Science of the Total Environment 645 (2018) 646–654

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Delving the environmental impact of roundwood production from poplar plantations

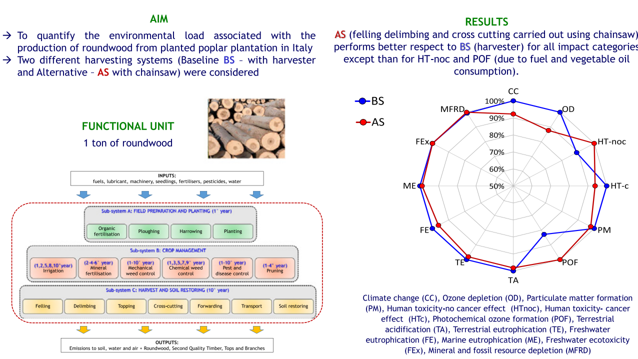
Daniela Lovarelli [b], Alessandra Fusi [a], Roberto Pretolani [a], Jacopo Bacenetti [a,*]

[a] Department of Environmental and Policy Science, Università degli Studi di Milano, Via G. Celoria 2, 20133 Milan, Italy
[b] Department of Agricultural and Environmental Science, Università degli Studi di Milano, Via G. Celoria 2, 20133 Milan, Italy

HIGHLIGHTS

- The environmental impact of timber production from poplar plantations was evaluated.
- Two different harvesting solutions were compared: harvester (BS) and chainsaw (AS).
- Field preparation-planting and harvesting are never hotspot processes.
- Emissions from fertilizer are the hotspot for acidification, eutrophications and PM.
- Alternative scenario (AS) results better for 10 of the 12 evaluated impact categories.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 May 2018
Received in revised form 29 June 2018
Accepted 29 June 2018
Available online xxxx

Editor: D. Barcelo

Keywords:
Life Cycle Assessment
Harvesting solutions
Mechanization
Poplar
Timber
Italy

ABSTRACT

The environmental impact of timber production from poplar plantation was evaluated by means of Life Cycle Assessment (LCA) using an attributional approach. A comparison was performed between a baseline scenario and an alternative one in which different harvesting operations were identified. An economic allocation was adopted to solve the multi-functionality of the studied process, by taking into account the price of the main product and of co-products. Sensitivity analysis was performed on alternative mass allocation and yield variations that derive from using high sustainability plants or from climate stress. A different characterization method was also analyzed.

Among the different field operations, crop management involves a higher impact respect to field preparation-planting and harvesting-soil restoring. Emissions related to fertilizers' applications are the main responsible for acidification, eutrophications and particular matter formation. The results show that the modelling of the environmental impact of timber production is robust. The alternative scenario resulted better than baseline for all impact categories (impact reduction ranging from 0.1% to 12.4%), except for HT-noc (+12.2%) and POF (+20.6%), due to fuel and oil consumption in the chainsaw used for harvesting.

In the next years, introducing high-sustainability clones (characterized by higher yield and higher resistance to pests and drought) could be an effective way for reducing the environmental impact of poplar roundwood production.

1. Introduction

European consumption of wood-based products has reached record levels in recent years, mostly driven by the market demand from the "end-use" sectors of residential construction, furniture, cabinets,

* Corresponding author.
E-mail address: jacopo.bacenetti@unimi.it (J. Bacenetti).

https://doi.org/10.1016/j.scitotenv.2018.06.386

flooring and mouldings (González-García et al., 2011a). Among the wood-based products, timber derives from roundwood and is commonly associated with building and construction materials, as well as with many common aspects of today's world.

Roundwood derives from forestry activities and from dedicated plantations and, among these lasts, poplar plantations play the main role (FAO, 2016). In 2016, the area dedicated to traditional planted poplar plantations was 31.4 Mha, of which Canada (21.8 Mha) and China (8.5 Mha) are the countries with the highest dedicated area (FAO, 2016). Worldwide, 18.3 million ha (58%) are managed for multi-purposes, 9.4 million ha (30%) are planted primarily for wood production, 2.9 million ha (9%) for environmental protection and 0.9 million ha (3%) are managed for biomass production for fuelwood. In the same year, wood removal worldwide accounted for 12.2 million m^3 of roundwood.

According to the International Poplar Commissions (FAO, 2016), the proportion of end-use products from planted poplars was particle/fibre board (51%), plywood (17%), veneer (16%), wood pulp (6%), sawn wood (5%), wood chips (4%) and logs/pulp logs and fuelwood (1%). In Europe, the most important countries for poplar production are France (0.2 Mha), Spain and Turkey (0.1 Mha), followed by Italy. In Italy, the area dedicated to traditional poplar cultivation is continuously decreasing (about 50,000 ha in 2016) due to competition with other more profitable agricultural crops and with more competitive poplar products imported from other countries (Pra and Pettenella, 2017). As a reaction to this state, the Italian poplar sector has launched a number of research programs to develop innovative uses for poplars and to create new clones with high resilience to salinity, drought and pests (Rosso et al., 2013; Pra and Pettenella, 2017). The new poplar varieties were selected by public and private organisations for their fast growth capabilities and positive tolerance to disease/pest, which results in increased productivity and reduced economic and energetic costs compared to the traditional “I-214” clone.

