Comparative life cycle assessment of certified and non-certified wood

Final Report

Prepared for: **PEFC**

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Quantis offers cutting-edge services in environmental footprinting (multiple indicators including carbon, water and biodiversity), eco design, sustainable supply chains and environmental communication. Quantis also provides innovative LCA software, Quantis SUITE 2.0, which enables organizations to evaluate, analyze and manage their environmental footprint with ease. Fuelled by its close ties with the scientific community and its strategic research collaborations, Quantis has a strong track record in applying its knowledge and expertise to accompany clients in transforming LCA results into decisions and action plans. More information can be found at www.quantis-intl.com.

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PROJECT INFORMATION	
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Associated files	This report is associated with the processes modeled in Quantis SUITE 2.0

1 Context

PEFC is the world's largest forest certification system. To assess the environmental benefit of forest management certification, PEFC commissioned Quantis to realize a life cycle assessment (LCA) of certified and non-certified wood.

A pre-project was performed to evaluate if it was possible to realize a LCA based on the PEFC forest management standards. This first stage of the project reviewed (i) the PEFC meta standard (PEFC ST, 1003:2010) , (ii) the national standards for three selected countries, Malaysia (MC&I, 2002), Brazil (ABNT, 2004) and Russia (RNCFC, 2006) and (iii) available data on non-certified forest for comparative base (e.g., ecoinvent). The review objectives were:

- to identify possible indicators and data needed to assess the difference between certified and non-certifiable forestry and to perform a comparative LCA of certified and non-certifiable wood;
- to brainstorm on how to use LCA to create insights in the difference between certified and non-certifiable wood from an environmental point of view.

The main conclusion of the standards review is that there is no sufficient data to compare certified to non-certified forest across common environmental attributes on a global average scale (e.g., due to variance between countries). However, an important difference between certified and non-certified wood that influences quantifiable environmental impacts within the context of LCA is the assurance that certified products are not derived from deforestation activities.

The worldwide recognized life cycle inventory (LCI) database ecoinvent (Ecoinvent Centre, 2010) includes wood production and harvesting processes, but mainly coming from sustainably managed forests (without deforestation, no use of fertilizers or pesticides). Within ecoinvent only two types of wood are coming from deforested area. It is therefore not possible to differentiate between certified and non-certified wood using the ecoinvent database. The wood processes available in the database are underestimating the impact of wood products if they are used to assess non-certified wood products. Therefore, differentiated datasets in ecoinvent need to be created which consider how non-certified wood potentially contributes to global deforestation.

The goal of this study is to create new processes for non-certified wood. As a first approximation, only the environmental impacts from deforestation are considered (other differences such as pesticide or fertilizer use are not considered so far). This enables to differentiate between certified and non-certified wood, without and with deforestation respectively. A global average approach is taken, meaning that when buying non-certified wood products there is no active encouragement against deforestation as there is no traceability to prove otherwise.

2 Method

There are three main steps for the creation of these new datasets:

1. Identification of the amount of deforestation related to non-certified wood extraction
2. Evaluation of the environmental impacts related to deforestation and due to wood extraction (‘deforestation process’)
3. Creation of the datasets in ecoinvent format and in Quantis SUITE 2.0[1]

2.1 Identification of deforestation related to non-certified wood

Deforestation is defined as (i) the direct human-induced conversion of forested land to non-forested land (Decision 11/CP.7, UNFCCC, 2001) and (ii) the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold (FAO 2001). While the main drivers of deforestation vary among countries, it is commonly recognized that agriculture, urban expansion, infrastructure and mining all play significant roles. Unsustainable logging is often also a driver for forest degradation and to a lesser extent for deforestation (Hosonuma et al. 2012).

This dataset focuses on unsustainable logging and its role in deforestation. As forest management certification provides assurances for the sustainability of forest management, it is considered that uncertified forest operations bare the responsibility of forestry’s role in deforestation. Therefore, since certified wood provides evidence that no deforestation took place, it is assumed that deforestation is only related to non-certified wood. As first approximation, deforestation is considered as a permanent loss of primary forest. We are conscious that this is an over simplification. However, with current state-of-the-art in life cycle impact assessment, environmental quantifications bare large uncertainties which are not capable of distinguishing biodiversity effects between secondary and primary forest.

The data used to calculate the amount of deforestation related to wood extraction are presented in Table 2-1.

[1] Quantis SUITE 2.0 is a web-based, user friendly LCA software, developed by Quantis.

