Because clear felling is the common mode of final harvesting, this potentially leads to an underestimation of the total area that is needed to yield the total felling volumes.

Because of lack of information on the data of SLU (2006) it was not known to what wood type the felling data refer. The sum of all fellings reported by SLU (2006) is much lower than the gross fellings reported in SKS (2005). The difference between these two dataset, however, was about the same as the felled volume of fuel wood in SKS (2005). Therefore it was assumed that the data reported in SLU (2006) only refer to industrial round wood.

The historical conversion factors to convert the felled volumes to produced volumes were derived from the total removals (m^3 u.b.) and gross felling (total fellings minus losses; m^3 o.b.) data provided in SKS (2005).

2.2 Temperate forests

Wood production form forests in Australia, Chile, China, France, Germany, Japan, New Zealand, Poland, South Africa, and the USA have been used as examples for temperate forestry practices. The estimates for Australia, Chile, China and the USA are each based on vast geographic areas covered by very different climatic zones, forests and variation in harvesting practices. Only for calculation of wood production from the US forests it was possible to include geographical differences for growth conditions and harvested wood types.

Industrial round wood production in Australia, Chile, China, Japan, New Zealand and South Africa is mainly from productive plantations. China has relatively little (modified) natural forest areas left. Remaining natural forests are located in the Northeast and protected gallery forests for prevention of erosion and natural forests in remote inaccessible areas remain, but these are not available for wood production. In general natural forests are not silviculturally managed and the quality of the timber plantations in China is rather low, which results in relatively low production from forests and plantations when compared to for instance Germany and the USA.

German wood production is mainly from modified natural forests. In contrast to the other temperate countries in this report in Germany more than half (55%) of the wood is produced by commercial thinnings. This habit can be regarded to be representative for most of central European forests. For the USA it was not possible to make a distinction between clear felling and thinnings. Therefore the total US production was attributed to clear felling. The modified natural forests in the US were found to be only slightly more productive than those in Germany.

The data from Germany are based on the German forest inventory which can be assumed to provide accurate data. The wood productions per hectare for Germany and China were based on average growing stock per hectare for mature forests which gives the best estimate of potential harvests per hectare. The wood production per hectare for the USA was based on the product of NAI per hectare and rotation cycle. Since rotation cycles were mainly based on expert knowledge and may also vary within the USA, the accuracy of the production per hectare very much depends on the reliability of this expert knowledge.

2.2.1 Australia

Australia's total land area is 768 million hectares of which 20% is covered by forests and woodlands (6% forest, 14% woodlands) with Eucalypt and Acacia as the most important species. Now a popular plantation species all across the world, almost all of the approximately 700 Eucalypt species were originally endemic to Australia. Most Eucalypt species are evergreen hardwoods and are adapted to natural cycles of fire. The principle land-use in woodlands is grazing with a limited amount commercially managed for timber production.

The total forest plantation estate in Australia currently covers approximately 1.23 million hectares, mostly dominated by exotic softwoods (948,000 ha) such as *Pinus radiata*. Australia's goal is to almost triple the total area of forest plantation to 3 million hectare. New plantations, however, are planted with Eucalypt species and most states have policies in place of not converting natural forests to plantations. Timber from plantations now exceeds the timber produced from natural forests, both in volume and value with most timber produced along the coast and southern regions.

There appears to be a strong contrast between the very productive plantations and the low productive native forests in Australia. The structure of these native forests varies widely from open savannah type woodlands to very close forest. The harvested volumes in native forests were based on average standing stocks from UNECE/FAO (2000) and expert knowledge and were estimated to be 40 m^3 ha^{-1} o.b. for both wood types. This may potentially have led to an underestimation of harvests per hectare. The data for Australia therefore should be considered to be an educated guess. Only 40% of the total production is from these native forests, while the largest share comes from *Pinus radiata* and Eucalypt plantations. The average harvested volume of plantations was based on information on productivity of different plantation species (280 m^3 ha^{-1})

More information about forests and forest management in Australia can be found in DAFF (2003), WFI (2003a).

2.2.2 Chile

Chile stretches across more than 5000 km from north to south. As a result there are many different climate zones and forest types across Chile. The climate in the Northern region between Arica and Santiago (including the Atacama Desert) is very dry with <250 mm rainfall and temperatures around 18 °C. This zone has almost no forests (INFOR 2005). The zone between Santiago and Concepción has dry summers and winters with between 340 and 1200 mm of rain and medium temperatures. In this area there are little native forests, but it is an important area of forest plantations (INFOR 2005).

In 1995, 85% (Brown 2000) and in 1997, 87% (FAO 1999) of Chile's industrial round wood production (21.4 million m^3) (Brown 2000) came from forest plantations, mainly consisting of *Pinus radiata*. According references in Rüger et al., (2007), 95% of industrial round wood production is from forest plantations (probably in 1999) and according the same source 55% of the native forest had been substituted by plantations. High value timber production from native forests is low. Only 10% of wood from native forests is used as industrial round wood, while the main wood product of these forests is fuel wood (Arnold 2003).
In 1995, of the totally produced industrial round wood, 40% is exported, 31.4% is used as sawn wood, 4% is used in wood-based panels and 24.6% in wood pulp (Brown 2000).

In 1995 forest plantations were predominantly of temperate zone tree species, mainly *Pinus radiata* (Brown 2000), which constituted about 75% of the planted area in 1997 (FAO 1999) and 70.6% in 2005 (Table 3, FAO 2006c). At the same time Eucalyptus species made up approximately 17% of the planted forest area in 1997 (FAO 1999) and 24.5% in 2005 (FAO 2006c). The remainder of the planted forest area is covered with *Pseudotsuga menziessii* and *Populus* and *Accacia* species (Table 3, FAO 2006c).

After the plantation subsidy law of 1974 expired in 1994 the annual plantation rate considerably decreased (FAO 1999). A new subsidy law was passed early in 1998, but it only provides subsidies to small producers or those planting on degraded soil (FAO 1999).

Total planting during 1996 and 1997 was slightly less than 80,000 ha, of which new plantations were 42,500 ha and 44,300 ha respectively (FAO 1999). For the year 2000 the annual planting rate of new plantations was estimated to be 45,000 ha, but planting rate was expected to increase after 2000 (FAO 1999). Based on FAO (2006c), the annual change of plantation area between 1990-2000 was 61,300 ha yr^{-1} and between 2000-2005 it was 61,400 ha yr^{-1}. By the end of 2002 13% of the plantation forests were FSC certified (Arnold 2003).

Based on the fact that according the old plantation subsidy law re-planting after final harvest was mandatory it can be estimated that a total of approximately 35,000 ha of plantation were harvested annually at the second half of the 1990's. The annual net gain in forest area in Chile between 2000 and 2005 was 57,000 ha yr^{-1}, which was the 6[th] largest gain rate worldwide (FAO 2006a). However in the same FRA2005, FAO (2006a) reported an annual change rate for productive plantations between 2000 and 2005 of 61,000 ha.

Table 3
Forest plantations for production in Chile (data from FAO 2006c). Composition of species (%), minimum, maximum and average Net Annual Increment (NAI, m^3 ha^{-1} yr^{-1}), minimum, maximum and average harvested volumes (m^3 ha^{-1}).

	Share	**NAI (m^3 ha^{-1} yr^{-1})**		**Rotation cycle (yr)**			**Harvest (m^3 ha^{-1})**		
Species	%	Min	Max	Min	Max	Avg	Min	Max	Avg
Pinus radiata	70.6	14	34	18	28	23	260	580	420
Eucalyptus spp	24.5	15	36	8	12	10	130	400	265
Pseudotsuga menziessii	0.8	10	18	30	50	40	400	550	475
Populus spp.	0.3	28	42	10	16	13	300	500	400
Acacia saligna	0.2								
Acacia melanoxylon	0.12	10	20	15	45	30	200	400	300
Acacia dealbata	0.1	10	20	15	45	30	200	400	300
Other species	3.4								

Based on value of export, the most important destinations for Chilean forestry products are the EU (29.4%), China (10.4%), Japan (8.8%) and Mexico (7.0%) (INFOR 2005).

Chile's natural forests include the world's second largest expanse of temperate rain forest (Neira et al., 2002). About ninety percent of the native tree species are endemic to Chile and partly Argentina. An important endemic species is the Alerce tree (*Fitzroya cypressoides*), which is an endangered Red-List species (Conifer Specialist Group 2000). It has been logged since the middle of the 17th century. The largest concentration of the species, at the southern end of the Chilean depression, was exploited in the 18th and 19th centuries. By the early 1900s a third of the *Fitzroya* forests had been removed an present estimates of the area of remaining stands lie at 20,000 ha, 15% of their original size (Conifer Specialist Group 2000). Exploitation continued at such intensities that chances of re-growth and regeneration are annihilated. Restrictions laid down by the Chilean Government have not been adhered to and illegal logging in remote areas has been impossible to halt (Conifer Specialist Group 2000). A detailed description of the most important forest types in Chile, can be found in Neira et al., (2002)

Native forests are both converted into exotic tree plantations and selectively logged, but this is only a minority of the native forests (Neira et al., 2002). Before conversion to forest plantation, native forest are often degraded through high-grading, i.e. selective cutting of the biggest and best trees (Neira et al., 2002). In the past two decades also an average of 13,660 ha were destroyed each year by fire, of which 28% were set intentionally.

Most of the harvesting in primary forests is selective. Of the native primary forests that were altered in the period 1995-1997, 75.1% were selectively logged, 24.6% were burned, 0.3% were thinned and 0.1% were clear-cut (Neira et al., 2002). Thus of the logged primary forest area, 99.55% was selectively logged, 0.35% was thinned and 0.10% was clear cut. In these numbers regenerating secondary forests were not taken into account (Neira et al., 2002).

Using a process based simulation model, Rüger et al., (2007) showed that in the Valdivian temperate rain forests in Chile it is possible to sustainably (from a timber availability point of view) extract 6.5 m^3 ha^{-1} yr^{-1} by selective cutting with retention of large trees, when the harvest aim is 180 m^3 per harvest en a logging cycle of 20 years. However, in that case six out of 20 harvests (in 400 years simulations) had to be omitted, leaving room for discussion of the sustainability of these harvests. Yet apparently harvests of approximately 180 m^3 ha^{-1} are possible from Chile's native forests.

Donoso (1989) shows that 37% (185 m^3) of the total stand volume in the Andes and 32% (136 m^3) of the volume in managed stands in the coastal range are made up by commercial species. In native Lenga forests in southern Patagonia of Argentina and Chile, Nothofagus pumilo is the most important timber species (Pastur et al., 2000). These forests contain commercial wood volumes between 40-400 m^3. Most of the wood from this region is locally used with a focus to long logs. Therefore the volume harvested per hectare is only limited to 40-60 m^3 (Pastur et al., 2000). Cellino et al. (1998) determined for a shelter wood system (strip clear felling) in Lenga forests, final cuts ranging from 33 m^3 ha^{-1} to 266.5 m^3 ha^{-1} (all under bark). Therefore for selective logging a harvest of 50 m^3 ha^{-1} was estimated based on Pastur et al. (2000), and for clear felling a harvest of 180 m^3 ha^{-1} was estimated based on Donoso (1989), Cellino et al. (1998), Pastur et al. (2000) and Ruger et al. (2007). Further it was assumed that all wood produced by logging of (semi-)natural forest is all hardwood.

2.2.3 China

Most natural forests in China were cleared already centuries ago (e.g. Kunshan et al., 1997, WWF 2005). Remaining natural forests are in northeast China and the less densely populated parts of the northwest and southwest. Currently China is one of the world's largest importers of wood (importing around 100 million m^3), with Russia, Indonesia and Malaysia as the three largest suppliers (24 million m^3) (Chunquan et al., 2004). The demand will probably increase and despite the enormous afforestation projects and the heavy investments in new plantation projects for domestic industrial round wood production, it is likely that China will continue to depend on imports (Bull and Nilsson 2004,Kunshan et al., 1997, White et al., 2006, WWF 2005). For more information on forests and forest management in China see: Bull and Nilsson 2004, China Development Brief 2005,Kunshan et al., 1997, Shi and Xu 2000, WWF 2005. Most data probably exclude forest resources and production from Taiwan and Tibet (e.g. Kunshan et al., 1997).

No information was found on harvesting practices in China. The information provided in different publications, however, gives the impression that the main production system from (semi) natural forests is clear felling (e.g. Bull and Nilsson 2004,Kunshan et al., 1997, Rozelle et al., 2000). Therefore only a distinction is made in the following: clear felling of hardwoods and softwoods from natural forests and fast and slow growing hardwoods and softwoods from plantations. Additional to the official production numbers as presented in the different FAO statistics, Bull and Nilsson 2004 also estimated based on various sources that the amount of over cutting, or illegal logging was similar to the legally harvested amounts of industrial round wood (91 million m^3 in 1990, 87 million m^3 in the 1990's to 116 million m^3 in 2002 – probably this includes fuel-wood). Considering the scope of this study, these numbers were not further taken into account.

According Kunshan et al. (1997) 50.66% of the total forest area in China is coniferous (softwoods) forest and 49.3% is broadleaved (hardwoods), while softwoods make up 56% and hardwoods 44% of stocking volume. It was assumed that this distribution determined the fractions harvested of soft and hardwoods and that it is also valid for the forests actually available for wood supply, which are the near mature and mature timber forests. Most over-mature forests are not accessible (Bull and Nilsson 2004). Based on data in Kunshan et al. (1997), the average stocking volumes for the total forest area could be calculated (83.6 m^3 ha^{-1} as total average, 92.9 m^3 ha^{-1} for softwoods (=1.13 times the average), 74.2 m^3 ha^{-1} for hardwoods (=0.89 times the average). The average volume per hectare in forests available for wood supply was 110-112 m^3 ha^{-1} (Bull and Nilsson 2004).

To differentiate in volumes from soft and hardwood forests the same relative difference from the average as calculated from the data in Kunshan et al. (1997) were used. The average volume that can be felled from softwood forests then is 124 m^3 ha^{-1} (110 * 1.13) and for hardwood forests it is 98 m^3 ha^{-1} (110*0.89).

Because of lack of good data on plantations for China the same production values were assumed to be valid for plantations in China. This seems a reasonable assumption as in general the quality of timber plantations in China is very low (FAO 2001c) and reported production volumes for Acacia and Eucalyptus plantations were 65 m^3 ha^{-1} and 108 m^3 ha^{-1}. The amount of wood produced by plantations was calculated as the difference between total wood production and production form timber forests (Kunshan et al., 1997). The relative proportion of slow and fast growing plantations was determined based on data from Bull and Nilsson (2004).

When taking together all forest types, only 23% of the non-plantation forests is nearly mature or mature forest (Kunshan et al., 1997). Assuming this percentage is similar for all forest types for all years in the period 1990-2005, the area available for immediate industrial wood production is 23% of the timber forests as reported in (FAO 2005b).

Conversion factors
Bull and Nilsson (2004) found that a conversion factor of 57.5% is appropriate to convert from reported log consumption to log removal from the forest. They suspected that these losses were not taken into account for reporting figures to the FAO (i.e. that the numbers for wood removal and industrial round wood production reported in FRA-2005 (FAO 2006a) and FAO-stat (FAO 2009) show the consumption and not the removals.

For plantations average bark percentages were based on the data in the TBFRA 2000 (UNECE/FAO 2000) which had average bark percentages of 12% for hardwoods and 13% for softwoods. As trees from plantations are generally thinner than trees from (semi) natural forests (especially in short rotations) and the relative amount of bark is higher for thinner trees, for plantations 5% was added to the above bark percentages. For the total conversion factor 5% losses (see Brazil) were taken into account as well.

2.2.4 Germany

Total forest area in Germany increased by 6 percent since the middle of the 20th century and now covers about 10.8 million (30%) of the total land area

More information about forests and forest management in Germany can be found in:
WFI 2003b (see Box 2), BMVEL 2006, BMELV 2006.

Calculations, assumptions and references [Germany data].[Germany relevant] are provided in the comments of cells. Most data are from UNECE/FAO (2000) and BMELV (2005).

As a result of increased afforestation since the middle of this century the forest area of Germany increased by 6% since the middle of this century, accounting now for 10.8 million ha or 30% of the total land area. Considering the high population density of more than 225 people per square kilometre this represents a fairly high percentage.
Located in the temperate zone, originally deciduous trees covered about two thirds of the area. The virgin forests of Central Europe were dominated by beech (*Fagus sylvatica*), mixed with other hardwoods such as oak (*Quercus robur* & *Q. petraea*), ash (*Fraxinus excelsior*), maple (*Acer pseudoplatanus* & *A. platanoides*), or alder (*Alnus glutinosa*) depending on site conditions and climate. Only in higher elevations coniferous trees dominated the species mixture. The most important softwood species are silver fir (Abies alba), pine (Pinus sylvatica), spruce (*Picea abies*), and douglas fir (*Pseudotsuga menziesii*), introduced from the Pacific Northwest of the USA at the end of the last century. Particularly spruce, originally confined to montane and high montane zones, gained a substantially higher share over the centuries due to a softwood supporting forestry mainly aiming at high yield. Today hardwood trees cover only about one third of the forest area. The human-made extension of softwood species to areas where they do not represent part of the natural forest communities caused problems that became most obvious in severe wind throws and the spread of fungi and insects. During the last and most destructive storm in 1990, 60 million cubic metre of timber were felled -- twice the average annual harvest in Germany.
This, coupled with an inventory revealing that only two thirds of the actual growth rate of 6 m^3 $year^{-1}$ $ha^{-1}$are harvested caused a nosedive of wood prices after 1990. The situation was exacerbated by the opening of the formerly closed Eastern European countries which started to offer wood to prices German forestry could not compete with due to higher production costs.
Prices recover slowly and because of increasing deficits of the forest service there is an ongoing debate if wood production or other forestry values such as recreation and protection of watershed should be ranked at the same level or higher. It is declared goal of the States' forest services to pursue all these aims simultaneously and ecological forest management gained more and more support over the last years. Increasing air pollution and other human impacts caused severe damage to the forests in Germany and beyond, but are perhaps best documented in this country. The last nation wide sampling revealed that one quarter of forest trees in Germany show visible signs of damage. The results, however, vary widely depending on the region. The southern states (Bundeslaender) and particularly parts of eastern Germany are most heavily affected.
The future will show if the measure taken to stabilize forest ecosystems and to secure and maintain biodiversity in German forests are sufficient. At the moment forest and forestry are in an important transition period with results being unknown.

Box 1. Forest management practices in Germany. Text from: http://wfi.worldforestry.org/WF-germ.htm

2.2.5 Japan

Japan maintains some 25.1 million hectares of forest (about 70 percent of the nation's entire surface area). Natural forests account for 50 percent of this total, and planted forests, which consist mostly of conifers, for 42% (FAO 2006b), but 100% of these planted forests are for protection purposes. In 1990 Japan imported approximately 74% of the domestically used wood of which most came from Malaysia and the USA (Kochi University 1996).

Japan's growing stock of forest is 4.0 billion cubic meters, of which 2.3 billion cubic meters is planted forest. Forests which were planted after World War II are now finally ready for harvesting. The functions that forests play in soil conservation and the prevention of global warming need to be exercised in a sustainable manner by smoothly following the cycle of cutting, planting and tending planted forests.

Domestic round wood production totalled 17.2 million cubic meters in 2005, which is equivalent to only 30 percent of the peak in 1967 (52.7 million m^3). In 2005, Japan's self-sufficiency rate for lumber was 20 percent. Currently, Japan depends mostly on imported wood for pulp, woodchip and plywood material.

The slowdown in domestic wood production has resulted in a decline in the number of workers engaged in forestry. In 2005, there were 47,000 workers engaged in forestry, a level which represented only 70 percent of the number recorded five years before. Also, one out of four workers was aged 65 and over, highlighting the aging of the labour force.

Based on the volumes provided by Kochi University (1996) it was estimated that the total industrial round wood production in Japan is based on clear felling (final cut) with an average production of 154 m^3 ha^{-1}.

