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Environmental sustainability and economic matters of commercial types of common wheat

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Abstract: Common wheat, a fundamental commodity on international markets, is increasingly differentiated into commercial types on domestic markets to meet the demand of processing companies. Improver wheat, biscuit wheat, ordinary and superior bread-making wheat are commercial varieties with specific technological characteristics. Wheat farming systems are constantly evolving, and as a result, related environmental issues emerge. We applied an LCA (Life Cycle Assessment) analysis, where the functional unit was 1 tonne of grain for each typology and system boundaries were from cradle to farm gate. Primary data were used in the study, and special attention was paid to fertiliser use. From an LCA perspective, our findings show that nitrogen (N) plays an essential role in plant production although producing different waterborne and airborne emissions and nitrate leaching, for the 4 commercial typologies studied. Furthermore, the impact can be differentiated based on the technological features of the commercial types. Our results led us to observe that the four wheat types show contrasting economic and environmental performances.

Keywords: common wheat; grains; Life Cycle Assessment; sustainability

Wheat (*Triticum* spp.) is a grain cultivated worldwide and its market is global. It ranks in first place for total growing area and second place in the world in terms of production after maize (Ziolkowska et al. 2009). Wheat represents an essential crop to satisfy the demand both for food (66%) and feed (20%) as well as seeds (5%), by-products used in industry (3%) and others (6%) (International Grain Council 2018). The European Union (EU) is the biggest producer and represents 21% of the total world production of wheat. While the EU as a whole is a net exporter of wheat, totalling 33 million tons (Mt) annually, some European countries such as Spain, Italy, Greece and the Netherlands (European Commission 2017) import an amount of 7 Mt (International Grain Council 2018), both from other European countries and extra-EU countries.

Although common wheat is usually considered a commodity, there are actually different types of common wheat with dissimilar technological features (wheat for biscuits, improver or hard wheat, wheat for bread-making and superior bread-making wheat) (UN-COMTRADE 2018). The wheat grades are traded on the spot market with significant differences in quotations visible in most exchanges in EU countries and on the futures market (European Commission 2018). In fact, the CME Group gives quotations for four different futures, including Spring Red Wheat, Hard Red Wheat, Australian Wheat and EU wheat (CME Group 2018). The milling companies look for different protein content and other characteristics to satisfy the demand (for bread, biscuits, crackers and other bakery

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products) of processing companies (Ziegelbaeck and Breuer 2014; Di Vita et al. 2016).

The common wheat market demands a segmentation of supply and forces growers and wheat breeders to satisfy this request. The segmentation of the supply of common wheat is a challenge. Many studies focus on genetic, agronomic and geographic factors that influence the quality of wheat production. Breeding varieties with specific technological characteristics was argued in Nti and Barkley (2017) and Visioli et al. (2018). Farming system techniques including sowing time, disease control and overall nitrogen fertiliser management were shown in Blandino and Reyneri (2009), Blandino et al. (2015) and Morari et al. (2018). Johansson et al. (2001) analysed combinated cultivar and nitrogen application effects. The environmental impact of wheat cultivation in literature has been examined but, to our knowledge, there are no data available about the environmental impact of the different commercial types of wheat cultivation, hence the need to identify nitrogen behaviour.

Nitrogen application is fundamental for increasing wheat grain yield and protein content and influences environmental sustainability. Nitrogen fertilisation has greatly increased the worldwide production of wheat since World War II (Laratte et al. 2014), including France, the second world exporter after the USA. Nitrogen fertilisation may have a negative environmental impact and the pathways and magnitudes of N losses change greatly under different agro-technical procedures. N compounds such as N_2O, NH_3, NO_3^- can leak from a farming system by volatilisation and leaching (Wang et al. 2011).

On the basis of the twenty LCA (Life Cycle Assessment) applied on wheat cultivation, Achten and Van Acker (2016) state that wheat production leads to a high environmental impact, where the main input is N fertilising, which represents 60% of the energy demand and more than 80% of the global warming potential of the whole cultivation impact.