Table 2-1: Calculation parameters for deforestation related to non-certified wood extraction

Parameter	Value	Unit	Comment and reference
Area deforested per year	13’000’000	ha/year	Total area deforested per year in the world, FAO (2011).
Fraction of deforestation allocated to wood extraction	10%	%	Deforestation related to wood extraction, is an average among data from mongabay website ranging from 1% to 26% (http://rainforests.mongabay.com/deforestation_drivers.html). Houghton (reference used in ecoinvent; ecoinvent 2010) gives 8% of biomass extracted as wood. This fraction corresponds to the area deforested that has wood extraction as main driver.
Legal wood extraction	3’400’000’000	m^3/year	Total wood extraction based measured by FAO (2010), i.e. legal extraction.
Illegal wood extraction ratio	7.85%	%	Illegal logging ratio is based on Seneka Creek Associate (2004) that specifies the total wood production (total: 2’124’480’000 m^3/yr) and the suspicious volumes (total: 166’815’000 m^3/yr).
Certified wood ratio	26.5%	%	Certified wood ratio in the world is based on UNECE-FAO (2012) and corresponds to a ratio for round wood.
Calculated parameters	**Value**	**Unit**	**Comment and reference**
Deforestation allocated to wood	13’000’000 * 10% = 1’300’000	ha/year	Total deforested area multiplied by the fraction of deforestation that can be allocated to wood extraction
Illegal wood extraction	(3’400’000’000 / (1-7.85%)) * 7.85% = 289’718’108	m^3/year	Illegal wood corresponding to 7.85%, legal wood extraction from FAO (2010) corresponds to 92.15% of total wood extraction.
Total wood extraction	3’400’000’000 + 289’718’108 = 3’689’718’108	m^3/year	Sum of legal and illegal wood extraction
Certified wood extraction	3’400’000’000 * 26.5% = 901’000’000	m^3/year	The certified wood ratio is for legal wood extraction
Non-certified wood extraction	3’689’718’108 – 901’000’000 = 2’788’718’108	m^3/year	This corresponds to the total wood extraction minus the certified wood extracted.
Deforested area for non-certified wood	**1’300’000 / 2’788’718’108 = 0.000466**	**ha/m^3**	**Area deforested per m^3 of non-certified wood extracted**

Based on these parameters and calculations, **the area deforested to obtain a cubic meter of non-certified wood corresponds to 4.66 m^2.**

2.2 Evaluation of the environmental impacts of deforestation: deforestation process

The impacts related to deforestation are the following:

- Machines to cut the trees and transport them
- Infrastructures necessary for the machinery (access road, shed)
- Biomass burning and degradation
- Emissions due to land use change (LUC): carbon loss from soils and changes in other emissions (N_2O, CH_4, etc.) from soils
- Biodiversity loss
- Effect on pluvial system

The deforestation for wood process has been built based on the ecoinvent v3 draft process called "clear-cutting, primary forest to arable land/GLO" (Ecoinvent Centre, 2012).

2.2.1 Machines and infrastructure

As machinery use (power sawing and diesel) and infrastructure (occupation for construction site or access road) are already considered in the processes of wood extraction named " … at forest road" to which the deforestation process will be added, they do not need to be considered here. Therefore, they are put to zero in the deforestation process.

2.2.2 Biomass burning and emissions due to land use change

The forest biomass can be distributed among

- above ground (living) biomass (trees)
- below ground (living) biomass (roots and soil biomass)
- dead organic matter (litter or dead wood)

Litter or dead wood are not living biomass. They are assumed to burn or degrade, and emit the same substances as (living) biomass. The (living) biomass will either be extracted as wood, or burned or degraded. The Figure 2-1 explains how the total quantity of wood extracted, biomass burned and biomass degraded per hectare is calculated.

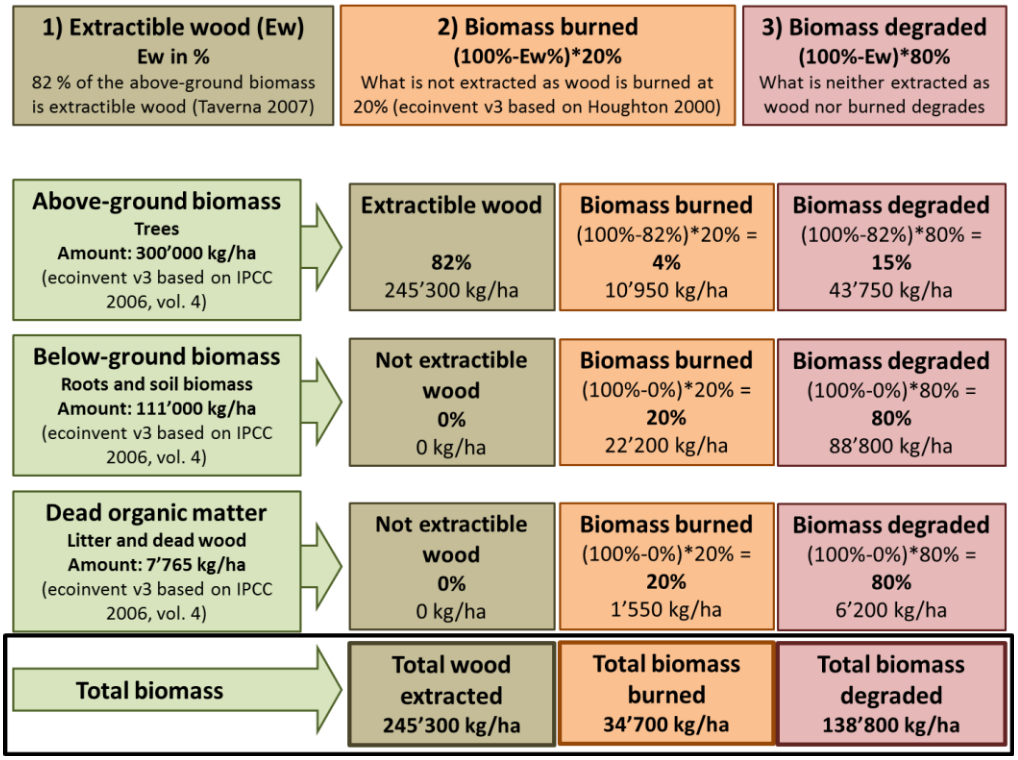

Figure 2-1: Calculation of the total wood extracted, total biomass burned and total biomass degraded in case of deforestation for wood.

