Science of the Total Environment 541 (2016) 210–217

Contents lists available at ScienceDirect

Science of the Total Environment

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

Environmental assessment of different harvesting solutions for Short Rotation Coppice plantations

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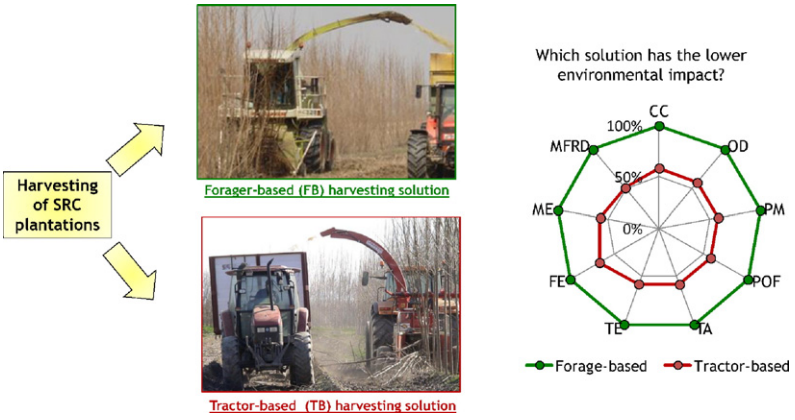
HIGHLIGHTS

- Two different harvesting solutions for Short Rotation Coppice were evaluated.
- There is a lack of information about the environmental impact of SRC harvesting.
- A forager based solution was compared with a tractor-based solution.
- Harvesting with self-propelled forager achieves better environmental performance.
- These differences are mainly related to the different machine productivity.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 2 June 2015
Received in revised form 16 September 2015
Accepted 17 September 2015
Available online 25 September 2015

Editor: D. Barcelo

Keywords:
Poplar
Woody biomass
Mechanization
Northern Italy
Short rotation forestry

ABSTRACT

Although several studies have been carried out on Short Rotation Coppice (SRC) plantations and on their environmental performances, there is a lack of information about the environmental impact of the harvesting operations. In this study, using LCA approach, the environmental performance of two different harvesting solutions for Short Rotation Coppice plantations was evaluated. In more details, for 2-years cutting time poplar plantations, harvesting with a self-propelled forager equipped with a specific header was compared in terms of environmental impact with a tractor-based solution.

The LCI was built with experimental data collected during field tests carried out over about 70 ha of SRC plantation in Northern Italy.

The following nine impact potentials were evaluated according to the selected method: climate change (CC), ozone depletion (OD), particulate matter (PM), photochemical ozone formation (POF), acidification (TA), freshwater eutrophication (FE), terrestrial eutrophication (TE), marine eutrophication (ME) and mineral, fossil and renewable resource depletion (MFRD).

Although harvesting with self-propelled foragers requires higher power and higher diesel consumption, it achieves better environmental performances respect to the harvest with the tractor-based solution. The tractor-based option is characterized by lower operative field capacity (about – 70% for all the evaluated impact

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http://dx.doi.org/10.1016/j.scitotenv.2015.09.095

categories except for MFRD, which is – 94% compared to the first option). The environmental differences are mainly related to the different machine productivity.
From an environmental point of view, respect to the harvesting with self-propelled foragers, the tractor-based solution can achieve a lower environmental impact only in small SRC plantations (<1–2 ha).

1. Introduction

In Europe, energy policies are increasingly promoting energy generation from renewable sources (i.e. EU target of 27% renewable energy by 2030 and 40% of GHG emission reduction) (European Commission, 2014). Among the different renewable sources, woody biomass is an interesting solution for energy generation in rural areas for both electricity (Negri et al., 2014) and heat production (Caserini et al., 2010; Cherubini et al., 2009). Woody biomass is produced from forestry management but also from dedicated plantations in which woody species are grown with energy purposes (Gasol et al., 2009; González-García et al., 2012a; Paris et al., 2010). In more details, with regard to this latter, Short Rotation Coppice (SRC) plantations are cultivations of woody crops (Poplar, Salix, Black locust, etc.) characterized by short cutting times (1–2 or 5–6 years), high plant density and a crop cycle ranging from 10 to 15 years during which several harvests take place (Paris et al., 2010; Bergante and Facciotto, 2011; Bergante et al., 2012; Fiala et al., 2010). Considering the different cutting time the SRC plantations can be divided in SRC (harvested each 1–2 years) and MRC (Medium Rotation Coppice, harvested each 5–6 years) (Bergante et al., 2012; Nielsen et al., 2014).

Differently from Northern Europe, where large amounts of woody biofuel are also produced from forestry (Anerud and Jirjis, 2011; Nielsen et al., 2014), in Italy, SRC represents an important biomass source for energy purposes (Manzone et al., 2009; Bergante et al., 2012); nevertheless, for MRF above all, the produced biomass can be employed also in paper industry as well as in the furniture sectors as plywood.