In Italy, the traditional poplar cultivation for plywood production is mainly located in the Po Valley Regions (Nervo et al., 2011). It is based on ten-year cycles and achieves high productivity and good wood quality, with wood production remaining the main purpose.

Besides these traditional poplar plantations (TPPs), in the last 30 years, about 6500 ha of poplar Short Rotation Forestry (SRF) (also called Short Rotation Coppice – SRC) have been planted in Northern Italy. SRC plantations are cultivations of woody crops (poplar, willow, black locust, and other fast-growth species) characterized by short cutting cycles (1, 2, or 5–6 years), high plant density (from 1000 to 12,000 trees per hectare), and a crop cycle ranging from 10 to 15 years, over which several harvests take place. Despite the possibility of growing different species, in Italy, SRC is mainly carried out with poplar clones (Manzone et al., 2014; Bacenetti et al., 2016). Although both cultivation systems are poliannual, between SRF and TPP there are several differences, among which the most important relate to crop management, number of harvests and cultivation purpose. Thus, differently from SRF, plants in TPP are felled only once at the end of the cycle, the main product is timber (for wood pulp, pallets, plywood and furniture) and the need to produce good quality timber involves intensive pest and pathogens controls. Finally, only top and branches can be used for energy purposes.

Regarding electricity production from renewable sources, Italian producers benefit of a specific subsidy framework and the Feed-in-Tariff (FiT) is granted to “renewable electric energy”. Specifically for electricity from biomass, higher FiTs are foreseen when biomass is a by-product instead of a specifically produced one. In this context, wood chips produced by chipping tops and branches of TPP allow to get the highest FiT, whereas wood chips from SRF determine a lower tariff because SRF is considered a dedicated crop (MISE, 2012).

Over the years, increasing attention has been paid to the environmental consequences related to agricultural productions and processing. Besides this, consumer awareness about this issue has grown and the demand for “environmentally friendly” products has increased (González-García et al., 2009a, 2010). Within this framework, in order to evaluate the environmental impact of products or services, the Life Cycle Assessment (LCA) method has been more and more applied (Curran, 1996). LCA is a holistic approach that uses a systematic set of procedures to convert inputs and outputs of materials and energy of a process into environmental impact. In this context, some LCA studies evaluated the environmental impact of plywood production (Puettmann and Wilson, 2007; Wilson and Sakimoto, 2007; Pommier et al., 2016), furniture (Gamage et al., 2008; González-García et al., 2011c) and other wood-products (Lippke et al., 2004; Asif et al., 2007; Perez-Garcia et al., 2007; González-García et al., 2009b, 2011a,b; Ramesh et al., 2010; Basbagill et al., 2013). Nevertheless, all of them focus on the processing phase, while seldom the attention is paid to the production of raw materials (i.e. roundwood). Moreover, despite the importance of poplar timber to produce pulpwood, plywood and furniture, there are no studies evaluating the environmental impact of timber production from TPP.

The aim of this study is to analyze the environmental impact of timber poplar production in Italy. To this purpose, the LCA approach was applied, the environmental hotspots (i.e. processes mainly responsible for the environmental impact) were identified and two scenarios involving different harvesting solutions were compared.

2. Materials and methods

The environmental impacts of poplar timber were estimated using the LCA method by following ISO 14040/44 recommendations (ISO, 2006). The Standards ISO 14040/44 involve defining goal and scope, functional unit and system boundary, collecting inventory data, assessing the environmental impacts and interpreting results. The attributional approach was used to model the poplar production process. This approach, differently from the consequential one, is commonly used to study the life cycle of a product as it is, based on collected average data and without considering market effects or any influence external to the system boundary (United Nations Environment Programme, 2011). Thus, the inventory data were attributed to the functional unit of the product system in accordance with a normative rule, and evaluating the environmental burdens directly linked to timber production. The goal of the LCA study, data and assumptions are discussed below.

2.1. Goal and scope definition

The goal of this study is to quantify the environmental load associated with the production of roundwood from planted poplar plantations in Italy.

Poplar cultivation practice is quite standardized in its traditional conformation; in particular, guidelines for integrated (Allegro et al., 2014; Regione Lombardia, 2017) and sustainable production practices were developed to help farmers achieving high yields and good quality products, and minimizing the environmental impact of this production system.

The research questions in this study are as follows:

- How much is the environmental impact related to the production of 1 t of poplar timber in plantations managed according to the guidelines for integrated production?
- What are the processes mainly responsible for this impact?
- Can the impact of poplar timber be reduced?

The outcomes of this study will be useful for:

- LCA practitioners involved in sectors in which poplar timber is used as raw material;
- technicians and farmers' associations that are interested in identifying, from an environmental point of view, the most critical