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The influence of forest management systems on the environmental impacts for Douglas-fir production in France

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HIGHLIGHTS

- Two different forest management scenarios (intensive and extensive) were assessed.
- Thinning steps due to the use of large machines are the environmental key factors.
- Minor differences were identified comparing the results with other forest studies.

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ABSTRACT

The environmental wood profile, all over its life cycle, is a subject of interest for industries within the forest sector. Douglas-fir is a wood species with multiple applications and high productivity. In Europe, France is the country with the largest area dedicated to the cultivation of this tree species.
This study aims to quantify the Douglas-fir forestry environmental impacts under different management practices performed in France. This study presents detailed life cycle inventories of both intensive and extensive scenarios, including all the processes from site preparation to logging activities.
The results showed that stand establishment operations, tending and logging were the main stages responsible for the environmental impacts in both scenarios. The requirement of numerous thinning steps prior to the final cutting, which require machines with large fuel consumption, also had a negative influence. The logging stage, which includes the final cutting and the corresponding forwarding and loading onto trucks, also accounted for a significant contribution to all the categories. When the environmental results were compared with other life cycle studies on pine, eucalyptus and spruce, similar trends were identified in spite of the different management practices (low or high intensive scenarios), system boundaries and forest systems intensity (frequency of activities) considered.

1. Introduction

Forests produce wood, a renewable raw material with multiple uses and applications. European wood production in 2011 reached 687.7 million m^3, of which 73% was industrial roundwood to produce paper, furniture or building materials while 13% was used for heating and cooking (FAO, 2012). The three most important European countries in terms of wood production are Sweden (72.1 Mm^3), Germany (56.1 Mm^3) and France (53.5 Mm^3).

The Kyoto Protocol has promoted the forest relevance to mitigate climate change and to balance greenhouse gas (GHG) emissions (UNFCCC, 1997; Briceño-Elizondo et al., 2006). However, the forest systems management involves other environmental effects which occur during their life cycle. In this sense, the forest sector has paid special attention to provide information on environmental performance in order to be competitive, especially in some European countries such as Norway (Michelsen et al., 2008). Examples of environmental impacts derived from wood production are changes in the organic carbon content in the soil (Milà I Canals et al., 2007), eutrophication and climate change. Eutrophication is related to nutrient release (NH_3 and N_2O) associated with mineral fertilizing (Seppala et al., 1998; Sonne, 2006; Dias

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et al., 2007). Climate change is mainly associated with greenhouse gases emissions derived from the fossil fuel use in forest machines (González-García et al., 2012).

Numerous studies have been performed concerning the environmental burdens identification and quantification derived from forest management activities in countries with an extended tradition in the forest sector such as Scots pine and Norway spruce in Sweden, Finland and Norway (Berg, 1997; Berg and Karjalainen, 2003; Berg and Lindholm, 2005; González-García et al., 2009a; Berg and Karjalainen, 2003; Michelsen et al., 2008) or maritime pine and eucalyptus in Portugal and Spain (Dias et al., 2007; Dias and Arroja, 2012; González-García et al., 2009b). In these reports, representative plantations dedicated to wood production for industrial applications (energy, paper or boards) were assessed in detail. However, no detailed environmental studies have been performed for forest operations in France despite its importance for European wood production.

Douglas-fir (*Pseudotsuga menziesii*) is one of the premier timber trees in the world. It is a forest species naturally occurring in the west coast of North America (Hermann and Lavnder, 1999; Sonne, 2006) although it has been extended geographically in many temperate regions of Australia, New Zealand and South America and it is expected to continue spreading due to climate change (Hermann and Lavnder, 1999). Douglas-fir has been introduced in Europe, becoming one of the most important species due to the favorable site conditions in Scotland, Denmark and Germany (Hermann and Lavnder, 1999).

Douglas-fir forests have increased in importance in recent years for two main reasons: high productivity (Heidingsfelder and Knoke, 2004) and physiological adaptability (Albrecht et al., in press). Douglas-fir wood presents very good mechanical and processing properties, being considered as a suitable raw material for outdoor elements with good dimensional stability, moderate resistance to fungal decay, low treatability and maneuverability in stages of drying, cutting and assembling (Kutnik et al., 2011). Moreover, this type of wood can be used in construction materials which are not treated with wood preservatives (Hans Sauter, 2008). Nowadays, Douglas-fir is discussed as an alternative to other economically important coniferous species such as Norway spruce. The reason is that Norway spruce is facing reduced vitality and a significant reduction in area due to difficulties in coping with increasing temperatures (Spiecker et al., 1996). The impacts and effects of climate change (rising atmospheric CO_2 concentration, higher temperature, flooding, droughts, etc.) on European forests are currently affecting tree species growth and distribution but also soil matter decomposition (AGRI-2007-G4-06, 2008).

