sustainability

Article

Economic and Environmental Assessment of Conventional versus Organic Durum Wheat Production in Southern Italy

Christian Bux [1], Mariarosaria Lombardi [2], Erica Varese [3] and Vera Amicarelli [1,*]

[1] Department of Economics, Management and Business Law, University of Bari Aldo Moro, 70124 Bari, Italy; christian.bux@uniba.it
[2] Department of Economics, University of Foggia, 71121 Foggia, Italy; mariarosaria.lombardi@unifg.it
[3] Department of Management, University of Turin, 10132 Turin, Italy; erica.varese@unito.it
* Correspondence: vera.amicarelli@uniba.it

Abstract: Conventional and intensive agriculture systems represent an environmental challenge. This research aims at evaluating the economic and environmental implications of conventional and organic durum wheat production in Southern Italy by applying material flow analysis and the crop accounting method. The purpose is to evaluate and compare the natural resource consumption, waste generation and economic profitability of conventional and organic durum wheat farming, respectively. The functional unit is one hectare of cultivated land. System boundaries encompass all agronomic operations, from cradle to gate. The research applies a bottom-up approach and relies on either primary or secondary data. It emerges that organic durum wheat production reduces the use of synthetic chemical and phytosanitary products, as well as plastic waste, by up to 100%. Moreover, it decreases diesel use by 15%, with a consequent reduction in CO_2 emissions, and also avoids soil and groundwater pollution. From an economic perspective, gross income for conventionally farmed durum wheat is still 55% higher compared to organic production. Public authorities should boost environmental sustainability by supporting organic production from either an economic or a social perspective, by enhancing the sharing of best practices, by certification for farmers' groups, by research and innovation, and by incentives in taxation. Overall, this research represents a further step towards the adoption of sustainable agricultural practices.

Keywords: crop accounting; environmental sustainability; material flow analysis; resource management; organic farming; sustainable agriculture

Citation: Bux, C.; Lombardi, M.; Varese, E.; Amicarelli, V. Economic and Environmental Assessment of Conventional versus Organic Durum Wheat Production in Southern Italy. *Sustainability* **2022**, *14*, 9143. https://doi.org/10.3390/su14159143

Academic Editor: Michael S. Carolan

Received: 6 July 2022
Accepted: 24 July 2022
Published: 26 July 2022

1. Introduction

Conventional and intensive agriculture systems represent an environmental challenge [1]. Although the food system as a whole has enhanced agricultural yields through the adoption of monitoring crops' growth [2], accurate weather prediction technologies [3], and novel crop protection methods [4], to meet demand for food commodities and reduce hunger [5], such a rapid rise in productivity has had a detrimental effect on the environment. Among other issues, agricultural production is responsible for soil degradation, biodiversity losses, water pollution and climate change [6,7]. As reported by Ritchie and Roser [8], half of habitable land worldwide is used for agriculture, accounting for over 51 million km^2. For crop production (excluding animal feed), a figure of over 11 million km^2 of land has been estimated. Further, crop production for human consumption accounts for over 21% of food production emissions, equivalent to approximately 2.8 Gt of CO_2eq [9]. In Italy, agricultural greenhouse gas (GHG) emissions have been estimated at 418 kt of CO_2eq and represent the highest in Europe after Germany (810 kt of CO_2eq) and France (443 kt of CO_2eq) in 2019.

In the field of wheat production, Ritchie and Roser [8] have estimated that more than 3.8 m^2 of land is required to cultivate one kilogram of wheat, while the entire wheat chain generates more than 1.5 kg of CO_2 per kilogram of product (i.e., more than 50% is due to land use and farm management operations). Conventional crops are characterized by higher yields and profits compared to organic ones [10]. However, better economic performance is supplemented by negative externalities. From the environmental perspective, conventional crops cause soil depletion, groundwater pollution, and atmospheric contamination, as well as requiring extensive use of agrochemicals [11]. Further, from the economic and societal perspective, conventional crops are less likely to meet the increasing market demand for sustainable products [12], thereby frustrating international and national directives on sustainable production strategies, such as the Farm to Fork Strategy [13]. On the other hand, organic farming is defined as a system which relies on ecosystem management rather than external agricultural inputs and which eliminates the use of synthetic inputs such as synthetic fertilizers and pesticides, veterinary drugs, genetically modified seeds and breeds, preservatives, and additives [14]. It provides a sustainable alternative to conventional farming [15] since energy use per hectare of land. and levels of GHG emissions are both lower compared with conventional crops [16]. From the ecological perspective, organic farming does not revolutionize the soil structure, does not release polluting substances into nearby water bodies by leaching, and does not use chemicals which damage the ecosystem [17].

Recent studies [18] have found that although organic farming provides reliable environmental benefits and contributes towards food safety and food security goals, it also increases variability in crop yields, producing financial risks for farmers in terms of volatile profitability. This brings to light a critical issue in terms of environmental protection and economic growth: organic farms promote biotic abundance, soil carbon, and profitability, but conventional farms produce higher yields [18]. On the other hand, it has been argued that ecological and economic outcomes depend either on the adoption of different management systems (i.e., conventional or organic) or on crop types, underlining that each case must be treated individually.

In the quest for a fair trade-off between economic growth and environmental protection, the present research aims at evaluating the economic and environmental impacts of conventional and organic durum wheat (*Triticum turgidum* L. subsp. *durum*) production in the Apulia region (Southern Italy) by material flow analysis (MFA) and by crop accounting.

