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EVOLUÇÃO DO IMPACTE AMBIENTAL DO USO DO SOLO DO EUCALIPTO GLOBULUS NO CONTEXTO DA AVALIAÇÃO DO CICLO DE VIDA

EVOLUTION OF LAND USE ENVIRONMENTAL IMPACT OF EUCALYPTUS GLOBULUS IN THE CONTEXT OF LIFE CYCLE ASSESSMENT

EVOLUCIÓN DEL IMPACTO AMBIENTAL DEL USO DEL SUELO DEL EUCALYPTUS GLOBULUS EN EL CONTEXTO DE LA EVALUACIÓN DEL CICLO DE VIDA

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RESUMO

Introdução: A área de floresta de eucalipto glóbulos em Portugal Continental tem apresentado um aumento sistemático nos últimos 50 anos. Em 20015 era a espécie com maior ocupação florestal representando 26,2% do total da área florestal portuguesa. Embora entre 2005 e 2015 a ocupação do solo pelo eucalyptus globulus tenha crescido cerca de 7,5%, o volume existente aumentou ligeiramente (0,2%). Os incêndios florestais tiveram um forte impacto sobre isso com uma área total queimada de 1,1 milhão de hectares durante este período.
Objetivo: Devido ao seu valor económico (líder nacional em exportações de alto valor acrescentado) e social (contribui para a geração de milhares de empregos) este estudo tem como objetivo avaliar a evolução do impacte ambiental do eucalipto glóbulos no uso do solo entre 2005 e 2015.
Métodos: Foi utilizada a metodologia de avaliação do ciclo de vida e escolhido o método ILCD 2011 Midpoint + disponível no software SimaPro, para avaliar o impacte ambiental do uso do solo.
Resultados: O impacte ambiental do uso do solo de 1 m^3 de árvores de eucalipto glóbulos, em pé, na floresta, foi em 2005 de 21832 Kg C déficit e em 2015 de 23430 Kg C déficit, o que significa um aumento de cerca de 7,3%, durante este período.
Conclusão: A transformação da área de floresta natural em caminhos florestais é o processo que mais contribui para o impacte ambiental no uso do solo, com aproximadamente 78%. A ocupação florestal é o segundo processo mais importante, representando cerca de 19,5% do total da categoria de impacte e a ocupação de caminhos florestais representa apenas 3%.

Palavras-chave: avaliação do ciclo de vida; eucalipto glóbulos; floresta; uso do solo

ABSTRACT

Introduction: The eucalyptus globulus forest area in Continental Portugal has shown a systematic increase over the last 50 years. In 20015 it was the species with the highest forest land occupation representing 26.2% of the total Portuguese forest area. Although between 2005 and 2015 the occupation of the soil by eucalyptus globulus had grown about 7.5%, the existing volume increased slightly 0.2%. The wildfires had a strong impact on this with a total burnt area of 1.1 million hectares during this period.
Objective: Due to its economic value (national leader in exports of high added value) and social (contributes to the generation of thousands of jobs) this study aims to assess the evolution of the environmental impact of eucalyptus globulus on the land use between 2005 and 2015.
Methods: The life cycle assessment methodology is followed and the ILCD 2011 Midpoint+ method available in the SimaPro software was chosen to assess the land use environmental impact.
Results: Land use impact category of 1 m^3 of eucalyptus globulus trees, standing, in forest, was 21832 Kg C deficit in 2005 and 23430 Kg c deficit in 2015 that means an increased about 7.3% during this period.
Conclusion: Transformation to forest road (from natural forest) is the process that most contributes for the land use impact with approximately 78%. Forest occupation is the second most important process representing about 19.5% of the total impact category and forest road occupation represents only 3%.