The method applied to calculate the impact from biomass burning and degradation is the same as the one applied in the ecoinvent v3 process for clear-cutting (Ecoinvent Centre, 2012). The sole difference incorporated is the amount of extracted/extractible wood. Here we assumed that all extractible useable wood is extracted (and therefore not released as carbon emissions) as we model deforestation impacts for wood products. The amount of extractible useable wood is calculated based on Taverna et al. (2007). Taverna et al. (2007) gives the amount of biomass that is related to useable wood, i.e. the amount of biomass extracted to obtain 1 m3 of useable wood (stemwood with bark). In ecoinvent processes of wood extraction "at forest road", the wood is under bark. Therefore we are interested in amount of biomass that represents wood (85%) with bark (10%) and crown (2.3%) but without stump (2.7%) over the entire above-ground biomass (i.e., total biomass (150%) without roots (31%)), see Figure 2-2: Table extracted from Taverna et al. (2007)): (85% + 10% + 2.3%) / (150% - 31%) = 82%.

Tab. 7 > Composition of the living tree biomass[37]

Stemwood with bark, with stump	100 %	Of which: stemwood without bark, without stump: 85 % bark: 10 %, crown: 2.3 %, stump: 2.7 %
Roots	31 %	
Needles/leaves	4 %	
Branch brushwood	12 %	
Branch compact wood	3 %	
Total living tree biomass	**150 %**	
Potentially utilizable: stemwood in the bark, without stump + branch compact wood + branch brushwood	112 %	

Figure 2-2: Table extracted from Taverna et al. (2007), detailing the composition of the living tree biomass

As specified in Figure 2-1, 20% of the biomass that is not extractible wood is burned (Houghton 2000). This assumption derives from the ecoinvent v3 process for clear-cutting (Ecoinvent Centre, 2012) and can be challenged, however, we decided here to stay consistent with ecoinvent v3. The inventory for biomass burning has been calculated the same way as in ecoinvent, i.e., the substance emissions (incl. CO_2) in kg per kg biomass burned (based on Andreae and Merlet 2001) and the choice of the substances emitted.

For degraded biomass, only CO2 emissions are considered and they are calculated based on the carbon content of the biomass (47%, ecoinvent v3, based on IPCC 2006 vol. 4).

It is considered that emissions from soil are included in the burning and degradation of below ground biomass. The other emissions due to land use change (N_2O or CH_4) are not considered here as not enough data is available on this issue and in ecoinvent.

2.2.3 Biodiversity loss

Within LCA, biodiversity loss is measured through the potential fraction of species that get lost due to an activity (Potentially Disappeared fraction of species, PDF). As a first simplification, it is considered that all species disappear when deforestation occurs. In LCA the environmental impact to restore an area of land over a certain time period into its original situation (after or not after the land is used for other purposes) is measured in PDF.m2.year and named restoration. This impact of restoration is fully attributed to deforestation. A restoration time of 100 years is applied. As restoration from clear land to forest does not happens at once but regular over time, the impact is divided by two as explained in Figure 2-3.

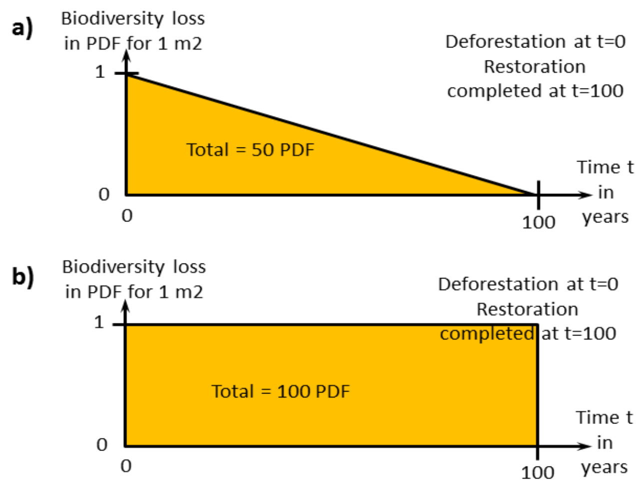

Figure 2-3: Restoration of biodiversity loss due to deforestation after 100 years. PDF stands for Potentially Disappeared Fraction of species, where 1 indicates 100% disappearance of species. a) Progressive restoration, realistic scenario considered in this study. b) Brutal restoration after years, not realistic scenario.

Therefore for 1 m^2 deforested, 100% species disappear over 1 m^2 of land during 100 years, divided by 2 for the gradual change, which results in an impact on biodiversity of 50 PDF-m^2-year.

