Available online at www.sciencedirect.com
ScienceDirect
http://www.elsevier.com/locate/biombioe

Energy and economic evaluation of a poplar plantation for woodchips production in Italy

Marco Manzone [a,*], Sara Bergante [b], Gianni Facciotto [b]

[a] University of Turin, Via Leonardo da Vinci, 44, 10095 Grugliasco, Torino, Italy
[b] Consiglio per la Ricerca e la sperimentazione in Agricoltura (CRA), Unità di ricerca per le Produzioni legnose fuori foresta (PLF), Strada Frassineto Po, 35, 15033 Casale Monferrato, Alessandria, Italy

ARTICLE INFO

Article history:
Received 31 July 2013
Received in revised form
9 October 2013
Accepted 22 November 2013
Available online 18 December 2013

Keywords:
Short rotation coppice
Biomass production
Economic evaluation
Energy consumption
Manpower required

ABSTRACT

In Europe, farmers prefer the very Short Rotation Coppice (vSRC) cultivation model, with a very high plant density (5500–14,000 p ha^{-1}) and a harvesting cycle of 1–4 years; while in Italy, recently, the farmers prefer the Short Rotation Coppice (SRC) method, with a high plant density (1000–2000 p ha^{-1}) and a harvesting cycle of 5–7 years. This is because the most recent poplar hybrids have enhanced productivity and improved the biomass quality (calorific value), as a result of a better wood/bark ratio.

In order to evaluate, from the energy and economic point of view, a poplar SRC, in the river Po Valley, an *ad hoc* study was made and a specific model was developed.

On the basis of this cultivation technique, an energy and economic evaluation of a poplar SRC in Northern Italy was realised. In detail, were considered data of poplar growth, in a plantation for the production of 6 year whips, in Western Po Valley, considering a SRC duration of 6 years and a biomass (15 Mg ha^{-1} dry matter – D.M. per year) harvest at the end of cycle (6 years). In this computing system it was pointed out that the SRC is very interesting from an energy point of view, since the output/input ratio results to be higher than 18. The same is not true for the poplar SRC from an economic point of view. In order to obtain economic SRC sustainability, the biomass price should be at least 115 € Mg^{-1} D.M. A large biomass diffusion will be possible only with an increase of the biomass market value, or with economic sustain for its production.

1. Introduction

The cultivation of crops for biomass production on good, arable soils allows to increase the energy production, with many advantages from the environmental point of view. This solution increases the farmers' revenues and leads to advantages for the environment [1–5].

In the last 10 years, the cultivation of crops for biomass production has been inserted in the cultural plans of several farms, particularly in Northern Italy; farmers take advantage of their low input requirement and the added possibility of exploiting set-aside areas [6]. In Italy, there are two different methods of cultivation: very Short Rotation Coppice (vSRC), with very high density, from 5500 to 14,000 plants ha^{-1} and harvested with a rotation period of 1–4 years and Short Rotation Coppice (SRC) with a high density from 1000 to 2000 plants ha^{-1} and harvested with a rotation of 5–7 years [7,8]. In Europe, the farmers prefer the vSRC cultivation model [9–13], while in Italy, recently, the farmers prefer the

* Corresponding author.
E-mail address: marco.manzone@unito.it (M. Manzone).
0961-9534/$ – see front matter
http://dx.doi.org/10.1016/j.biombioe.2013.11.012

previously described SRC method, because the most recent poplar hybrids have enhanced productivity and improved the biomass quality (high calorific value), as a result of a better wood/bark ratio [14–17]. Furthermore, it is also preferred, because in the rural development plans of the main Regions of northern Italy, the establishment of this cultural model is financed.

Most of the studies carried out until now in Italy have focused only on the vSRC method, as they are more spread throughout the territory; little has been yet experienced on the SRC method [18,19].

In order to evaluate from the energy and economic point of view a poplar SRC in the river Po Valley an *ad hoc* study was made and a specific model has been developed.