Keywords: life cycle assessment; eucalyptus globulus; forest; land use

RESUMEN

Introducción: El área de bosque globular de eucaliptos en Portugal continental ha mostrado un aumento sistemático en los últimos 50 años. En 20015 era la especie con mayor ocupación forestal representando el 26,2% del total de la superficie forestal portuguesa. Aunque entre 2005 y 2015 el uso de la tierra por Eucalyptus globulus creció alrededor de un 7,5%, el volumen existente aumentó ligeramente (0,2%). Los incendios forestales tuvieron un fuerte impacto en esto con un área total quemada de 1,1 millones de hectáreas durante este período.
Objetivo: Por su valor económico (líder nacional en exportaciones de alto valor agregado) y valor social (contribuye a la generación de miles de empleos) este estudio tiene como objetivo evaluar la evolución del impacto ambiental de los glóbulos de eucalipto en el uso del suelo entre 2005 y 2015.
Métodos: Se utilizó la metodología de evaluación del ciclo de vida y se eligió el método ILCD 2011 Midpoint + disponible en el software SimaPro para evaluar el impacto ambiental del uso del suelo.
Resultados: El impacto ambiental del uso del suelo de 1 m3 de eucaliptos en pie, en el bosque, fue en 2005 de 21832 kg de C de déficit y en 2015 de 23430 kg de C de déficit, lo que significa un aumento de alrededor de 7,3% durante este período.
Conclusión: La transformación del área de bosque natural en senderos forestales es el proceso que más contribuye al impacto ambiental en el uso del suelo, con aproximadamente un 78%. La ocupación forestal es el segundo proceso más importante, representa aproximadamente el 19,5% de la categoría de impacto total y la ocupación de senderos forestales representa solo el 3%.

Palabras Clave: evaluación del ciclo de vida; eucalipto globulus; bosque; uso de la tierra

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INTRODUCTION

Eucalyptus forest has existed in Portugal and Europe since the second mid-19th century and has shown a systematic increase in Continental Portugal over the last 50 years (CELPA 2016; ICNF 2020 a). According to National Forest Inventory (ICNF 2020 b) in 20015 eucalyptus globulus was the specie with the highest forest land occupation (845,000 hectares) representing 26.2% of the total Portuguese forest area. Although between 2005 and 2015 the occupation of the soil by eucalyptus globulus had grown about 7.5%, the existing volume increased slightly 0.2% mainly due wildfires. During this period, an average of more than 44.7 thousand hectares (Kha) per year were burnt because of an average of 20753 forest fires per year (Pordata 2020). Furthermore, the severity of wildfires in Portugal in 2017 with a total burnt area of more 539 Kha, equivalent to 500 Kha in forest space, comprising 329 Kha in forest stands and 170 Kha in scrublands (ICNF 2019), certainly caused an important degradation on the existing volume of eucalyptus. Forest fires like land conversion, tillage, overgrazing, and soil erosion are anthropogenic causes of soil organic matter (SOM) loss (Brandão and Milà i Canals 2013).

Eucalyptus forest are multifunction systems that provide forest products (e.g., wood), non-forestry (e.g., essential oils) and environmental (e.g., carbon sequestration). Portuguese eucalyptus globulus is a leader in exports of goods with high national added value, contributes to the generation of thousands of jobs and creates value for forest owners and for the economic agents involved (CELPA 2016).

Life cycle assessment (LCA) is one of the standardized (ISO 2006 a,b) techniques being developed to better understand and address the environmental aspects and potential environmental impacts throughout a product´s life cycle from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle-to-gate).

To assess the environmental impacts associated with the production of eucalyptus wood in Portugal the LCA (ISO, 2006 a,b) have been applied to some products of eucalyptus (Lopes et al. 2003; Vieira et al. 2010; Dias & Arroja 2012). The products contribution for a series of impact categories were used in these studies like global warming, acidification, eutrophication, human toxicity, abiotic depletion, etc., but no one assessed the impacts caused by land use (land occupation and land transformation) that is essential for the full assessment of forest products (Doka et al 2002; Perminova et al 2016).

Impacts of land occupation and land transformation on biodiversity, biotic production, and soil quality have been studied by some authors (Hauschild et al 2011; Mattila et al 2012; Faragò et al 2019; Perminova et al 2016). Hauschild et al (2011) evaluated various methods of land use impact in the context of LCA and considered that the most appropriate among the existing approaches in the European context is the method by Milà i Canal at the midpoint level. This method has a focus on soil quality, and its indicator describes the changes in soil organic matter (SOM) associated with land interventions (Milà ì Canals et al. 2007).

keeping in mind the economic, social, and environmental relevance of eucalyptus globulus, the aim of this study is to assess the evolution on land use impact category of Portuguese eucalyptus between 2005 and 2015. The results of this study can be important to support future decision-making regarding the best management options for Portuguese forest planning.