2.2.6 New Zealand

Forest plantations in New-Zealand predominantly consist of tree species form temperate zones, mainly *Pinus radiate* (Brown 2000, FAO 2006c, Table 4). In 1995 99% of New Zealand's industrial round wood production came from forest plantations (Brown 2000). According in 2001 round wood removals from indigenous forests totalled 53,000 m^3, while the total removals from plantations totalled 19.4 million m^3 (MAF 2003), which means that in 2001 99.7% of total wood is produced by forest plantations. Therefore for New-Zealand only wood production from plantations was taken into account.

Data from the FRA2005 country report (FAO 2005f) for the years 1990, 2000 and 2005 were used as the basis for the calculations of industrial round wood production in New-Zealand, assuming for all this years 100% production from plantations instead of 99% (Brown 2000). Fraction soft- or hardwood was based on FAOstat production data for softwoods (98.6%) and hardwoods (1.4%). The conversion factor was based on information in the TBFRA2000 (UNECE/FAO 2000) were removals as percentage of fellings was given as 85%, and the bark percentage of softwoods is 12.9% and of hardwoods is 5.6%. Felled volumes per hectare were based on averages for soft and hardwoods from Table 4.

Table 4
Productive forest plantations in New Zealand (source: FAO 2006c*).*

Species	**Share**	**NAI (m^3 ha^{-1} yr^{-1})**		**Rotation cycle (yr)**			**Harvest (m^3 ha^{-1})**		
	%	**Min**	**Max**	**Min**	**Max**	**Avg**	**Min**	**Max**	**Avg**
Pinus radiata	89	17	20	25	32	28.5	440	620	530
Pseudotsuga menziessii	6	13	16	30	60	45	400	930	665
Other softwoods	2	8	11	25	40	32.5	200	410	305
Hardwoods	3	12	15	12	40	26	140	510	325

2.2.7 Poland

Poland's forests of 9,192,000 hectares (2005) have undergone substantial changes as a result of both expansion of agriculture and the demand for timber. Even at the end of the 18th century there was still a 40% forest cover in Poland (according to its borders at that time), but this figure had fallen to just 20.8% by 1945. Deforestation and associated destruction of stand species structure resulted in a decrease of biological diversity in forests and landscape depletion, soil erosion and disturbance of the overall water balance. Reversal of this process came about in the period 1945–1970, when Poland's forest cover increased to 27% as a result of the afforestation of 933,500 hectares. At present, 28.8% of the country's area is covered with forest.

Forests in Poland are mainly publicly owned (82.3%), including the forests under management of the State Forests NFH, which is 78.2% of the total forest area. In fact, the ownership structure of forests in the post-War period remained unchanged. However, there has been a notable rise in the share of total forest area protected within National Parks – from 1.0% in 1985 up to 2.0% in 2005.

Poland has mainly retained forest on the poorest soils which is reflected in the structure of forest habitat types. Coniferous forests predominate in the habitat structure of the State Forests NFH, accounting for 56.9% of the total forest area, while the broadleaved forest habitats cover 43.1% of which 3.9% are Alder and floodplain forests.

Coniferous species dominate in Polish forests, covering nearly 75.6% of forest area. In the lowlands the prevalent species is pine (accounting for 67.40% along with larch) where it finds the optimal climatic and site conditions within its Euro-Asiatic natural range, thus being cable of developing a number of important ecotypes (e.g. the Taborska pine or Augustowska pine).

The estimated timber resources under the management of the State Forests NFH and in other forms of ownership is about 1,860 million m3 of gross merchantable timber. More than 70% of timber resources is pine; the share of pine in private and commune forests in total forest resources is 55%.With regard to the forest area (except for land associated with forestry) the average stand volume within the State Forests NFH was at the level of 226 $m3ha^{-1}$ (2005), while in private or commune forests – 119 $m3ha^{-1}$ (1999). The weighted average used in our calculations is 202 $m^3\ ha^{-1}$.

Productive function of forests
The volume of timber harvested (felled volume) in 2005 in Poland amounted to 29,725,000 m3 of net merchantable timber, including 1,124,000 m3 – from stands in private forests and 198,000 m3 from stands in National Parks. In the State Forests NFH this figure was 28,164,000 m3 of net merchantable timber (or c. 105.6% of the approximate prescribed cut) of which 12,216,000 m3 (95.2% of prescribed cut) was obtained from final cut and 15,948,000 m3 (114.9% of prescribed cut) – from intermediate cut.

The volume harvested in sanitation felling, as well as wood obtained from dead trees, windbreaks and windthrows as a result of natural processes, wind disturbance, outbreaks of pest insects, disturbances in water relations, air pollution and weather anomalies amounted to 5.8 million m3, or 20.8% of the total harvest of merchantable timber. However, sanitation felling is not considered separately in the models.

For comparison, the harvest volume in 1985 was 12.6 million m3 representing 58.9% of the total harvested merchantable timber, in 2002 – 10.4 million m3, or 40.5% (mainly in connection with the damaging effects of the ecological disaster in the Piska Primaeval Forest) and in 2004 – 6.3 million m3 – 22.1%. In 2005, 5,616,000 m3 of merchantable timber was harvested under the clear-cut system which corresponds to 19.9% of total harvest. The clear-cut area totaled 25,000 hectares and was lowest over the past 20 years, with 43,000 hectares of clear-cut area in 1980 and 1992 and over 30,000 hectares on average. The reduction in the size of clear-cut area is indicative of the progress in the ‘ecologisation’ of forest management.

Calculations
The analysis of the Polish industrial round wood production for the years 1990, 2000 and 2005 are summarized in the worksheet “Poland relevant” of the excel file “Poland data GWP.xls”. The used sources are TBFRA2000 (UNECE/FAO 2000) and FAOstat (FAO 2007) and SFIC (2006a, 2006b).

We assumed that the produced volume per ha is the weighted average of the standing volume in state forests and in private (or community) forest in 2005, which is 202 $m^3\ ha^{-1}$ for softwood and hardwood. We also assumed that the shares of hardwood and softwood of clear fellings based on SFIC (2006a, 2006b) is equal to their shares provided in FAO-stat for 1990, 2000 and 2005 (FAO 2007).

The conversion factor is calculated using the fraction annual removal/fellings data for commercial use in Poland from TBFRA2000 (UNECE/FAO 2000, table 48, 49 and 51).

2.2.8 South Africa

Forest plantations are predominantly planted with temperate zone tree species, mainly with *Pinus radiata.* In 1995 almost 100% of South Africa's total industrial round wood production (17.6 million m^3) came from forest plantations (Brown 2000). About 16% of the forests in South Africa are productive plantations (FAO 2006b). Pinus and Eucalyptus species are the most important species in the country's forest plantation programme (table Table 5).

Natural forests in South Africa are legally protected (FAO 2005i). However, an insignificant amount of industrial round wood is extracted from the Tsitsikamma-Knysna forest (1,500 m^3), which will not be taken into account in this study.

Table 5
Productive forest plantations in South Africa (source: FAO 2006c).

Species	Share	NAI (m^3 ha^{-1} yr^{-1})		Rotation cycle (yr)			Harvest (m^3 ha^{-1})		
	%	Min	Max	Min	Max	Avg	Min	Max	Avg
Pinus patula	25.2	12	18	25	35	30	300	450	375
Eucalyptus grandis	23.5	18	24	7	9	8	160	240	200
Eucalyptus nitens	16.2	22	28	7	9	8	160	240	200
Pinus elliottii	14.5	12	18	25	35	30	300	450	375
Acacia **(Wattle)**	8.6	10	12	9	12	10.5	90	120	105
Pinus radiata	4.5	12	16	28	35	31.5	280	450	365
Pine other	3.6	10	14	25	30	27.5	280	380	330
Pinus taeda	1.9	10	14	25	30	27.5	280	380	330
Pinus pinaster	1.1	10	14	25	30	27.5	280	380	330
Other	0.9	12	16	10	12	11	140	200	170

Data from the FRA2005 country report (FAO 2005i) for the years 1990, 2000 and 2005 were used as the basis for the calculations of industrial round wood production in South Africa, assuming for all these years 100% production from plantations (Brown 2000). Fractions soft- or hardwoods were based on FAOstat (1990 and 2000 50% softwood and 50% hardwood, and in 2005, 31% softwood and 61% hardwood. The Produced volumes are based on the FRA2005 country report (FAO 2005i) with correction for over bark to under bark. For bark percentage for softwoods 12.9% and hardwoods 5.6% and the ratio between removals over fellings (85%), the same data as for New Zealand (UNECE/FAO 2000) were used, because species and climate were considered to be reasonably similar.

2.2.9 United States of America

In the U.S.A. forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation is classified as timberland (Smith et al., 2004). In 2002 the total forest land area was 303,089,000 ha, of which 203,783,000 ha were classified as timberland. Total forest land was 93% natural forest and 7% planted forest. Of the planted forest 86.7% was softwood forest, 4.5% was hardwood forest and 8.7% was mixed forest. Of the natural forest 48.8% was softwood forest, 38.5% was hardwood forest and 11.5% was mixed forest.

For timberland in the Western USA only data were provided for the total area of timberland, but not for area classified as planted or natural separate. Of the total area of timberland 39.7% (80,828,862) was softwood forest 45.3% (92,314,383) and 14.6% (29,748,230) was mixed forest.

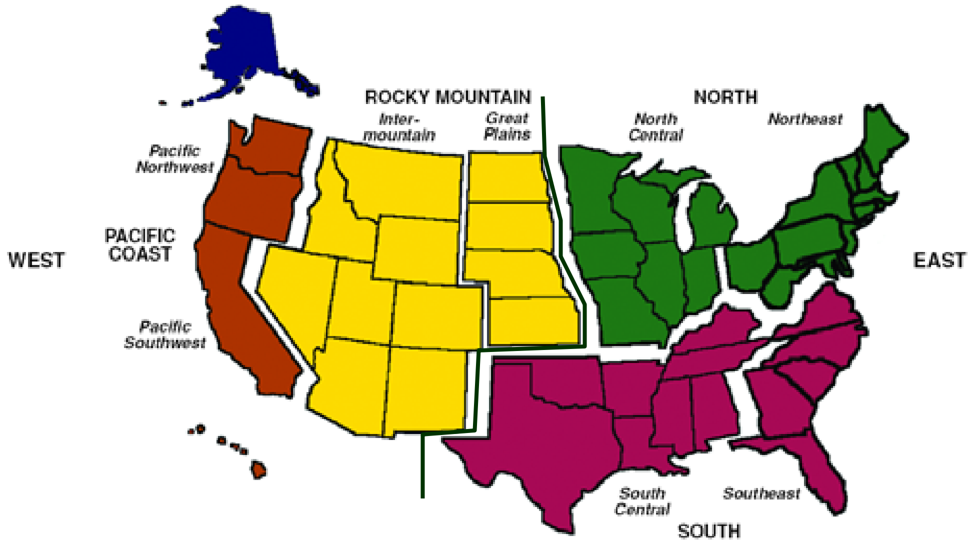


Figure 3
Forest resource reporting regions and subregions of the United States. Source: Smith et al. (2004). Primary hardwood regions are the North and South (together East) (Bowyer 2004).

Most of the urban forest across the United States are not taken into account as forestland in national and regional or state forest statistics (Bowyer 2004). The contribution to wood production of those forests will thus neither show up in the numbers provided here.

In 2001, for the U.S. net growth exceeded removals by 33 percent (Smith et al., 2004). That is, the Nation's forest inventory accrued more volume than it lost by mortality and harvest by nearly one third. Recent declines in harvesting on public lands in the West have significantly deviated from historic growth/removals patterns and have placed more pressure on eastern forests that are predominantly in private ownership (Smith et al., 2004). Therefore privately owned forestland comprised about 57% of all forestland, but 71% of all timberland and 92% of removals form growing stock (Bowyer 2004).

In 2001, about 64% of the volume of timber removals was softwoods and 36% was hardwoods, compared with 69% and 31%, respectively, in 1986. This reflects a trend toward rising hardwood removals in response to new product technologies using hardwoods (Smith et al., 2004).

Calculations
Area and volume of timberland are divided over forest types and forest characteristics (planted or natural). For compilation of the data the following assumptions have been made concerning forest types (Table 6).

Table 6.
Conversion of forest types used in Smith et al., 2004 (see this source for description of the forest types) to forest types used here (softwood, hardwood or mixed forest).

Eastern forest types		**Western forest types**	
Forest type in source	**Forest type used here**	**Forest type in source**	**Forest type used here**
White-red-jack pine	Softwood	Douglas-fir	Softwood
Spruce-fir	Softwood	Ponderosa pine	Softwood
Longleaf-slash pine	Softwood	Western white pine	Softwood
Loblolly-shortleaf pine	Softwood	Fir-spruce	Softwood
Oak-pine	Mixed	Hemlock-Sitka spruce	Mixed
Oak-hickory	Hardwood	Larch	Softwood
Oak-gum-cypress	Mixed	Lodgepole pine	Softwood
Elm-ash-cottonwood	Hardwood	Redwood	Softwood
Maple-beech-birch	Hardwood	Other softwoods	Softwood
Aspen-birch	Hardwood	Western hardwoods	Hardwood
		Pinyon-juniper	Softwood

From comments in Smith et al. (2004) it appears that approximately 5.5 million hectares of forest in the West are planted, primarily to augment natural regeneration after a harvest and ensure adequate stocking of desired species. The species planted are usually native, making these stands difficult to detect during field sampling. No data are available on production from these Western plantations. Of the total softwood plantation area in the US, 65% is located in the Southern region. In this region wood from Pine plantations therefore makes up an important share of the total round wood production (32% of all softwoods and 22% of total round wood from the southern USA in 2002 (Cubbage and Siry 2006)). In the presented data therefore only the pine plantations of the Southern USA were included separately as (fast growing) softwood plantations.

There was some discrepancy between the total area of timberland and the sum of timberland area for different forest types. For the data of 2002 therefore the total timberland area was used and the percentages of each forest type were used to calculate area for each forest type from the total area.

Felled and produced volumes
For the total produced volumes of industrial soft and hardwood in 1990, 2000 and 2005, the data from FAOstat (FAO 2009) were used. The production from the plantations in the southern USA is 20% of the total soft round wood production in the USA (see sheet [calculations] and Cubbage and Siry (2006)). There exist large differences in type of wood production across the USA (Smith et al., 2004). In the North-western region 95% of the industrial round wood produced is softwood, in the Southern region this is 69%, while in the Northern region 75% of the production consists of hardwoods.

The (potential) harvests per hectare from clear felling could be calculated from NAI values (m^3 ha^{-1} yr^{-1}) from Reston and Bothell (1999), who gave values for the different forestry regions of the USA in combination with estimates of the felling cycles (Table 17), 80 years for softwoods, 30 years (Cubbage et al., 2007) for softwood plantations and 130 years for hardwoods. The NAI values for the Southern USA were, however, 0.77 times lower in the Forest inventory and Analysis data base (see Cubbage and Siry 2006). Since the NAI values in Reston and Bothell (1999) appeared to be too high, these were corrected by a factor 0.77. The average harvest per hectare for clear felling in the USA was based on the harvests in the different forestry region and the share (Smith et al., 2004) of each forestry region in the total US industrial round wood production.

There was no information available that allowed calculating the production from clear felling and thinning separately. Therefore the total wood production from natural forests was attributed to clear felling.

The conversion factors for calculation of total felled volume (over bark) from produced volume under bark were based on the fraction of logging residues Smith et al. (2004) and a 14% bark percentage (UNECE/FAO 2000). The conversion factors were 1.24 for softwoods and 1.35 for hardwoods.

Growing stock
U.S. data for growing stock include volume in live sound trees of good form larger than 12.7 cm dbh. to a 10-cm top diameter over bark. It does not include volume of live sound trees of poor form (these 'cull' trees account for about 6 percent of the current total live tree volume), volume above a 10-cm bole top to stem tip for all live trees, or volume of live trees less than 12.7 cm dbh (Smith et al., 2002).

2.3 Tropical forests

For most tropical countries no extensive forest and logging data are available from official websites (or data and literature are available in national languages). Relative numbers of management types, harvested areas, timber yields, losses, damage and growing stock can be found in separate scientific publications. Generally these data relate to smaller area or regions within a country. However, relative figures can be used to make projections for whole countries or larger area. For the tropical countries addressed in this report, Brazil, Indonesia, Malaysia and Nigeria, the FRA 2005 data were used as a basis for produced volumes.

In tropical forestry often a distinction is made between two types of selective logging (logging of only a limited number of commercial species), conventional logging (CL) and reduced impact logging (RIL). During RIL a number of (combinations) of measures are implemented with the purpose to minimise the damage to the residual forest, and in particular future timber trees, as much as possible. During CL those precaution measures are not taken. Although RIL is an emerging harvesting system that receives a lot of attention by forest researchers, its implementation beyond pilot and research-scale experiments is modest. Hence, in contrast to conventional selective logging, data on RIL are mostly based on experimental harvesting under controlled conditions. Although generally the difference between CL and RIL in harvested volumes is not large, the difference in damage to the forest is. Consequently higher yields can be sustained by RIL than CL.

The estimates of felled volumes per hectare for the different management types were based on values in scientific literature. The values reported in different studies in the same regions often showed large variations, possibly leading to high uncertainties. This variation is due to combinations of differences in experimental harvesting set-up, variation in harvesting practices by different logging companies and by variations in available commercial volumes of wood in forests. The FAO (2004a) report gives a good overview of literature with relevant data concerning both conventional and reduced impact logging.

In almost all the treated tropical countries illegal logging is an important source of wood production. It's not clear whether and how these volumes appear in the official statistics, but probably they are excluded. In this study illegally harvested volumes have neither been incorporated in the statistics.

Nowadays in none of the treated tropical countries clear felling is regarded as a forest management system. But in all countries, except Nigeria, clear felling is used for land conversion. In Nigeria so little forest is left, that clear felling is not possible anymore.

Most of the wood production in Brazil is for the local market and only recently the export increased to 36% of the production. The commercial forest resource of Nigeria is almost depleted. For all tropical countries the share of industrial round wood from plantations is increasing form 1990 to 2005. There are, however, large differences among the countries. In 2005, for instance, Indonesia and Malaysia depended on plantations for approximately 12% of their industrial round wood production, Brazil for 33% and Nigeria for 44%.

The volumes felled per hectare under selective logging were highest in Indonesia (93 m^3 ha^{-1}) and Malaysia (65 m^3 ha^{-1}), followed by Nigeria (44 m^3 ha^{-1}) and lowest in Brazil (31 m^3 ha^{-1}). This reflects a higher share of commercial species in forests in Indonesia and Malaysia compared to forest in Brazil, but it probably also indicates highly unsustainable harvest intensities in Indonesia.

For RIL it was assumed that the produced volumes would be similar to those of conventional selective logging (CL). Because generally the harvesting losses and damage to the residual forest is halved in comparison to CL, the volumes that need to be felled under RIL are considerably lower than those of CL. In Nigeria no RIL is applied.

2.3.1 Brazil

Brazil is a large country, with a land area of approximately 8.5 million km^2. In the FRA 2005 (FAO 2006a) it was estimated that the total area of planted and native forest is 4.8 million km^2. However, because the country has no national forest inventory the estimates on forest cover varies widely (e.g. Blate et al., 2002, Thiel and Viergever 2006). Also estimates of the removal of wood vary among the different sources. For example the total amount of industrial round wood harvested in 2005 varied even within different FAO sources. In FAOSTAT (FAO 2009) the reported volume for 2005 was 248,226,619 m^3 while in the FRA 2005 290,476,000 m^3 were reported, a difference of 42 million m^3 or 17%.