Therefore 1 m^2 of the elementary flow “transformation, from forest, primary” is considered to correspond to an impact on biodiversity of 50 PDF-m^2-year. This latter value is part of the impact assessment methodology and is not part of the inventory process data.

2.2.4 Effect on pluvial system

It is known that deforestation can affect the pluvial system. Deforestation means less evapo-transpiration. But not enough data is available on this topic and it is therefore not included in the modeling. This could be added in future improvements of the model.

2.2.5 Multiple output process

Deforestation for wood results in wood products as output, but could also result into agricultural land afterwards. Part of the emissions from the land transformation from deforestation could be allocated to each of these two outputs. But as we are here interested in the building of a process of deforestation for wood and as it is unknown what is done with the land afterwards, it has been decided that this deforestation is 100% allocated to the wood extraction. This is a simplification which can give an overestimation of reality and therefore can be challenged. However, we decided to keep this allocation in order to be consistent with the choices made in the ecoinvent database.

2.2.6 Deforestation for wood products process

Table 2-2 describes the process of deforestation for wood extraction as it is built in Quantis SUITE 2.0 and using the naming convention of ecoinvent.

Table 2-2: Deforestation for wood products process description, named consistently with ecoinvent v3 'Clear-cutting, primary forest for round wood production GLO U'.

Clear-cutting, primary forest for wood production GLO U (Q 1.0)				
This process assesses the impacts related to deforestation related to wood extraction. It is based on the process "clear-cutting, primary forest to arable land/GLO" from ecoinvent and is adapted. **All the inputs and outputs are given for 1 ha deforestation for wood products.**				
Resources	**Sub-comp.**	**Amount**	**Unit**	**Comments**
Transformation, from forest, primary	land	1	ha	Land transformation allocated to wood extraction.
Transformation, to forest, intensive, clear-cutting	land	1	ha	Land transformation allocated to wood extraction.
Occupation, construction site	land	0	m^2a	The occupation for access road and other construction is considered in the process "… at forest road" and therefore erased here to avoid double counting when the deforestation process will be used together with processes of wood "… at forest road".
Materials/fuels		**Amount**	**Unit**	**Comments**
Power sawing, without catalytic converter/RER		0	hr	Power sawing is considered in the process "... at forest road" and therefore erased here to avoid double counting when the deforestation process will be used together with processes of wood "… at forest road".
Diesel, burned in building machine/GLO		0	MJ	Diesel is considered in the process "... at forest road" and therefore erased here to avoid double counting when the deforestation process will be used together with processes of wood "… at forest road".
Emissions to air		**Amount**	**Unit**	**Comments**
Carbon dioxide	low. pop.	(1.58 * 34'700) + (138'800 * 47%/12*44) = 294'025	kg	Emissions related to biomass burning (34'700 kg biomass / ha) and biomass degradation (138'800 kg biomass / ha with 47% carbon content).
Carbon monoxide, fossil	low. pop.	0.104 * 34'700 = 3609	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Methane, fossil	low. pop.	0.0068 * 34'700 = 236	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Ethene	low. pop.	0.00195 * 34'700 = 68	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Ethyne	low. pop.	4.0E-5 * 34'700 = 1.4	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Propene	low. pop.	0.00055 * 34'700 = 19	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Benzene	low. pop.	0.0004 * 34'700 = 14	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Toluene	low. pop.	0.00025 * 34'700 = 8.7	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.

Formic acid	low. pop.	0.0011 * 34’700 = 38	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Acetic acid	low. pop.	0.0021 * 34’700 = 73	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Formaldehyde	low. pop.	0.0014 * 34’700 = 49	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Acetaldehyde	low. pop.	0.00065 * 34’700 = 23	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Methanol	low. pop.	0.002 * 34’700 = 69	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Phenol	low. pop.	6.0E-6 * 34’700 = 0.2	g	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Acetone	low. pop.	0.00062 * 34’700 = 22	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Furan	low. pop.	0.0048 * 34’700 = 167	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Isoprene	low. pop.	1.6E-5 * 34’700 = 0.56	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Ammonia	low. pop.	0.0013 * 34’700 = 45	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Cyanide	low. pop.	0.0034 * 34’700 = 118	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Nitrogen oxides	low. pop.	0.0016 * 34’700 = 56	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Acetonitrile	low. pop.	0.00018 * 34’700 = 6.2	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Particulates, < 2.5 um	low. pop.	0.0091 * 34’700 = 316	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Particulates > 2.5 um, and < 10 um	low. pop.	0.0083 * 34’700 = 288	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Sulfur dioxide	low. pop.	0.00057 * 34’700 = 20	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Dinitrogen monoxide	low. pop.	0.0002 * 34’700 = 6.9	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Ethane	low. pop.	0.0012 * 34’700 = 42	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Propane	low. pop.	0.00015 * 34’700 = 5.2	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Terpenes	low. pop.	0.00015 * 34’700 = 5.2	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Ethanol	low. pop.	1.8E-5 * 34’700 = 0.62	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Xylene	low. pop.	6.0E-5 * 34’700 =2.1	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Ethylbenzene	low. pop.	2.4E-5 * 34’700 = 0.83	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.