1. METHODS

The Life Cycle Assessment method recommended in the ISO 14040/44 (ISO 2006a; ISO 2006b) standards was adopted in this study. It includes four phases: goal and scope of the study where the functional unit and the system boundary take place; inventory analysis that includes data collection and building the inventory table; impact assessment that transforms the data in the inventory table into impact categories indicators using the characterization factors; and interpretation of the results.

1.1 Goal and scope of the study

Functional unit and system boundary

The functional unit (FU) is given as 1 m^3 of eucalyptus globulus, standing, in forest and the function of the system being studied is to produce eucalyptus trees for different uses.

The system boundary for the product system being studied is represented in Figure 1. The activities/substances included in the boundary are related with regeneration of eucalyptus trees in the forest. The output is eucalyptus trees standing in forest and the inputs are those related with the occupation and transformation of land.

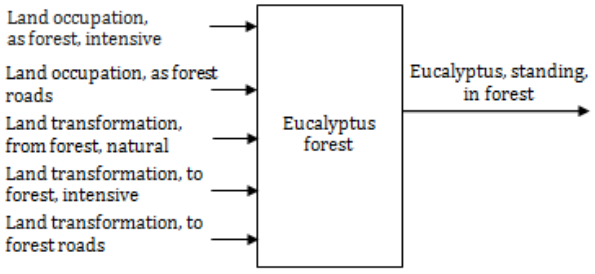

Figure 1 - Eucalyptus system boundary (gate-to-gate)

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2.2 Inventory analysis

Published data in various sources were used in the study (Table 1). Data for land occupation and volume growing of eucalypt in the Portuguese forest were obtained from the National Forest Inventory (IFN 5 and IFN6) (ICNF 2020 b). The time from tree plantation to final harvest was collected from Almeida (2008). The length and width of forest roads were based in the Faias et al (2007) and IC_EQUAL (2007) studies, respectively. The remaining data were calculated according to Table 1.

Table 1 - Datasets for land use/occupation and production of eucalyptus globulus in Continental Portugal

Nr.	Eucalyptus globulus	Mean value		Units	Source
		2005	2015		
1	Land occupation (IFN6) ($x10^3$)	785.9	845	ha	ICNF 2020 b
2	Volume (growing) ($x10^6$)	43.221	43.310	m^3	ICNF 2020 b
3	Rotation length (time from birth/plantation to final tree harvest)	12		Years (yr)	Almeida 2008
4	Forest road length	71.3		m/ha	Faias et al. 2007
5	Forest road width	3.50		m	IC-EQUAL 2007
6	Forest road area	0.024955		m^2/m^2	Calculated [1]
7	Yield (including forest roads)	0.0055	0.005125	m^3/m^2	Calculated [2]
8	Yield (excluding forest roads)	0.005641	0.005256	m^3/m^2	Calculated [3]
9	Land use, forest	177.281	190.253	m^2/m^3	Calculated [4]
10	Land use, forest roads = Land transformation, forest road	4.537	4.869	m^2/m^3	Calculated [5]
11	Land occupation, forest	2127	2283	$m^2.yr/m^3$	Calculated [6]
12	Land transformation, forest	181.818	195.122	m^2/m^3	Calculated [7]
13	Land occupation, forest roads	54.447	58.431	$m^2.yr/m^3$	Calculated [8]

[1] Forest road area = (Forest road length x Forest road width)/10000
[2] Yield (including forest roads) = volume (growing) / Land occupation / 10000
[3] Yield (excluding forest roads) = Yield (including forest roads) / (1 - Forest road area)
[4] Land use, forest = Yield (excluding forest roads)$^{-1}$
[5] Land use, forest roads = Forest road area / Yield (including forest roads)
[6] Land occupation, forest = Land use, forest x Rotation length
[7] Land transformation, forest = Land use, forest + Land use, forest roads
[8] Land occupation, forest roads = Land use, forest roads x Rotation length

Although land occupation of eucalyptus increased 7.5% the production increased slightly 0.2%, between 2005 and 2015 as we can see in Table1. The yield (average standing volume of eucalyptus per hectare) is very low (55 $m^3.ha^{-1}$ in 2005 and 51.25 $m^3.ha^{-1}$ in 2015) with a still decreasing tendency.
The total forest area was allocated to the eucalyptus even though forests and forest roads are multifunction, like carbon sequestration, recreation, etc. The same allocation procedure was made by Werner et al (2007).