To the best of the authors' knowledge, there have been no studies which have combined these two methodologies to assess similarities and differences between these two types of farming systems in terms of natural resource consumption, waste generation and economic profitability. The originality of the present research thus relies on considering these factors in an attempt to fill in the academic data gaps. Specifically, the MFA produces transparent, comparable and replicable data, both quantitative and qualitative, and it identifies the hotspots of these two farming systems.

Finally, this research contributes to the integration of academic and practitioner knowledge in the field of durum wheat farming, representing a further step towards the adoption of sustainable agricultural practices.

2. Theoretical Background

Durum wheat is the tenth most important crop worldwide and is cultivated in three main areas, namely: the Mediterranean basin; the northern United States and Canada; and the desert areas of the southwest United States and northern Mexico [19]. In addition, durum wheat is the most cultivated cereal crop in the Mediterranean basin [19] and is essential in the Mediterranean diet, being the basis for the production of four different products: pasta, couscous, bulgur and bread.

On a global scale, durum wheat annual production has declined from 37 Mt in 2018 to 33.6 Mt in 2020 (−9%) [20] and represents approx. 4% of entire wheat production (895 Mt in 2020) as reported by FAOstat [21]. It is estimated that the European Union (EU) produced 7.3 Mt of durum wheat in 2020, with a cultivated land area of 2,199,000 ha and an average yield of 4 t/ha [22]. Italy is the largest EU producer of durum wheat, accounting for approx.

4 Mt cultivated on 1,210,415 ha of land. The Apulia region is the biggest producer of durum wheat in Italy, recording 0.99 Mt of durum wheat production in 2020 (24% of total Italian production) [23]. Moreover, the Apulia region has the largest area of Italy devoted to durum wheat farming, estimated at 344,400 ha in 2020, compared to 283,870 ha in 2010 (+21%) [24].

Several articles on durum wheat have been published in Italy in the fields of environmental sciences, social sciences, energy, and business management. In terms of organic farming, durum wheat is cultivated on more than 140,000 ha (10% of the total durum wheat cultivated land). Southern Italy, including Apulia, Sicily, Calabria and Molise, has contributed most to the organic conversion, covering over 50% of all organic cultivated land in Italy [25]. From the consumption perspective, of the rate of durum wheat self-sufficiency (apparent production/consumption) has been estimated at 56% [26].

Lately, researchers have applied the life cycle assessment (LCA) to improve the management of agri-food companies involved in whole-grain durum wheat pasta production, and to assess the energy and environmental impacts of durum wheat bread [27]. Such studies have estimated that the major environmental impacts along the entire wheat chain are generated during the cultivation stage, but no comparison has yet been made between conventional and organic farming. Furthermore, Todorović et al. [28] have investigated the different impacts of water and nitrogen on durum wheat eco-efficiency in the Mediterranean area, highlighting the need to adopt agronomic practices with low use of resources and higher eco-efficiency. Sustainable practices must address both precision agriculture and optimization of water and fertilizers, enhancing environmental, resources and economic performances at the same time. Similar results have been obtained by Alhajj Ali et al. [29], which have estimated wheat-cultivation-related GHG emissions and have evaluated lower carbon footprints associated with improved productivity and minimum inputs. Results like these suggest that the main contributors to negative emissions are farm inputs, as well as nitrogen fertilizers and pest management techniques [29,30]. As regards water footprints, several authors have stressed the importance of responsible water use [30,31] and have highlighted organic pest control and proper manure use as drivers to reduce water consumption towards sustainable practice levels [32,33].

As regards the comparison between conventional and organic wheat farming, several articles have investigated organic wheat quality and consumers' preferences [34,35] but few authors have compared the economic and environmental impacts associated with conventional and organic durum wheat farming, respectively. Montemurro and Maiorana [36] have estimated that conservative agricultural practices such as crop rotation, shallow tillage and organic fertilizers can reduce environmental impacts and contribute towards sustainable agriculture, whereas Tudisca et al. [37] highlighted a higher gross margin for organic durum wheat compared to the conventional crop, due to lower variable costs and higher production values. Further in-depth comparisons between conventional and organic crops have been conducted by Fagnano et al. [38], with the aim of evaluating the agronomic, technological, sensory and sanitary qualities of grains and pasta, but without assessing environmental consequences. In the field of water consumption analysis in Italy, relevant literature has considered the water footprint to evaluate the environmental and sustainable performance of companies. Ruini et al. [39] considered this indicator with respect to pasta production, highlighting its role in informing better decision-making regarding plant management, supplier collaboration and interaction between policy-makers and communities [40].

In addition to the environmental impacts of durum wheat production, and the economic savings arising from the adoption of innovative technologies [41], researchers have been interested in contractual arrangements within the Italian durum wheat sector [42]. It has emerged that Italian farmers are more likely to accept contractual clauses related to food quality than to adopt sustainable agronomic practices, highlighting the need to align economic incentives with environmental goals through measurable socio-environmental targets in contractual clauses [43]. It means that farmer preferences towards conventional or organic practices are not only financially driven but depend on several variables, such as social or financial ones [24].

3. Materials and Methods

The present research applies: (i) the MFA, to compare conventional and organic durum wheat production in terms of natural resource consumption and waste generation (Section 3.1); and (ii) the crop accounting method, to calculate economic indicators, such as gross income, total revenues and total costs (Section 3.2). The present research adopts a stepwise approach, as proposed by Bux and Amicarelli [44], and Hendriks et al. [45], as follows: (a) identification of the qualitative system, including functional unit, material flows and system boundaries definition; (b) assessment of the quantitative system along the entire supply chain, including energy and water use; (c) calculation of either the conventional or the organic durum wheat production level through an input–output table [46,47]; and (d) evaluation of the results by the crop accounting method. Section 3.3 describes the data collection process according to a bottom-up approach, which relies both on secondary data, taken from national and international reports, scientific research and official databases; and primary data, provided by a Southern Italian farm located in the Apulia region.