Several methodologies are suitable to assess the environmental impacts of farming practices (Kubankova et al. 2016) and the Life Cycle Assessment represents an effective method, able to analyse the sustainability of wheat cultivation, evaluating its environmental impact through a systemic approach (Chiriaco et al. 2017).

In this paper, an ISO LCA method was applied to different types of commercial wheat in the Piedmont region, in Northwest Italy, where the experimental plots are located, and analysed throughout their first phase of the life cycle (i.e. cultivation), with the aim of assessing and comparing their environmental performance. We also present a brief description of some economic indicators regarding production costs and prices deriving from the "Special wheat project" focused on testing some recent wheat varieties to strengthen local and short supply chains of speciality wheat strains (with high gluten, waxy starch and antioxidant content).

PRODUCTION AND FLOW OF COMMON WHEAT IN THE EUROPEAN UNION

The official statistical data show that common wheat is registered without any distinction between different commercial types. In 2017, official statistics reported that China is the leading country producer in the world, producing approximately 130 million tons, followed by India (95 Mt), Russia (82 Mt), the United States (47 Mt) and France (38 Mt) (International Grain Council 2018).

Since wheat cultivation has different productive performances depending on the area in which it is cultivated, we deemed it important to extract from the official statistics (Eurostat 2018), the last four-year means (2010–2013 and 2014–2017) in terms of surface cultivated, harvested production and yield of common wheat in EU standard humidity. A breakdown of the average values of common wheat cultivation (Table 1), allows for the identification of current trends in wheat farming in the European Union.

The evolution of the EU cultivated surfaces over the period considered shows a slight increase in the overall trend (+2.7%). Nevertheless, this trend does not appear to be common and generalised for all the countries considered. In Lithuania, the United Kingdom and Poland the cultivated surfaces increased, whereas Denmark and Italy registered a marked decrease of surface. Taking into account the average cultivated areas of the most recent period (2014–2017), common wheat cultivation is mainly concentrated in four countries: France, Germany, Poland and Romania, representing 53% of EU areas totally assigned to this crop (Eurostat 2018).

The overall trend in the EU is positive (+12%) for the average production detected during the two periods considered, and almost all countries show more or less relevant increases, whereas Spain and Italy reveal a certain reduction.

Concerning the yield variations in the same time frame, with a few exceptions of some Mediterranean countries (Spain, Italy and France) all nations show

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Table 1. Trend of common wheat cultivation in the EU

Country	Surfaces (1 000 ha)			Production (1 000 t)			Yield (t/ha)		
	2010–2013	2014–2017	variation (%)	2010–2013	2014–2017	variation (%)	2010–2013	2014–2017	variation (%)
France	4 933	5 067	+2.7	35 044	35 226	+0.5	6.99	6.96	–0.4
Germany	3 169	3 205	+1.2	23 425	25 704	+9.7	7.40	8.02	+8.4
Poland	2 154	2 369	+10.0	9 049	11 056	+22.2	4.08	4.64	+13.7
Romania	2 045	2 091	+2.3	6 365	8 446	+32.7	3.12	4.05	+29.8
United Kingdom	667	843	+26.3	13 749	15 435	+12.3	7.35	8.38	+14.0
Spain	1 753	1 790	+2.1	6 046	5 642	–6.7	3.49	3.15	–9.7
Bulgaria	1 168	1 159	–0.8	4 671	5 557	+19.0	3.96	4.79	+21.0
Hungary	1 024	1 018	–0.6	4 155	5 242	+26.2	4.05	5.19	+28.1
Czech Republic	835	834	–0.1	4 324	5 222	+20.8	5.17	6.26	+21.1
Lithuania	591	809	+37.0	2 363	3 847	+62.8	3.94	4.75	+20.6
Denmark	673	616	–8.5	4 586	4 744	+3.4	6.86	7.71	+12.4
Italy	582	543	–6.8	3 151	3 023	–4.1	5.39	5.27	–2.2
Other Countries	3 866	3 742	–3.2	12 054	15 457	+28.2	3.12	4.13	+32.5
EU	23 461	24 086	+2.7	128 982	144 599	+12.1	5.50	6.00	+9.2