The Amazon region which generally receives most attention was estimated to be covered by 3.4 million km^2 of natural forest (FAO 2005a). Apart from the Amazon rain forest there are 4 other important biomes with considerable forest cover: Cerrado and Pantanal with 641,151 km^2 forest (mainly woodland, savannah and dry forest), Caatinga (semi-arid scrub forest, an important source for fuel wood (MMA 2001)) with 478,205 km^2 of forest and the Atlantic rain forest covering 225,715 km^2. It is estimated that of the latter only 7 to 8 percent of the original forest is left (Thiel and Viergever 2006). The depletions of the hardwood stocks in the south, coupled with the construction of strategic access roads have transformed logging in the Amazon region from a minor activity restricted to the floodplain forests bordering the major rivers to a major industry. In the 1970's over half of the wood production took place in the south of Brazil, but currently more than 85-90% of total production comes from the Amazon (Blate et al., 2002, Thiel and Viergever 2006). Therefore in this report the focus will be on the wood production from Amazon forests.

Amazon forest

Logging is one of the principal land uses in the Amazon (Lentini et al., 2004). In 1998 the majority of the wood production (86%) was for the national market, while only 14% of the produced volume was exported (Lentini et al., 2004). In 2004 the proportion exported almost doubled to 36%, mainly due to favourable foreign exchange rates and increased demand for tropical timber in Europe, the USA and Asia (Lentini et al., 2005b).

In the Brazilian Amazon (Figure 4), timber can be legally produced by authorised land clearance or from managed forests (Thiel and Viergever 2006) (Table 7). Based on the considerable disparity between the legally harvested volumes and the amounts consumed by the forest industry it is estimated that substantial amounts of the produced wood is from illegal/unauthorised sources. For example Lentini et al. (2004) estimated that in 2001 47% of the wood processed was illegally harvested, while others estimated it to be as high as 80% (Thiel and Viergever 2006 and references therein) or even 90% (GPTIRID 2004 in Thiel and Viergever 2006).

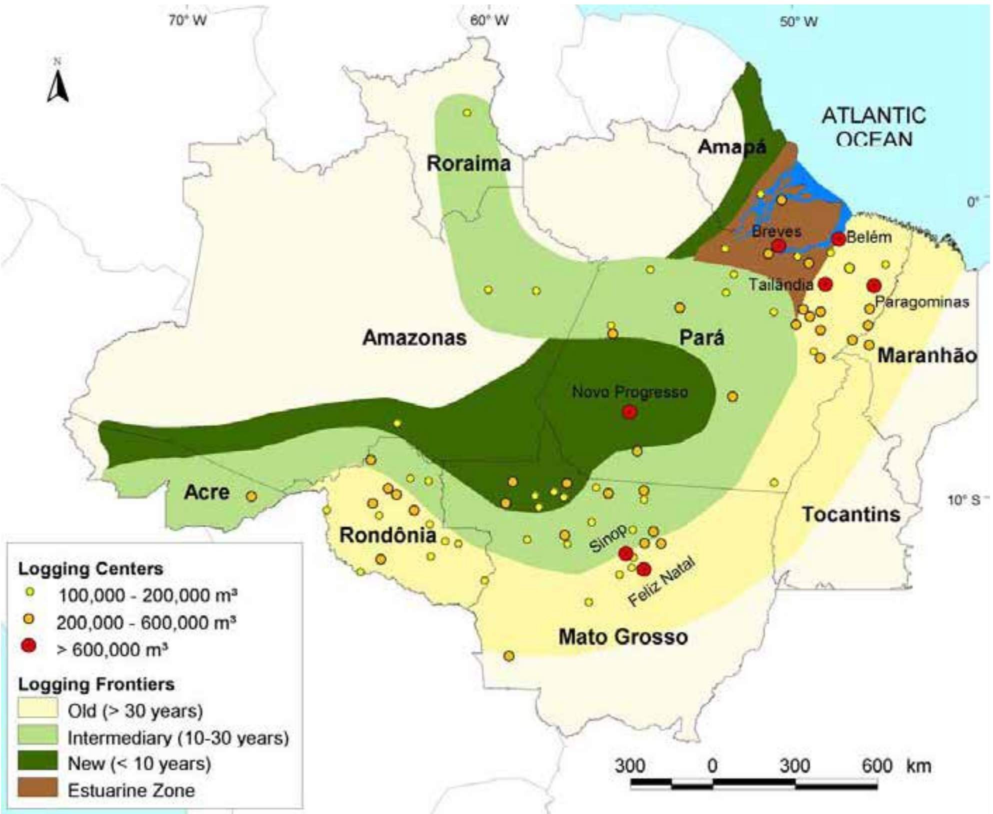


Figure 4.

Expansion of the logging frontier in the Brazilian Amazon, 2004 (from Lentini et al., 2005b).

Table 7.

Produced volumes from authorized timber harvesting (authorised land clearing and approved management plans) and total area covered by management plans (not necessarily all of this area is harvested) in the Legal Amazon 1998, 2000-2004. Data from Lentini et al., 2004 and Lentini et al., 2005a.

Harvest type	1998	2000	2001	2003	2004
Volume from authorised land clearance (m^3)	5,390,000	5,283,200	5,566,200	2,772,500	4,674,400
Volume from Management Plans	unknown	4,134,500	9,373,200	8,217,000	9,353,100
Total volume	-	9,417,700	14,939,400	10,989,500	14,027,500
Total area covered by Management Plans (ha)	1,766,000	184,900	340,400	315,900	342,300

Clear-felling is not a forest management type in the Brazilian Amazon, but historically logging and agricultural frontiers evolved in a mutually beneficial fashion. Annually large areas of land are deforested for agricultural purposes. In general, ranchers sell trees to finance forest conversion. For loggers it is easier and less expensive to buy wood from areas of forest conversion than to obtain it through forest management plans. Loggers in turn open access roads for agriculture and offer transportation. In addition they frequently are involved in the opening of roads in response to local political interests. In this report, however, the wood production from conversion is presented as clear felling.

RIL vs. conventional selective logging
Most of the used data sources are studies from the 1990's, when development of RIL techniques was an important issue within forestry research (although foresters have been recommending implementation of methods that reduce the impact of logging for nearly a century (see Putz et al., 2000a)). Most data and information on effects and productivity of harvesting with RIL are therefore based on experimental situations.

The adoption of more sustainable forest management and RIL practises by logging companies is very slow (Blate et al., 2002, Lentini et al., 2004,Putz et al., 2000a). For instance, in 2001, the volume of wood extracted from forest with management plans based on criteria suggested by Brazil's environmental agency, IBAMA (Institute of the Environment and Renewable Natural Resources), represented only one third of the wood harvested in the Brazilian Amazon (Lentini et al., 2004).

However, no extensive data of the area on which RIL is implemented are available. Blate et al. (2002) interviewed 12 people in Brazil (including seven representatives of logging companies) about the level of implementation of RIL practises (Table 8). The area represented by the seven Brazilian companies interviewed is about 800,000 ha. They found that the number of companies beginning to adopt key aspects of RIL increased since 1995. In 1995 almost no companies applied practises that minimised impact of logging or increased efficiency. However, in 1999 four companies with management areas of some 81,000 ha had incorporated planning and other pre-RIL elements in their operations, while in 2000 six companies (> 385,000 ha) were implementing key aspects of RIL. Aspects these companies had in common were that they were large and vertically integrated with access to capital and large forest areas and all invested in appropriate technology and trained personnel (Blate et al., 2002).

Table 8.
Extent to which specific RIL practices have been implemented by producers in the Brazilian Amazon from 1995-2000. Numbers are on a 0 to 4 scale; 0 = no one; 1 = few; 2 = some; 3 = most; 4 = all. Producers were assessed in two classes: east refers to companies situated east of Manaus, west refers to companies operating, e.g. in Acre. From Blate et al., 2002).

Practice	West Brazil	East Brazil
Forest Management Plan approved	2	3
Annual Operating Plan approved	1	3
Annual operating coupe demarcated	2	3
100 percent census ≥ felling diameter limit	1	2
Mapping	1	2
Vine cutting	1	2
Minimum road & skid trail network	1	3
Bridges and culverts	2	3
Log decks	1	2
Crop trees marked	2	3
Crop trees checked	1	3
Future crop trees marked	0	2
Directional felling	0	2
Low stumps	1	3
Maximum bole and branch use	2	3
Road/skid trail planning	2	3
Skidding w/minimal soil disturbance	2	2
Watercourse protection	2	3
Maximum bole and branch use	2	3
Road/skid trail planning	2	3

Practice	West Brazil	East Brazil
Skidding w/minimal soil disturbance	2	2
Watercourse protection	2	3
Seed trees and/or other efforts for regeneration	2	2
Safety equipment	2	3
No hunting	2	3

However, no extensive data of the area on which RIL is implemented are available. Blate et al. (2002) interviewed 12 people in Brazil (including seven representatives of logging companies) about the level of implementation of RIL practises (Table 8). The area represented by the seven Brazilian companies interviewed is about 800,000 ha. They found that the number of companies beginning to adopt key aspects of RIL increased since 1995. In 1995 almost no companies applied practises that minimised impact of logging or increased efficiency. However, in 1999 four companies with management areas of some 81,000 ha had incorporated planning and other pre-RIL elements in their operations, while in 2000 six companies (> 385,000 ha) were implementing key aspects of RIL. Aspects these companies had in common were that they were large and vertically integrated with access to capital and large forest areas and all invested in appropriate technology and trained personnel (Blate et al., 2002).

Várzea and terra firme forests

Generally two main forest types are distinguished in the Brazilian Amazon, várzea and terra firme forests. Várzea forest, or floodplain forests, lie next to rivers and are subjected to daily (e.g. Amazon estuary) or seasonal (e.g. beyond about 800 km up the Amazon river) flooding (Barros and Uhl 1995). Terra firme forests are on dry lands that are not seasonally flooded. The wood from terra firme forests is, generally, more dense (i.e. heavier) and is therefore valued more than that of várzea forest.

During an assessment in 1990-1991 in várzea forests, Barros and Uhl (1995) found that trees were in most cases still felled by axe; wood cut by chainsaws was present in only 19% of the 63 mills visited. In 90% of the cases trees were extracted from the forest manually, while in the few other cases alternative techniques such as water buffalo (8%) or hand operated winches were employed (Barros and Uhl 1995). In general the logs from várzea forests are transported to mills over water as log rafts.

In contrast to várzea forests, in terra firme forests a more mechanised approach is used (Barros and Uhl 1995); Chainsaws are always used for felling and skidders and trucks are used to transport logs from the forest interior to the river's edge or public road. Timber from terra firme forests are, generally, transported to the mills over water on barges or over land by trucks. Current logging in várzea forest was estimated to provide 25% of the wood used in the Amazon (estimation not based on data: Blate et al., 2002). The volume harvested from these várzea forests ranges from 5 to 10 m^3 ha^{-1} (Uhl 1990 in Macedo and Anderson 1993, Blate et al., 2002)

Uhl et al. (1997) distinguished two types of selective logging for várzea forest and three types for terra firme forests in the eastern Amazon in Brazil (Table 9). As forest frontiers age (see Figure 4) and infrastructures and access to markets improve, logging in terra firme forests changes from highly selective with low impact to a more generalist harvest with high impact (Uhl et al., 1997). They concluded that only in rare instances forests in the Brazilian Amazon are managed sustainably for timber production (in 1997).

Were possible in the data a distinction was made between terra firme and várzea forests. Most of the scientific literature, however, is based on terra firme forests.

Table 9.
Types of logging in the eastern Amazon in Brazil in the 1990's (from Uhl et al., 1997)

Model	Selectivity of timber harvest	No. of species harvested	No. of trees harvested per ha	Economic / social system
Várzea –traditional	Highly selective low impact	1-2	1-2	Paternalistic - local people
Várzea – contemporary	General harvest high impact	± 50	>10	Cottage industry-local families
Terra firme -incipient frontier	Highly selective low impact	1	<1	Big business -diversified well-capitalized company
Terra firme -new frontiers	Somewhat selective moderate impact	5-15	1-3	Small family business - from outside region
Terra firme - old frontiers	General harvest high impact	100-150	5-10	Large family business - from outside region

Calculations
The data from the FRA 2005 country report for Brazil (FAO 2005a), which gives all volumes over bark, were used as a basis for further elaboration.

From the data presented in Nepstad et al. (1999; Table 10) it was calculated that the average volume selectively harvested per hectare was about 25 m^3 over bark (it was assumed that volumes presented in scientific papers are volumes over bark). This value was supported by data provided in various other papers (Uhl and Vieira 1989, Uhl and Kauffman 1990, Uhl et al., 1991, Johns 1991, Verissimo et al., 1992, Silva et al., 1995, Barros and Uhl 1995, Johns et al., 1996, Ivo et al., 1996, Gerwing et al., 1996, Uhl et al., 1997, Holdsworth and Uhl 1997, FAO 1997, Barreto et al., 1998, Holmes et al., 2002a, Holmes et al., 2002b, Schulze and Zweede 2006).

From this harvested volume, the felled volume per hectare (m3 over bark) was calculated by adding the losses due to improper felling and trees felled but left in the forest. For conventional selective logging (CL) the losses were estimated to be 25% of the harvested volume (see section on conversion factors below) and for RIL these losses were estimated to be 4% of the harvested volume. This results in 31.25 m^3 o.b. felled per hectare for CL and 26 m^3 ha^{-1} for RIL.

Uhl et al. (1991) estimated that on average 127 m^3 ha^{-1} of harvestable wood was present in cleared stands. This value was further used as volume felled per hectare in the cases of clear felling in Brazil.

Total volumes harvested from native forests (excluding plantations) for industrial round wood production for the years 1990, 2000 and 2005 were taken from the FRA2005 country report (FAO 2005a). Based on the relative share of these two management types in the overview provided in Lentini et al. (2004 and 2005a) (see Table 7) the total harvested volumes were distributed over the two main management types selective logging (both CL and RIL) and clear felling. Subsequently, guided by the results from Blate et al. (2002, Table 8), the share of selective logging was subdivided in CL and RIL assuming that in 2000 in about 30% of the selectively logged forests key aspects of RIL were implemented and in 2005 in about 50% of the selectively logged forest. Until 1995 no RIL was applied in Brazil (Blate et al., 2002).

Table 10.
Round wood production, logging intensity and rates (1996-97), and deforestation in the Brazilian Amazon (Nepstad et al., 1999).

State	**Total no. of mills**	**Mills studied (%)**	**Round wood production (10^6 m^3)**	**Intensity of logging (% of production)***			**Forest area affected (km^2 yr^{-1})**			**Original forest area (km^2)**
				Low	**Med.**	**High**	**Logging 1996-97**	**Deforestation 1993-95**	**1996**	
Acre	25	55	0.3	100	0	0	120-210	720	430	152,394
Amapa	89	80	0.2	100	0	0	80-140	0	0	137,444
Amazonas	20	60	0.7	100	0	0	290-500	950	1,020	1,531,122
Maranhão	52	49	0.7	0	0	100	160-200	830	1,060	145,766
Mato Grosso	708	48	9.8	100	0	0	4,080-7,000	7,610	6,540	527,570
Pará	1,324	43	11.9	11	61	28	3,560-4,910	5,470	6,130	1,183,571
Rondônia	272	55	3.9	25	75	0	1,320-1,920	3,310	2,430	212,214
Roraima	25	52	0.2	100	0	0	80-140	230	210	172,425
Tocantins	18	53	0.1	100	0	0	40-70	490	320	30,325
Total	2,533	48	27.8	49	41	10	9,730-15,090	19,610	18,140	4,092,831

*: Low intensity logging 19 (14-24) m^3 ha^{-1}; medium intensity, 28 (24-32) m^3 ha^{-1}; high intensity, 40 (35-45) m^3 ha^{-1}.

The total area harvested in 1990, 2000 and 2005 by each management type ([AreaHarvestedAnnua]) was calculated using the volumes harvested per hectare (see above) and the total volumes harvested by each management type. Subsequently the total volume felled per hectare could be calculated using the area harvested annually and felled volumes.

Plantations
In 2005 Brazil had about 5,383,729 ha of productive plantation from which 138,177,000 m^3 o.b. industrial round wood and 74,649,000 m^3 o.b. fuel wood were extracted (FAO 2005a).

The FRA2005 country report for Brazil lists the total areas of the most important types of forest plantations for 1990, 2000 and 2005) Data for 1975 and 1980 were taken from FAO (1995). Most important forest plantation types exist of *Pinus* spp. (fast growing softwood) *Eucalyptus* spp. (fast growing hardwoods), *Araucaria angustifolia* (slow growing softwood), *Tectona grandis* (Teak, slow growing hardwood), *Mimosa scabrella* (fast growing softwood, but mainly used for production of fuel wood and therefore excluded from the analysis), Populus (fats growing hardwood) Acacia (fast growing hardwood) and *Hevea* (Rubber, slow growing hardwood).

For each of these plantation species the production per ha was assessed from various literature sources (Couto and Betters 1995, FAO 2001b, FAO 2003, Colorado State University 2003, Carvalho 2003, Bhat and Ma 2004). If no production per ha was found, it was calculated using mean annual increment (MAI, m^3 ha^{-1} yr^{-1}) and rotation time (yr).

The share of each plantation type in the total round wood production from plantations was not available and therefore it was assumed that this is distributed according to the potential production of each type. This potential production was determined taking into account the rotation length and assuming that the total area of this plantation type would be mature enough to harvest. If for instance the rotation length is 15 years, the area with plantation 15 years ago determines the maximum potential production now. To determine this potential production in 1990 for Eucalyptus, Populus and Acacia the plantation area from 1980 was used and for the other species the area covered in 1975 was used. For the potential production in 2000 for Eucalyptus, Populus and Acacia the plantation area from 1990 was used, for Pinus that of 1980 and for the other species the area covered in 1975 was used. For the potential production in 2005, for Acacia the plantation area of 2000 was used, for Eucalyptus and Populus the area of 1990 was used, and for the other species the area covered in 1980 was used.

For each plantation type the relative distribution of potential productions in 1990, 2000 and 2005 was then used in combination with the total removal of industrial round wood to determine for each type the actual production (volume, m^3 o.b.) in 1990, 2000 and 2005. This total production was the again divided by the production per hectare to get for each type the total plantation area (ha) harvested.

Conversion factors

The average bark percentage were based on the data in the TBFRA 2000 (UNECE/FAO 2000) which had average bark percentages of 12% for hardwoods and 13% for softwoods. As trees from plantations are generally thinner than trees from (semi) natural forests (especially in short rotations) and the relative amount of bark is higher for thinner trees, for plantations 5% was added to the above bark percentages. This 5% is not based on data, but still included to discount for the anticipated higher bark percentages.

Based on various sources (Uhl et al., 1991, Gerwing et al., 1996, Uhl et al., 1997, Barreto et al., 1998, Holmes et al., 2002b) the losses due to improper felling and trees that were felled but left in the forest was estimated to be 25% (range: 3-35%) for conventional selective logging and around 4% for RIL (range: 1-9%). The contribution of improper felling to the losses during conventional selective logging was about 5% (2-7%; Uhl et al., 1997, Barreto et al., 1998). For clear felling and plantations it was assumed that there are only losses due to improper felling (5%).

The used conversion factors to convert from felled volume (m^3 over bark) to produced volumes (m^3 under bark) then are the sum of the bark percentage and losses (Table 11).

Table 11

Conversion factor giving the felling volume (over bark) per cubic metre of round wood production (under bark) for different management types and species types. This conversion factor is based on the bark percentage and the percentage losses due to improper felling and felled trees left in the forest.

Management type	Species type	Bark percentage (%)	Losses (%)	Conversion factor
Selective (CL)	**Hardwood**	12	25	1.37
Selective (RIL)	**Hardwood**	12	4	1.16
Clear felling	**Hardwood**	12	5	1.17
Plantation	**Hardwood**	17	5	1.22
	Softwood	18	5	1.23

Sustainability

Using a yield simulation model for the Tapajos forest in the eastern Amazon, van Gardingen et al. (2006) found that the current management regulations of a maximum extraction of 35 m^3 ha^{-1} in combination with a 30 year felling cycle was not sustainable. Only a limited number of the tested potential management options were found to be marginally sustainable. The best of these were the combinations of 10 m^3 ha^{-1} yield and a cutting cycle of 30 years or 20 m^3 ha^{-1} with a 60-year cutting cycle.