3.1. Material Flow Analysis

The MFA can be defined as "a systematic assessment of the state and change of materials flow and stock in space and time" [47] and has been applied with success at micro-, meso- and macro levels [48]. Some studies have explored local cereal supply chains from an economic, social and environmental perspective to aid decision-making [49], while others have evaluated energy use, GHG emissions, land use, use of pesticides, and blue water footprints associated with cereal production [50].

The authors selected one hectare of land as functional unit. Some authors have proposed 1 t of wheat produced as a functional unit [51,52], but such a unit is excessively influenced by the yield level, thereby compromising results and leading to incomparable outcomes [53]. Although the analysis of conventional durum wheat was conducted from October 2014 to June 2015, while the investigation of organic durum wheat was carried out between October 2019 and June 2020, the research relies on common characteristics in terms of structure and composition of the soil, organic endowment, crop in precession and water endowment.

As regards the system boundaries, the analysis encompasses all agronomic operations [54], from agricultural production to storage and warehouse operations (i.e., from cradle to farm gate). Conventional durum wheat production system boundaries include: (a) plowing, harrowing, and sowing; (b) fertilization; (c) chemical weeding and phytosanitary treatments; (d) combine harvesting (for third parties), straw harvesting (for third parties), and transport. Organic durum wheat system boundaries include: (a) light harrowing (or false sowing), sowing, tillage, and harrowing; (b) mechanical weeding; (c) combine harvesting (for third parties), straw shredding (for third parties), and transport. From a circular economy perspective, the straw on the field is subjected to shredding and sent to the fertilization phase together with the manure. The cradle-to-gate boundaries allow researchers to replicate the MFA in other geographical areas, and to compare trends and results obtained over time [55]. As regards the organic farming, durum wheat was cultivated according to a defined organic regime, as stated by the Council Regulation (EC) 824/2007 on organic production and labelling of organic products [56].

As regards the investigation of material flows, the authors consider material inputs such as seeds, fertilizers (i.e., urea, N, K, K_2O, O_2) and herbicides, as well as plastic nets for collecting and storing straw. Further, considering resource and energy inputs, the research takes water and diesel consumption into consideration. On the output side, the authors give an account of CO_2 emissions, plastic and paper waste (e.g., packaging), fertilizers and pollutants, wheat losses and straw. For an assessment of water consumption, the authors consider the average rainfall trends for the reference years (i.e., from October 2014 to June 2015; and from October 2019 to June 2020) recorded by Protezione Civile Puglia [57]. Rainfall trends have been considered comparable in both years [58,59]. For conventional farming, it is estimated that rainfall represents 90% of the entire water consumption by durum wheat, whereas for organic farming the figure is 100%. Overall, conventional farming requires 5225–5775 L/ha, whereas organic farming requires approx. 3610–3990 L/ha. As regards the organic method applied in the research, it assumes no use of synthetic fertilizers and chemicals, when ancient and indigenous grains are considered.

Figure 1 illustrates system boundaries and material flows for either conventional or organic durum wheat production. Cultivation and seeding include operations such as deep harrowing, ploughing, harrowing and seeding, followed by fertilization and chemical weeding for conventional durum wheat. In addition, mechanized harvesting and transport from field to warehouse are taken into consideration.

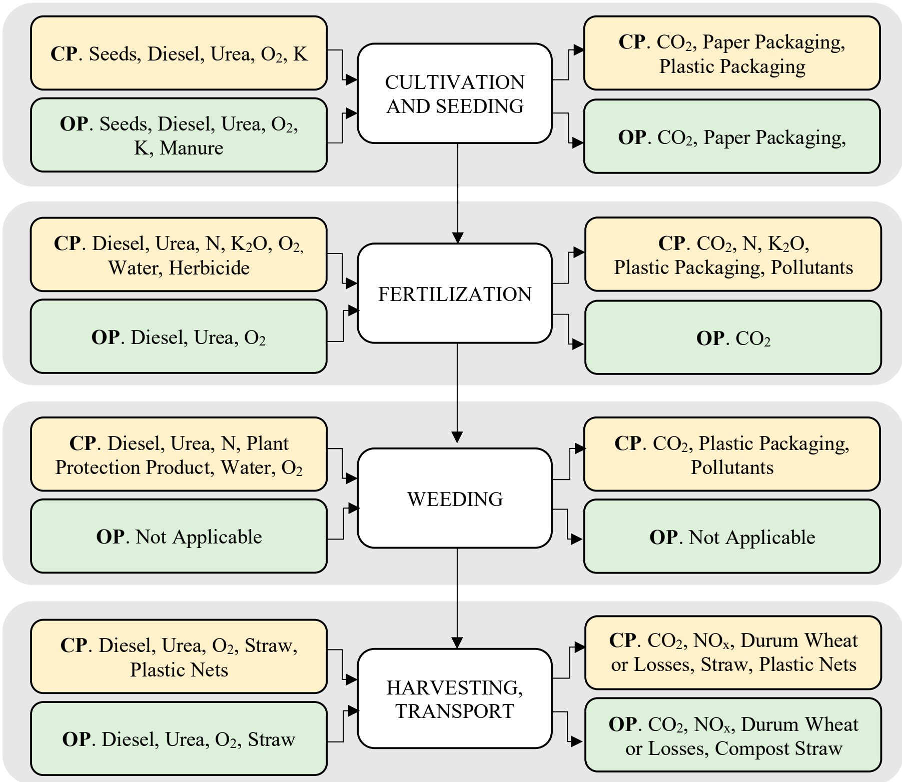

Figure 1. System Boundaries and Material Flows for the Durum Wheat Production. Notes: CP = conventional durum wheat production (yellow panels); OP = organic durum wheat production (green panels). Source: Personal elaboration by the authors.