Source: our elaboration on Eurostat data (Eurostat 2018)

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significant increases (9.2%, Table 1). This trend, which appears more widespread for the Eastern European countries, can be seen in the high dynamism of agronomic and genetic innovation of cultivated species.

As far as Italy is concerned, it is a net importing country and it is interesting to highlight which countries are the most important suppliers of common wheat for its domestic market. Thus, Table 2 shows the total quantities imported by Italy, which amount to almost 5 Mt, and the main supplier countries: the importance of the top four countries, i.e. Hungary, France, Austria and Ukraine is evident as they provide 57% of imported common wheat.

METHODOLOGY

The environmental analysis of wheat production "from cradle to farm gate" is performed based on the LCA approach in accordance with ISO Standard 14040: 2006 (Blanc et al. 2018).

The potential environmental impacts are evaluated including raw material acquisition, production, use and disposal.

In order to perform this study mid-point characterisation factors were used. The following environmental impact indicators were considered: climate change (*CC*), cumulative energy demand (*CED*), terrestrial acidification (*TA*), freshwater eutrophication (*FE*), marine eutrophication (*ME*), terrestrial ecotoxicity (*TE*), freshwater ecotoxicity (*FEC*), marine ecotoxicity (*MEC*).

The SimaPro 8 software (PRé Consultants 2013) and the Ecoinvent 3.0 database were used to analyse the data collected during the inventory phase.

Table 2. Importation of common wheat in Italy (2017)

Countries	Quantity (t)	(%)
Hungary	1 154 770	23.2
France	673 526	13.6
Austria	542 286	10.9
Ukraine	462 027	9.3
Bulgaria	432 487	8.7
Republic of Moldova	306 278	6.2
Germany	298 270	6.0
USA	221 469	4.5
Romania	192 256	3.9
Other countries	686 458	13.8
World	4 969 827	100.0

Source: UN-COMTRADE (2017)

In order to compare the results obtained from the four commercial wheat types analysed, a mass-based functional unit (*FU*) of 1 tonne was selected.

As the cultivation phase produces both grain (main product) and straw (by-product), which is sold for livestock applications, it is necessary to perform an allocation procedure to identify which environmental impact refers to the main product and which to the by-product (Sierra-Pérez et al. 2018). In the case study an economic allocation was performed, in accordance with other studies (Chiriaco et al. 2017), considering 75% for the main product and 25% for the by-product.

Variable production costs for the four commercial wheat types for the phase of cultivation were identified in the context of "Special wheat project". Costs were calculated using 1 tonne as a reference and dividing the items by operation category. The average data for production costs refer to 2014–2015 and 2015–2016 of experimental plot cultivation, while market prices refer to 2015 and 2016 (Granary Association of Milan 2018).

DATA COLLECTION

Most of the relevant information was acquired over the last 5 years of production for each type of commercial wheat considered. Chemical and rheological parameters, such as protein content and dough properties, correspond to different quality categories of common wheat. Common wheat has been classified according to Foca et al. (2007) into the following categories: improver wheat, ordinary bread making wheat, superior bread making wheat and wheat for biscuits. The data used in the LCA inventory refer to average crop yields (Table 3).