Post-logging mortality

In selectively logged forest many trees are left damaged, but not directly killed. These damaged trees have substantially higher mortality rates than individual trees in un-logged stands (e.g. Putz et al., 2000b, Holmes et al., 2002a, Schulze and Zweede 2006). This can lead to larger canopy openness and increased susceptibility to forest fires and wind-throw in logged forests (Schulze and Zweede 2006). Losses of residual timber stocks as a consequence of these two types of post-logging mortality were not taken into account in the estimation of conversion factors.

2.3.2 Congo , Democratic Republic of

The Democratic Republic of the Congo (DRC) has about 135 million hectares of natural forests - 10 percent of the world's tropical forests and about 45 percent of those in Africa. The forests are composed of lowland forests, closed montane forests, closed forests, open and gallery forests, transition forests, savannahs and mangroves.

Products and trade

The harvesting rate is low, given an estimated production potential of about 6 million cubic metres. Less than 100,000 ha of forest are now allocated each year for harvesting, as against 87,924 ha in 1996, 87,550 ha in 1997 and 68,609 ha in 1998. The share of industrial operators has been estimated at about 98%, while that of small-scale enterprises (with pit saws) is only 2%. Low harvesting rate is related not only to a lack of access and infrastructure, but more especially to the state of conflict and instability the country has been experiencing over the past ten years.

Harvesting has steadily become concentrated in the more accessible zones and in inhabited zones such as Kivu (where more than 50,000 m^3 a year are currently being extracted). There is an endemic situation of illegal extraction.

Besides timber, forests meet about 90% of the people's fuel requirements, especially in large urban centres such as Kinshasa. Fuel wood consumption has been estimated at about 6 million m^3. Especially shifting cultivation for food production is an important driver of forest degradation. It takes over an area of forest that is estimated at about 532,000 ha each year (see also chapter 3 on forest conversion). This phenomenon has been exacerbated by the huge influx of refugees following the tragic events in Rwanda in 1994, a situation continuing today with the inter-Congolese conflict.

History of Logging

In 1949 major changes in the forestry of the Democratic Republic of Congo occurred, for example the classifying of logs was adapted and several foreign forest industry companies were established. This was also the first year when production was registered. In the beginning of the1960s the production of industrial round wood was roughly 1.5 million m^3, and has been growing since. In 1998 it was 2 million m^3 more. The production of fuel wood is about 11 times larger. Nevertheless, the country still possesses almost half of Africa's rainforests.

Forest management plans

Of all existing plantation areas - there were 97,000 ha in the year 2000 - only about four percent have actually benefited from intensive forest management, involving silvicultural treatments and management plans. At the present time, and with the exception of the work of SPIAF which has produced several management plans for natural forests, there is no intensive forest management in the DRC.

A major objective of national forest management policy is to promote forest harvesting on the basis of sustained yields backed by efficient forest industries so as to enhance the contribution of the sector to DRC's socio-economic development.

Harvesting practices
Companies undertaking forest activities in the Democratic Republic of Congo can be placed into a number of categories. One major foreign-owned company is responsible for more than one third of all logging. This company has its own river transport system for logs, sawn wood and veneer upstream of Kinshasa, as well as its own road transport system from Kinshasa to the Atlantic port.

Exploitation is mostly concentrated in the western part of the country, near the ocean, and the harvesting methods are quite similar to those commonly utilized in tropical forests. After the felling there is either cross-cutting of the tree into logs on the felling site and skidding of the logs to the landing, or skidding of the bole to the landing and cross-cutting it there. The logs are usually transported on trucks straight to the factory or to the harbour.

The Government is not directly involved in forest exploitation in the DRC, and therefore there are no public logging companies. Forest harvesting is regulated by two legal procedures. The first is small-scale logging using cross-cut saws, for which a simple felling permit is sufficient and with no compulsory reforestation. The second is large-scale industrial logging, basically for export.

Forest harvesting in the DRC is selective. The most important species exploited are *Afzelia pachloba, Diospyros crassiflora, Entandrophragma angolense, Entandrophragma candollei, Entandrophragma cylindricum, Entandrophragma utile, Millettia laurentii, Terminalia superba*, (FAO 2008c). In the case of timber for mining purposes and for charcoal, clear-felling is the practice in harvest areas. Reforestation the following year accompanied by a five-year reforestation plan is compulsory.

Calculations
Selective logging is mainly done by extracting 1 to 2 large trees (>60 or >80 cm DBH) per ha totalling approximately to 0.1 to 13 m^3 (Marien, J.-N., personal communication, FAO 2004a, Ruiz Perez et al., 2005), with an average productivity of 6.1 m^3 ha^{-1}. The volume of timber currently harvested in DRC appears to be only a small fraction of the sustainable yield, even if accounting for the likely significant levels of illegal logging (ITTO 2006). It was assumed that no RIL is applied in DRC (FAO 2004a).

No direct information was available on the losses and conversion factor for harvested to produced volumes in DRC. Therefor information was used from better studied sites in Cameroon with similar logging practices and species as in DCR. Losses amount to 30%. For conversion from over bark to under bark the same bark percentages were used as for Malaysia and Indonesia (15%). The resulting conversion factor to convert o.b. harvested volume to u.b. produced volume is 1.8.

2.3.3 India

India is the seventh largest country in the world with a total surface of 3.29 million km^2 (79 times larger than the Netherlands). The country has 1% of the global forest area within it's borders with 16% of the world's human population. In the latest forest inventory in 2002 India's forest cover was estimated to be about 67.8 million hectares (Kishwan et al., 2007), or 20.6% of the country's area. The area of forest per inhabitant of 0.08 ha is one of the lowest in the world, with an average per caput availability of forest land of 0.64 ha (MOEF 1999). The average annual forest productivity in India of 0.7 m^3 ha^{-1} yr^{-1} is relatively low compared to the world's average of 2.1 (MOEF 2002).

Of the total forest area, 5.1 Mha (7.5%) is classified as very dense forest (>70% canopy cover), 33.9 Mha (50%) as moderately dense forest (40-70% canopy cover) and 28.8 Mha (42.5%) as open forest (10-40% canopy cover) (Kishwan et al., 2007). In qualitative terms the dense forest in almost all the major states has been reduced and forest degradation is a matter of serious concern in India.

Since independence in 1952, until the 1980's the national forest policy (NFP) considered forests as an important source of direct revenue, putting the forest subordinate to the development needs of India. From the 1980's onwards the conservation of forests became more important. This was reflected in the latest NFP from 1988 in which the importance of management plans is recognised. This resulted in a paradigm shift from production oriented forests management to more conservation oriented management (Kishwan et al., 2007). This change in views towards forest management has seriously affected the forest based industries in India, which heavily depended on supply of raw materials from state forests. As a result the import of timber has risen and industries have started obtaining raw material from private tree growers (Kishwan et al., 2007) with trees outside forests.

After China, India has the world's largest plantation area with more than 32 million ha (17% of world's total plantation areal) (FAO 1999). The most important plantation species are *Eucalyptus* spp., *Acacia* spp. and *Tectonus grandis* (teak) with a share of respectively 25%, 20% and 8% in 2000 and 20%, 1% and 22% . Other commonly planted broadleaves are *Albizia* spp., *Azadirachta indica*, *Casuarina equisetifolia*, *Dalbergia sissoo*, *Gmelina arborea*, *Populus* spp. *Prosopis* spp., *Shorea robusta* and *Terminalia* spp (FAO 1999). Among conifers, *Cedrus deodara* and *Pinus roxburghii* occupy a major area. *Pinus patula* and *P. caribaea* have been planted to a limited extent (FAO 1999).

Products

Forests formally contribute 1.7% to India's GDP. India produces a wide range of processed forest (wood and non-wood) products ranging from sawn wood, panel products and wood pulp to bamboo, rattan ware and pine resin. The paper industry produces over 3 million tonnes annually from more than 400 mills, but a substantial amount of the raw material to produce that volume comes from non-wood fibre like bamboo (MOEF 2006). The industrial round wood production harvested in 2005 was about 23,2 million m3 (FAO 2007). This supply of timber is for about 50% from forest plantations (MOEF 2006) and the wood production is showing a negative growth rate. India is the world's largest consumer of fuel wood. The country's consumption of fuel wood is about five times higher than what can be sustainably removed from forests, but a large percentage of this fuel wood is grown and managed outside forests.

Calculations

As basis for total production of industrial round wood the volumes as reported in FAO-stat were used. The production data reported in the FRA 2005 country report for India (FAO 2005c) were not used because they show a strong decreasing trend in round wood production that is not supported by the data of FAOstat (FAO 2007) and neither by other reports and papers.

The total plantation area of 32 million ha as reported by the FRA2000 (FAO 1999) is in strong contrast to the 3.2 million ha of forest plantations as reported for the FRA 2005 (FAO 2006b, FAO 2006c). In the FRA 2005 reports, however, also semi-natural forest was distinguished. In 2005 60% of the semi-natural forest area was productive (66% in 1990, 62% in 2000; FAO 2006c). Since the underlying data of species composition, MAI, rotation length were exactly the same for the planted component of *productive* semi-natural forest and productive forest plantations, these were combined and regarded as productive forest plantations within the current study.

The fraction of industrial round wood produced form forest plantations increased gradually from 45% to 48% to 52% in respectively 1990, 2000 and 2005 (MOEF 2006). We assumed that in this respect there is no difference between soft and hardwoods. Thus for 2005 52% of the total round wood production was attributed to plantations, both for soft and for hardwoods and the remaining percentage was attributed to clear felling and selective logging. No direct information is available, however, on the relative contribution of these two management types to wood production. Therefore the total area under each management type was estimated based on the predominant management type in the different forest types (Table 12). From this can be estimated that 66% of the modified natural forest area will be clear felled and 35% is subject to selective logging. Subsequently this relative distribution of area was combined with felled volumes per ha to calculate the potential total production for each management type (below).

The reported average standing stocks in India are very low (43 m^3 ha^{-1}; Straatsma and Jansen (2005) and 69 m^3 ha^{-1}; FAO (2005c)), probably due to the large area of intermediate-open and degraded forests. Because no information is available on harvested volumes per hectare, the average growing stock per hectare was used as an estimate for felling volume from clear felling. Because this likely is an underestimation of the harvest volumes, the higher value of 69 m^3 ha^{-1} (FAO 2005c) was used.

Also no information on felled and produced volumes per hectare were available for selective logging. Therefore the average ratio (0.58) of harvested volumes between selective logging and clear felling inferred from the Malaysian (0.42) and Indonesian (0.74) data was used to estimate the felled volume of selective logging from the felled volume of clear felling (0.58*69= 40 m^3 ha^{-1}).

Table 12

Main forest management type per forest type in India. Forest type and area are from MOEF (1999). Forest management type is interpreted from FAO (2008c)

Forest type	Area (Million ha)	Forest management
Tropical wet evergreen forest	4.5	Selective
Tropical Semi Evergreen Forest	1.9	Selective
Tropical moist deciduous forest	23.3	Clear felling
Littoral and swamp forest	0.7	
Tropical dry deciduous forest	29.4	Coppice
Tropical Thorn forest	5.2	-
Tropical dry evergreen forest	0.1	Selective
Subtropical broad-leaved hill forest	0.3	-
Subtropical pine forest	3.7	Selective
Subtropical dry evergreen forest	0.2	Selective
Motane wet termperate forest	1.6	Selective
Himalyan moist temperate forest	2.6	-
Himalayan dry termperate forest	0.2	-
Sub alpine	3.3	-
Moist alpine scrub forest	3.3	-
Alpine forest	3.3	-

The total potential production of clear felling and selective logging was estimated based on the total forest areas available for both management types (see above) and the felled volumes per hectare for each. The ratio between these potential total fellings were used as estimate of the contribution of both management types to industrial round wood production; 18% selective logging and 82% clear felling. This is, however, only a very rough proxy and this parameter should be updated if new information becomes available.

The used conversion factors of 1.2 for clear felling and 1.65 for selective logging were the based on the average between Indonesia and Malaysia.

2.3.4 Indonesia

The description (Box 2) of forest management in Indonesia was taken from FAO's website of Indonesia's country profile for the forestry sector (http://www.fao.org/forestry/site/25550/en/idn/). More information can also be found in e.g., MoF (1998), Brown (2002) and ITTO (2006).

The data from the FRA2005 country report for Indonesia (FAO 2005d) were used as the basis for total industrial round wood production and production from natural and planted forests. The low values for production in 2005 in the FRA2005 data are probably an underestimation as a result of deficient reporting since the decentralisation of the forestry system in Indonesia in 1999 (see Brown 2002).

Therefore the data from FRA2005 were adjusted based on the relative difference between the 2000 and 2005 production data in FAOstat (FAO 2009), i.e. production of industrial round wood in 2005 is 97% of that in 2000. In general the production statistics as reported by Indonesia appear to be rather unreliable, while illegally harvested volumes appear to be more than double the official statistics (Brown 2002, Freezailah et al., 2002).

The share of selective logging is based on data in Brown (2002). 'HPH' and 'Hutan rakyat' were considered to be selective, which is 46% of total round wood production and 63% of production from natural forests. No direct information was available on the shares of CL and RIL within the selectively logged forests. ITTO (2006) estimated, however, that about 6% of the forest in Indonesia is managed sustainably. Subsequently it was assumed that this sustainably managed area is harvested according at least basic RIL practices. It was further assumed that before 1995 no RIL was applied and that the share of RIL in total harvesting was the same in 2000 and 2005. Clear felling produced 27% of all round wood and 63% of production from natural forests.

The harvested volumes presented in different studies on selective logging (both RIL and CL, see FAO 2004a) widely vary (30-250 m^3 ha^{-1}). Most reported average harvests were around 40-80 m^3 ha^{-1}. Using 60 m^3 ha^{-1}, and taking into account the losses (Table 13), estimated volume felled per hectare was 93 m^3 o.b. ha^{-1} for CL and 76 m^3 o.b. ha^{-1}. The volume of commercial trees per hectare varied between 100 and 150 m^3 o.b. ha^{-1} (FAO 2004a). Therefore 125 m^3 o.b. ha^{-1} was used as the felled volume per hectare for clear felling.

According to the data in Brown (2002) 81% of the industrial round wood from plantations is from fast growing species (hardwoods and softwoods), and 19% is from slow growing (Teak) plantations. It was assumed that these shares were similar for all years. The share of softwood plantations (only fast growing) was based on the produced volume of softwoods as provided by FAOstat (FAO 2009), for which it was assumed that the total industrial softwood came from plantations. The produced volumes per hectare used for the different plantation types were the same as for Malaysia.

No data were found on the harvesting of rubber wood in Indonesia. It is likely, however, that this wood from rubber plantations is, or will become, an important source of valuable round wood.

Conversion factors
The same bark percentage was used as for Malaysia (Table 13). In forests harvested according conventional logging, losses amount to about 50-60% of the harvest (several references for Indonesia in FAO 2004a) while these losses are reduced by approximately 50% using RIL techniques (several references in FAO 2004a). For plantations the same loss percentages were used as for Brazil (5%) and.

There has been active forestry on Java for centuries but on the Outer Islands the development of the forest sector began late. When forest exploitation began, the timber industry had not yet developed so that until the end of the 1970s all logs were exported to other countries from the Outer Islands. The Indonesian Government began to award forest concessions to private companies under the 1970 Forestry Law, which grants concessionaires the sole right to cultivate and exploit forests in their concession areas. Log production from these forests consistently increased from 1995 until the late 90s, but started to decrease in 1998 in conjunction with the economic crisis. In 1999 a ban on log exports from 1985 was lifted.

National responsibility for forest management in Indonesia rests with the Ministry of Forestry and Estate Crops (MoFEC). The Ministry provides policy and guidelines for managing forest; it delegates management of production and limited production forests to private concessions and state-owned enterprises, and designates conversion forests for timber harvests followed by conversion to agricultural and other non-forest uses. Implementation is done by forestry state enterprises, private companies, NGOs and communities.

The conversion of forestland to estate crops has not been constrained to control the market, either by Government or industrial infrastructure. Licenses for forest conversion are obtained upon request and the process by which forest areas are declared conversion forest is neither regulated nor transparent.

The Basic Forestry Law of 1967 established the basis for commercial exploitation of forests by providing MoFEC with the authority to grant HPH (Hak Pengusahaan Hutan) timber concession licenses in areas designated as production and limited production forests. The Government regulation of 1970 provides the HPH holder with a non-transferable right for 20 years, and stipulates that the concessionaire follow the principles of sustainable forest management as prescribed by the Indonesian selective logging and planting system. The system prohibits harvesting trees with a diameter of less than 50 cm in production forest and less than 60 cm limited production forest, and to follow a 35-year rotation to permit adequate regeneration. Swamp forest and lowland dipterocarp forests are subject to slightly different management regulations.

The ministry and the HPH holder sign an agreement that contains rules for long-term planning, harvest levels based on annual work plans, land rehabilitation after harvests and community development. The applicant guarantees the establishment of a vertically integrated forest industrial activity in association with the concession.

The different fees the concessionaire is obliged to pay include an annual area-based fee paid at the granting of the concession, the reforestation fee per cubic meter of wood harvested and a royalty on logs charged on the basis of weight or volume.

Illegal logging is a major problem, and it is thought to account for a harvest of roughly the same size as official production. The MoFEC has been conducting serious efforts to reduce this logging by strengthening administrative control and security patrol.

Exploitation of the forests in Indonesia is mainly done by private and state-owned timber companies, which hold a HPH, for 20 years. Concession agreements exist for even longer than 20 years. The exploitation is supervised by the Ministry of Forestry and Estate Crops. Each concessionaire has to prepare an annual management plan which comprehensively addresses the sustainable management of the concession area. This plan should specify the inventory works, road network development and maintenance, production, marketing, employee training, equipment usage, practical operational research, silvicultural activities on the logged areas and community development. The concessionaire is also required to submit for approval a 5-year management plan and an overall management plan that covers the entire duration of logging operations as well as an environmental impact assessment report for the concession area.

Indonesia has adopted a 35-year rotation system and the forest area is divided into 35 compartments of equivalent size. Every year, one compartment is harvested, so that the first compartment will be re-harvested after 35 years. A concessionaire is required to harvest previously unlogged forest first to prevent pre-mature re-logging.

Conversion forests are usually logged by clear cutting, whereas other concessions are harvested by selective logging. The cutting is done by using heavy chain saws, and the logs are normally extracted from the forest by bulldozers. Tracked skidders also seem to be gaining ground. Since high lead logging is no longer permitted, there are - or at least have been - fairly large trials with other methods of cable logging. Concession holders often lack skilled manpower and guidance from field foresters, which affects the logging efficiency and the stand quality.

Box 2. Forest management practices in Indonesia. Text from: http://www.fao.org/forestry/site/25550/en/idn/

Table 13
Conversion factor giving the felling volume (over bark) per cubic metre of round wood production (under bark) for different management types and species types in Indonesia. The conversion factor is based on the bark percentage and the percentage losses due to improper felling and felled trees left in the forest.

Management type	Species type	Bark percentage (%)	Losses (%)	Conversion factor
Selective (CL)	Hardwood	15	55	1.70
Selective (RIL)	Hardwood	15	27	1.42
Clear felling	Hardwood	15	5	1.20
Plantation	Hardwood	20	5	1.25
	Softwood	21	5	1.26

2.3.5 Malaysia

The description (Box 3) of forest management in Malaysia was taken from FAO's website of Malaysia's country profile for the forestry sector (http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=MYS&subj=5). More information can be also be found in e.g. Thang (1987), Mok (1992), FDPM (2006), ITTO (2006) and Wells (2006).