3.2. Crop Accounting Method

As regards economic data, the authors consider a pre-pandemic scenario (i.e., baseline) and apply an estimate, budget, and costing tool defined as crop accounting. This represents a useful tool for crop enterprise management, since it considers all costs of growing crops until harvesting time [60]. In the case of conventional durum wheat, such an approach accounts for the costs of plowing, harrowing, sowing, fertilization, weeding, phytosanitary treatment, harvesting, and transport to the collection center. For organic production, the approach encompasses the costs of subsoiling, harrowing, sowing, fertilization (soil improver), mechanical weeding, harvesting, shredding, and transport to the collection center. This method calculates the gross income as the difference between total revenues and total costs associated with 1 t of durum wheat per ha (i.e., the functional unit). Either secondary data (i.e., national and international reports, scientific research, database), or primary data (i.e., site-specific data provided by a Mediterranean farm) are used to calculate the economic indicators.

3.3. Data Collection

Data collection represents a challenging step in MFA [61]. In Southern Italy, there is a lack of reliable, up-to-date data concerning water, nitrogen and carbon recycling, and the same applies in the case of carbon and nitrogen dioxide emissions [62]. Moreover, some criticalities are related to agricultural and transport operations on behalf of third parties. Bottom-up approaches provide more detailed information on material flows, offering a suitable empirical basis for practitioners and for academic research [63]. Furthermore, to acquire reliable data on conventional and organic durum wheat, the authors have adopted the research triangulation paradigm [64,65]. Such an approach combines data and observations at farm level and helps in boosting the credibility and validity of research findings [66]. As regards single material flows, data relating to seeds, fertilizers, diesel, urea, electricity and herbicides have been provided by an Apulian farm and compared with secondary data from scientific articles applying the life cycle assessment in Sicily [25], as well as the carbon and water footprints of Italian production [27–29]. Moreover, data related to nitrogen and water inputs have been compared to those provided by Todorović et al. [26] in the Mediterranean area. Straw, plastic and paper waste are primary data, whereas CO_2 emissions have been compared with Tedone et al. [17] and Alhajj et al. [27], which investigated GHG emissions from durum wheat production.

Table 1 illustrates the input–output table for either conventional or organic durum wheat production. As regards data uncertainties, the authors have determined a ± 5% error rate which encompasses measurement errors associated with the databases needed to conduct the MFA, data gaps due to confidentiality rules, errors due to assumptions or simplifications, and errors due to conversions into mass weight or the downscaling of data [67]. In addition, such an error rate takes into consideration the variability of agricultural activities. As regards rainfall trends, data have been taken from Protezione Civile Puglia [57]. Further, groundwater used by the crop has not been estimated, and rainwater has not been discounted by the crop coefficient of waste use [68].

Table 1. Input–Output Table for the Durum Wheat Production (Functional Unit: 1 ha).

Input–Output Table			Conventional Production		Organic Production	
Material Flows		**Unit**	**Min.**	**Max.**	**Min.**	**Max.**
Input	Seeds	kg/ha	142.5	157.5	142.5	157.5
	N	kg/ha	118 $^{\alpha}$	131 $^{\alpha}$	204 $^{\beta}$	226 $^{\beta}$
	P	kg/ha	57	63	28.5 $^{\gamma}$	31.5 $^{\gamma}$
	K	kg/ha	95	105	68.4	75.6
	Diesel	MJ/ha	148.2	163.8	127.3	140.7
	Urea	L/ha	11.4	12.6	8.6	9.5
	Electricity	MJ/ha	6070.5	6709.5	5198.4	5745.6
	Herbicides	kg/ha	4.7	5.2	0	0
	Water	L/ha	5225 $^{\delta}$	5775 $^{\delta}$	3610 $^{\varepsilon}$	3990 $^{\varepsilon}$
Output	Durum wheat	kg/ha	3087.5	3412.5	2185	2415
	Straw	kg/ha	2850	3150	1995	2205
	Paper waste	kg/ha	3.8	4.2	3.8	4.2
	Plastic waste	kg/ha	6.4	7	0	0
	CO_2 emissions	kg/ha	399	441	339.1	374.9

Notes: $^{\alpha}$ 20% from culture in precession, 80% of synthetic nitrogen; $^{\beta}$ 12% from culture in precession, 82% from soil conditioner, 6% from straw burial; $^{\gamma}$ 100% from soil conditioner and straw burial; $^{\delta}$ 10% from water treatments, 90% from rainfall; $^{\varepsilon}$ 100% from rainfall. Source: Personal elaboration by the authors.

4. Results and Discussion

4.1. MFA Results

Figure 2 illustrates the MFA for 1 ha of conventional durum wheat while Figure 3 shows the MFA for 1 ha of organic durum wheat. Organic farming does not rely on mineralized fertilization; it requires urea, K fertilizers and manure. From a circular perspective, natural fertilizers come from straw compost and residual straw elements. Additionally, no plastic packaging is generated during cultivation and seeding, fertilization or weeding. As regards diesel consumption, less fuel is required either for cultivation and seeding (−25%), or for fertilization (–55%). Considering that herbicides and plant protection products are not applied, and a weeding stage is not carried out, an additional 8.8–9.8 L/ha of diesel are saved. On the contrary, more diesel is required for the straw shedding stage (+43%). From a waste management perspective, plastic waste is totally avoided (from –7 to –6.4 kg/ha), and CO_2 emissions are reduced by approx. 15% (from 399–441 kg/ha to 339–374 kg/ha).

