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# Organic production systems: Sustainability assessment of rice in Italy

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ABSTRACT

Even though organic practices are getting more and more widespread, there is scant of information on their environmental impacts. A comprehensive approach is needed in order to take into account, on the one hand, the lower amount of inputs normally used (e.g. pesticides) in organic systems and, on the other hand, the lower yield they usually imply.

The aim of this study is to assess the environmental profile of organic rice cultivation in a farm located in Pavia district (Lombardy). To this purpose, a Life Cycle Assessment methodology, with a cradle-to-field gate perspective, was applied. Inventory data were collected in a rice farm located in Lomellina where organic rice has been cultivated over about 70 ha in the past 15 years.

The environmental profile of organic rice was analysed in terms of 11 different impact categories: climate change (CC), ozone depletion (OD), particulate matter (PM), human toxicity (HT), Photochemical ozone formation (POF), terrestrial acidification (TA), terrestrial eutrophication (TE), freshwater eutrophication (FE), marine eutrophication (ME), freshwater ecotoxicity (FEx), and mineral and fossil resource depletion (MFRD).

The results suggest that the main environmental hotspots for organic rice are: the emissions of methane from the flooded fields, the production of compost, the nitrogen emissions associated with the application of fertiliser and the mechanisation of the field operations.

Finally, different mitigation strategies have been proposed and investigated. Among these strategies, the substitution of organic compost with cattle manure appears to bring the greatest benefits in 9 out of 11 impact categories. Such benefits range from approximately 13% up to 51%, depending on the impact categories considered. The introduction of aerations during the cultivation period can reduce only climate change (about −9%) but increase all the other environmental effects.



## 1. Introduction

There is general consensus that food production and consumption are related to negative effects on the environment and that they must become more sustainable (Defra, 2005; Renzulli et al., 2015). Considering the remarkable share of the agricultural activities in the environmental impact of food products, in the last years, several researches have evaluated the agricultural processes from an environmental perspective (CEC, 2003; Roy et al., 2009; Renzulli et al., 2015). More recently increasing attention has been paid to assess the benefits arising from the implementation of mitigation strategies (Roy ey al., 2007; Harada et al., 2007; Weiss and Leip, 2012; Bacenetti et al., 2015b).

Among cereals, maize, wheat and rice are the most analysed crops from an environmental perspective (FAO, 2013a, 2013b); nevertheless, most of the available studies assessed the conventional cultivation systems of these cereals, whilst the organic practices are less investigated (Hokazono and Hayashi, 2012; Renzulli et al., 2015; Hokazono and Hayashi, 2015).

As regard to rice, in Italy, 219,500 ha were cultivated in 2014 (+1.38% respect to 2013, with a total production of 1,466,000 t) mainly in Northern Italy and, in particular, in the districts of Pavia, Vercelli and Novara (Enterisi, 2013; Enterisi, 2014). In Europe, where about 425,000 ha are cultivated to rice (Enterisi, 2014), Italy represents the major rice producer with Northern Italy accounting for about 55% of European rice area. The conventional cultivation is by far the most common agricultural system; however, the organic one is becoming more and more important. According to the SINAB (2015), in 2014, the rice area dedicated to organic rice was 9,528 ha

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(4.3% of the overall rice area) with a total production of 57,070 t (3.5% of the rice production).

Rice cultivation system, both conventional and organic, causes a considerable environmental impact (Milà i Canals et al., 2006; Leip, 2007; Blengini and Busto, 2009; Xu et al., 2013; Hatcho et al., 2012; Fusi et al., 2014; Kanta Gaihre et al., 2014). In fact, besides soil and water pollution, energy and inputs (e.g., fertiliser, seeds, etc.) consumption, paddy fields (irrigated or flooded) are responsible for large methane emissions. According to the Fifth Assessment Report (IPCC, 2013), paddy rice cultivation (11%) is a major source of global $CH_4$ emissions and it is responsible for 9-11% of agricultural GHG emissions (about 0.52 $GtCO_2eq/yr$ mainly due to methane emissions). Thus, rice cultivation contributes to a great extent of the global warming phenomenon (Roy et al., 2007, 2009). Furthermore, in conventional rice production, the extensive application of plant protection products (mainly herbicides) in combination with wrong agricultural practices results in environmental concerns such as risks for human health and contamination of natural resources (Capri and Karpouzas, 2007).

To assess the environmental performances of agricultural activities, different methods have been developed. Among these, the Life Cycle Assessment (LCA) method is the most used. LCA is a standardised methodology designed for the holistic assessment of the environmental impacts and resources used associated to a product throughout its entire life cycle production process; by using LCA it is possible to analyse the potential environmental impacts of products (processes or services) throughout their whole life cycle (ISO, 2006).