Mainly in Northern Regions (Lombardy and Veneto) of Italy, thanks to public subsidy frameworks, over the years about 7000 ha of SRC have been cultivated (Bergante and Facciotto, 2011; Fiala and Bacenetti, 2010; Bacenetti et al., 2012; González-García et al., 2012b; Manzone et al., 2009). Poplar clones are the most used for SRC, but experiences have been carried out also with *Salix* spp. and *Robinia pseudoacacia* L. (Bergante and Facciotto, 2011; Bergante et al., 2012; Manzone et al., 2009). Some studies highlighted that Salix clones biomass yield can be higher than that of poplar (Paris et al., 2010; Bergante et al., 2012; Nielsen et al., 2014; Rosso et al., 2013). Among the different options, 2 and 5 years cutting times are the most widespread. Although originally used, the annual one has no more been adopted due to issues related to survival and planting costs. In Italy, even if better economic performances and better biomass quality are related to SRC with a 5-years cutting time, the main share of SRC (about 75%) is cultivated with a 2-years cutting time (Barontini et al., 2014; Guidi et al., 2008; Nassi o di Nasso et al., 2010; Fiala and Bacenetti, 2012a,b; Testa et al., 2014).

Harvesting operations in SRC include felling, chipping, and chips transporting to the collecting point, where biomass is temporarily stored before sale. In the plantations with 5-years cutting time, felling and chipping are separated because the stem basal diameters reach 0.20–0.25 m; thus, felling and chipping simultaneously would require very high power foragers. On the contrary, in biannual SRC, basal diameters at the harvest are not greater than 0.12–0.14 m, therefore, it is possible to fell and chip simultaneously the stems using different harvesting units: tractor-based (TB) or forager-based (FB) (Manzone et al., 2009; Spinelli et al., 2006; Spinelli et al., 2009). Foragers are equipped with headers specifically developed to harvest SRC plantations (Spinelli et al., 2006; Spinelli et al., 2009; Fiala and Bacenetti, 2012a,b).

Besides the economic aspects, also the environmental ones must be carefully evaluated in order to improve the sustainability of this renewable energy source. To this regard, studies carried out in the past years highlighted that among the field operations carried out over the whole crop cycle, the harvest is the one with the highest environmental impact (Gasol et al., 2009; Fiala et al., 2010; Bacenetti et al., 2012; González-García et al., 2012b; Fiala and Bacenetti, 2012a,b). This impact is mainly caused by high fuel consumption (Fiala and Bacenetti, 2012a, b; Spinelli et al., 2006; Spinelli et al., 2009). To deepen the knowledge concerning the SRC environmental sustainability, particular attention must be paid on assessing the environmental impact of harvest.

In the last decade, in order to evaluate the environmental performances of agricultural processes, Life Cycle Assessment (LCA) has become more and more employed. LCA is a methodology that aims to analyze products, processes or services from an environmental perspective [ISO 14040, 2006] (ISO, 2006), providing a useful and valuable tool for agricultural systems evaluation (Fusi et al., 2014; Noya et al., 2015; Bacenetti et al., 2015b; Niero et al., 2015; Renzulli et al., 2015) as well as for renewable energy sources such as firewood (Pierobon et al., 2015), pellet (Fantozzi and Buratti, 2010) and biogas (Bacenetti et al., 2013; Lijó et al., 2014a; Lijó et al., 2014b; Lijó et al., 2015; Ingrao et al., 2015).

In this context, the aim of this paper is to analyze the environmental performances of two different harvesting solutions for SRC poplar plantations harvested every 2-years. Besides, to highlight the environmental hotspots for this operation, the main purpose of the study is to analyze the effect of technical and operative parameters (e.g., field capacity, machine productivity) affecting the environmental impact of different technical solutions.

2. Materials and methods

2.1. Goal and scope definition

The goal of this study is to assess the environmental impact of the harvest solution for SRC plantation with 2-years cutting time. The selected cutting time is the most widespread option for poplar SRC cultivation in Northern Italy where, at the end of the 2nd growing year, stems have a basal diameter lower than 0.14 m.

The research questions can be summarized as follows:

1) What is the environmental impact of the harvesting operation in SRC poplar plantations?
2) What are the main environmental hotspots associated with this operation?
3) Which are the site-specific and operational parameters that mainly affect the environmental performances of harvesting operation?

The study outcomes can be useful for farmers and farmer associations involved in SRC plantation, for agricultural contractors as well as for local policy makers involved in the woody-bioenergy process. Finally, the achieved results can be up-scaled either to SRC plantation with longer cutting time, but where lower temperatures (e.g., Central and Northern Europe) reduce the annual growth or to Salix plantations where the higher number of stems per stump reduces the basal diameter (Christersson and Sennerby-Forsse, 1994; Perttu, 1998; Bergante et al., 2012; Nielsen et al., 2014).