Calculations
It was assumed that since the introduction of the Selection Management System in the 1970's the modified MUS has been abandoned gradually and that in 1990 most forests areas were logged using the SMS (P. Zambon, pers. communication). It is also assumed that clear felling is only being used for conversion of forests and on state lands (forested areas earmarked for future development - FAO 2005e). Mok (1992) reported that in 1990 the total log production of about 18.8 million m3 comprised 7.8 million m^3 (41%) from PFE's, 4.7 million m^3 (25%) from state land and 6.3 million m^3 (34%) from agri-conversion (oil-palm and rubber). Hence in 1990, 41% of the round wood production is from SMS logging and plantations and 59% is the result of clear felling. Because the rate of increase in total area of Oil-palm plantations (most important source of agri-conversion) was linear from 1990 to 2003 (FAO 2005e) it was assumed that the share of clear felling is the same in each year.

FAO (2002) estimated that total annual production from plantations was 1,800,000 m^3. Because this is the only estimate found, this value was used for all years. FAO (2002) also estimated that in 2000 rubber plantations produced 2 million m^3 of wood logs. It was assumed that this was also the case in 2005, while rubber wood was not utilised in 1990. Using the production value used for *Hevea* in Brazil (107 m^3 ha^{-1}), the total area of rubber plantations harvested annually is estimated to be 18,691 hectare. To calculate the total production (m^3 over bark) by selective logging, the 3.8 million m^3 production from plantations was subtracted from the 41% of the total round wood production in 2000 and 2005, and 1.8 million m^3 in 1990. Harvested areas then were calculated for each management type by dividing the produced volumes by the volume produced per hectare (below) (see sheet [Malaysia data].[Calculations]).

In Peninsular Malaysia, two silvicultural systems are practiced, the Malayan Uniform System (MUS) and the Selective Management System (SMS). The MUS is effectively a system for converting virgin tropical lowland dipterocarp forest into an approximately even-aged forest containing a high proportion of the commercial species to be managed under the uniform system. This is achieved by clear-felling mature trees down to a minimum diameter at breast height (DBH) of 45 centimetres. This is followed by the release of selected natural regeneration of varying ages, aided by systematic poison girdling of defective and non-commercial species. The MUS focuses mainly on the seedlings and saplings that are expected to form the bulk of the next harvest. This has led to much heavier poison girdling of trees than is necessary and also drastic opening of the canopy. Hence, over the years this emphasis has led to a more discriminating approach to poison girdling and a more conservational approach in silviculture treatments (known as the “modified” MUS).
The SMS was introduced in the 1970s when the MUS was found to be unsuitable for managing hill dipterocarp forests in Peninsular Malaysia. The comparatively more difficult terrain, uneven stocking, lack of natural regeneration on the forest floor, and uncertain seedling regeneration after logging meant the MUS failed to promote adequate post-harvest rehabilitation. Problems with erosion and difficulties in regenerating the logged forest did not favour drastic opening of the canopy. SMS operates on a 25-30 year cutting cycle with an expected net outturn of 30-40 cubic metres per hectare. The minimum cutting dbh prescribed for dipterocarp species is 50 centimetres. The cutting limit for non-dipterocarp species should not be less than 45 centimetres dbh, while the residual stocks should incorporate at least 32 sound commercial trees per hectare with a diameter class of 30-45 centimetres. Similar systems are practiced in Sabah and Sarawak.

Forest harvesting in Malaysia is regulated and controlled. An Area Control approach is used whereby a certain area of forest is designated for harvesting each year. This is done through the allocation of an annual felling coupe based on resource availability and current forest management practices. For example, the annual coupe for Peninsular Malaysia during the period 1995-2000 was 46 000 hectares. These areas are allocated as forest concessions using a licence tender process. Harvesting systems require both pre- and post-felling inventories to be carried out, while harvest volumes are closely monitored to ascertain accurate royalty payments.
Harvesting in Malaysia is largely mechanized with roads and skid trails built. Yarding is generally done using tractors and skidders, although cable yarding systems are used in locations where roading options are limited. Malaysia is, however, implementing a large number of innovative projects designed to develop better techniques for reduced impact logging. These include, for example, the testing of helicopter logging in Sarawak (under an ITTO funded Sarawak Model Forest Management Area project implemented by the Sarawak Forestry Department in partnership with Sarawak Timber Association). This project is developing a variety of measures to encourage efforts towards sustainable forest management, including airborne video-recording and mapping, computer-aided road-building and design, and comparative studies of PATH logging, RIL logging, helicopter logging and conventional logging. In Sabah, an ongoing carbon-offset driven rehabilitation project involves planting high value dipterocarps and fruit trees in areas of logging disturbance. The Sabah pilot programme, supported by Forests Supporting CO2 Emissions (FACE), includes mapping, pre-selection and marking of marketable timber, pre-harvest cutting of climber vines, slope and riparian restrictions on logging, weather restrictions on logging, lowering the impact of access roads through planning, use of directional felling techniques, planning of skid trails, and eliminating the use of bulldozer blades on skid trails.
The modified MUS and SMS promote reduced impact logging, with an emphasis on reducing residual damage to future crop trees. Environmental impact assessments are required for logging areas greater than 500 hectares.
In an effort to optimize the utilization of forest and mill residues, as well as promote trade in under-utilized species, Malaysia has undertaken a variety of studies with cooperation from various agencies. Research has also been intensified in reduced impact logging and low impact logging technologies. The use of modified excavators and skyline mobile yarding for log extraction is also being evaluated. In order to alleviate the negative impacts of road construction on forests and the environment, forest road specifications have been revised and applied to logging since 1999.

Box 3. Forest management practices in Malaysia. Text from http://www.fao.org/countryprofiles/ index.asp ?lang=en&iso3=MYS&subj=5)

The harvested volumes presented in different studies on selective logging (both RIL and CL) widely vary (30-175 m^3 ha^{-1}). Most results in these studies are, however, obtained from experimentally harvested forests. According to Thang (1987) and Mok (1992) the average net harvests are around 40-45 m^3 ha^{-1}. Taking into account the losses (Table 14), the estimated volume felled per hectare was 65 m^3 o.b. ha^{-1} for CL and 55 m^3 o.b. ha^{-1}. The total growing stock of industrial round wood per hectare was indicated to be 135 m^3 u.b. ha^{-1} (155 m^3 o.b. ha^{-1} at bark percentage of 15%, see below) (FAO 2005e). Therefore 155 m^3 o.b. ha^{-1} was used as the felled volume per hectare for clear felling. Taking into account 5% losses, this results in a harvest of 147 m^3 ha^{-1} (over bark).

No data were found on the shares of CL and RIL within the areas harvested according the Selective Management System. Therefore it was assumed that 90% of the forests that are certified under the MTCC (Malaysian Timber Certification Council) criteria (since 1998) are harvested according at least basic RIL practices. The value 90% was used because probably unintentionally, but also intentionally, the guidelines are not always followed. Certification audit reports could potentially be used to further refine this number, but generally such reports are not publicly available.

In 2004 the forests of eight states, covering 4.5 million ha in Peninsular Malaysia (excluding 171,000 ha of plantations) and 60,000 ha in Sarawak, had been certified according the national MTCC standard (ITTO 2006). Additionally 64,808 ha of natural forests are certified under the FSC standards as of October 2005. Hence in total roughly 4.62 million ha are certified. The total area of natural forest PFE for production was 11.18 million ha (12.6 million ha in 1990) (ITTO 2006). Based on these numbers it was estimated that in 2004 (90%*4.62/11.18= 37% of the forest is harvested according RIL practices, and 63% using conventional logging practices). It was assumed that before 1995 no RIL was applied and that the share of RIL in total harvesting was the same in 2000 and 2005.

The total wood removal in 2005 as presented in FAO (2005e) was based on linear regression with the data of 1990 and 2000. Because there is a steep decline in production between 1990 and 2000 this will not give a correct estimate for 2005. Because the FRA2005 data of 1990 and 2000 are based on FAOstat, the current FAOstat (FAO 2009) data for 2005, that have become available in the meantime, will be used.

Plantations
The share of the most important plantation species was based on the distributions of potential total production of each species (see calculations in sheet [Malaysia data].[Plantations]). This potential production was calculated for each species by summing up the potential production of each size class, which in turn was determined by multiplying its total area (FAO 2002) and production per hectare (FAO 2002). See FAO (2002) for further information on the utilisation of species.

Conversion factors
Bark percentage used in Malaysia is 15% (FAO 2005e), which is 3% higher than the value used for Brazil. For the plantations, therefore, 3% is added to the bark percentages as used for Brazil (Table 14). In forests harvested according conventional practices, losses amount to about 30-60% of the harvest while theses losses are reduced by 50% using RIL techniques (e.g. Thang 1987, Mok 1992, Tay et al., 2002). For plantations the same loss percentages were used as for Brazil.

Table 14
Conversion factor giving the felling volume (over bark) per cubic metre of round wood production (under bark) for different management types and species types in Malaysia. The conversion factor is based on the bark percentage and the percentage losses due to improper felling and felled trees left in the forest.

Management type	Species type	Bark percentage (%)	Losses (%)	Conversion factor
Selective (CL)	Hardwood	15	45	1.60
Selective (RIL)	Hardwood	15	23	1.37
Clear felling	Hardwood	15	5	1.20
Plantation	Hardwood	20	5	1.25
	Softwood	21	5	1.26

2.3.6 Mexico

History of Logging
All kinds of vegetation are found in Mexico, with the tropical and subtropical forests situated in the southeastern part of the country relatively rich in mahogany (*Swietenia macrophylla*) and, to a lesser extent, Spanish cedar (*Cedrela odorata*). These species have been commercially exploited particularly by British logging companies in the latter half of the 19th and first half of the 20th century. Later on, concessions were granted in the 1950s, and the logging was conducted by selective felling of the most valuable species, which lead to over exploitation of them (Pérez et al 1990, Richards 1992). In Mexico approximately 31.3 million ha, slightly less than half of all forests, are classified as tropical forests, while 34.1 million ha are classified as temperate forests (CCMSS 2006).

Tropical forest management
In the past the forest authority (SARH) granted concessions to logging companies, but currently all harvesting permits should be granted to forest owners. With local people, organised in “ejidos” getting more rights to the forest most of the tropical forests are managed and logged by these ejidos or communities. These Ejidos also take care of marketing and processing of the wood (Richards 1992).The permanent forest area is divided up on the basis of a *25 year cutting cycle* (Richards 1992). In the ejidos with the largest forest areas and with commercial timber stocks, forest activities now represent an important contribution to the generation of both income and employment (ITTO 2005). The logging technologies used are generally still rudimentary resulting in relatively low harvest intensities (Klooster and Masera 2000), but well-organized ejidos use more advanced methods in terms of operational planning and equipment. Environmental impacts of logging activities are limited due to the small number of trees felled, the flat terrain and the technology used (ITTO 2005). Current selective harvesting practices typically open up less than 5% of the forest canopy (ITTO 2005). Timber extraction occurs mainly between January and April in the dry season, so damage to the forest floor is minimised.

Total timber stocks in the high and medium forests in the tropical zone of Mexico, have an average of 168 m^3 ha^{-1}, while in the low forest this is only 24 m^3 ha^{-1} (ITTO 2005). The felling diameter limit has been set at 55 cm for mahogany (Negreros-Castillo et al., 2003) and at 35 cm for secondary species.

Plantations
Mexico has ca. 200,000 ha of forest plantations (Brown 2000). Pines (including: *Pinus patula*; *P. ayacahuite*; and P. *strobus* var. *chiapensis*) account for most of the area of forest plantations planted with softwood species, while a wide range of species (including: *Eucalyptus*; *Acacia*; and *Casuarina* species) can be found in

the forest plantations planted with hardwoods ((Brown 2000)). More than 60 percent of the plantations in Mexico are classified as non-industrial forest plantations. Most productive plantations are located in the tropical south-eastern part of Mexico.

In approximately five years, timber from Commercial Forest Plantations (CFP) could account for 10% of the total national production (ITTO 2005), without taking into consideration rubber wood that is being produced from old plantations (with an estimated production of 5,000 to 10,000 m^3 per year). In the long term, the CFPs are expected be the main source of tropical timber in Mexico.

Forest production

Mexico's timber production is made up of 82% conifers (mainly pine species), 12% oaks and other broadleaved species, and only 4% of valuable and tropical timber species (ITTO 2005). In 2002, the production of tropical round wood was only 278,000 m^3. Out of this total, 8.6% were high-value timber species such as mahogany and cedar, and the rest were secondary species. Most of the valuable species are used for sawn wood with less than 10% being used for posts, piles and round rafters. Secondary species are used for sawn wood (44%), firewood and charcoal (30%), posts and piles (7%), sleepers (8%), and veneer and plywood (2%) (ITTO 2005).

Most of the produced round wood is for domestic use. Industrial round wood production in 2003 was 6.28 million m^3, of which an estimated 781,000 m^3 was non-coniferous and 606,000 m^3 was tropical.

Approximately 2% (163,000 ha) of the total managed forest area (7,880,000 ha) is managed sustainably (see ITTO 2006). Like for other countries, it was assuemd that sustainably managed forests were harvested using RIL techniques.

2.3.7 Nigeria

The description (Box 4) of forest management in Nigeria was taken from FAO's website of Nigeria's country profile for the forestry sector (http://www.fao.org/forestry/site/25526/en/nga/). More information can be also be found in e.g. Olaleye and Ameh 1999, Aruofor 2000, Aruofor 2001 and ITTO 2006.

Most forests in Nigeria have been substantially degraded (Okoji 2001, ITTO 2006). The wood processing sector is rundown (ITTO 2006). There is a critical shortage of raw material for the timber industry and subsequently the sector runs at only 30-40% of the installed capacity (ITTO 2006).

Calculations

The data from the FRA2005 country report for Nigeria (FAO 2005g) were used as the basis for total industrial round wood production and production from natural and planted forests. Because the data for industrial round wood production of 1990 in the country report were calculated erroneously, for 1990 the FAOstat data were used and converted to over bark volume using a factor 1.15 (FAO 2005g).

With the data provided in Olaleye and Ameh (1999) could be calculated that in 2000 13% of total industrial round wood production was from (modified) natural forests and 87% from plantations. It was assumed that these shares were also valid for 1990 and 2005.

Based on a description of forest management in Okoji (2001) and ITTO (2006) it was concluded that most logging from (modified) natural forests in Nigeria is selective (conventional). Currently no forests in Nigeria have been certified and according ITTO (2006) no area of sustainable forest management could be determined. Therefore it was assumed that RIL is not practised in Nigeria. Harvest intensity in selectively harvested forests in Nigeria is relatively low at approximately 30 m^3 ha^{-1} over bark (FAO 2004a). When taking into account the losses (Table 15), the average felled volume amounts to 43.8 m^3 ha^{-1} o.b.)

> Nigeria´s forests have been and are exploited mainly for the supply of fuelwood, industrial timber and pole requirements. The high forest is the main source of industrial round wood (logs), a small quantity coming from the riparian forests and the woodlands in the savannah regions and from plantations. The main supply areas have been the south-western states. Initially, the forest reserves in the high forest zone were managed for timber production on a felling cycle of 100 years, which was reduced to 50 years, then to 25 years and even less to make larger areas available for exploitation. At the beginning of the 1990s there were more than 1,100 private sawmills operating, and a few plywood, pulp and paper mills, with a total annual intake of over 6 million m3. The capacity utilization in the Nigerian sawmilling industry has been low, due to factors such as lack of wood raw material supply, the limited absorptive capacity of the domestic market and the technical problems of mill management. The quality of logs supplied to mills from the natural forests has been on the decline and the log diameters have been decreasing.
>
> The forest lands are mainly State owned with most of the moist forests under concessions. The present system of exploitation in forest reserves is controlled mainly by concession policy, which varies depending on the State. The management and control of forest reserves is vested in the State Governments without involvement of the private sector.
>
> Forests are sub-divided into numbered square-mile compartments, and forest exploitation is managed under working plans prepared by the Governmental forestry department. Almost all logging is designed and executed by the private sector. Control of concessionaires is by area and by girth limit, which is 60-90 cm dbh, depending on the species. Volume extracted is carefully measured and recorded, although fees are generally charged on an area basis.
>
> ***Box 4. Forest management practices in Nigeria. Text from: http://www.fao.org/forestry/site/25550/en/nga/***

Plantations

In 2000 Nigeria had 375,000 ha of plantations, comprising of 110,000 ha of *Gmelia arborea* (fast growing hardwood), 95,000 ha of other fast growing hardwoods, 74,000 ha of Teak (slow growing hardwood) and 86,000 ha of other fast growing hardwoods. The volumes per hectare available for harvesting at the end of the rotation were based on FRA2000 data (FAO 2001a) for *Gmelia arborea* and data from FAO (2003) for Teak. For the other two species groups the average growing stock (m^3 ha^{-1}) for plantations as reported in FAO (2005g) was used. The share of each species group in wood production was based on the distribution of potential productions (area * volume available for harvesting) of the different plantation types. It was assumed that these shares were also valid for 1990 and 2005

Conversion factor

Because no information on harvesting losses was found, the average value for Africa of 46% was used (FAO 2004a). The bark percentage used in Nigeria is 15% (FAO 2005g). Similar to the other tropical plantations, 5% was added to the bark percentage to account for the smaller trees sizes and a 5% loss was used.

Table 15.

Conversion factor giving the felling volume (over bark) per cubic metre of round wood production (under bark) for different management types and species types in Nigeria. The conversion factor is based on the bark percentage and the percentage losses due to improper felling and felled trees left in the forest.

Management type	Species type	Bark percentage (%)	Losses (%)	Conversion factor
Selective (CL)	**Hardwood**	15	46	1.61
Plantation	**Hardwood**	20	5	1.25

2.4 Damage during selective logging and reduced impact logging

Stand density data and logging damage were gathered from scientific literature for both conventional logging (CL) methods and reduced impact logging (RIL).

Our aim was to express logging damage in cubic meter of timber damaged per cubic meter of timber harvested. Therefore we collected data on the pre-harvest stand density, harvest intensity and the extent of damage caused by the logging operation. As these data is often described in different units we had to estimate the volumetric damage (*D*) in different ways.

When harvest intensity and initial stand densities were given in m^3 and damage was expressed as percentage of the initial stand we assessed *D* as:

$$D = \frac{\left(V_{(t0)} \times d_{(is)}\right)}{V_{(e)}} \qquad (1)$$

where $d_{(is)}$ is the extent of damaged trees as percentage from the initial stand $V_{(t0)}$ and $V_{(e)}$ is the harvest intensity or volume extracted in m^3.

When harvest intensity and initial stand densities were given in m^3 and damage was expressed as percentage of the residual stand *D* was determined as:

$$D = \frac{\left(V_{(t0)} - V_{(e)}\right) \times d_{(rs)}}{V_{(e)}} \qquad (2)$$

with $d_{(rs)}$ being the extent of damaged trees as percentage from the residual stand.

In four cases damage and stand densities were expressed in m^2 basal area. Here we estimated the volumetric damage (*D*) as:

$$D = \left(\left(\frac{BA_{(t0)}}{BA_{(e)}} \times V_{(e)}\right) - V_{(e)}\right) \times \frac{d_{(is)}}{V_{(e)}} \qquad (3)$$

or as:

$$D = \left(\left(\frac{BA_{(t0)}}{BA_{(e)}} \times V_{(e)}\right) - V_{(e)}\right) \times \frac{d_{(rs)}}{V_{(e)}} + 1 \qquad (4)$$

in which $V_{(e)}$ is the harvest intensity in m^3, BA is the basal area of the initial stand (*t0*) or the extracted trees (*e*). Equation 3 uses damage as percentage of the residual stand and equation 4 uses damage as percentage of the initial stand.
Finally, where data was only given as the number of trees we estimated the *D* as the volume of trees that died (*m*) divided by the volume of each tree that was extracted (*e*). Tree volume was assumed conical.

$$D = \frac{n(m) \times \left(\pi \times 0.5 \times DBH_{(m)}^{2} \times \frac{H_{(m)}}{3}\right)}{\pi \times 0.5 \times DBH_{(e)}^{2} \times \frac{H_{(e)}}{3}} \qquad (5)$$

where *n(m)* is the number of trees that died during the logging operation, DBH is the diameter at breast height and H is the tree height.

