Renewable and Sustainable Energy Reviews 38 (2014) 775–780

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Economic evaluation of introduction of poplar as biomass crop in Italy

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ARTICLE INFO

Article history:
Received 18 March 2014
Received in revised form
29 May 2014
Accepted 6 July 2014
Available online 24 July 2014

Keywords:
Annual gross margin
CAP subsidy
Durum wheat
Farm
Market value
Short Rotation Coppice

ABSTRACT

Lignocellulosic biomass production deriving from agro forest species, as well as poplar (*Populus* spp.), has denoted an increase in last years in UE also thanks to a series of policies aimed at reducing emissions of greenhouse gases and promoting renewable sources. In Italy poplar represents the main agro forest species and it is cultivated according to two different methods: very Short Rotation Coppice (vSRC) and Short Rotation Coppice (SRC). The aim of this paper has been to evaluate the economic feasibility of poplar as energy crop in the southern Italy and specifically to consider its competitiveness with respect to conventional crops. In particular, an economic analysis in a representative case study located in the Sicilian hilly hinterland has been carried out, by comparing the direct costs and incomes of poplar (both vSRC and SRC) and durum wheat. Results showed that only introduction of SRC plantation could increase the farm competitiveness, while vSRC could be economically advantageous only with a substantial increase of biomass market price and/or CAP subsidy. However, the introduction of poplar should grant a better contribution to climate change mitigation with respect to annual crop, improving the greenhouse gases balance and diminishing the environmental impact of agricultural activity.

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1. Introduction

Since the seventies, environmental issues have reached a very important role in the international debate, leading to ever increasing number of studies about the problem of global warming. These last denoted that the increase of 2 ppm per year of greenhouse gases (GHG) over the last fifty years had no equal in history [1].

This has led in recent years to a series of policies aimed at reducing emissions of greenhouse gases and promoting electricity producing plants by renewable sources rather than fossil fuels ones [2].

Renewable energy sources such as hydropower, biomass, geothermal, wind and solar represent a viable alternative to traditional fossil fuels both for the benefits in terms of reduced impact on the environment as well as established by the Kyoto Protocol, and for their ability to be renewable and not subject to depletion [3,4].

European Union defined a policy in support of renewable sources with the Directive 2009/28/EC (better known as the “20–20–20” targets) that set as objective for EU the achievement of a share of 20% from renewable sources in 2020 in the consumed energy mix [5].

Among renewable sources from which it is possible to generate electricity or heat, UE solid biomass (wood, wood waste, pellets and other green or animal waste) in 2012 reached a value of

Abbreviations: GHG, greenhouse gases; LCA, life cycle assessment; SPS, Single Payment Scheme; SRC, Short Rotation Coppice; vSRC, very Short Rotation Coppice

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http://dx.doi.org/10.1016/j.rser.2014.07.054

Table 1
Primary energy production of solid biomass in UE in 2012 [6].

Country	Production (Mtoe)
Germany	11,811
France	10,457
Sweden	9449
Finland	7919
Poland	6851
Spain	4833
Austria	4820
Italy	4060
Romania	3470
Portugal	2342
Others	16,329
Total UE	**82,341**

primary energy equal to 82.3 Mtep [6], increasing by 57.0% with respect to 2000 (Table 1).

This increase was due also to lignocellulosic biomass production deriving from agricultural activity, especially for several agro forest species, as well as poplar (*Populus* spp.), willow (*Salix* spp.), acacia (*Robinia pseudoacacia*) and eucalyptus (*Eucalyptus* spp.), that allow lower emissions compared to annual crops, leading to lower environmental impacts [7–12].

According to many studies, in fact, the use of lignocellulosic crops for energy purposes may contribute significantly to the reduction of global GHG emissions, if produced in a sustainable way with regard to costs and land-use change [13,14].

However, bioenergy is not necessarily carbon neutral because emissions of CO_2, N_2O and CH_4 during crop production may reduce or completely counterbalance CO_2 savings of the substituted fossil fuels.

The CO_2 balance of energy crops can be estimated by C stock changes in above and below ground biomass and in soils. This strongly depends on the previous land-use and former C stock levels, especially for the largest terrestrial C pool, the soil organic carbon (SOC) pool. Land-use types with high SOC stocks, such as grasslands on organic soils, are more susceptible to land-use change to conventional energy crops than low C systems, such as croplands [15]. On the other hand, perennial energy crops may help to recapture SOC that was previously lost by cultivation [16].