PAH, polycyclic aromatic hydrocarbons	low. pop.	2.5E-5 * 34'700 = 0.87	kg	Emission factors given in kg species per kg dry matter burned is taken from (Andreae and Merlet 2001). Burning of 20% of the biomass.
Output		**Amount**	**Unit**	**Comments**
Clear-cutting, primary forest for wood production GLO U (Q 1.0)		1	ha	

2.3 Creation of the datasets in ecoinvent format and in Quantis SUITE 2.0

The deforestation for wood product process has been created in Quantis SUITE 2.0 as described in the Table 2-2. In ecoinvent, the wood processes are structured as described in Figure 2-4.

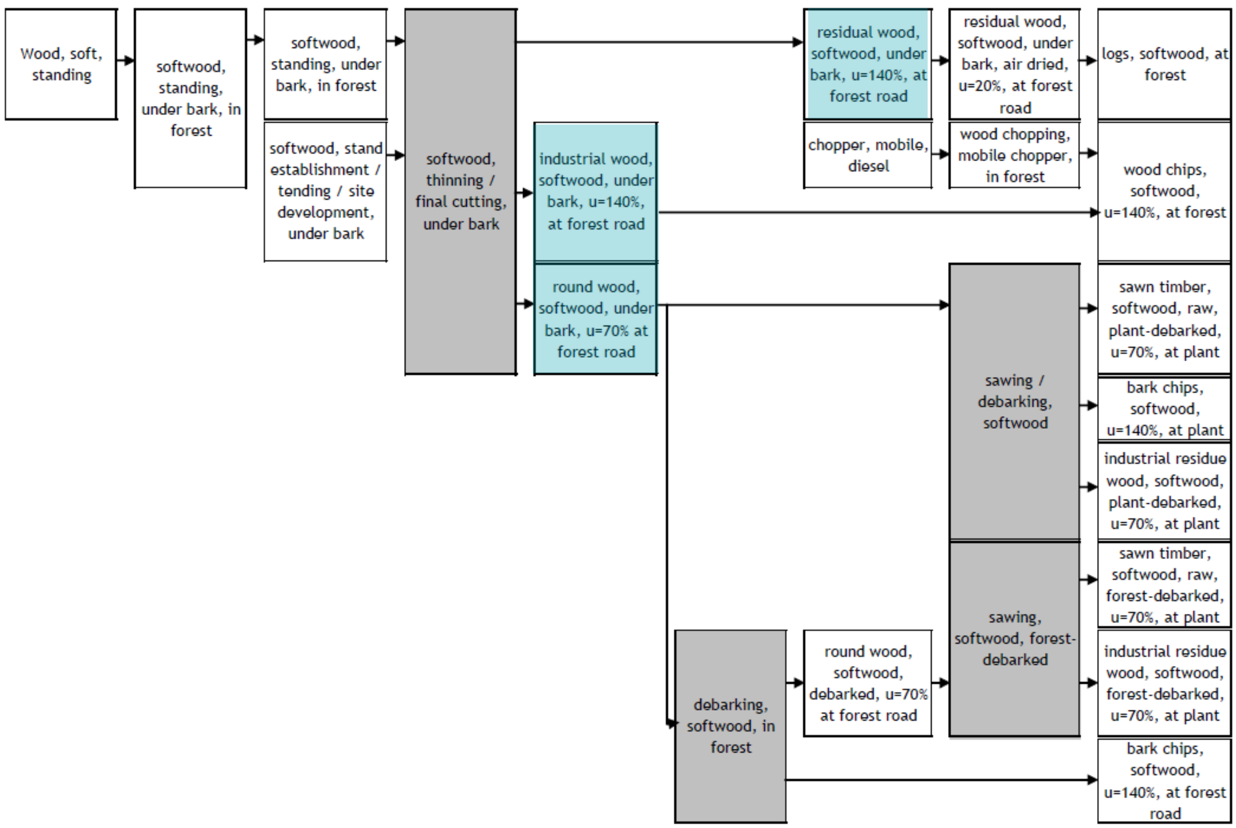

Figure 2-4: Softwood production in ecoinvent, figure taken from the ecoinvent report n°9. White boxes are processes that can be found in the ecoinvent database. Grey boxes are multi-output processes that are not directly in the database (but that can be obtained summing up the correct amount of the co-products related). The processes highlighted in blue are the ones that are updated with the deforestation process. Hardwood production has the same processes organization.

The deforestation process is added to the following ecoinvent processes:

- *"Round wood, softwood, under bark, u=70% at forest road / RER"*
- *"Industrial wood, softwood, under bark, u=140% at forest road / RER"*

- *"Residual wood, softwood, under bark, u=140% at forest road / RER"*
- *"Round wood, hardwood, under bark, u=70% at forest road / RER"*
- *"Industrial wood, hardwood, under bark, u=80% at forest road /RER"*
- *"Residual wood, hardwood, under bark, u=80% at forest road / RER"*

These processes consider the impacts from motor manual processes for thinning and final cutting and the transport of the products to the nearest forest road, as well as the impact from the underlying process *"wood, standing, under bark"* (being, carbon dioxide uptake, and land transformation). For round wood, the tree is cut, disbranched with a chainsaw, and pulled out of the forest. Industrial wood and residual wood (branches and small trees) is harvested with chainsaws and cut into suitable pieces. Chips are mainly made from industrial wood directly chopped at location, while split wood is made from residual wood through cutting one meter logs, splitting and piling them.