The methods used for calculating the logging damage for each of the data sources used is given in Table 16.

Table 16.
*Method of calculating logging damage for the data sources that were used and the type of logging concerned. CL=conventional logging, RIL=reduced impact logging. * reference in FAO 2004a*

Method	Source	Country	CL	RIL
Direct from source	Johns et al., 1996	Brazil	X	X
	Uhl et al., 1991	Brazil	X	
	Verissimo et al., 1992	Brazil	X	
	Kilkki 1992	Papua New Guinea	X	
Equation 1	Sist et al., 1998	Indonesia	X	X
Equation 2	Fox 1968*	Malaysia	X	X
	Richter 2001	Malaysia	X	X
	de Graaf et al., 1999	Suriname	X	
Equation 3	Sist et al., 2003	Malaysia	X	X
Equation 4	Bertault and Sist 1997	Indonesia	X	X
Equation 5	Parren and Bongers 2001	Cameroon		X

For each of the two logging regimes considered we used the average of all cases (CL,n=10; RIL, n=7) to estimate the total volumetric logging damage.

The different methods applied to estimate the logging damage determine the level of uncertainty of the single estimates. The damages that could directly be taken from the source have the lowest uncertainty. Equations 1 and 2 were the most direct way of calculating the volumetric damage that occurred under both logging regimes, and hence yielded the most reliable estimates. These are based on the damage percentage of either the pre- harvest or the post-harvest stand. The parameters needed for this method (initial stand volume, harvest intensity and percentage of damage) were given in the majority (i.e.7 out of 12) of cases.

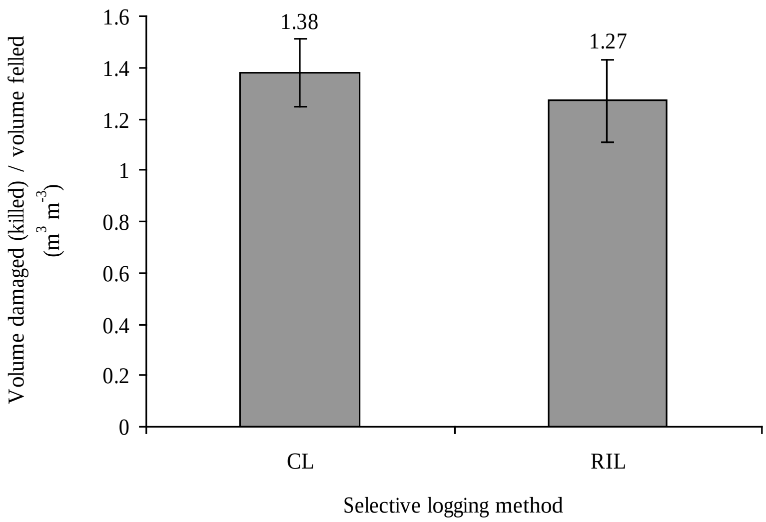


Figure 5
Average damage in m3 wood per m3 felled for conventioanl selective logging (CL) and reduced impact logging (RIL).

The different methods applied to estimate the logging damage determine the level of uncertainty of the single estimates. The damages that could directly be taken from the source have the lowest uncertainty. Equations 1 and 2 were the most direct way of calculating the volumetric damage that occurred under both logging regimes, and hence yielded the most reliable estimates. These are based on the damage percentage of either the pre- harvest or the post-harvest stand. The parameters needed for this method (initial stand volume, harvest intensity and percentage of damage) were given in the majority (i.e.7 out of 12) of cases.

Results of equation 3 and equation 4 are probably less reliable because the initial stand volume was estimated indirectly using the given basal areas of the extracted trees and the pre-harvest stand.
Equation 5 clearly gives the least reliable result because the volume of a tree was assumed equal to a geometrical cone. Therefore this method likely results in the highest standard error of the five equations that were used. Considering the limited data available, it was however the best educated estimate of *D*. We used this method in only 1 of the cases so that its error in the overall estimate will be relatively small.

A number of assumptions made in this study are important to consider when interpreting the results:

1. Damaged trees were assumed dead unless otherwise indicated. Only a few of the articles classified the damage and indicated the potential of recovery.
2. Post-logging inventories were not done in identical periods after logging, which might result in over- or underestimation of the damage.
3. The post-logging inventories used different criteria. In some of them only commercial trees were measured while others incorporated all trees. Also, the monitored diameter classes differed among studies.
4. The logging history of the study sites and cutting cycles are not considered, so that there is no distinction between initial stands. Only stem density and/or volume were considered. It could thus be that the initial stand refers to an un-logged forest or to a previously logged forest stand.

2.5 Rotation cycles

Overview of recovery times and rotation cycles for different management systems, climate zones, regions and forest type are shown in Table 17. For some of the countries more specific information is presented in the main text.

Table 17
Recovery times (time after harvesting needed to recover to a stage where harvesting is possible again in a sustainable way) and rotation cycles (used/prescribed in the concerning region). In Western countries the length of the rotation cycle is likely to coincide with the time needed to maximum productivity. Fast growing hardwood species like birch, poplar, eucalyptus and acacia are mainly used for pulp and paper. Values in table are based on the author's expert judgement.

Management system	Climate	Region	Forest type	Recovery time (years)	Rotation cycle (years)
Clear felling	Boreal	All	Softwoods	50	100
			Hardwoods	50[1]	100
	Temperate	All	Softwoods	40	80
			Hardwoods	70	130
		Oceania	Softwoods	Slightly Shorter than "All"	
		South -Africa	Softwoods	Slightly Shorter than "All"	
		Asia (China)	Softwoods	Slightly Shorter than "All"	

Management system	Climate	Region	Forest type	Recovery time (years)	Rotation cycle (years)
	Tropical	All	Hardwoods	80	150+
Selective	Tropical	All	Hardwoods	60-120	20-60
Selective + RIL	Tropical	All	Hardwoods	30-80	20-60
Plantation	Boreal	All	Softwoods	50	100
			Hardwoods	50[1]	100
	Temperate	All	Softwoods	20	40
			Hardwoods	20[2]	40[2]
		Asia (China)	Softwoods		30
			Hardwoods (slow growing)		30
			Hardwoods (fast growing)		10
	Tropical	All	Hardwoods (fast growing)	7-30	7-30
			Hardwoods (slow growing)	20-70	20-70
			Softwoods (fast growing)	15-40	15-40
			Softwoods (slow growing)	40-60	40-60

1) fast growing species like birch and poplar; 2) fast growing species like poplar and eucalyptus

3 Forest conversion

In recent years (2000-2005) deforestation occurred at the rate of some 13 million hectares per year which is about 0,3% of the global forest area (4,000 billion ha; FAO 2006a). A large part of this area is converted in agricultural fields and is permanently lost as forest area. However, some of the deforested areas are reforested again, either by natural regeneration or as forest plantations with for instance rubber wood or other fast growing tree species. In addition, other areas which were previously not under forests (e.g. old agricultural fields, degraded shrub lands etc.) are being afforested at an increasing rate, compensating the loss in forest areas. In the Forest Resource Assessment 2005 (FAO 2006a) it is stated that reforestation, landscape restoration, and natural expansion of forests have reduced the gross loss of forest area from -13 million ha per annum to a total net global loss of -7.3 million ha per year between 2000-2005.

From 2000-2005 South America and Africa experienced the largest net loss of forests area of 4.3 and 4.0 million hectares per annum respectively. In the same period net annual forest area loss in both North and Central America and Oceania was about 350 000 ha each. Asia had a net loss of some 800 000 ha per year in the 1990s, but had a net gain of 1 million hectares per year from 2000 to 2005, mainly caused through the large a-forestation area reported by China. Forest areas in Europe expanded throughout 1990 to 2005.

In the IMAGE model it is assumed that all standing timber from deforested areas is harvested and brought onto the market. However, increasingly it is being realized that this may not be a realistic assumption, as logging practices used in converting forest into other land-use may be different from standard logging practices during forestry activities. While deforestation in most cases is caused by land clearing for agricultural or other land purposes, logging is typically selective and in most tropical forests only 10-20% of the standing biomass is harvested (Strand 2004). Brown and Pearce (1994) also indicate that it is hard to assess the role of logging in deforestation. They stress the importance of logging given the role that consumers in developed countries play in providing impetus for tropical deforestation. In a great number of tropical countries slash and burn practices are commonly applied to clear forest areas for agricultural use. In contrast, in a sample of 45 countries Capistrano (1994) found a strong positive correlation between industrial logging and deforestation of closed broadleaf forests.

Deforestation and timber production are seem to be closely linked in the Amazon (e.g. (Ferraz 2001). However, it is difficult to get a clear idea of the exact amount of extracted timber from deforestation based on official reports. For instance, the amount of timber extracted in the Brazilian Amazon increased by 345% between 1980 and 1995 during a time of increasing deforestation (e.g. Laurance 2000). Although deforestation rates kept growing after 1995, the IBGE figures suggest that the amount of timber extracted decreased considerably (Ferraz 2001). Deforestation is done either by large scale schemes or by small-holders (Nepstad et al., 2001). In both cases most of the standing volume is logged, and the remaining non-commercial stems are being slashed and burnt (Nepstad et al., 2001).

In Central Kalimantan (Indonesia) it is well know that in converting the forest area for the Mega-Rice Project a significant part was burnt, either deliberately or un-deliberately (e.g. Page et al., 2002). Likewise, fire is also an important cause of deforestation in Brazil, either through large scale burning after El Nino events, or through slash & burn activities of small farmers (Nepstad et al., 2001). During the El Nino event of 1998 at least 20,000 km2 of the forest floor was burnt in the Brazalian states of Roraima and Para (Nepstad et al., 2001). To what extend the trees were burnt by these ground fires is not explained. Both these experiences show that often only a limited percentage of the standing volume of trees of the converted forest areas is brought onto the timber markets.

Illegal logging is another factor which makes it hard to estimate the amount of timber which is produced during forest conversion. In many (mainly tropical) countries, controlled (selective) logging is often followed by illegal harvesting. This often leads to heavily degraded forest, which is then converted into other land-use types. As mentioned in chapter 0, in the Amazonian forest there is a considerable difference between the legally harvested timber volume and the amount consumed by the forest industry, suggestion that a substantial amount of the timber is from illegal origin with estimates ranging between 47-90% of the wood being illegally harvested (Lentini et al., 2004, Thiel and Viergever 2006 and references therein). The illegal nature of the various activities makes it hard to calculate how much timber is being harvested and how much logging losses there are.

In this study we investigate how much forest area is annually converted into other land-use types, and how much industrial round-wood is harvested during these conversion operations. This information will be used to further refine the calculation of timber harvesting in the IMAGE model.

We will address the following four questions:

- How much forest area is annually converted into non-forest land-use types (ha yr^{-1})?
- What percentage of the converted forest areas has produced timber (% of converted forest area; or ha yr^{-1})?
- How much timber is being harvested from these conversion areas (m^3 ha^{-1} yr^{-1})?
- How much round wood has been produced from the timber which was harvested from conversion areas in each country (m^3 yr^{-1})?

In our analysis we focus on 22 of the major timber producing countries in the boreal, temperate and tropical zone. They include the 17 countries with highest wood production for each of the climatic zones as used in Chapter 2. In addition, Japan, Poland, Turkey, India, and Mexico were included, resulting in the following list of countries:

- Boreal Forests (4 countries: Canada, Finland, Russian Federation, Sweden)
- Temperate forests (11 countries: Australia, Germany, Chile, China, France, Germany, Japan, New Zealand, Poland, South Africa, Turkey, United States of America)
- Tropical forests (7 countries: Brazil, Democratic Republic Congo, India, Indonesia, Malaysia, Mexico, Nigeria)

3.1 Methodology & data

To be able to calculate the total amount of industrial round wood from conversion area per country data on (1) deforestation rates and (2) timber production from conversion areas were needed. Below we describe how these data were obtained.

3.1.1 Deforestation rates

Deforestation rates were based on data provided by FRA 2005 (FAO 2006a) which is the most recent and up to date forest inventory data available. It has been noted in chapter 2 that there are differences between FRA and other global inventories like the TBFRA-2000 UNECE/FAO (2000). However, differences were relatively small and are beyond the scope of this study.

The FRA 2005 gives total forest areas (including native forests and plantations) for 1990, 2000, and 2005. Based on these total forest areas the net losses in forest area between 1990-2000 and 2000-2005 are calculated. In fact, the net loss in forest area is based on the gross deforestation minus the growth in forest area (new plantations through reforestation or landscape restoration, and natural expansion of forests). As we are interested in gross deforestation rates in this study we calculated gross deforestation by subtracting the growth (or decline) in plantation-area from the net annual forest change. In doing this, we assumed that growth in plantation area covered the reforestation and landscape restoration areas in a country. As we were not able to find rates on natural expansion of forests this was not included in the gross deforestation rates. See Box 5 for further explanation on deforestation and forest change dynamics (from FAO 2006a).

The figure below is a simplified model illustrating forest change dynamics. It has only two classes: forests and all other land. A reduction in forest area can happen through either of two
processes. Deforestation, which is by far the most important, implies that forests are cleared by people and the land converted to other uses, such as agriculture or infrastructure. Natural disasters may also destroy forests. When the area is incapable of regenerating naturally and no efforts are made to replant it, it, too, reverts to other land.

An increase in forest area can also happen in two ways: either through afforestation, i.e. planting of trees on land that was not previously forested, or through natural expansion of forests, e.g. on abandoned agricultural land – which is quite common in some European countries.

Where part of a forest is cut down but replanted (reforestation), or where the forest grows back on its own within a relatively short period (natural regeneration), there is no change in forest area.

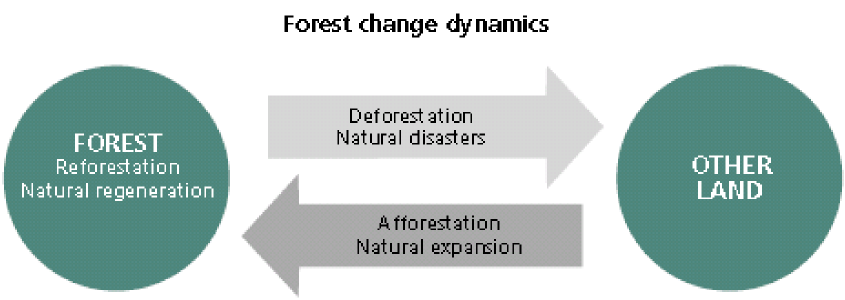
For FRA 2005, countries were asked to provide information on their forest area for three points in time. This allows calculation of the net change in forest area over time. This net change is the sum of all negative changes due to deforestation and natural disasters and all positive changes due to afforestation and natural expansion of forests.

Countries were not requested to provide information on each of the four components of net change, as most countries do not have such information. This makes estimation of the deforestation rate difficult and no attempt has been made to do so at the country level. Rather, an estimate of the global deforestation rate has been made as follows:

The total net loss for countries with a negative change in forest area was 13.1 million hectares per year for 1990–2000 and 12.9 million hectares per year for 2000–2005. Since the net change rate takes into account afforestation efforts and natural expansion of forests, the rate of deforestation might be higher still. On the other hand, Brazil, which accounts for 21 percent of the total net loss in the period 1990–2000 and 24 percent in 2000–2005, calculated its forest area in 2005 and 1990 based on information from 2000 and the sum of annual figures of the area of forests cleared. It did not take into account to what extent the land use of these areas had changed and to what extent cleared lands had been abandoned and had reverted to forest through natural regeneration. Such naturally regenerated secondary forests are thought to be quite extensive, but insufficient information is currently available to estimate the extent. Thus the area of deforestation and the net loss of forests in Brazil are likely overestimated.

Taking these considerations into account, the global deforestation rate was estimated at 13 million hectares per year during the period 1990–2005, with few signs of a significant decrease over time.

Box 5. **Deforestation and net change in forest area (from FAO 2006a).**



3.1.2 Timber production from conversion areas

In order to calculate the industrial timber production from converted forest areas three steps were needed:

A. The percentage of converted area from which timber was harvested.
   In this step we estimated for each country what percentage of the gross converted forest produced timber. This estimate was based on various data sources like national forest inventories, scientific publications, and personal communications.

B. The volume of timber felled per hectare during conversion of forest (felling volume).
   For 11 of the 24 countries the figures on the average timber volumes harvested per hectare by clear felling as presented in chapter 2 were used. For the remaining countries figures were based on various sources, the main reference being FAO (2006a). When no relevant references were found an estimate was given based on similar forest types in the same region. Ultimately, when no data where available for similar forest types either the average global growing stock of forests was used (110 m3 ha-1; FAO 2006a). When needed, figures were adjusted for logging losses due to improper felling.

C. The volume of industrial round wood produced from conversion areas in each country.
   Conversion factors to calculate the volume of industrial round wood (under bark) based on the volume (over bark) of felled timber were adapted from chapter 0. These conversion factors were used to calculate the total volume of industrial round wood per country, based on figures derived above under A and B.

In the following section we present and discuss the data on deforestation rates and timber harvesting and production per country, grouped in the three geographical zones mentioned above.

3.2 Deforestation rates and round wood production

3.2.1 Forest areas and deforestation rates

Table 1 shows the forest area, net deforestation rates, and plantation area for 22 countries, based on the FRA 2005 (FAO 2006a). The forest areas (including native forests and plantations) are given for 1990, 2000, and 2005 in the first three columns. The following 4 columns show the net annual change rate in forest area between 1990-2000 and between 2000-2005 (=gross deforestation – growth in forest area, see section 2.1).

The last three columns of Table 18 give the area of forest plantations for 1990, 2000, and 2005. These data were used to calculate the gross deforestation rates (which are shown in Table 19).

The first two columns of Table 19 give the gross deforested area between 1990-2000 and 2000-2005 for the 22 countries. These values where calculated by subtracting the growth (or decline) in plantation-area (Table 18, last three columns) from the net annual forest change (Table 18, columns 4 and 6). In the 3rd and 4th column of Table 19 the deforested area from which wood was harvested is given. Based on the estimated volume of harvested round wood per ha (column 5) the total volume of industrial round wood which was produced from deforested areas in each country is calculated in the last column of Table 19. When for a country the deforestation rate was zero the remaining fields for that country were not filled and were given the code n.r. (not relevant).

Table 18
Forest areas, net annual change rate, and forest plantation areas in the 22 major timber producing countries in 1990, 2000, and 2005 (FAO 2006a).

Country	Forest Area (1000 ha)			Net Annual change rate (1000 ha yr^{-1} and %)				Area of forest plantations (1000 ha)		
	1990	2000	2005	1990-2000		2000-2005		1990	2000	2005
Boreal Zone										
Canada	310,134	310,134	310,134	0	0	0	0	0	0	0
Finland	22,194	22,475	22,500	28	0.1	5	n.s.	0	0	0
Russian Fed.	808,950	809,268	808,790	32	n.s.	-96	n.s.	12,651	15,360	16,962
Sweden	27,367	27,474	27,528	11	n.s.	11	n.s.	523	619	667
Temperate Zone										
Australia	167,904	164,645	163,678	-326	-0.2	-193	-0.1	1,023	1,485	1,766
Chile	15,263	15,834	16,121	57	0.4	57	0.4	1,741	2,354	2,661
China	157,141	177,001	197,290	1,986	1.2	4,058	2.2	18,466	23,924	31,369
France	14,538	15,351	15,554	81	0.5	41	0.3	1,842	1,936	1,968
Germany	10,741	11,076	11,076	34	0.3	0	0	0	0	0
Japan	24,950	24,876	24,868	-7	n.s.	-2	n.s.	10,287	10,331	10,321
New Zealand	7,720	8,226	8,309	51	0.6	17	0.2	1,261	1,769	1,852
Poland	8,881	9,059	9,192	18	0.2	27	0.3	32	32	32
South Africa	9,203	9,203	9,203	0	0	0	0	1,204	1,352	1,426
Turkey	9,680	10,052	10,175	37	0.4	25	0.2	1,839	2,304	2,537
USA	298,648	302,294	303,089	365	0.1	159	0.1	10,305	16,274	17,061
Tropical Zone										
Brazil	520,027	493,213	477,698	-2,681	-0.5	-3,103	-0.6	5,070	5,279	5,384
DR Congo	140,531	135,207	133,610	-532	-0.4	-319	-0.2	0	0	0
India	63,939	67,554	67,701	362	0.6	29	n.s.	1,954	2,805	3,226
Indonesia	116,567	97,852	88,495	-1,872	-1.7	-1,871	-2	2,209	3,002	3,399
Malaysia	22,376	21,591	20,890	-78	-0.4	-140	-0.7	1,956	1,659	1,573
Mexico	69,016	65,540	64,238	-348	-0.5	-260	-0.4	0	1,058	1,058
Nigeria	17,234	13,137	11,089	-410	-2.7	-410	-3.3	251	316	349

Table 19

Gross deforested areas, the deforested area from which wood was harvested, volume of harvested round wood, and the amount of oundwood produced from deforestation for the 22 major timber producing countries in 1990, 2000, and 2005.

