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The contribution to climate change of the organic versus conventional wheat farming: A case study on the carbon footprint of wholemeal bread production in Italy

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A B S T R A C T

Despite many studies in literature demonstrate the environmental sustainability of organic food, a debate is still open in the scientific community on the effect of organic farming on global warming and climate change mitigation. This paper aims to contribute to a more informed debate on the actual contribution to climate change in terms of GHG emissions of organic and conventional agriculture. For this purpose, the production process of an organic vs conventional wholemeal bread locally produced in central Italy by a small-medium bakery enterprise was compared and the carbon footprint (CF) was assessed by means of the life cycle assessment (LCA) methodology.

We found that the CF of 1 kg of the conventional wholemeal bread was 24% less respect to the same organic bread, with 1,18 and 1,55 kg CO_2eq respectively. On the contrary, if the CF is assessed per unit of cultivated area (hectare), wheat organic cultivation showed a better performance in terms of GHG emissions than conventional by 60%, with 1,15 and 2,87 Mg CO_2eq ha^{-1} respectively. The higher CF per unit of organic product is due to the lower yield per unit of area cultivated with organic farming and to the consequent attribution to a smaller amount of products of the GHG emissions generated in the field phase of the life cycle. Whereas, the CF per hectare is higher when conventional practices are applied due to the higher use of raw materials (higher seed density, agrochemicals for fertilization and plant protection) respect to the same organic system.

Results of the study demonstrate that organic farming for wheat cultivation in Italy is a low-carbon agriculture with a lower contribution to climate change in terms of GHG emissions per hectare respect to the conventional wheat cultivation, although implications of the reduced productivity and the consequent need of more cultivated land should be considered. However, more research is needed to better explore the potential of organic farming and to improve organic food production, optimizing the balance between the use of resources and yields, to ensure sufficient organic food supply at global level.

A more comprehensive assessment of the actual GHG emitted in the atmosphere from both organic and conventional agricultural systems can be provided when the CF is assessed per unit of area, in addition to the CF per product unit, especially if also the carbon sink of the agrosystem is included.

1. Introduction

Food production plays an important role in the context of climate change and agriculture in particular is a major driver of climate change representing a major source of anthropogenic GHG emissions. About 10% of the European GHG emissions in 2013 (EU-

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NIR, 2015) and about 24% of global GHG emissions in 2010 were attributed to the agricultural activities, as cultivation of crops and livestock, and deforestation for agricultural purposes (IPCC, 2014). These values rise if raw materials and agrochemical production, industrial process for food transformation, transport and trade of agricultural and food products are attributed to the sector. The main international agreements as the Kyoto Protocol and the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC), as well as the main related European Decisions and Regulations, ask for concrete actions to mitigate global climate change and reduce GHG emissions. Consequently, substantial mitigation efforts in the agricultural sector are needed in order to meet the global climate goals.

On the other hand, in the last years food consumers are paying more and more attention to their choices opting for healthy, local and fresh food, with growing interest also about the sustainability of food chain (Galli et al., 2015; Renzulli et al., 2015). In this regard, the production and consumption of organic food is increasing worldwide and will increase in the future to the point that global organic food market is projected to grow of over 16% by 2020 (Techsci, 2015). In Italy, the organic farming involved about 1,4 million of hectare in 2014, corresponding to the 11% of the total cultivated land (SINAB, 2015). This trend is projected to increase considering also the considerable support to organic production provided by the main European financial instrument for the agriculture sector represented by the Common Agricultural Policy (CAP) for the period 2014–2020.