For the 6 processes above, 4.66 m^2 of the deforestation process is added and multiplied by an allocation factor. The process *"wood, standing, under bark"* gives three co-products: round wood, industrial wood and residual wood. An economic allocation is applied to give the impact of *"wood, standing, under bark"* to each of these three co-products as per Table 2-3. The same allocation amount is applied for the deforestation process.

Table 2-3: Amount of "wood, standing, under bark" needed to produce 1m3 round wood, industrial wood or residual wood (allocation amount in m3 / m3), using to economic allocation (= eco.alloc). Due to their price, more "wood, standing, under bark" is required for round wood and less for industrial wood or residual wood.

Ecoinvent process	Wood, standing, under bark	m^3 output / m^3 wood standing	Eco. alloc.	Alloc. amount (m^3 / m^3)
Round wood, softwood, under bark, u=70% at forest road / RER	softwood, standing, under bark	0.65	0.86	1/0.65*0.86 = 1.32
Industrial wood, softwood, under bark, u=140% at forest road / RER		0.24	0.09	1/0.24*0.09 = 0.38
Residual wood, softwood, under bark, u=140% at forest road / RER		0.12	0.05	1/0.12*0.05 = 0.44
Round wood, hardwood, under bark, u=70% at forest road / RER	hardwood, standing, under bark	0.51	0.82	1/0.51*0.82 = 1.61
Industrial wood, hardwood, under bark, u=80% at forest road /RER		0.33	0.12	1/0.33*0.12 = 0.36
Residual wood, hardwood, under bark, u=80% at forest road / RER		0.16	0.06	1/0.16*0.06 = 0.38

As the deforestation process and the underlying process *"wood, standing, under bark"* contain both land transformation, a correction is made to avoid double counting. The deforestation process contains the following transformation flows *"transformation, from forest, primary" and "transformation, to forest, intensive, clear-cutting"* (see Table 2-2). The objective is avoid double counting with the transformation processes from the original wood process "*wood, standing, under bark",* which are "*transformation, from forest, extensive"* and "*transformation, to forest, intensive*". Double counting is avoided by subtracting the two land transformations of the original wood process from the 6 processes above using the same amount as added deforestation (i.e., 4.66 m^2 multiplied by the allocation amount).

The processes ending with "RER" correspond to a European location. These are recalled into "GLO", for a global location, as non-certified wood is generally from unknown location. Furthermore, the new datasets created have the addition of "non-certifiable":

- *"Round wood, softwood, non-certified, under bark, u=70% at forest road / GLO"*
- *"Industrial wood, softwood, non-certified, under bark, u=140% at forest road / GLO"*
- *"Residual wood, softwood, non-certified, under bark, u=140% at forest road / GLO"*
- *"Round wood, hardwood, non-certified, under bark, u=70% at forest road / GLO"*
- *"Industrial wood, hardwood, non-certified, under bark, u=80% at forest road /GLO"*
- *"Residual wood, hardwood, non-certified, under bark, u=80% at forest road / GLO"*

3 Results

The impact assessment method IMPACT 2002+ vQ2.2 (Humbert et al. 2012) was used to analyze the new datasets. It was customized by adding a characterization factor for the elementary flow "transformation, from primary forest". Appendix 1 gives an overview of the impacts on global warming (aka "greenhouse gas emission" or "carbon footprint"), ecosystem quality and human health for all 6 wood processes and two paper processes created. Table 3-1 shows the impacts of 1 m^2 deforested area.

Table 3-1: The impacts on global warming, ecosystem quality and human health for 1 m^2 area deforested

Damage category	Clear-cutting, primary forest for wood production GLO U (Q 1.0)	Unit
Global warming	31	kg CO_2-eq/m^2
Ecosystem quality	50	PDF-m^2-year/m^2
Human health	2.7E-5	DALY/m^2

Figure 3-1 presents the environmental impacts of non-certified round softwood, considering a 4.66 m^2 contribution to deforestation for each m^3 of round softwood put on the market. Regarding global warming, deforestation is the main contributor to the impacts (more than 90%). The other impacts are related to the diesel burned (both directly for the wood extraction and the sawing, and indirectly behind the site development). For ecosystem quality, the main contributor to the impacts is the deforestation (about 65%) while the land occupied by the tree standing in forest is the second contributor (about 30%). Regarding human health, the deforestation corresponds to about 90% of the impacts of round softwood and the remainder is related to the diesel burned (due to the direct emissions of particulate matter).