2.3 Life cycle impact assessment (LCIA)

In LCIA the environmental impacts are classified, evaluated by what is most important to the study, and translate them into environmental themes such as land use. The ILCD 2011 Midpoint+ V1.11 method available in SimaPro 9.1 PhD software (PRé Consultant 2020) was chosen to translate the data from the inventory table into the land use impact category. Indicators of this method describes the changes in soil organic matter (SOM) associated with land interventions and are expressed as kilogram C, reflecting changes in soil organic carbon (Hauschild et al 2011). This method considers the following activities: occupation, forest, intensive; occupation, traffic area, rail/road embankment; transformation, from forest, natural; transformation, to forest, intensive; and transformation, to traffic area, rail/road embankment.

3. RESULTS AND DISCUSSION

With the help of SimaPro 9.1 PhD software (PRé Consultant 2020), data from Table 1 were used to build the inventory table (Table 2). In this table, the result of transformation, from forest, natural is equal to the result of transformation, to forest, intensive plus the result of transformation, to traffic area, rail/road embankment.

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Table 2 - Inventory table per functional unit (1 m^3 of eucalyptus, standing, in forest)

Activity/Substance	Compartment	Subcompartment	Unit	Eucalyptus, standing, in forest	
				(2005)	(2015)
Occupation, forest, intensive	Raw	land	m2a	2127	2283
Occupation, traffic area, rail/road embankment	Raw	land	m2a	54.447	58.431
Transformation, from forest, natural	Raw	land	m2	181.818	195.122
Transformation, to forest, intensive	Raw	land	m2	177.281	190.253
Transformation, to traffic area, rail/road embankment	Raw	land	m2	4.537	4.869

Using ILCD 2011 Midpoint+ V1.11 method the land use impact per functional unit for the years 2005 and 2015 was assessed. The comparative results by substance are presented in Tab. 3 and illustrated in Fig. 2.

Table 3 - Land use impact per functional unit (1 m^3 of eucalyptus, standing, in forest) using ILCD 2011 Midpoint+ method

Activity /Substance	Compartment	Sub-compartment	Unit	Eucalyptus, standing, in forest	
				(2005)	(2015)
Occupation, forest, intensive	Raw	Land	kg C deficit	4255	4566
Occupation, traffic area, rail/road embankment	Raw	Land	kg C deficit	653	701
Transformation, from forest, natural	Raw	Land	kg C deficit	-3636	-3902
Transformation, to forest, intensive	Raw	Land	kg C deficit	3545	3805
Transformation, to traffic area, rail/road embankment	Raw	Land	kg C deficit	17015	18260
Total			kg C deficit	21832	23430

From the Table 3, the total carbon deficit attributed to FU in 2005 was 21832 kg C deficit and 23430 kg C deficit in 2015. It means that, in this period, the deficit in carbon increase of approximately 7.3%. Transformation, to traffic area, rail/road embankment with 17015 Kg C deficit in 2005 and 18260 Kg C deficit in 2015 was the activity/substance that contributed with the largest value for the total. Occupation, forest, intensive was the second most significant activity with a land use impact of 4255 Kg C deficit in 2005 and 4566 Kg C deficit in 2015. Occupation traffic area was the activity that presented the lower impact on land use with 653 Kg C deficit and 701 Kg C deficit in 2005 and 2015, respectively.
It should be noted that the impact on land use by the land transformation from forest natural into forest intensive is null. It means that from the -3639 Kg C deficit (credit) in 2005 and -3902 Kg C deficit in 2015 of the activity transformation, from forest, natural, -3544 Kg C deficit in 2005 and -3902 Kg C deficit in 2015 are due to the transformation, to forest, intensive. The remaining – 91 Kg C deficit in 2005 and -97 Kg C deficit in 2015 are attributed to the land that was transformed from forest natural into traffic area.