2. Materials and methods

A series of data were collected, both in the nursery and in the poplar SRC plantation, nearby the experimental farm "MEZZI" of CRA-PLF, close to Casale Monferrato (AL), during 2006–2012 period. All the cultural operations for poplar plantation were analysed: the working time and both machines and manpower requirements were recorded on the field, in compliance with CIOSTA (Comité International d'Organisation Scientificue du Travail en Agricolture) methodology, on at least 5.000 m^2 surface areas and for periods not shorter than 2 h [20].

The developed model allowed the determination of manpower and energy requirements, as well as the costs analysis considering different crop density and biomass production. The model considers a continuous poplar SRC plantation: the whole acreage is divided into different "modules", each corresponding to 1 year of the crop cycle, allowing to refer all costs to annuity. Regarding the economic and energetic evaluation, a 6 years rotation, with harvesting carried out at the end of the cycle and with a starting poplar plants density of 1100 for hectare was considered, with a 3.00 × 3.00 m spacing and a mean production of 15 Mg ha^{-1} D.M. $year^{-1}$ [21,22]. For all post-emergency treatment, it was supposed to use traditional tractors with 4 RM, with a maximum width of 2.2 m. In detail, for the nursery and the poplar SRC plantation it was assumed to prepare the soil with ploughing at 40 cm depth after seed bed fertilization – 500 kg ha^{-1} of 8,24,24 (N,P,K).

Secondary tillage was carried out by two harrowing interventions, while for the plantations of rods (1.20–2.00 m in length), an Allasia V1 planter was considered [23] (Fig. 8). The cultural operations assumed for the SRC cultivation and nursery were fertilization and weed control, both necessary to allow a high production of biomass [24,25]. Finally, it was assumed to use a heavy cultivator for stumps removal (Tables 1 and 2).

For biomass harvesting, a chipper prototype Gandini Bio-harvester (purchase cost € 60,000) was used, with a tractor of 190 kW Case Magnum 260 EP (purchase cost € 170,000) (Fig. 9). The working capacity of the Gandini Bio-harvester is about 60 t h^{-1} (about 120 plants h^{-1}) [26]. For the transport of the biomass in the farm (about 400 m distant), two tractors with trailers were used. The average cost of the Gandini Bio-harvester was determined considering contractors costs.

The manpower requirement was determined considering the number of operators and the working time to carry out every cultural operation.

The energy consumption was determined considering both direct costs – fuel and lubricant consumption – and primary energy – machine, equipment and mineral fertilizer energy contents (Table 3) [27]. Machine fuel consumption was determined by refilling the machine tank at the end of each working phase. The tank was refilled using a 2000 cm^3 glass pipe with 20 cm^3 graduations, corresponding to the accuracy of our measurements.

The lubricant consumption was determined in function of the fuel consumption using a specific algorithm setup by Piccarolo [28].

Table 1 – Cultural operation and amounts of production factors considered in the model.

	Operation (n°)	Type of operation	Material used
Start of the cycle	1	Seed bed fertilization	8,24,24–N,P,K (500 kg ha^{-1})
	1	Soil preparation	
Cultural operation at the first year	1	Top dressing	Urea (87 kg ha^{-1})
	1	Pre-emergence chemical weed control	Metaclor (1700 g ha^{-1})
			Linuron (500 g ha^{-1})
			Pendametilin (800 g ha^{-1})
	1	Insecticides application	Chloropyrifos-methyl (120 g ha^{-1})
			Cypermethrin (12 g ha^{-1})
			Fenitrothion (285 g ha^{-1})
	2	Mechanical weed controls	–
	1	Irrigation	–
Cultural operation after the first year	1	Top dressing	Urea (218 kg ha^{-1})
	1	Insecticides application	Chloropyrifos-metyl (120 g ha^{-1})
			Cypermethrin (12 g ha^{-1})
			Fenitrothion (285 g ha^{-1})
	2	Mechanical weed control	–
	1	Irrigation	–
End of the cycle	1	Biomass harvest	–
	1	Stumps removed	–