With regard to cultivation techniques, it should be observed that the same inputs and phases (soil preparation, sowing, fertilisation, pest and weed man-

Table 3. Average yield, range for each wheat commercial typology

Commercial wheat type	Yield (t/ha)	Range (t/ha)
Wheat for biscuits	6.91	6.03–7.76
Ordinary bread making wheat	6.85	6.27–7.86
Superior bread making wheat	6.70	5.74–7.97
Improver wheat	6.42	6.20–7.41

Source: Foca et al. (2007)

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agement, harvest) were considered for all the cases studied. In order to evaluate the environmental impacts related to each stage, the following inputs were considered: production of seeds for sowing; fertilizer production and application to the field; production and application of fungicides and insecticides; machinery manufacture and use; water and energy use.

Diesel and lubricant consumption were calculated using working time and horse power of machinery for all agricultural work processes and emissions, in accordance with Samaras et al. (2009).

Emissions from fertilisers, such as N_2O, NH_3, and NO_3^-, were assessed taking into account the agricultural practices and the soil and climate parameters referring to the area studied (Brentrup et al. 2000).

Pesticides, insecticide emissions and water consumption for product solubilisation were considered based on the Ecoinvent database v.3.0 (Hischier 2007).

There is no impact due to land use change; in fact, the land used for crops has been arable for a long time.

RESULTS AND DISCUSSION

Although N plays an essential role in plant production, nitrogen compounds are dispersed into the atmosphere and hydrosphere, causing unwanted effects on the environment (Zerulla et al. 2001). In Figure 1, ammonia volatilisation, nitrous oxide emissions and nitrate leaching for different commercial wheat types were calculated.

We considered a value of 100% for improver wheat, in both N_2O volatilisation and NH_3 emissions, while the values for other wheat classes are 92% for wheat for biscuits, 95% for ordinary bread making wheat and 96% for superior bread making wheat.

In contrast, the quantity of leached NO_3^- shows more significant differences between the four commercial wheat types: primarily wheat for biscuits has the greatest impact; secondly, the variation between classes is more significant. Using 100% for biscuit wheat, superior bread making wheat gives a result of 50%, ordinary bread making wheat of 27% and finally, improver wheat with a value of 16% (about 6 times less than biscuit wheat).

Intensive cropping systems subject the environment to damaging nitrogen, phosphorous and pesticides levels (Charles et al. 2006); therefore, to complete the environmental impact evaluation of our wheat cropping system, the Life Cycle Assessment method was used.

In Figure 2, impact categories of LCA for each commercial wheat type are shown. As is widely acknowl-