Currently, the European countries with the highest number of Douglas-fir plantations are France, Germany, United Kingdom and the Netherlands (Hermann and Lavnder, 1999). Among the different varieties, the coastal kind is preferred to the interior one in European forestry since it has higher growth rates although it presents lower drought tolerance and is affected by late frosts (Hermann and Lavnder, 1999; Reyer et al., 2010). The purpose of this study was to evaluate the environmental impacts associated with Douglas-fir wood production in France by using the Life Cycle Assessment (LCA) methodology, from a cradle-to-gate perspective (i.e. from the extraction of the raw materials to the loading of the logs onto trucks). The choice of Douglas-fir as the target species also offered the possibility of analyzing its cultivation under different management regimes.

2. Materials and methods

LCA is a methodology used to evaluate the environmental burdens associated with a product (process or activity) by identifying natural resources consumption and emissions associated with its entire life cycle and to identify and propose improvement opportunities for a better environmental performance (ISO 14044, 2006).

2.1. Case studies

Two Douglas-fir scenarios located in France were assessed from a cradle-to-gate perspective: an intensive management (IS) and an extensive management scenario (ES). Differences between scenarios lie on the application or absence of agro-chemicals (fertilizers and herbicides), forest processes repetition intensity (e.g. thinning activities) and pruning stages, which imply different biomass yield and lifespan (47 years for IS and 60 years for ES). Both plantations are located in the same French region, the Grand Massif Central, which includes, among others, the regions of Auvergne-Limousin and Bourgogne (Fig. 1). On average, this region has a semi-oceanic climate with continental influence, especially in the North-east zone. Trees are exposed to the best precipitation conditions with an average rainfall of more than 1000 mm/yr and average temperatures ranging from 10 °C to 12 °C. French Douglas-fir forest is young, since 87% of the stands do not exceed 40 years old. From a general point of view, difficulties in selling the first thinning have led to dense Douglas-fir plantations in many cases.

2.2. Functional unit

According to the different forest management practices, the lifespan per rotation varies to the scenarios under study. ES produces around 1133 m^3 of wooden biomass per 1 ha and rotation (60 years). IS produces approximately the same biomass amount after 47 years. Therefore, in this study the assessment and comparisons were based on a single Douglas-fir rotation under extensive conditions (60 years), which should be equivalent to 1.3 Douglas-fir rotations under an intensive regime.

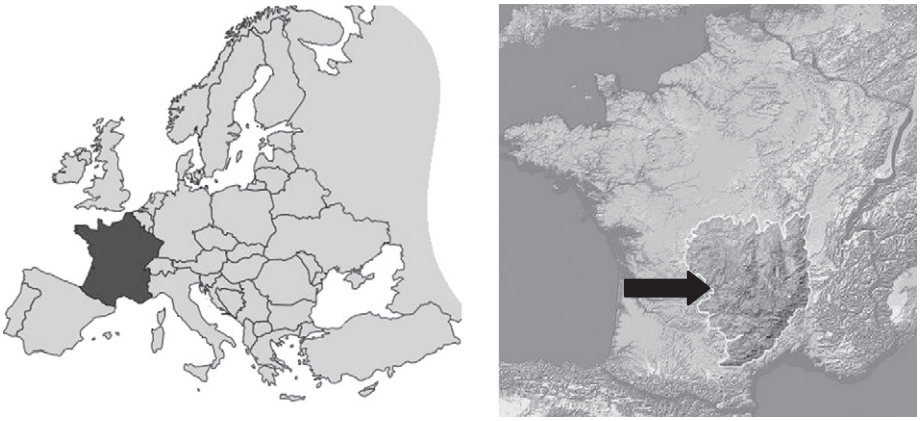

Fig. 1. French Douglas-fir plantation in the Grand Massif Central (South-central France) under study.