Concerning the rice production system, some studies have been carried out in order to highlight its environmental impact (Leip and Bocchi, 2007; Hatcho et al., 2012; Blengini and Busto, 2009; Xu et al., 2013; Fusi et al., 2014); however, few of them are focused on organic rice production system (ORP) (Romani and Beltarre, 2007; Hokazono and Hayashi, 2012; Hokazono and Hayashi, 2015). With respect to the conventional rice production system (CRP), the organic one is characterised, on the one hand, by great yield variations and, on average, by yield reductions of about $^1/_3$ (Sinap, 2015) but, on the other hand, by fewer inputs used, the application of organic fertiliser instead of the mineral ones and the ban of chemicals for pest control. Therefore, without a comprehensive evaluation of all the operations carried out across the life cycle it is not possible to conclude which production systems, between ORP and CRP, shows the better environmental performance.

The aims of this study are: (i) to evaluate the environmental impact of ORP system in Northern Italy; (ii) to identify the environmental hotspots; (iii) to compare organic and traditional rice production systems; (iv) to propose possible mitigation strategies for ORP paying particular attention to the water management, organic fertilizers selection and crop residues valorisation.

## 2. Materials and methods

Life cycle assessment (LCA) has been used to estimate the environmental impacts of organic rice production system, following the ISO 14040/44 methodology (ISO, 2006) and the EPD guidelines developed for "Arable Crops" (Environdec, 2014).

### *2.1. Goal and scope definition*

The goal of this study is to assess the environmental impact of organic rice production (ORP) in Northern Italy and, in particular, in Lombardy region. In more details, a representative farm for ORP was evaluated. In this farm, organic rice has carried out for several years and in 2014, 19 paddy fields were growth with a global agricultural area of 70.3 ha.

The environmental hotspots for ORP have been identified and different mitigation strategies have been proposed and analysed.

### *2.2. Description of Organic Rice Production (ORP) system*

Rice is one of the most widespread cereals in Italy; in the eastern part of the Po Valley area (45°19′00″N, 8°25′00″E), it represents the main annual crop and an important revenues source for farmers. Although still now cultivated over a small area, interest about organic rice and its environmental performance is fast growing.

In temperate regions such as Italy, the rice (*Oryza sativa* spp. L.) is grown as a summer crop. In the northeast of Po Valley, the local climate is characterised by an average annual temperature of 12.7 °C and rainfall is mainly concentrated in autumn and spring (average annual precipitation is 745 mm). Thanks to the good water availability, in this climatic conditions, rice is mainly cultivated in flooded fields; the water has the main aim to keep the temperature and therefore prevent spikelet sterility in spring when cold air flows from the Alps.

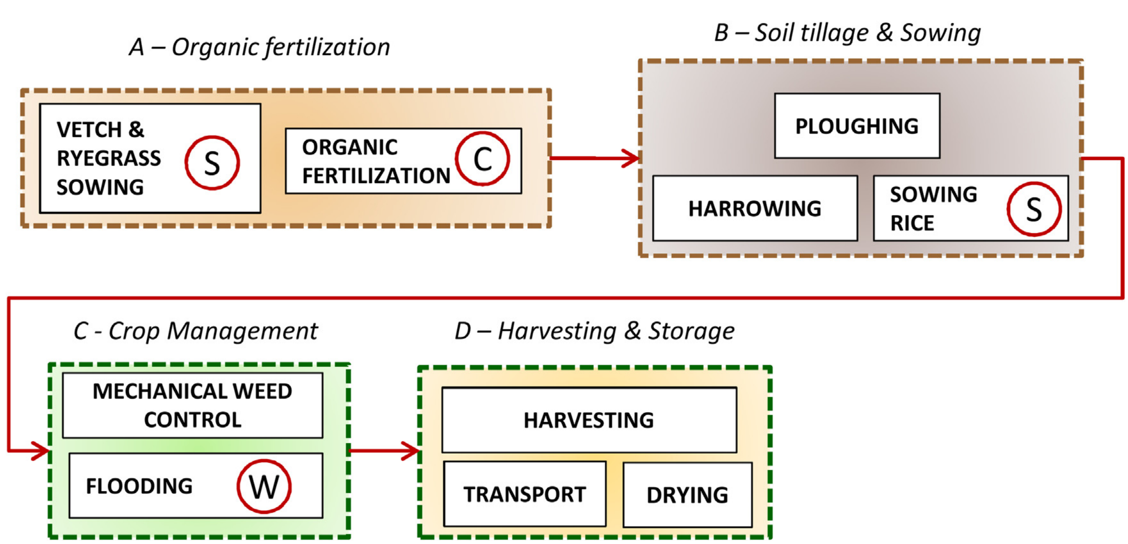


**Fig. 1.** Organic rice production (ORP) system (S = seeds, C = compost, W = water).