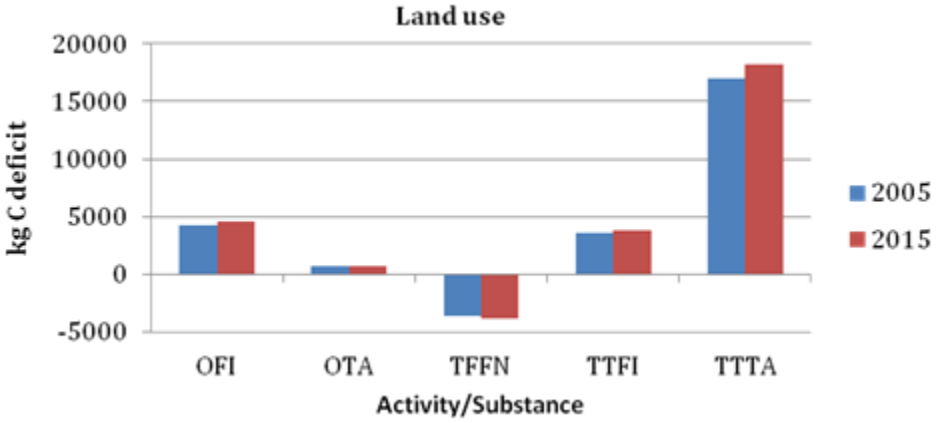

Figure 2 - Comparative land use environmental profile of eucalyptus, standing, in forest in 2005 and 2015 using ILCD 2011 Midpoint+ method. Acronyms: OFI (Occupation, forest, intensive); OTA (Occupation, traffic area, rail/road embankment); TFFN (Transformation, from forest, natural); TTFI (Transformation, to forest, intensive); TTTA (Transformation, to traffic area, rail/road embankment)

As illustrated in Fig. 2, transformation, to traffic area, rail/road embankment (TTTA) was the activity with the largest contribution to the total amount representing 78 %. Occupation, forest, intensive (OFI) was the second most representative activity with approximately 19.5% of the total value followed by occupation, traffic area, rail/road embankment (OTA) that accounted for 3%. Transformation, from forest, natural (TFFN) presented a positive contribution (minus sign) to the land use impact of eucalyptus.

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CONCLUSION

This paper presents the land use impact evolution expressed as kilogram C deficit per m^3 of Portuguese eucalyptus between 2005 and 2015 by using the life cycle assessment methodology and the SimaPro 9.1.1 PhD software.
Land use impact from land transformation into forest roads are much higher than impacts from land occupation which agrees with the results of the study carried out by Sandin et al. (2013) in cotton and wood-based fibers.
The land use impact of eucalyptus increases of approximately 7.3% from 2005 to 2015. Land transformation into forest roads is the most relevant activity representing approximately 78 % of the total impact while forest land occupation represents only 19.5%. The 6.8% reduction in eucalyptus productivity in the period under study, as a result of forest fires and other anthropogenic causes, plays an important role in the evolution of eucalyptus land use impact.

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REFERENCES

Almeida A. (2008). The Eucalyptus in Portugal: Environmental Impacts and Scientific Research (in Portuguese). *Silva Lusitana, 16 (2),* 275-276.

Brandão M. and Milà i Canals L. (2013). Global Characterisation Factors to Assess Land Use Impacts on Biotic Production. *The International Journal of Life Cycle Assessment, 18,* 1243-1252. https://doi.org/10.1007/s11367-012-0381-3

CELPA - Associação da Industria Papeleira, (2016). The sustainability of eucalyptus plantations in Portugal (in Portuguese). Lisboa: Celpa.

Dias A. & Arroja L. (2012). Environmental impacts of eucalypt and maritime pine wood production in Portugal. *Journal of Cleaner Production, 37*, 368–76. https://doi.org/10.1016/j.jclepro.2012.07.056

Doka G., Hillier W., Kaila S., Köllner T., Kreißig J., Muys B., Quijano J., Salpakivi-Salomaa P., Schweinle J., Swan G. & Wessman H. (2002). The Assessment of Environmental Impacts caused by Land Use in the Life Cycle Assessment of Forestry and Forest Products. Final Report of Working Group 2 "Land use" of COST Action E9. http://ww.seeds4green.org/sites/default/files/COSTE9LandUseDoka.pdf

Faias S., Morais P., Dias S., Morão S., Tomé M., Páscoa F. & Ôchoa P. (2007). FORSEE – A European network of pilot zones for the evaluation of criteria and indicators for sustainable forest management (in Portuguese). Relatório final do projecto nº 20 programa INTERREG IIIB – Espaço Atlântico (pp. 192). Lisboa: Universidade Técnica da Lisboa, Instituto Superior de Agronomia, Centro de Estudos Florestais.