Country	Gross Area Deforested (1000 ha yr^{-1})		Deforested area from which timber extracted (1000 ha yr^{-1})		Average volume harvested per ha (m^3 o.b. ha^{-1})	Volume round wood produced from conversion areas (1000 m^3 yr^{-1})	
	1990 - 2000	2000 - 2005	1990 - 2000	2000 - 2005		1990-2000	2000-2005
Boreal Zone							
Canada	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
Finland	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
Russian Fed.	239	416	120	208	155	12,774	22,234
Sweden	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
Temperate Zone							
Australia	372	250	372	250	40	12,101	8,117
Chile	4	4	4	4	117	344	327
China	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
France	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
Germany	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
Japan	12	0	12	n.r.	145	1,347	n.r.
New Zealand	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
Poland	0	0	n.r.	n.r.	n.r.	n.r.	n.r.
South Africa	15	15	11	11	69	603	603
Turkey	9	22	5	11	138	526	1,244
USA	232	0	232	n.r.	116	19,681	n.r.
Tropical Zone							
Brazil	2,702	3,124	1,351	1,562	127	146,663	169,550
DR Congo	532	319	532	319	38	13,769	8,260
India	0	55	n.r.	55	69	n.r.	3,151
Indonesia	1,951	1,951	975	975	125	101,604	101,604
Malaysia	49	123	49	123	155	6,303	15,888
Mexico	453	260	413	237	110	37,821	21,722
Nigeria	416	416	416	416	125	44,466	44,466

n.r. = not relevant (when deforestation rate was zero)

3.2.2 Timber production from conversion areas - Boreal Forests

Canada

Canada's total land area covers 922 million ha of which some 44% (402 million ha) is covered by forest and woodlands (FAO 2006a). This forest area remained un-changed during 1990, 2000 and 2005 (Table 18). As there are no forest plantations in Canada also the gross change of forest area remained zero. We therefore assume that Canada does not convert forest area into other land-uses, and consequently, there is no timber produced from deforestation activities.

Finland
Finland covers a total land area of 33.8 million ha, with 22.5 million ha under forests and 0.8 million ha covered with woodlands (FAO 2006a). Between 1990-2000 the total forest increased by 280,000 ha, and between 2000 and 2005 with another 25,000 ha (Table 18). There are no forest plantations in Finland. Based on these data we assume that there is no deforestation and thus no timber production by forest conversion in Finland.

Russian Federation
Between 1990 and 2000 there has been a small net increase of forest area in the Russian Federation of 320,000 ha (Table 18). Between 2000 and 2005 there was a net loss of 480,000 ha of forest. However, because there was a significant growth in plantation areas (Table 18), the gross loss in forest areas was 239,000 ha per annum between 1990-2000, and 416,000 ha per annum between 2000-2005 (Table 19).

Not all deforestation resulted in timber harvesting. Fire is a major problem in Russian forests. The most wide spread type of disturbance is forest fire that occurs on an estimated 1.4–10 million ha annually (Krankina et al 1997). The FRA (FAO 2006a) reports that annually 1.3 million ha of forest is disturbed by fire. Also reports by Wetland International and other NGO's report the large scale fires and associated smog and haze problems for the (peat) forests of Russia (refs Goldammer 2003). However, forest fires do not completely destroy forests, leaving older trees alive (Dixon and Krankina, 1993). We estimate that half of all merchantable timber from the cleared forest areas was harvested and that the other half is destroyed by wild-fire. We realize that this is a very rough guess but no better estimates could be determined within the scope of this study.

On average 155 m^3 timber ha^{-1} is harvested during clear felling in Russian federations forests with an conversion factor to account for losses of 1.45 (chapter 2). Based on this information the Russian Federation is estimated to produce annually 12.7 and 22.2 million m^3 of round wood between 1990-2000 and 2000-2005 respectively (Table 19).

A major uncertainty in the Russian data is caused by the widespread illegal logging, which is sometimes estimated to be as much as the official figures (e.g. Vandergert and Newell 2003). However, in the scope of this study it was not possible to further address the exact level of uncertainty in the Russian figure.

Sweden
Between 1990 and 2005 the net forest area in Sweden has grown steadily by 11,000 ha per year (Table 18). During the same period the forest plantation area in Sweden expanded from 523,000 to 667,000 ha. When we discard the forest plantation area, the gross increase in forest area was some 1,000 ha per year on average in that period. Based on these data we assume that in Sweden no forests was converted between 1990-2005

3.2.3 Timber production from conversion areas - Temperate Forests

Australia
The total net forest area of Australia decreased from 167,9 million ha in 1990 to 163,7 million ha in 2005 (Table 18). As the area under forest plantations increased over the same period from 1,0 to 1,8 million ha, the gross area deforested per annum was 372,000 (1990-2000) and 250,000 ha yr^{-1} (2000-2005) (Table 19).

Like Russia, Australia has also suffered lately from major wildfires, but these were mainly in the southern, Mediterranean States. Unfortunately the FRA (FAO 2006a) does not provide data on the forest area disturbed by fire for Australia. Also, most deforestation is taken place in the marginal forest lands of Central NSW and Queensland which is mostly done by mechanical methods (Peter van der Meer, personal observation). We therefore assume that all harvestable wood was indeed being harvested from these converted areas.

On average 40 m^3 timber ha^{-1} is harvested during clear felling Australian forests (Chapter 2). Using a conversion factor of 1.23 (Chapter 2) leads to a total amount of 12.1 and 8.1 million m^3 ha^{-1} of round wood being produced annually between 1990-2000 and between 2000-2005 respectively (Table 19).

Chile

In Chile there has been a small net gain in forest area between 1990 and 2005 (Table 1). This gain in forest area is due to the rapid development of forest plantations (Table 18), often at the cost of native forest (e.g. (Echeverria et al., 2006). The gross loss in forest area per annum is estimated at 4,200 ha yr^{-1} between 1990 and 2000 and 4,000 ha yr^{-1} between 2000-2005.

Fire is an important natural phenomenon of Patagonian forest, with strongest fires occurring after El Niño and La Niña events (Veblen et al., 1999). However FAO (2006a) reports that only 28,000 ha (0.18%) of the forest area is annually disturbed by fire in Chile. We therefore assume that all merchantable timber from the cleared forest areas was harvested.

The average growing stock for Chile is 117 m^3 ha^{-1} (FAO 2006a). For the conversion factor we used the average value for clear felling in 2000 (1.43; Chapter 2). This resulted in an annual round wood production of 344,000 and 327,000 m^3 yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 19).

China

Between 1990 and 2005 the net forest area in China has grown with some 40 million ha (Table 18). About one third of this increase in net forest area was due to the growth in forest plantation area in this period (13 million ha). The remainder of this increase in forest area was due to other factors which are not further explained. This indicates that there was none deforestation occurring in China since 1990.

France

Net forest area in France has grown slightly between 1990 and 2005 (Table 18). As the increase in forest plantation area during the same period was even smaller, we conclude that there was no forest converted in France between 1990 and 2005.

Germany

Like in France, net forest area in Germany has grown slightly between 1990 and 2005 (Table 18). As Germany reported to have no forest plantation, we conclude there was no forest converted in Germany between 1990 and 2005.

Japan

In Japan there was a small decrease in forest area between 1990-2000 (-7,000 ha yr^{-1}, Table1). During the same period the plantation area grew by some 5,000 ha yr^{-1} (Table 18). Based on these figures we assume that Japan had a gross annual deforestation rate of 12,000 ha yr^{-1} between 1990-2000 (Table 19). There was no deforestation in Japan between 2000-2005.

Fire is not a major concern in Japanese forests (FAO 2006a). We presume that all harvestable wood was indeed being harvested from the converted areas in Japan. The average growing stock or Japanese forests is 145 m^3 ha^{-1} (UNECE FAO 2005). Taking into account 5% for losses during harvesting we estimate that on average 138 m3 timber is harvested per ha. For the conversion factor we used the average value for hardwoods and softwoods in New Zealand (1.27; see Chapter 2). The estimated annual round wood production between 1990 and 2000 was 1,3 million m^3 yr^{-1} (Table 19).

New Zealand
New Zealand experienced an annual net growth in forest area of 51,000 and 17,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). This increase in area was entirely due to the increase in forest plantation area. The gross change in forest area was exactly zero meaning there was no forest area being converted into other land-uses in New Zealand between 1990-2005.

Poland
Poland saw a small net increase in forest area of 18,000 and 27,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). As Poland is virtually without any forest plantations there was in fact a gross growth of forest area in Poland. We therefore assume that there was no forest area being converted into other land-uses in Poland between 1990-2005.

South Africa
The gross forest area in South Africa did not change between 1990-2005 (Table 18). However, during this period the forest plantation area had increased with some 15,000 ha yr^{-1}, which makes us assume that South Africa had a gross annual deforestation rate of 15,000 ha yr^{-1}.

Although fire is an important feature of many of the South African Mediterranean-type vegetation, we do not believe it is used extensively as a means to clear the forest. FAO (2006a) do not provide data on the amount of forest disturbed by fire. However, it is likely that in some areas it has happened un-intendedly during clearing operations. We therefore assume that timber was harvested from 75% of the cleared forest area.

The average growing stock for South Africa 69 m^3 ha^{-1} (FAO 2006a). For the conversion factor we used the average value for hardwoods and softwoods in New Zealand (1.27; see Chapter 2). This resulted in a average annual round wood production from forest conversion of 603,000 m^3 yr^{-1} (Table 19).

Turkey
Turkey had a net annual increase in forest area of 37,000 and 25,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). During this whole period the forest plantation area had increased with some 47,000 ha yr^{-1}, which makes us assume that South Africa had a gross annual deforestation rate of 9,000 ha yr^{-1} (1990-2000) and 22,000 ha yr^{-1} (2000-2005) (Table 19).

In Turkey fire destroys annually 8,000 ha of forest (FAO 2006a), which is similar to the annual area deforested. Unfortunately there is no information whether these two are indeed linked. As a rough estimate we assume that half of the deforested area in Turkey was cleared by fire, and consequently we assume that only from half the deforested area the standing timber had been harvested.

The average growing stock for Turkey forests is 138 m^3 ha^{-1} (FAO 2006a). The conversion factor to account for losses due to felling losses and bark logging from felled to produced volume is 1.22 (UNECE/FAO 2005). This resulted in an average annual round wood production from forest conversion of 526,000 m^3 yr^{-1} (1990-2000) and 1.24 million m^3 yr^{-1} (2000-2005) (Table 19).

USA
The USA had a net annual increase in forest area of 365,000 and 159,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). During this period the forest plantation area had increased with some 597,000 ha yr^{-1} (1990-2000) and 157,000 ha yr^{-1} (2000-2005). This means that the USA had a gross annual deforestation rate of 232,000 ha yr^{-1} between 1990 and 2000, and a small gross increase of 2,000 ha yr^{-1} between 2000 and 2005 (Table 19).

In the USA 2.1 Mha of forest is annually disturbed by fires (FAO 2006a). Most of these fires however occur in National Parks or other production forests. Most land-conversion takes place in smaller units and not in large-scale forest conversion operations. We did not find evidence that fire is being used in land conversion, and we therefore assume that for the whole deforested area all standing timber has been harvested.

The average growing stock for USA forests is 116 $m^3 ha^{-1}$ (FAO 2006a). To account for losses due to improper felling during logging we again used the value of 5% (cf chapter 2) resulting in an average of 110 m^3 timber harvested per ha.

For the conversion factor (1.37) we used the values given in Chapter 2; 1.29 for softwoods, and 1.51 for hardwoods, which were weighted according the fraction of total timber removals by each wood type (64% softwoods and 36% hardwoods in 2001). The estimated annual timber production from deforestation between 1990-2000 then is 19.7 million $m^3 yr^{-1}$ for all timber combined (Table 19).

3.2.4 Timber production from conversion areas - Tropical Forests

Brazil

Brazil has the highest gross deforestation rate of all countries studied. Compensated for the growth in plantation area (from 5.1 to 5.4 Mha between 1990 and 2005) the gross annual deforestation rate was 2.7 Mha yr^{-1} from 1990-2000, and 3.1 Mha from 2000-2005 (Table 19).

In the El Nino related events in 1998 at least 2 Mha forest was affected by ground-fire ((Nepstad et al., 2001). It is unclear how much forest was in total affected by fire in the period between 1990 and 2000. However, they also indicate that more than 1,8 Mha of forest and pasture land was accidently burnt in escaped management fires. It is evident that fire is a regular feature of Amazonian forests, and because of the forest fire feedback repeated burning makes forests more susceptible to burning of the complete vegetation. Based on these and other observations for 1990-2005 (e.g. Laurance 2000 and Laurance 2005) we estimate that about 50% of deforested area in Brazil was cleared by burning and did not yield to timber production.

In Chapter 2 it is indicated that the average amount of commercial round wood harvested from Amazonian forest during clear fell operations is 127 $m^3 ha^{-1}$ (based on Uhl et al., 1991). Applying the same conversion factor due to bark-losses and felling losses (Chapter 2) the average annual round wood production from forest conversion in Brazil was estimated at 146.7 million $m^3 yr^{-1}$ (1990-2000) and 169.6 million $m^3 yr^{-1}$ (2000-2005) (Table 19).

DR Congo

The DR Congo had a net annual decrease in forest area of 532,000 and 319,000 ha yr^{-1} in the periods 1990-2000 and 2000-2005 respectively (Table 18). As there are no plantations reported for DR Congo we assume that these figures represent the gross deforestation rate.

There are no data on fire frequency for Congo (FAO 2006a). We assume that most clearing is done by slash and burn on relatively small scale. In these cases most of the merchantable wood is being harvested and sold. We therefore assume that all timber from deforested areas was harvested.

The average growing stock of Congo forest is 170 $m^3 ha^{-1}$ (FAO 2006a), but the commercial volume is only approximately 37.5 m^3 ha^{-1} (FAO 2004a), which subsequently was taken as volume harvested per hectare. We do not have data on conversion factors (for over bark to under bark and losses). We therefore apply the figure for Brazilian forest (1.27), also being a tropical rain forest, resulting in 145 m^3 round wood produced per hectare. The average annual round wood production from forest conversion in DR Congo is then 13.8 million $m^3\ yr^{-1}$ for 1990-2000, and 8.3 million $m^3\ yr^{-1}$ for 2000-2005 (Table 19).

India

India had a net annual increase in forest area of 362,000 and 29,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). During this period the forest plantation area had increased with some 85,100 ha yr^{-1} (1990-2000) and 84,200 ha yr^{-1} (2000-2005). This means that India had a gross annual increase in forest of 276,000 ha yr^{-1} between 1990-2000, and a gross annual decrease of 55,000 ha yr^{-1} between 2000-2005 (Table 19).

Fire is annually disturbing some 3,7 Mha of forest in India (FAO 2006a). However, these fires are mainly used a way to manage the forest and there is no evidence of any large scale deforestation using fire in India (Schmerbeck et al., 2007). We therefore assume that all timber from deforested areas was harvested.

India has reported to have a growing stock of 69 $m^3\ ha^{-1}$ (FAO 2006a), which was taken as volume harvested per hectare. The wood conversion factor as used for clear felling was also applied to forest conversion. (1.20 – the average between clear felling in Indonesia and Malaysia), resulting in 57.5 m^3 round wood produced per hectare. The average annual round wood production from forest conversion in India is then 3.2 million $m^3\ yr^{-1}$ for 2000-2005 (Table 19).

Indonesia

Indonesia had a net annual deforestation rate of 1.87 Mha yr^{-1}, both between 1990-2000 and 2000-2005 (Table 18). During this period the forest plantation area had increased with some 79,000 ha yr^{-1} (1990-2000 and 2000-2005), resulting in a gross annual deforestation rate 1.95 Mha yr^{-1} between 1990-2005 (Table 19).

Although the FAO (2006a) states that fire disturbed only 122,000 ha per year in Indonesia, we suspect that the real area burnt each year is much higher. Large scale deforestation, often using fire, was regular practice during the last decade mainly on Kalimantan (e.g. Langner et al., 2007). As stated before it is well known that in converting the forest area for the 1.4 Mha Mega-Rice Project in Central Kalimantan a significant part was burnt, either deliberately or un-deliberately (e.g. Page et al., 2002). We estimate that half of the area deforested in Indonesia was cleared by burning and did not yield to timber production.

To determine the volumes harvested and produced the same values as for clar felling were used (chapter 0; 125 and 104.2 $m^3\ ha^{-1}$ with a conversion factor of 1.2). The average annual round wood production from forest conversion in Indonesia can then be estimated as 101.6 million $m^3\ yr^{-1}$ for both 1990-2000 and 2000-2005 (Table 19).

Malaysia

Malaysia had a net annual deforestation rate of 78,000 and 140,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). During this period the forest plantation area had decreased as well with some 29,000 ha yr^{-1} (1990-2000) and 17,000 ha yr^{-1} (2000-2005) (Table 18), meaning the gross deforestation rate was 49,000 and 123,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 19).

Fire did disturb only 1,000 ha yr^{-1} between 1990 and 2000 (FAO 2006a). Fire is also not known to be associated with large scale clearing in Malaysia, and generally all timber is harvested in clearing activities (F. Chai, personal communication).

In Malaysia the volume harvested by clear felling is 155 $m^3\ ha^{-1}$ (Chapter 2), with a conversion factor of 1.2 to get produced volumes. Using these figures we estimate that the average annual round wood production from forest conversion in Malaysia was 6.3 million $m^3 yr^{-1}$ between 1990-2000, and 15.9 million $m^3 yr^{-1}$ between 2000-2005 (Table 19).

Mexico

Mexico had a net annual deforestation rate of 348,000 and 260,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 18). Between 1990 and 2000 the forest plantation area had grown with some 106,000 ha yr^{-1}. Between 2000 and 2005 the area in forest plantations remained the same. Consequently the gross deforestation rate in Mexico 453,000 and 260,000 ha yr^{-1} between 1990-2000 and 2000-2005 respectively (Table 19).

Fire is an important disturbance agent in the more drier forests of Mexico; according to the FAO (2006a) some 194,000 ha of forest is annually disturbed by fire. However, fire is often part of the ecological system, and many species are adapted to major wildfires (e.g. Snook (1996). Alix-Garcia (2007) found that only 9% of the deforestation in Mexico was caused by wildfire. We therefore assume that 91% of all timber from cleared land is being harvested.

The FAO (2006a) does not give a growing stock for Mexican forests. We were also not able to get an average value elsewhere, maybe one of the reasons being that Mexico covers many different forest types (from tropical evergreen to dry deciduous and temperate forests) with probably a large variation in growing stocking. We therefore took the global average forest stocking rate (110 $m^3 ha^{-1}$) as given by the FAO (2006a).

Using a conversion factor of 1.2 we estimate that the average annual round wood production from forest conversion in Mexico was 37.8 million $m^3 yr^{-1}$ between 1990-2000, and 21.7 million $m^3 yr^{-1}$ between 2000-2005 (Table 19).