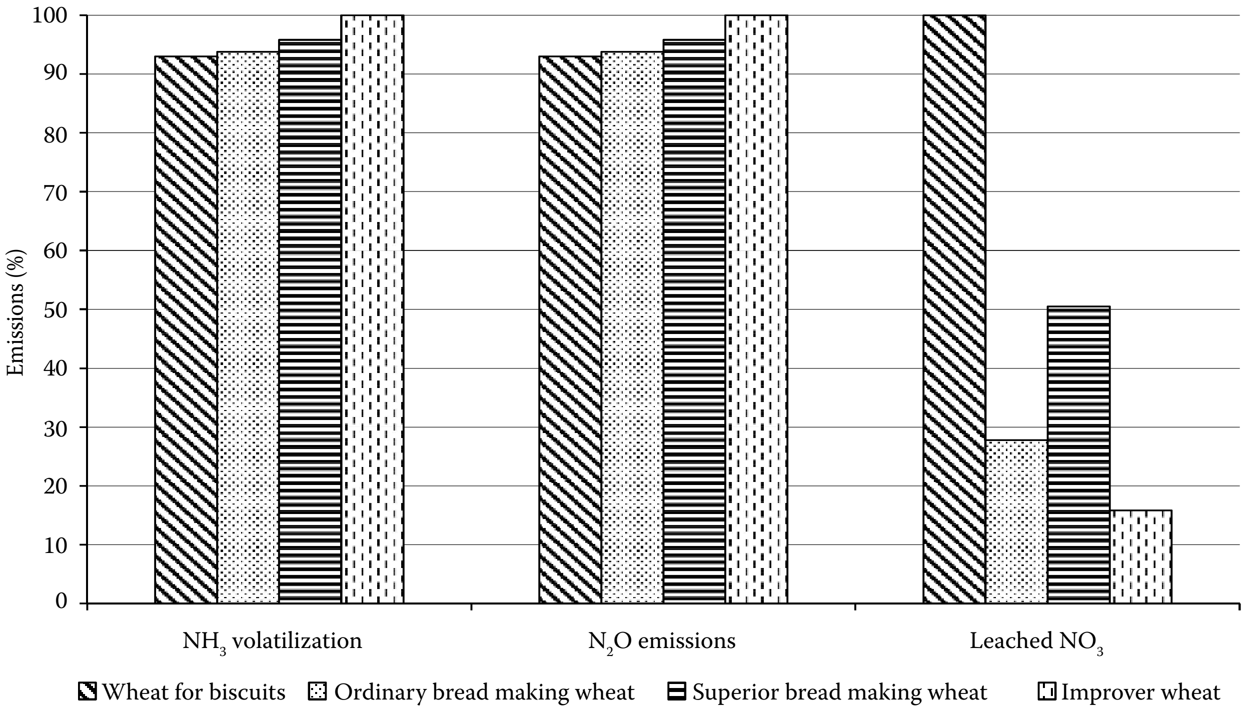

Figure 1. Nitrogen emissions – airborne and waterborne

Source: own processing

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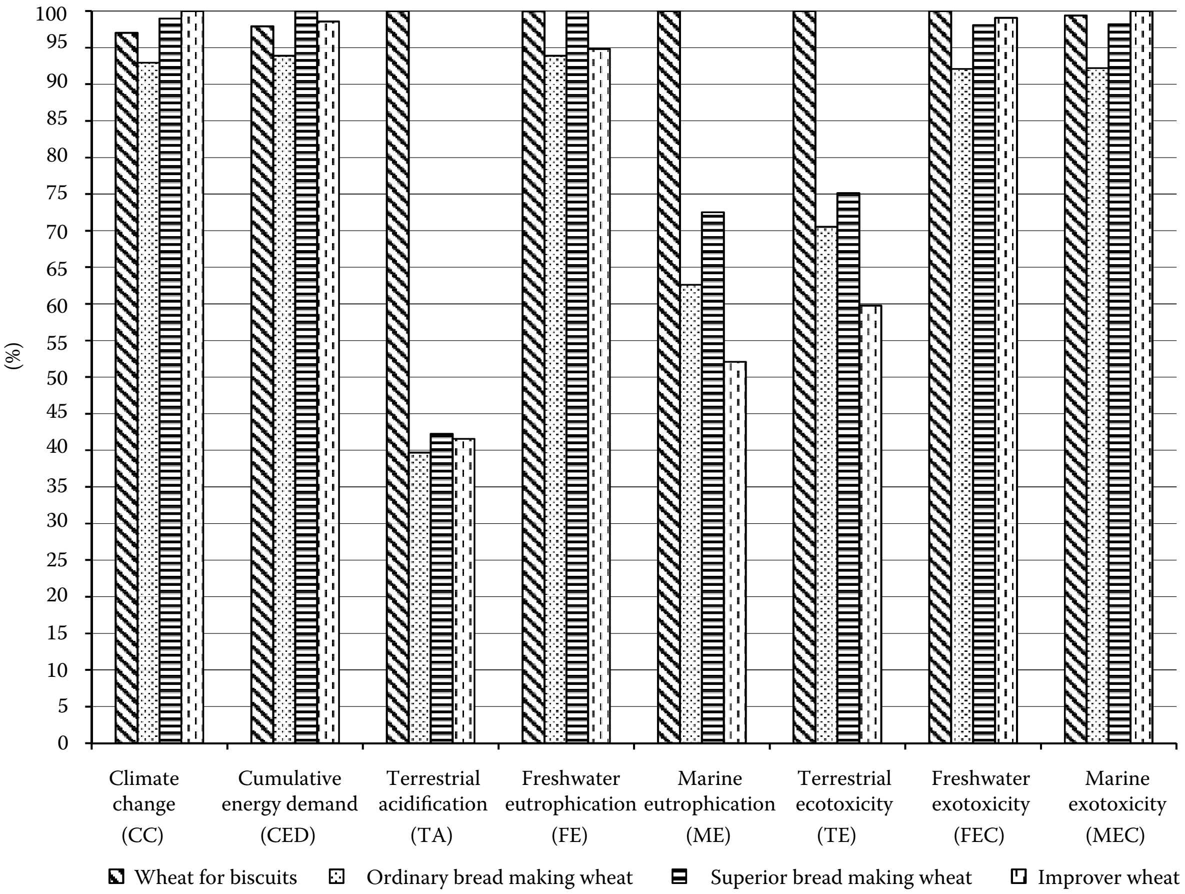