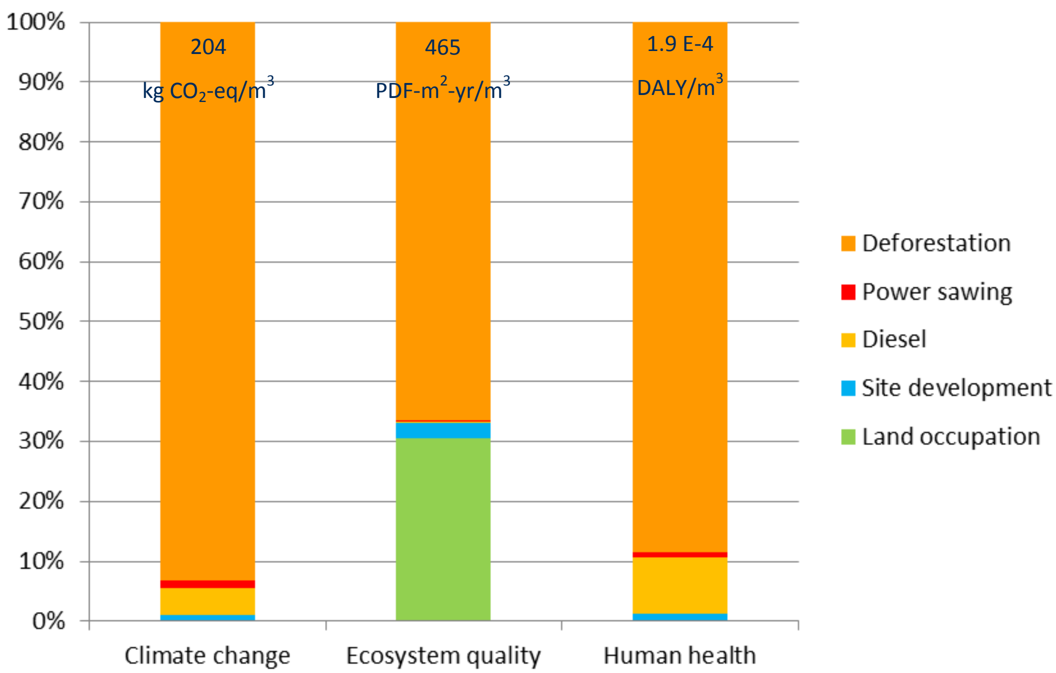

Figure 3-1: The impacts on global warming, ecosystem quality and human health for 1 m^3 of non-certified round softwood, considering a 4.66 m^2 contribution to deforestation for each m^3 of non-certified round softwood put on the market (*"Round wood, softwood, non-certified, under bark, u=70%, at forest road, GLO"*)

Figure 3-2 shows the impacts of non-certified round softwood (considering a 4.66 m^2 contribution to deforestation) in comparison with those of certified softwood. As the deforestation impacts are very important for climate change and human health (as shown above), the non-certified wood has about 10 times higher impact than the certified wood. Regarding ecosystem quality, certified wood is about 65% less impacting than non-certified. This value varies depending on the type of wood.

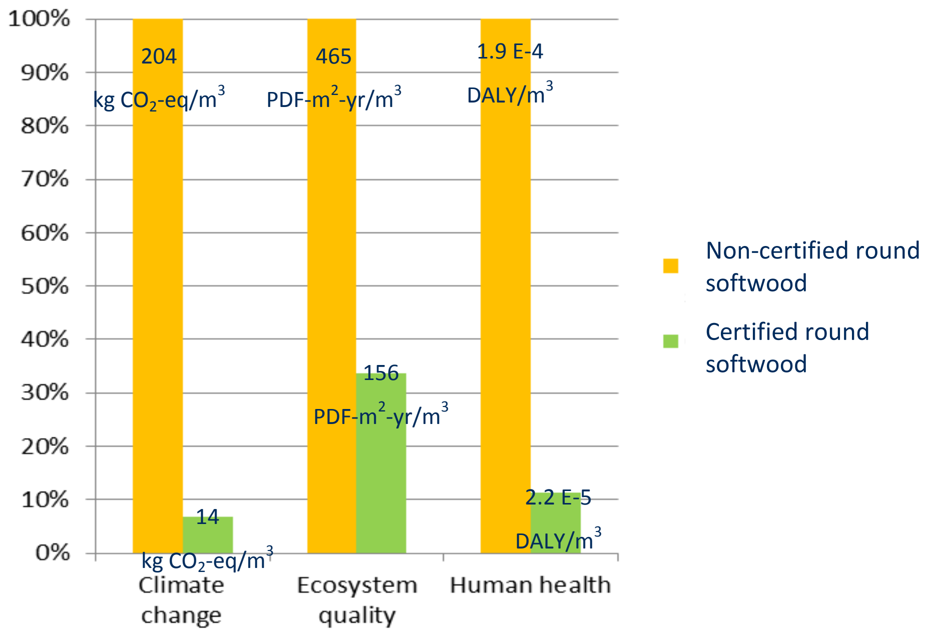

Figure 3-2: Comparison between certified (*"Round wood, softwood, under bark, u=70% at forest road/RER")* and non-certified round softwood considering a 4.66 m^2 contribution to deforestation ("*Round wood, softwood, non-certified, under bark, u=70%, at forest road/GLO"*)