As regards the results from the water consumption analysis, it emerges that 5225–5775 L of water, of which 4702–5198 L is rainfall, are required to produce 3087–3413 kg of conventional durum wheat. The water consumption rate is estimated at 1.69 L/kg, of which 0.17 L/kg is the result of from irrigation. On the other hand, 3610–3990 L of water (100% rainfall) are required to produce 2185–2415 kg of organic durum wheat. The water consumption rate is assessed at 1.65 L/kg.

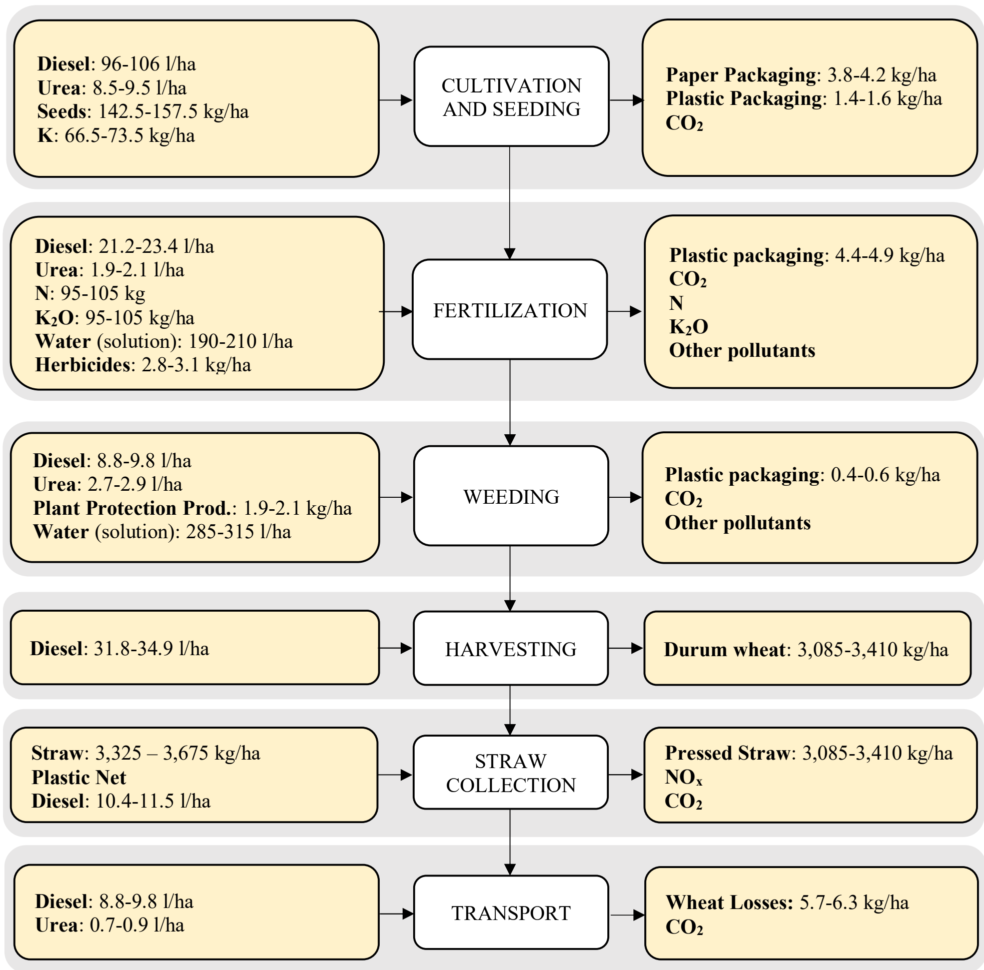

Figure 2. Material Flow Analysis for 1 ha of Conventional Durum Wheat. Source: Personal elaboration by the authors.