Figure 2. Life Cycle Assessment analysis results
Source: own processing

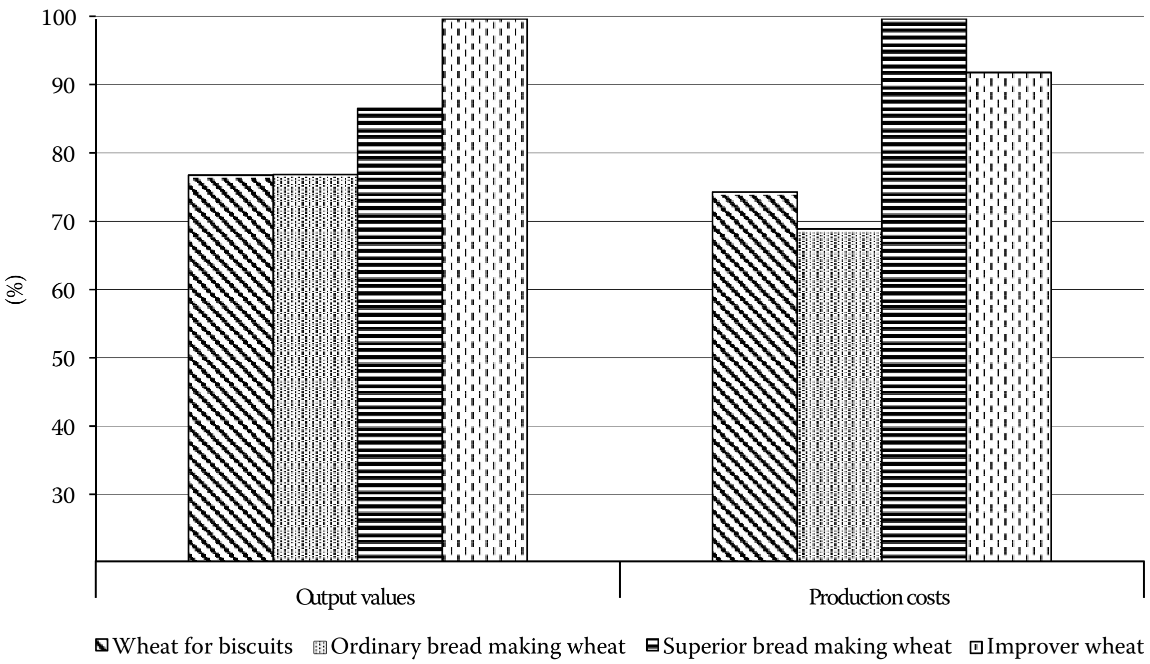

Figure 3. Production costs and output values for the four wheat typologies
Source: own processing

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edged, one of the main challenges in wheat cultivation is the demand for energy reduction. In fact, non-renewable energy is the source mainly used (Achten and Van Acker 2016). Our work shows how improver wheat has the greatest impact on climate change (*CC*), because of the higher quantity of greenhouse gas emissions released into the air during cultivation phases (N_2O volatilisation and NH_3 emissions). In contrast, no difference of *CED* among the four commercial types of wheat is noted – about 6% between the one with the least impact (ordinary bread-making wheat) and the one with the greatest impact (superior bread-making wheat).