As regard N_2O emissions during crop production depend on the amount of N fertilizer, pedo-climate conditions, oxygen availability and soil microorganisms [17,18], while CH_4 field emissions, may only be significant in organic soils with high ground water tables and their sink strength depend mainly on their porosity [19,20].

In literature, the evaluation of environmental impacts and energy balances associated with biomass production and/or management usually has been performed by applying life cycle assessment (LCA) analysis. LCA is defined as a methodology for the comprehensive assessment of the impact that a product or service has on the environment throughout its life cycle [21–23].

In Italy, in recent years, lignocellulosic species have become very popular and inserted in the cultural plans of several farms, with over 5000 ha already planted [24]. Poplar represents the main agro forest species [25,26] and it is cultivated according to two different methods: very Short Rotation Coppice (vSRC) and Short Rotation Coppice (SRC). The first method is characterized by a high planting density (5500–14,000 plants ha^{-1}) with a harvest carried out every 1–4 years, while the second one is based on a lower planting density (1000–2000 plants ha^{-1}) with a harvest ranging from 5 to 7 years [27–29].

Most of the studies carried out until now in Italy have focused only in the Northern Italy, where poplar is more spread [30]. So the aim of this paper has been to evaluate the economic feasibility of poplar as an energy crop in the southern Italy and specifically to consider its competitiveness with respect to conventional crops. In particular, it has been carried out an economic analysis in a representative case study located in the Sicilian hilly hinterland, by comparing the direct costs and incomes of poplar (both vSRC and SRC) and durum wheat (*Triticum durum*) and analyzing if introduction of poplar for biomass production could increase the farm competitiveness, reducing the risk management. Besides, in order to evaluate also the environmental impacts of introduction of biomass plantation with respect to annual crop, it has been carried out a literature review of several studies regarding the LCA analysis, GHG emissions and carbon balance of poplar as energy crop.

2. Materials and methods

Since economic profitability is the most important factor for the adoption of poplar for biomass energy for a farmer, it has been evaluated the economic feasibility of the introduction of poplar in cultural plans for Sicilian farmers. In particular, it has been carried out an economic analysis in a representative case study located in the hilly hinterland, by comparing the direct costs and incomes of poplar (both vSRC and SRC) and durum wheat (*T. durum*).

For each cropping system the economic analysis referred both the yield and the cost items to the current prices of the last crop year (2012/2013) and it has been considered that farming operations were carried out exclusively through rental (soil tillage, fertilization, pesticide treatments, harvest, and transport).

As regard to the technical–economic data of durum wheat have been collected through a questionnaire by means of direct interviews to farmer [31–33].

Durum wheat represents the main traditional crop of this area, where it is cultivated especially as monoculture and the average production is equal to 40 q ha^{-1} with a sale price of 20 € q^{-1} [34].

The annual gross margin (or profit) of durum wheat has been obtained from the difference between the annual revenues, including gross production value and Single Payment Scheme (SPS) according to the Council Regulation (EC) no. 73/2009 [35] and direct costs.

For vSRC model it has been considered a total duration of 14 years, which includes seven rotations of two years each (harvest every two years). The planting density was equal to 6667 plants ha^{-1} (3.00×0.50 m^2) with an average production of 20 Mg ha^{-1} D.M. $year^{-1}$ and a biomass market price of 80 € Mg^{-1} D.M. [36].

With regard to SRC model it has been taken into consideration a 15-year cycle, which provides three rotations of five years each (harvest every five years). The planting density was 1111 plants ha^{-1} (3.00×3.00 m^2), the average biomass production equal to 15 Mg ha^{-1} D.M. $year^{-1}$ and the wood chips market value of 100 € Mg^{-1} D.M. [37].

As farmers usually consider the annual income to evaluate whether a certain cultivation is favorable, it has been applied the method of discounted cash flow (DCF) by comparing SRC and vSRC poplar plantation with an annual crop, as in other studies [38–41]. Therefore, the net present value (*NPV*) of the overall plantation was calculated according to the following formula:

$$NPV = \sum_{k=0}^{n} \frac{C_k}{(1+r)^k} \quad (1)$$

where *NPV* is discounted annual cash flows; C_k represents the annual cash flow, obtained from the difference between the annual inflows and the annual outflows; k is the time of the cash flow; n corresponds to the lifetime of investment (equal to 14 years for vSRC and 15 years for SRC); r is the discount rate