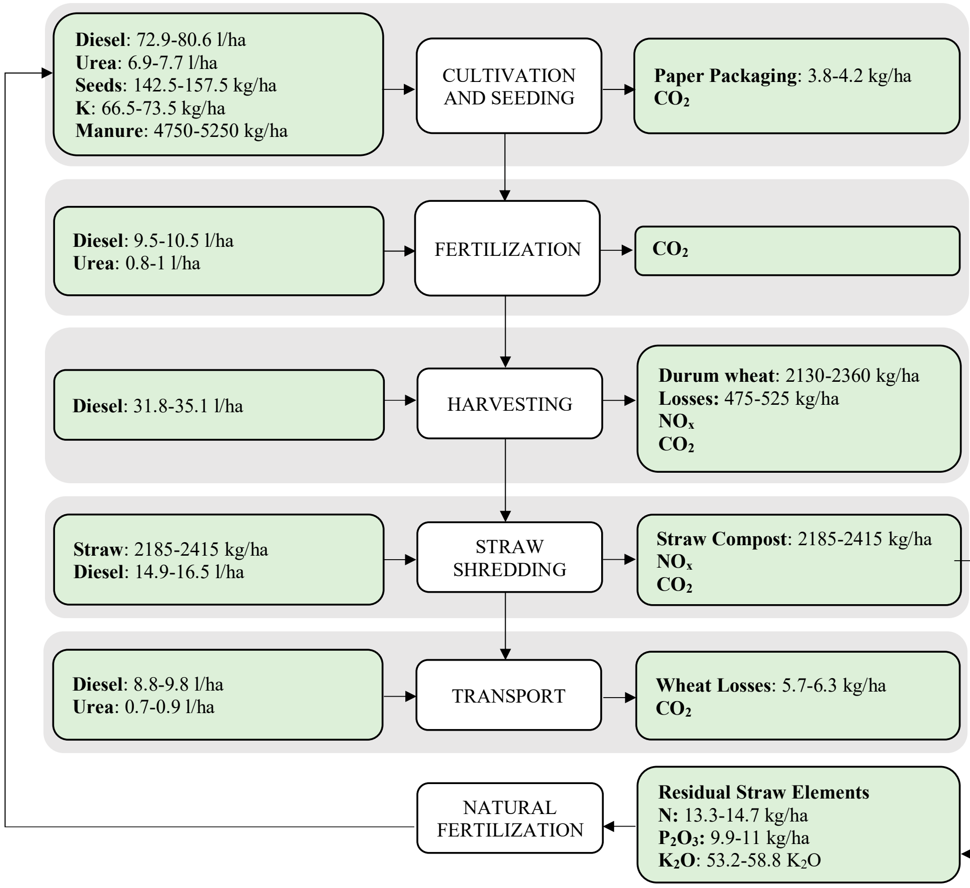

Figure 3. MFA for 1 ha of Organic Durum Wheat. Source: Personal elaboration by the authors.

Crop accounting for conventional and organic durum wheat considers average yields of 3.2 t/ha and 2.3 t/ha, respectively, while average prices are estimated at EUR 300/t for conventional durum wheat in 2014/2015 and EUR 420/t per organic durum wheat in 2019/2020. As regards straw, its price has been estimated at EUR 90/t and its yield at 3 t/ha. Table 2 illustrates the crop accounting for conventional and organic durum wheat production. At first glance, although conventional production costs are higher than organic production costs (+21%), it emerges that conventional durum wheat is more profitable (in terms of gross income) compared to organic durum wheat production. From an operational perspective, organic farming is less expensive considering that complex and environmentally impacting operations (i.e., plowing, cover fertilization, weeding, phytosanitary treatments) are absent. On the other hand, organic farming does not generate any revenues from straw selling, since straw is used as natural fertilizer for further cultivation and requires additional operations such as subsoiling (75–82 EUR/ha), basic fertilization (228–252 EUR/ha), mechanical weeding (57–63 EUR/ha), and collection and shredding (133–147 EUR/ha).

Table 2. Crop Accounting for Conventional and Organic Durum Wheat Production in EUR/ha.

Crop Accounting Method		CDW (Min.)	CDW (Max.)	ODW (Min.)	ODW (Max.)
Revenues	Revenues durum wheat	912	1008	917.7	1014.3
	Revenues straw	256.5	283.4	0	0
	Total revenues (*a*)	*1168.5*	*1291.5*	*917.7*	*1014.3*
Costs	Plowing	190	210	0	0
	Subsoiling	0	0	75.05	82.3
	Harrowing	123.5	136.5	47.5	52.5
	Sowing	190	210	190	210
	Cover fertilization	128.3	141.8	0	0
	Basic fertilization	0	0	228	252
	Weeding	59.9	66.2	0	0
	Mechanical weeding	0	0	57	63
	Phytosanitary treatments	80.8	89.3	0	0
	Collection	114	126	0	0
	Collection and shredding	0	0	133	147
	Transport to the collection center	39.9	44.1	31.4	34.7
	Total costs (*b*)	*926.5*	*1023.8*	*762*	*842*
	Gross income (*a–b*)	*242.3*	*267.8*	*156*	*172*

Notes: CDW = Conventional durum wheat; ODW = Organic durum wheat. Source: Personal elaboration by the authors.

4.2. Managerial Implications

Among its strengths, organic durum wheat farming enhances water retention and soil porosity through the presence of roots and soil microfauna. Moreover, from an environmental point of view, organic farming ensures lower environmental impacts by reducing the use of synthetic chemicals and phytosanitary products by up to 100% [69]. Similar benefits occur in terms of plastic waste, which is also reduced up to 100%, and the use of diesel, which is reduced by 15% (with consequent reduction in CO_2 emissions). In the same light, soil and aquifer pollution is avoided, as is the use of external materials, with associated damage to the surrounding environment (i.e., flora and fauna) [70]. From an economic perspective, organic production guarantees a positive, albeit reduced, margin. Finally, compliance with the Council Regulation EC/824/2007 on organic production and labeling of organic products allows for more attention, more analysis and the acquisition of experience in soil management by agricultural operators [71]. Considering future opportunities for organic durum wheat production, it is now possible to sign supply chain contracts cheaper than those signed for conventional production [72]. Moreover, genetic improvement and assisted evolution technologies, wheat grafting and the use of more efficient biostimulants could all be used in the future [73].

On the other hand, some weaknesses in organic farming have been evaluated, which may suggest a continuing preference for conventional rather than organic farming. Organic crops are affected by fungal diseases and erosion, and incur rather high production costs [74,75]. Furthermore, the required land use is higher than with conventional crops. It is estimated that, with a 25 to 64% increase in land use, there is a 20% to 45% lower yield compared to conventional crops (i.e., conventional yield is 3.2 t/ha, whereas organic yield is 2.3 t/ha). In terms of threats from climate change and the related consequences for crop variability, this price differential between organic and conventional products and market competitiveness in terms of price and/or consumer choice should not be underestimated.

From an economic perspective, organic farming provides lower gross incomes compared to conventional farming. Although farmers take care of the water–energy–food nexus in farming [76,77] and its related environmental consequences (i.e., higher waste generation, increased CO_2 emissions, higher water consumption), and even if resource-efficient, resilient and productive food systems are seen as fundamental to pursue sustainable development, still entrepreneurs pursue financial objectives [78]. In the light of the crop accounting results, it emerges that farmers are still more interested in cultivating conventional durum wheat compared to organic, since gross incomes are approx. 55% higher. Public authorities should boost environmental sustainability by supporting organic production from either an economic or social perspective. Key tools to enhance sustainable development could include networking for sharing best practices, certification for groups of farmers rather than for individuals, research and innovation, as well as providing economic benefits for organic producers, including incentives in taxation [79].