Wheat for biscuits has higher values in the following categories: terrestrial acidification (*TA*), marine eutrophication (*ME*), terrestrial ecotoxicity (*TE*), freshwater ecotoxicity (*FEC*) and freshwater eutrophication (*FE*). The impact of improver wheat is higher in marine ecotoxicity (*MEC*) and climate change (*CC*). As stated by Chiriaco et al. (2017), fertiliser production and application contribute to global warming, due to NH_3 and N_2O emissions, in accordance with other studies; the nitrogen fertilisation in wheat cultivation is the main hotspot in the life cycle in terms of contribution to climate change.

As shown in Figure 3, the production costs and the output value, expressed in percentages, highlight the differences between the four commercial categories. The highest market value is represented by improver wheat, followed by superior bread-making wheat and ordinary bread-making wheat, whereas wheat for biscuits has the lowest unitary value of the commercial group. Production costs are higher for two classes, superior bread-making wheat and improver wheat due to the smaller yields of these two typologies.

CONCLUSION

The analysis performed produced some interesting findings about wheat, an important worldwide commodity. Firstly, growing common commercial wheat types generates an environmental impact, and secondly, the impact can be differentiated based on the technological features of the cultivated commercial types.

The LCA study clearly shows that the impact is different between improver wheat, bread-making wheat, superior bread-making wheat, and biscuit wheat. Our work confirms the results of Laratte et al. (2014) stating that the use of synthetic nitrogen fertiliser is one of the main drivers influencing global warming potential (GWP) and other LCA indicators, offering a global view of the significant impact categories of different wheat typologies.

Another related result shows that the best management of nitrogen fertilisation is important for all operators involved in the wheat supply chain (growers, wheat buyers and processors). At the same time, the best management of nitrogen fertilisation also has to comply with social responsibility by reducing the environmental impact. Thus, on the basis of the above-cited literature, we would consider it useful for the breeding programs to include a joint assessment of technological and environmental performances. Therefore, we expect that agronomic research will provide suitable responses to the issue of nitrogen management strategies in relation to different farming practices in the field.

Furthermore, consumer preferences and determinants of consumption highlight the increasing awareness of taking into account the environmental implications of production processes (Baudino et al. 2017), as demonstrated by the growing interest in forms of environmental declaration such as in the Environmental Product Declarations (Schau and Fet 2008). Moreover the prospective aspects and the future effects of grain cultivation on the environment may also be included in the political decision-making process.

Our preliminary economic evaluations, which will be examined in detail in the subsequent phases of the research, show that economic values and environmental impacts do not have the same performance. Improver wheat is the class with the greatest impact in terms of NO_2 and NH_3 emissions, climate change and marine toxicity, but the lowest leaching nitrate, and reaches the highest market value. On the other hand, wheat for biscuits is the class with the greatest impact with regard to *TA*, *FE*, *ME*, *FEC*, *MEC* variables and its output value is the lowest.

Our study shows that there is a lack of statistical data about commercial classes of wheat production at national and international levels, even though the market has recognised this segmentation with quotations for each class. Furthermore, our results are more important in countries such as Italy, in which the amount of wheat imported is considerable and the generated environmental impact of importation is already significant.

Finally, our study shows some limits due to the narrow area studied and the fact that only one N management strategy has been investigated. However, this is the first

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LCA study involving the four commercial typologies of wheat. In the future, the aim is to investigate the whole agrifood chain for each type of commercial wheat, in addition to the economic and environmental performance of different cultivars using varied management strategy techniques.

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