The same comparison is made with paper coming from certified wood (taken from ecoinvent v2, but with Scandinavian wood and electricity replaced by European wood and electricity mix) and non-certified wood (where 100% non-certified wood is used as input to the process "paper") in Figure 3-3. The benefit to use paper based on certified wood in comparison with non-certified one is of 6% to about 25%, depending on the damage category considered. The differences are smaller than for wood because there are various other contributors to the impacts of paper, mainly chemicals and energy use that are the same between certified and non-certified paper. Regarding climate change, over 80% of the impacts of non-certified paper relates to activities outside the forest (e.g., transport, energy use for manufacturing or bleaching), while only a small part derives from forest activities itself. Therefore, the benefit of using certified paper can only be reached from this smaller part. The same applies for the human health but to a lesser extent. For ecosystem quality, the forest activity has a higher contribution to the overall impacts of paper and therefore the potential benefit of certified paper is larger for ecosystem quality than for the other indicators.

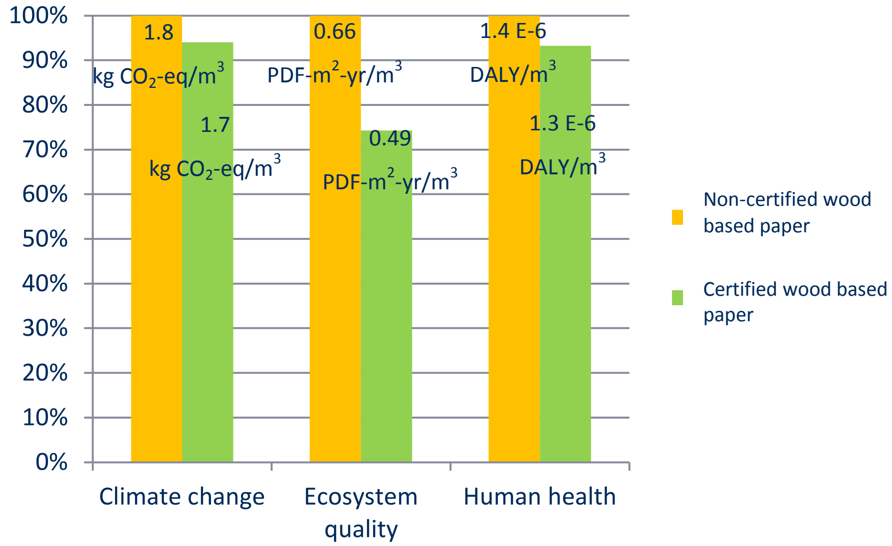

Figure 3-3: Comparison between certified and non-certified wood based paper (*"Paper, wood containing, LWC, non-certified wood, at plant/GLO"* and *"Paper, wood containing, LWC, certified, at plant/GLO"*)

The datasets are downloadable at: http://www.quantis-intl.com/publications.php

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5 Appendix 1

Appendix 1 gives an overview of the impacts on global warming, ecosystem quality and human health for 12 wood processes and two paper processes.

Processes	Climate change	Ecosystem quality	Human health
	kg CO_2-eq / m^3	PDF-m^2-yr / m^3	DALY / m^3
Round wood, softwood, non-certified, under bark, u=70% at forest road / GLO	205 (100%)	465 (100%)	1.9E-4 (100%)
Round wood, softwood, under bark, u=70% at forest road / RER	14.0 (7%)	156 (34%)	2.2E-5 (11%)
Industrial wood, softwood, non-certified, under bark, u=140% at forest road / GLO	64.4 (100%)	136 (100%)	5.9E-5 (100%)
Industrial wood, softwood, under bark, u=140% at forest road / RER	9.19 (14%)	46.7 (34%)	1.0E-5 (17%)
Residual wood, softwood, non-certified, under bark, u=140% at forest road / GLO	73.2 (100%)	155 (100%)	6.7E-5 (100%)
Residual wood, softwood, under bark, u=140% at forest road / RER	10.5 (14%)	53.1 (34%)	1.2E-5 (17%)
Round wood, hardwood, non-certified, under bark, u=70% at forest road / GLO	246 (100%)	782 (100%)	2.2E-4 (100%)
Round wood, hardwood, under bark, u=70% at forest road / RER	13.9 (6%)	407 (52%)	2.0E-5 (9%)
Industrial wood, hardwood, non-certified, under bark, u=80% at forest road /GLO	58.9 (100%)	176 (100%)	5.3E-5 (100%)
Industrial wood, hardwood, under bark, u=80% at forest road /RER	6.91 (12%)	92.2 (52%)	7.4E-6 (14%)
Residual wood, hardwood, non-certified, under bark, u=80% at forest road / GLO	62.4 (100%)	187 (100%)	5.6E-5 (100%)
Residual wood, hardwood, under bark, u=80% at forest road / RER	7.27 (12%)	97.8 (52%)	7.8E-6 (14%)
	kg CO_2-eq / kg	PDF-m^2-yr / kg	DALY / kg
Paper, wood containing, LWC, non-certified wood, at plant/GLO	1.76 (100%)	0.665 (100%)	1.4E-6 (100%)
Paper, wood containing, LWC, certified, at plant/GLO	1.65 (94%)	0.494 (73%)	1.3E-6 (93%)