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Rapeseed for energy production: Environmental impacts and cultivation methods

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ABSTRACT

This study involves an environmental impact analysis of rapeseed production in Italy to identify the highest and lowest impact of the method of cultivation. The environmental analysis included five farming units, which were extracted from a sample of 251 rapeseed farm units (2751 ha) using cluster analysis. Using the Life Cycle Assessment (LCA) method, we evaluated the environmental performance of the five units, showing how the cultivation practises and the type/quantity of input can cause environmental impact. Practises of intensive farming with high fertilization and mechanization (machinery and fertilizers production and application) are responsible for the greatest environmental impact. When the level of productivity is low, the impact is still higher. The most damaged environmental category is "human health", even if the impact on "ecosystem" and "resource depletion" is critical. The potential feasibility to integrate economic cost with the environmental results was just approached.

1. Introduction

The European Commission has recently adopted a "bioeconomy" strategy to enhance economic growth and to reduce fossil fuel dependence through renewable energy. According to the analysis carried out by the European Renewable Energy Council, in the EU scenario of 100% renewable energy future by 2050, biomass will potentially supply about 36% of the total European primary energy consumption [1].

Renewable resource use has reached high levels in Italy. Bioenergy, biomass, and biogas have high growth potential, making them the most important sources of energy after hydroelectric power.

Among oil crops, rapeseed can play a fundamental role in the development of a bioeconomy [2] and is considered strategic for establishing the biodiesel supply chain in Italy [3]. As well known, rapeseed is generally used as forage in summer-autumn sowing and for the production of seeds. From seeds, it

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is possible to obtain oil and press cake. While the press cake is used as a high-protein animal feed, rapeseed oil can be used as diesel fuel, either as biodiesel, directly in heated fuel systems, or blended with mineral diesel for powering motor vehicles. In Italy, rapeseed cultivation (*Brassica napus*, L.) for energy production has increased from 3500 ha in 2006 to 24,500 ha in 2009 [4]. Nowadays it represents the primary feedstock for biodiesel in Europe, accounting for two thirds of the total input in biodiesel production [5].

The EU is also the world's largest biodiesel producer [5] and Italy is Europe's fourth-biggest producer after Germany, France, and Spain, with its 19 biodiesel plants, a capacity of 2.3 Tg y^{-1} and a annual turnover of 1.9 G€ [6]. The EU Renewable Energy Directive [7], encourages the production and use of biofuels by establishing a binding minimum target for renewable energy sources of 10% of final energy use in the transport sector by 2020. The Directive issued this target in order to respect emission reduction regulations of the greenhouse gases (GHG), to improve the energy security supply, and to increase the use of renewable energy sources thus reducing the dependence on oil imports. The biofuel Directive recognizes that the increase in the use of biofuels should be accompanied by a detailed analysis of their environmental impacts, in order to avoid any potential negative effect as much as possible.

The agricultural production phase generates a significant environmental impact with respect to the biodiesel production chain [2] and is the cause of 7% of the total greenhouse gases emitted in Italy, ranking in between the energy sector (82.8%) and the industry sector (6.1%) [8]. Increased interest in dedicated biomass crops requires attention: the environmental impacts, the increased price of agricultural products, and the sustainability of bioenergy crops, have become arguments capable of limiting the development of the bioenergy sector. Several studies have addressed the "hot topic" of bioenergy's environmental sustainability using the Life Cycle Assessments (LCA) method [9–11].

Studies have recently assessed the environmental impact of rapeseed cultivation in areas with varying climates and agricultural practises (i.e. annual vs. perennial energy crops; organic vs. conventional cultivation methods) [12]. In any study, productivity is upheld as an important discriminating parameter [13]: rapeseed cultivation has a lesser impact when compared with autumn-winter cereals per unit of surface; however, if the reference unit is by kg produced, the results change and the impacts can be similar (e.g., ecotoxicity of marine and terrestrial ecosystems) or even worse (e.g., potential greenhouse effect).

When compared to other oil crops, rapeseed was found to be highly capable of reducing greenhouse gas emissions [14]. Rapeseed, deemed more environmental sustainable to crops such as soy or oil palm, because of its capability to improve biodiversity, reduce erosion, and maintain organic matter in the soil [15]. Palm oil performs more efficiently than rapeseed oil for acidification, ozone depletion, photochemical smog and eutrophication impacts [16], even though results are not always comparable due to different assumptions. Compared to sunflower (*Helianthus annuus* L.), rapeseed production has a less environmental impact [17], 30% energy demand less than that of sunflower, and lower water consumption [17].

Using the LCA methodology, this study assesses the environmental impacts caused by rapeseed production on a sample of Italian farms. A life cycle calculations was performed to compare different intensity cultivation practises and to determine which agricultural phases have a higher environmental impact and which impact categories are the most relevant. The ultimate goal was to show how LCA tool implementation at firm level could improve the environmental performance along the agricultural phase of the chain. The integration with economic aspects could make LCA tool even more appealing in assessing a global performance of firms.

2. Materials and methods

2.1. Data

The data were collected from the SUSCACE Project [3] during the years 2009–2010 (Table 1 and Fig. 1) and referred to 2751 ha of rapeseed cultivated on 251 farm units. For each unit, the data concern cultivation practises (e.g., surface, yield, previous crops), the main characteristics of the plantation (e.g., date of planting, crop density, row spacing) and inputs used in production (manpower, machine power, fertilisers, pesticides, and others).

Two aspects of the dataset must be highlighted. First, the data refers to two years during which environmental and other external conditions could have affected cultivation practises, leading to yield variability. Even though using data on a longer time span could increase the reliability of results, the effect that exceptional external events have on farming could be mitigated but not eliminated. The use of clustering techniques to synthesize the whole sample into a few homogeneous groups and their representative farms allows us to consider different situations of individual farming units.

Second, the dataset represents just over 11% of Italian oil rapeseed production; thus, the following analysis is not intended to be representative of national and regional scales.

We selected some variables measuring the intensity of production for each soil unit: planted surface, productivity per hectare, landscape type (flat, hilly); inputs per hectare of fertiliser (NPK compounds), herbicides, pesticides, equipment

Table 1 – Main sample data (Source: [3]).

Italian regions	Hectares (%)	Average regional surface (ha)	Flatland (%)
Abruzzo	0.3%	9.0	100.0
Basilicata	9.3%	42.6	33.3
Emilia Romagna	61.3%	10.7	94.9
Friuli Venezia Giulia	0.3%	3.6	0.0
Lombardy	3.9%	15.5	100.0
Marche	0.5%	1.0	21.4
Apulia	21.2%	16.2	66.7
Tuscany	0.3%	0.9	12.5
Umbria	0.3%	0.8	36.4
Veneto	2.5%	7.7	100.0
Total sample	100.0%	11.0	79.7