Faragò M., Benini L., Sala S., Secchi, M. & Laurent, A. (2019). National inventories of land occupation and transformation flows in the world for land use impact assessment. *The International Journal of Life Cycle Assessment, 24*, 1333–1347. https://doi.org/10.1007/s11367-018-01581-8

Hauschild, M., Goedkoop, M., Guinee, J., Heijungs, R., Huijbregts, M., Jolliet, O., Margni, M., & de Schryver, A. (2011). Recommendations for life cycle impact assessment in the european context - based on existing environmental impact assessment models and factors (International Reference Life Cycle Data System - ILCD Handbook). Luxembourg: Publications Office of the European Union.

FLORESTAR, SUSTENTABILIDADE DA FLORESTA (2007). Guia prático de intervenção em áreas florestais sensíveis aos riscos: risco de incêndio/erosão/fitossanitário. Lisboa: Publicação do Gabinete de Gestão IC-EQUAL.

Instituto da Conservação da Natureza e das Florestas (2020 a). Florestas. Fileiras da Floresta. Importância Económica http://www2.icnf.pt/portal/florestas/fileiras/econ

Instituto da Conservação da Natureza e das Florestas (2020 b). Inventário Florestal Nacional - IFN5 e IFN6: Relatório Final http://www2.icnf.pt/portal/florestas/ifn

Instituto da Conservação da Natureza e das Florestas (2019). Portugal Market Report 2019. http://www2.icnf.pt/portal/florestas/fileiras/resource/doc/import-economica/2019-10-31 -Portugal-Market-Report-2019.pdf

International Standard Organization (2006 a). EN ISO 14040:2006. *Environmental management – Life cycle assessment – principles and framework*. Geneva, Switzerland: ISO

International Standard Organization (2006 b). EN ISO 14044:2006. *Environmental management – Life cycle assessment – requirements and guidelines*. Geneva, Switzerland: ISO.

Lopes E., Dias A., Arroja L., Capela I. and Pereira F. (2003) Application of the life cycle assessment to the Portuguese pulp and paper industry. *Journal of Cleaner Production, 11(1)*, 51–59. https://doi.org/10.1016/S0959-6526(02)00005-7

Milà ì Canals L., Romanyà J. and Cowell S. (2007). Method for assessing impacts on life support functions (LSF) related to the use of 'fertile land' in life cycle assessment (LCA). *Journal of Cleaner Production, 15* (15), 1426–1440.

Perminova T., Sirina N., Laratte B., Baranovskaya N. and Rikhvanov L. (2016). Methods for land use impact assessment: A review. *Environmental Impact Assessment Review, 60*, 64–74. https://doi.org/10.1016/j.eiar.2016.02.002

Pordata (2020). Base de Dados de Portugal Contemporâneo. Fundação Francisco Manuel dos Santos. https://www.pordata.pt/

PRé Consultant (2020). SimaPro Software, version 9.1. PRé Consultants. https://simapro.com/

Sandin G., Peters G.M. and Svanström M., (2013). Moving down the cause-effect chain of water and land use impacts: an LCA case study of textile fibres. *Resources, Conservation and Recycling, 73*, 104–113. https://doi.org/10.1016/j.resconrec.2013.01.020

Vieira R., Canaveira P., Simões A. & Domingos T. (2010). Industrial hemp or eucalyptus paper? An environmental comparison using life cycle assessment. *The International Journal of Life Cycle Assessment, 15*, 368–375. doi:10.1007/s11367-010-0152-y

Werner F., Althaus H., Kunninger T., Richter K. & Jungbluth N. (2007). Life cycle inventories of wood as fuel and construction material. ecoinvent report No 9. Dubendorf: Swiss Centre for Life Cycle Inventories.