4.3. Limitations and Further Work

The present research provides environmental and socioeconomic data, addressing managerial concerns regarding the adoption of sustainable agriculture practices. Although this data concerns Southern Italian durum wheat crops, our research identifies broad hotspots of wheat production by comparing conventional and organic farming. Due to its replicability and comparability, it can be enlarged to other areas, as well as to other agricultural or processing practices. From the farmers' perspective, EU policies in the field of organic farming should encourage production and processing by stimulating conversion and reinforcing the entire value chain. Although the organic farming sector of the EU has increased by approx. 66% from 2010 to 2020 [80], farmers have reported insufficient access to stable markets for organic products, representing one of the largest barriers to economic viability, as well as a lack in information and technical assistance [74]. As a consequence, public authorities must boost consumer demand by preventing food frauds and strengthening consumer trust, improving traceability, reinforcing organic school schemes and facilitating the contribution of the private sector [80].

One means of boosting organic farming and increasing farmers' income is related to the diffusion of the organic certification, which could increase companies' visibility and consumers' trust. Starting from January 2022, the EU has activated a new organic legislation (Regulation EU 2018/848 on organic production and labelling of organic products), which ensures fair competition for farmers whilst preventing fraud and maintaining consumer reliance [80]. Among other things, the EU action plan aims to introduce simplified production rules, strengthen control systems along the entire supply chain, and implement an easier certification system for small farmers. In the light of the crop accounting analysis and considering the low incomes of organic durum wheat production, the adoption of group certification could represent a suitable instrument to both promote conversion to organic production methods, and maintain existing organic production, by reducing the costs of certification. Farmers could reduce either the cost of the control visit or the costs associated with bureaucratic requirements of organic certification, while maintaining quality assurance systems, and thereby counterbalance the lower incomes of organic production [81].

This research is limited by a lack of up-to-date data on water, nitrogen, carbon recycling and dioxide emissions by third parties. Moreover, results are influenced by meteorological and economic variables, such as market prices or inflation. In addition, the research is limited to a region of Southern Italy (Apulia) and does not allow the extension of its results to national or international realities. Although MFA provides transparent, comparable and replicable results under quantitative and qualitative perspective, and highlights hotspots in processes and stocks, more data are essential to guarantee reliability of results.

Future research directions might include the creation of a suitable inventory of durum wheat production in the Mediterranean area, by collecting data from as many farms as possible, and by calculating reliable eco-efficiency indicators [82]. The adoption of such indicators, which are based on the general concept of output maximization with resource consumption minimization, could be useful to identify the main environmental and economic criticalities in the organic and conventional durum wheat production, and they could also "capture the ecological efficiency of growth by measuring the efficiency of economic activities and its corresponding environmental impacts" [83]. Moreover, based on the present research, the authors are willing to apply the mass-balance approach to organic and conventional durum wheat production at the macro level (i.e., in Italy).

5. Conclusions

This research evaluated and compared natural resource consumption, waste generation and economic profitability in conventional and organic durum wheat farming by applying the MFA and the crop accounting method. The research focused on Southern Italy, specifically the Apulia region, which produces 0.99 Mt of durum wheat and represents 24% of the entire Italian production and over 13% of total EU production. Durum wheat represents a staple food, and it is the basis for the production of four essential products in the Mediterranean diet, namely, pasta, couscous, bulgur and bread.

It emerged that organic durum wheat production has lower environmental impacts, since the use of synthetic chemical and phytosanitary products, as well as the production of plastic waste, are reduced by up to 100% compared to conventional organic farming. Furthermore, such a sustainable agricultural practice allows for a decrease in diesel use of 15%, as well as related CO_2 emissions, which could be reduced from 399–441 kg/ha to 399–374 kg/ha. In addition, the adoption of organic farming practices enhances water retention and soil porosity through the presence of roots and soil microfauna. However, organic crops are subject to fungal diseases, erosion and rather high production costs.

From an economic perspective, although organic farming represents a more sustainable agricultural practice, its land use requirement is still higher, compared to conventional wheat production. It has been estimated that conventional yields are about 3.2 t/ha, whereas organic yields have been evaluated at 2.3 t/ha. Furthermore, the increase in land use is still associated with lower gross incomes, since the gross income for conventional durum wheat production is 55% higher, when compared to organic production.

Overall, public authorities should boost environmental sustainability by supporting organic production from either an economic or social perspective, and key tools to improve sustainable development and boost economic benefits while guaranteeing environmental protection must develop, including networking for sharing best practices among local farms, as well as enhanced certification for groups of farmers, research and innovation, and incentives in taxation.

Author Contributions: Conceptualization, C.B., M.L., E.V. and V.A.; methodology, C.B. and V.A.; software, C.B. and V.A.; validation, C.B. and V.A.; investigation, C.B. and V.A.; resources, C.B. and V.A.; data curation, C.B., M.L., E.V. and V.A.; writing—original draft preparation, C.B.; writing—review and editing, M.L., E.V. and V.A.; visualization, M.L., E.V. and V.A.; supervision, M.L., E.V. and V.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Page, G.; Ridoutt, B.; Bellotti, B. Location and technology options to reduce environmental impacts from agriculture. *J. Clean. Prod.* **2014**, *81*, 130–136. [CrossRef]
2. Fritz, S.; See, L.; Bayas, J.C.L.; Waldner, F.; Jacques, D.; Becker-Reshef, I.; Whitcraft, A.; Baruth, B.; Bonifacio, R.; Crutchfield, J.; et al. A comparison of global agricultural monitoring systems and current gaps. *Agric. Syst.* **2019**, *168*, 258–272. [CrossRef]
3. Konduri, V.S.; Vandal, T.J.; Ganguly, S.; Ganguly, A.R. Data Science for Weather Impacts on Crop Yield. *Front. Sustain. Food Syst.* **2020**, *4*, 52. [CrossRef]
4. Hazra, D.K.; Purkait, A. Role of pesticide formulations for sustainable crop protection and environment management: A review. *J. Pharmacogn. Phytochem.* **2021**, *8*, 686–693.