Nigeria

Nigeria had a net annual deforestation rate of 410,000 ha yr^{-1}, both between 1990-2000 and 2000-2005 (Table 18). During this whole period the forest plantation area had increased slightly with 6,500 ha yr^{-1}. Consequently, the gross annual deforestation rate for the whole period was 416,500 ha yr^{-1} (Table 19).

The FAO (2006a) does not provide fire data for Nigeria. Okore et al. (2007) describe three methods which are being used in Nigeria to clear forests (slash and burn, bulldozed non-windrowed and bulldozed windrowed) indicating that in all three methods the larger logs are being harvested. We thus assume that all timber from cleared land is being harvested.

The FAO (2006a) gives an average growing stock of 125 $m^3 ha^{-1}$ for the forests of Nigeria. To convert to volumes produced, the same conversion factor was used as for Brazil (1.17; 5% losses and 12% bark). For the whole period (1990-2005) the average annual round wood production from forest conversion in Nigeria was 44.5 million $m^3 yr^{-1}$ (Table 19).

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Appendix 1 - Conversion Factors

Conversion factors as used in the European forest sector outlook study (EFSOS, UNECE/FAO 2005; Table 20).

Table 20 . **Conversion factors as used in the EFSOS (UNECE/FAO 2005). Felling volume per m3of round wood production shows the conversion factors taking into account the under bark to over bark conversion, plus the differences between fellings and removals in countries (e.g. harvesting residues or losses).**

Country	Felling volume per m^3 of round wood production (m^3)	Volume of round wood (m^3 u. b.) required to produce 1 m^3 of:					
		Softwood sawnwood	Hardwood sawnwood	Particle board	Fibre board	Plywood	Veneer sheets
Austria	1.44	1.54	1.5	1.3	1.82	2	2.2
Belgium	1.16	1.6	1.6	1.4	1.8	1.9	1.9
Denmark	1.02	1.76	1.69	1.44	1.82	2.89	2.2
Finland	1.28	2.1	2.4	1.8	1.5	2.7	2
France	1.48	1.81	2.05	1.2	1.8	1.95	1.67
Germany	1.31	1.56	1.46	1.22	1.51	1.94	2.06
Greece	1.25	1.8	1.7	1.4	1.8	2.9	3.1
Iceland	1.4	1.76	1.69	1.44	1.82	2.89	2.2
Ireland	1.11	1.76	1.69	1.44	1.82	2.89	2.2
Italy	1.12	1.76	1.69	1.44	1.82	2.89	2.2
Luxembourg	1.15	1.6	1.6	1.4	1.8	1.9	1.9
Netherlands	1.43	1.64	1.57	1.44	1.82	1.89	1.89
Norway	1.25	1.76	1.69	1.44	1.82	2.89	2.2
Portugal	1.23	1.42	3.52	1.57	1.94	3.1	1.2
Spain	1.12	1.42	3.52	1.57	1.94	3.1	1.2
Sweden	1.21	2	1.9	1.4	1.7	2.3	2.2
Switzerland	1.37	1.7	1.8	1.4	1.6	1.5	1.9
United Kingdom	1.3	1.71	1.61	1.4	1.8	2.89	2.2
Albania	1.2	2	2	1.4	2.8	2.5	2.9
Bosnia and Herzegovina	1.25	1.8	1.7	1.4	1.8	2.9	2.2
Bulgaria	1.45	1.7	2.1	1.4	2.3	2.5	2.6
Croatia	1.24	1.8	1.7	1.4	1.8	2.9	2.2
Czech Republic	1.32	1.6	1.5	1.5	2.6	2.3	1.7
Estonia	1.33	1.7	1.6	1.4	1.8	2.9	2.2
Hungary	1.25	1.5	1.7	1.6	3.3	1.8	2
Latvia	1.37	1.7	1.6	1.4	1.8	2.7	2.2
Lithuania	1.32	1.6	1.7	1.8	2.6	2.3	2.2
Poland	1.44	1.5	1.4	1.8	1.8	2.3	1.9
Romania	1.43	1.7	1.6	1.7	2.1	2.3	2.9
Serbia and Montenegro	1.25	1.8	1.7	1.4	1.8	2.9	2.2
Slovakia	1.44	1.8	1.7	1.4	1.8	2.9	2.2
Slovenia	1.15	1.8	1.7	1.4	1.8	2.9	2.2
TFYR Macedonia	1.1	1.8	1.7	1.4	1.8	2.9	2.2
Turkey	1.22	1.8	1.7	1.4	1.8	2.9	2.2
Belarus	1.14	1.6	1.45	1.6	3	2.65	2
Republic of Moldova	1.76	2	2	1.4	2.8	2.5	2.9
Russian Federation	1.45	1.6	1.5	1.6	3	2.7	2
Ukraine	1.33	1.6	1.5	1.6	3	2.7	2

Table 21
Conversion factors as used in the European forest sector outlook study (UNECE/FAO 2005). Volume of round wood (under bark) required to produce one metric tonne of pulp product.

Country	Volume of round wood (under bark) required to produce one metric tonne of product (1000 kg)						
	Mechanical pulp	**Chemical pulp**	**Semi-chemical pulp**	**News print**	**Printing & writing paper**	**Other paper & paper board**	**Recovered paper**
Austria	2.48	4.48	2.86	3.2	4	3.39	3.8
Belgium	2.3	4.5	2.9	3.2	4	3.4	3.8
Denmark	2.48	4.48	2.86	3.2	4	3.39	3.8
Finland	2.4	4.7	2.2	3.2	4	3.4	3.8
France	**2.48**	4.48	2.86	3.2	4	3.39	3.8
Germany	**2.6**	4.7	2.7	3.2	4	3.39	3.8
Greece	2.5	4.5	2.9	3.2	4	3.4	3.8
Iceland	2.48	4.48	2.86	3.2	4	3.39	3.8
Ireland	2.48	4.48	2.86	3.2	4	3.39	3.8
Italy	2.48	4.48	2.86	3.2	4	3.39	3.8
Luxembourg	2.3	4.5	2.9	3.2	4	3.4	3.8
Netherlands	2.27	4.48	2.86	3.2	4	3.39	3.8
Norway	2.39	4.5	2.86	3.2	4	3.39	3.8
Portugal	2.48	4.48	2.86	3.2	4	3.39	3.8
Spain	2.48	4.48	2.86	3.2	4	3.39	3.8
Sweden	**2.3**	4.7	2.2	3.2	4	3.39	3.8
Switzerland	2.5	4.5	2.9	3.2	4	3.4	3.8
United Kingdom	2.16	4.48	2.86	3.2	4	3.39	3.8
Albania	1.2	4.5	2.9	3.2	4	3.4	3.8
Bosnia and Herzegovina	2.5	4.5	2.9	3.2	4	3.4	3.8
Bulgaria	2.3	5.3	2.3	3.2	4	3.4	3.8
Croatia	2.5	4.5	2.9	3.2	4	3.4	3.8
Czech Republic	2.6	5.3	2.9	3.2	4	3.4	3.8
Estonia	2.5	4.5	2.9	3.2	4	3.4	3.8
Hungary	2.5	4.5	2.9	3.2	4	3.4	3.8
Latvia	2.5	4.5	2.9	3.2	4	3.4	3.8
Lithuania	2.5	4.8	2.9	3.2	4	3.4	3.8
Poland	**2.6**	5.3	3.1	3.2	4	4.7	3.8
Romania	2.9	6.4	3.2	3.2	4	3.4	3.8
Serbia and Montenegro	2.5	4.5	2.9	3.2	4	3.4	3.8
Slovakia	2.5	4.5	2.9	3.2	4	3.4	3.8
Slovenia	2.5	4.5	2.9	3.2	4	3.4	3.8
TFYR Macedonia	2.5	4.5	2.9	3.2	4	3.4	3.8
Turkey	**2.5**	4.5	2.9	3.2	4	3.4	3.8
Belarus	2.5	5.21	2.9	3.5	4.2	3.8	3.8
Republic of Moldova	1.2	4.48	2.86	3.5	4.2	3.8	3.8
Russian Federation	**2.5**	5.2	2.9	3.5	4.2	3.8	3.8
Ukraine	2.5	5.2	2.9	3.5	4.2	3.8	3.8

Appendix 2 – Regional production data

Table A2.1

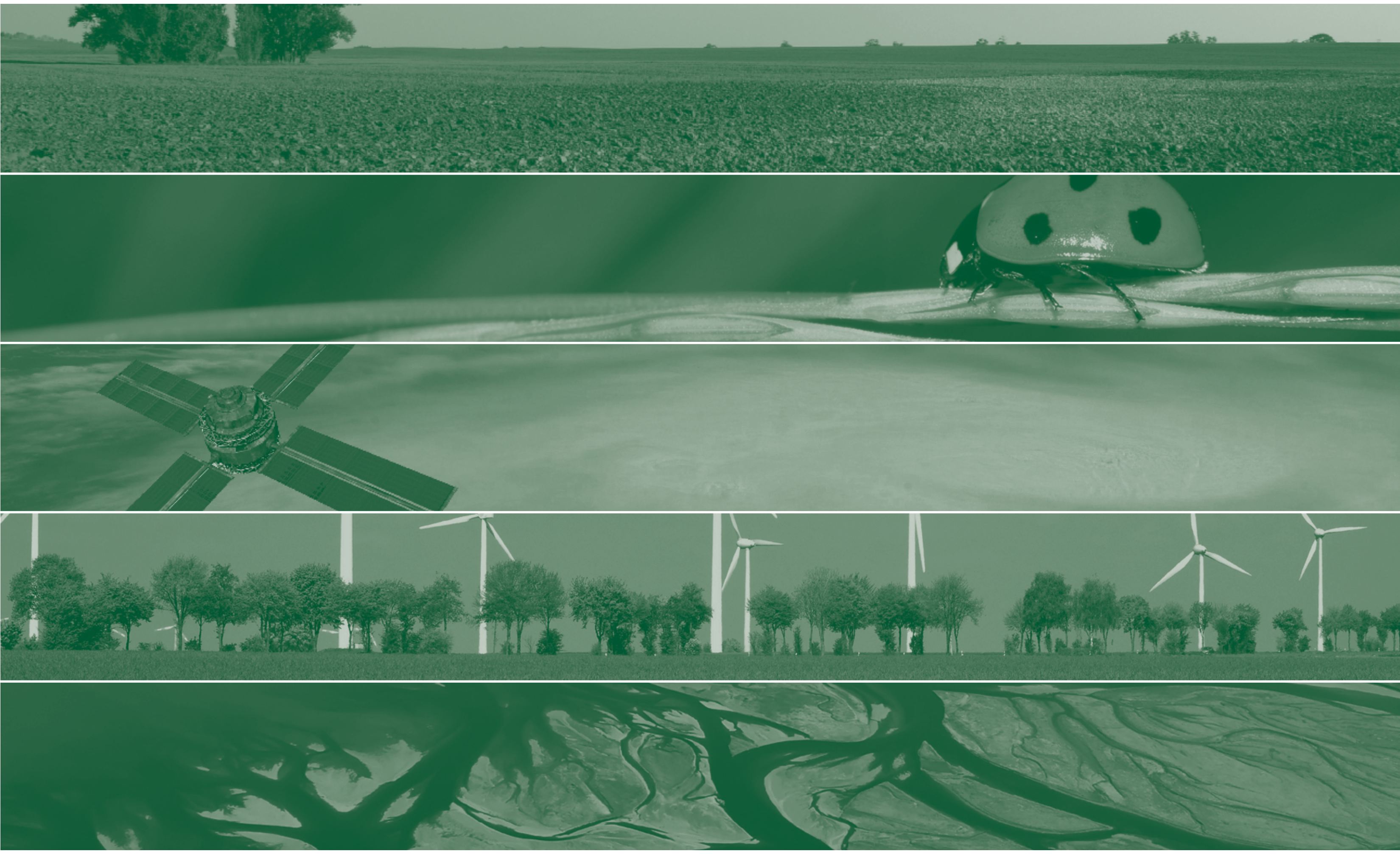
Regional production data in 1990 for industrial roundwood in total volume produced (1000 m^3 yr^{-1}), average volume cutdown per ha for each management type, corresponding volume removed per ha (accounting for felling losses, etc.) and the total area needed per management type to provide the produced industrial round wood.

	Volume (1000m^3 yr^{-1})						Volume cutdown/ha (m^3 ha^{-1})					Volume removed/ha (m^3 ha^{-1})					Area needed (km^2)					
Regions	Productive plantations	Clear cut	Selective cut CL	Selective cut RIL	Selective cut	Total	Productive plantations	Clear cut	Selective cut	Selective cut CL	Selective cut RIL	Productive plantations	Clear cut	Selective cut	Selective cut CL	Selective cut RIL	Productive plantations	Clear cut	Selective cut	Selective cut CL	Selective cut RIL	Total area
1 Canada	0	166,367	0	0	0	166,367	0	238	0			0	190	0			0	8,756	0	0	0	8,756
2 USA	62,440	347,738	0	0	0	410,178	306	359	0			247	282	0			2,528	12,331	0	0	0	14,859
3 Mexico	30	0	7,531	0	7,531	15,092	295		58	58		246		42	42		1	0	1,793	1,793	0	1,794
4 Rest Central America	15	0	3,776	0	3,776	7,567	295		58	58		246		42	42		1	0	899	899	0	900
5 Brazil	43,850	17,930	14,670	0	14,670	91,119	330	127	31	31		270	109	23	23		1,624	1,653	6,434	6,434	0	9,711
6 Rest South America	26,779	1,745	6,713	0	6,713	41,950	390	212	58	58		305	154	40	40		877	114	1,681	1,681	0	2,672
7 Northern Africa	1,035	0	426	0	426	1,887	390		16	16		312		11	11		33	0	405	405	0	438
8 Western Africa	16,645	0	9,861	0	9,861	36,367	390		16	16		312		11	11		533	0	9,373	9,373	0	9,907
9 Eastern Africa	5,082	0	3,011	0	3,011	11,104	390		16	16		312		11	11		163	0	2,862	2,862	0	3,025
10 Southern Africa	19,497	0	0	0	0	19,497	244		0			192		0			1,015	0	0	0	0	1,015
11 OECD Europe	4,524	235,888	0	0	0	240,412	173	457	0			121	350	0			374	6,749	0	0	0	
12 Eastern Europe		65,930	0	0	0	65,930		244	0				178	0			0	3,695	0	0	0	3,695
13 Turkey	492	5,652	0	0	0	6,144	173	228	0			121	178	0			41	317	0	0	0	357
14 Ukraine +		16,541	0	0	0	16,541		244	0				178	0			0	927	0	0	0	927
15 Asia-Stan		0	0	0	0	0		202	0				140	0			0	0	0	0	0	0
16 Russia +		257,802	0	0	0	257,802		155	0				107	0			0	24,094	0	0	0	24,094
17 Middle East		1,177	0	0	0	1,177			0					0			0	0	0	0	0	0
18 India +	12,330	14,195	3,549	0	3,549	33,623	257	69	40	40		214	58	24	24		576	2,469	1,460	1,460	0	4,505
19 Korea	615	1,194	0	0	0	1,809	117	111	0			95	71	0			65	169	0	0	0	234
20 China +	32,088	62,289	0	0	0	94,377	117	111	0			95	71	0			3,378	8,835	0	0	0	12,213
21 South East Asia	2,385	34,914	22,322	0	22,322	81,943	219	155	65	65		179	129	41	41		133	2,702	5,498	5,498	0	8,333
22 Indonesia +	2,603	18,353	22,431	0	22,431	65,818	198	125	93	93		162	104	55	55		161	1,761	4,101	4,101	0	6,023
23 Japan	0	29,141	0	0	0	29,141		154	0				125	0			0	2,331	0	0	0	2,331
24 Oceania	22,787	7,043	0	0	0	29,830	500	40	0			393	33	0			580	2,167	0	0	0	2,747
World	253,197	1,283,899	94,290	0	94,290	1,725,675											12,083	79,070	34,507	34,507	0	118,537

Table A2.2

Regional production data in 2005 for industrial roundwood in total volume produced (1000 m^3 yr^{-1}), average volume cutdown per ha for each management type, corresponding volume removed per ha (accounting for felling losses, etc.) and the total area needed per management type to provide the produced industrial round wood.

	Volume (1000m^3 yr^{-1})						Volume cutdown/ha (m^3 ha^{-1})					Volume removed/ha (m^3 ha^{-1})					Area needed (km^2)					
Regions	Productive plantations	Clear cut	Selective cut CL	Selective cut RIL	Selective cut	Total	Productive plantations	Clear cut	Selective cut	Selective cut CL	Selective cut RIL	Productive plantations	Clear cut	Selective cut	Selective cut CL	Selective cut RIL	Productive plantations	Clear cut	Selective cut	Selective cut CL	Selective cut RIL	Total area
1 Canada	0	208,813	0	0	0			238	0				190	0			0	10,990	0	0	0	10,990
2 USA	62,440	366,450	0	0	0		306	357	0			247	279	0			2,528	13,134	0	0	0	15,662
3 Mexico	30	0	4,425	873	5,298		295		56	58	49	246		42	42	42	1	0	1,261	1,053	208	1,263
4 Rest Central America	36	0	5,494	924	6,417		295		13	14	12	246		10	10	10	1	0	6,417	5,494	924	6,419
5 Brazil	43,850	19,589	23,348	10,006	33,354		343	127	30	31	26	273	109	23	23	22	1,606	1,805	14,707	10,240	4,467	18,119
6 Rest South America	29,126	1,761	19,697	1,257	20,954		409	231	30	31	26	295	166	42	45	22	989	106	4,982	4,420	561	6,076
7 Northern Africa	629	0	529	2	532		390		16	16	12	312		10	10	10	20	0	516	514	2	536
8 Western Africa	7,802	0	4,705	84	4,789		390		16	16	12	312		10	10	10	250	0	4,652	4,568	84	4,902
9 Eastern Africa	1,509	0	915	12	926		390		16	16	12	312		10	10	10	48	0	900	888	12	948
10 Southern Africa	23,579	0	0	0	0		216		0			172		0			1,371	0	0	0	0	1,371
11 OECD Europe	0	263,011	0	0	0		173	422	0			121	326	0			0	8,057	0	0	0	8,057
12 Eastern Europe		92,881	0	0	0			281	0				205	0			0	4,531	0	0	0	4,531
13 Turkey	526	12,625	0	0	0		173	227	0			121	151	0			43	836	0	0	0	880
14 Ukraine +		15,150	0	0	0			202	0				140	0			0	1,082	0	0	0	1,082
15 Asia-Stan		491	0	0	0			202	0				140	0			0	35	0	0	0	35
16 Russia +		164,563	0	0	0			155	0				107	0			0	15,380	0	0	0	15,380
17 Middle East		782	0	0	0				0					0			0	0	0	0	0	0
18 India +	13,095	10,065	2,516	0	2,516		257	69	40	40	33	214	58	24	24	24	612	1,750	1,035	1,035	0	3,398
19 Korea	1,577	66	0	0	0		113	111	0			93	71	0			170	9	0	0	0	179
20 China +	53,167	2,215	0	0	0		113	111	0			93	71	0			5,717	314	0	0	0	6,031
21 South East Asia	8,218	26,579	6,622	4,234	10,856		146	155	61	65	55	120	129	40	41	40	687	2,057	2,687	1,631	1,056	5,431
22 Indonesia +	8,110	9,384	10,323	1,147	11,470		241	125	91	93	76	197	104	55	55	54	411	901	2,102	1,887	214	3,413
23 Japan	0	11,939	0	0	0			154	0				125	0			0	955	0	0	0	955
24 Oceania	34,633	10,481	0	0	0		501	40	0			393	33	0			882	3,225	0	0	0	4,107
World	288,325	1,216,845	78,573	18,539	97,112	1,699,395											15,336	65,169	39,259	31,731	7,528	119,764



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