One of the most well-known and appreciated characteristics of organic food is the lower pesticide residual (Crinnion, 2010) which reduces the human health risk. Moreover, the main benefit clearly recognized to the organic farming practices is the environmental sustainability compared to conventional ones (Caporali et al., 2003; Birkhofer et al., 2008; Gomiero et al., 2011; Tuomisto et al., 2012), with a minor pressure of chemicals on environmental compartments and trophic chains, reduced negative impacts on biodiversity and improved agricultural soil and water quality and vitality. However, the effect of organic farming on global warming and climate change mitigation is instead a still open debate in the scientific community. Some studies in literature try to review findings for the main agricultural productions on the environmental impact of the two systems, with regards also to global warming potential (GWP) and effects on climate change, resulting in a large variability of outcomes (Tuomisto et al., 2012; Venkat, 2012; Meier et al., 2015). Depending on the boundary of the study, the adopted methodology, the soil and climatic characteristic of the agrosystem, the analyzed crops and the availability of primary data, organic farming is considered to perform better in some cases (Kavargiris et al., 2009; Litskas et al., 2011; Zafiriou et al., 2012) and worse in other cases (Williams et al., 2006; Venkat, 2012) in terms of GWP, compared to conventional farming. This is due often to the fact that different studies refer to different site conditions, soil and climate characteristic, methodological approach and management practices, therefore they are not easily comparable to assess the difference of impacts in organic vs conventional systems. The discussion is even more interesting especially if considering the robust evidence of long term enhancement of the soil organic carbon (SOC) of organic practices compared to conventional management (Robertson et al., 2000; Wright and Hons, 2005) and the apparently disadvantageous carbon footprint of most organic products compared to similar ones based on conventional agriculture.

The carbon footprint (CF) represents the overall GHG emissions associated to a unit of product, including its overall life cycle from cradle to grave (ISO, 2006b; Finkbeiner et al., 2006). The main point of weakness in the analysis of the carbon footprint of organic versus conventional products comes from the fact that the yield per unit of cultivated area is generally significantly lower when organic practices are applied compared with conventional farming. Consequently, in the organic farming production the environmental pressures and the GHG emissions generated in the field phase of the life cycle will be attributed to a smaller amount of products, resulting in an higher impact per unit of product, thus outweighing the general benefits of organic farming (Tuomisto et al., 2012). Although this is a general view, it is quite difficult to find real case studies where the same product is compared, differing solely for the organic or conventional farming practices and for the organic and non-organic labeling of its raw material.

To contribute to a more informed debate about the actual contribution to climate change in terms of GHG emissions of organic versus conventional farming, this study aims at analyzing and comparing the carbon footprint of the wholemeal bread produced with organic or conventional wheat flour by a small-medium bakery enterprise of central Italy.

Despite several CF analyses of bread are available either for organic or conventional bread, studies are not easily comparable as they refer to different kinds of bread, produced in different countries and at different scales (Andersson and Ohlsson, 1999; Espinoza-Orias et al., 2011; Jensen and Arlbjørn, 2014; Galli et al., 2015) and with various forms of agricultural management (Meisterling et al., 2009; Williams et al., 2010; Kulak et al., 2015). This work represents indeed an optimal case study for a correct and scientifically sound comparison of organic and conventional wholemeal bread production. In fact, both the organic and conventional wholemeal bread are produced using the same procedure, which hence differs only for the origin of the flour that comes from the same variety of soft wheat (*Triticum aestivum* L.) cultivated by organic and conventional local producers in the same geographical area (see methods). The comparison is therefore possible as the overall cultivation phase differs only for the management practices applied in the organic and in the conventional plots in the same geographical area, being yield and crop management strongly dependent on climate, soil characteristics, plant variety.

Despite the analyzed wheat-to-bread production process is representative of the average conditions of the national small-medium bakery enterprises of the Italian agrofood sector, the findings of this study could be of wide interest to different readers, ranging from the policy makers to scientists dealing with crop science and climate change, up to the final consumers, considering the global relevance of the wheat-to-bread chain. In fact, wheat is widely cultivated and traded in many areas of the world and bread is daily consumed in many countries worldwide, although wheat processing and baking are often influenced by local traditions and consumption patterns, particularly in Europe and in Italy where gastronomy represents a cultural heritage (Galli et al., 2015).

2. Methodology to assess the carbon footprint

The analyzed wholemeal bread production process, starting from the cultivation of wheat, takes place in the area of the Vulsino volcanic apparatus of central Italy, where the geological formation consists in volcanoclastic deposits, predominantly ignimbrites composed by tuffs, lapilli and inconsistent ash. The soils are classified as Entisols, Xeropsamments group in Soil Taxonomy (USDA, 2010); they are slightly acidic and well drained as a consequence of the xeric moisture regime, texture and slight inclination of the ground (generally less than 5%). The climatic conditions are characterized by average annual precipitations of about 1200 mm and average daily temperatures around 23 °C during the hottest month of July and around 5 °C during the coldest month of January.