5. Wiebe, K.; Sulser, T.B.; Dunston, S.; Rosegrant, M.W.; Fuglie, K.; Willenbockel, D.; Nelson, G.C. Modeling impacts of faster productivity growth to inform the CGIAR initiative on Crops to End Hunger. *PLoS ONE* **2021**, *16*, e0249994. [CrossRef] [PubMed]
6. Lo Piccolo, E.; Landi, M. Red-leafed species for urban "greening" in the age of global climate change. *J. For. Res.* **2021**, *32*, 151–159. [CrossRef]
7. Liao, C.; Tian, Q.; Liu, F. Nitrogen availability regulates deep soil priming effect by changing microbial metabolic efficiency in a subtropical forest. *J. For. Res.* **2021**, *32*, 713–723. [CrossRef]
8. Ritchie, H.; Roser, M. Environmental Impacts of Food Production. 2021. Available online: https://ourworldindata.org/environmental-impacts-of-food#citation (accessed on 17 February 2022).
9. Poore, J.; Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science* **2018**, *360*, 987–992. [CrossRef]
10. Froehlich, A.G.; Melo, A.S.S.A.; Sampaio, B. Comparing the Profitability of Organic and Conventional Production in Family Farming: Empirical Evidence from Brazil. *Ecol. Econ.* **2018**, *150*, 307–314. [CrossRef]
11. Ozturk, M.; Gul, A. *Climate Change and Food Security with Emphasis on Wheat*; Elsevier: Amsterdam, The Netherlands; Academic Press: Cambridge, MA, USA, 2020; pp. 1–29.
12. Eyinade, G.A.; Mushunje, A.; Yusuf, S.F.G. The willingness to consume organic food: A review. *Food Agric. Immunol.* **2021**, *32*, 78–104. [CrossRef]
13. European Commission. Farm to Fork Strategy, for a Fair, Healthy and Environmentally Friendly Food System. 2022. Available online: https://ec.europa.eu/food/farm2fork_en (accessed on 17 February 2022).
14. FAO. Organic Agriculture. 2022. Available online: https://www.fao.org/organicag/oa-faq/oa-faq1/en/ (accessed on 18 February 2022).
15. Halberg, N. Assessment of the environmental sustainability of organic farming: Definitions, indicators and the major challenges. *Can. J. Plant Sci.* **2012**, *92*, 981–999. [CrossRef]
16. Lynch, D.H.; Halberg, N.; Bhatta, G.D. Environmental impacts of organic agriculture in temperate regions. *CAB Rev.* **2012**, *7*, 1–17. [CrossRef]
17. Trydeman Knudsen, M.; Sillebak Kristensen, I.; Berntsen, J.; Molt Petersen, B.; Steen Kristensen, E. Estimated N leaching losses for organic and conventional farming in Denmark. *J. Agric. Sci.* **2006**, *144*, 135–149. [CrossRef]
18. Smith, O.M.; Cohen, A.L.; Rieser, C.J.; Davis, A.G.; Taylor, J.M.; Adesanya, A.W.; Jones, M.S.; Meier, A.R.; Reganold, J.P.; Orpet, R.J.; et al. Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis. *Front. Sustain. Food Syst.* **2019**, *3*, 82. [CrossRef]
19. Tedone, L.; Ali, S.A.; De Mastro, G. Optimization of Nitrogen in Durum Wheat in the Mediterranean Climate: The Agronomical Aspect and Greenhouse Gas (GHG) Emissions. In *Nitrogen in Agriculture—Updates*; Amanullah, A., Fahad, S., Eds.; IntechOpen: London, UK, 2019. [CrossRef]
20. Sicilian Wheat Bank. World Wheat Report 2020–2021. Available online: https://www.bancadelgrano.it/wp-content/uploads/2021/01/World-Wheat-Report-2020-2021.pdf (accessed on 20 June 2022).
21. FAOSTAT. Crops and Livestock Products. 2022. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 28 June 2022).
22. European Commission. Cereals Market Situation. *Committee for the Common Organisation of Agricultural Markets.* 2022. Available online: https://circabc.europa.eu/sd/a/92653d37-7fff-40c1-8d5e-b6bb3625c04a/EU%20cereals%20market.pdf (accessed on 30 June 2022).
23. Istat. Coltivazioni: Cereali, Legumi, Radici Bulbi e Tuberi. 2022. Available online: http://dati.istat.it/Index.aspx?QueryId=33702 (accessed on 20 June 2022).
24. Istat. Statistiche Report. Coltivazioni Agricole. Annata Agraria 2019–2020 e Previsioni 2020–2021. 2021. Available online: https://www.istat.it/it/files//2021/04/Previsioni-coltivazioni-agricole.pdf (accessed on 30 June 2022).
25. Sinab. Bio in Cifre. 2020. Available online: http://www.sinab.it/sites/default/files/share/BIO%20IN%20CIFRE%202020.pdf (accessed on 23 February 2022).
26. Ismea. Cereali—Supply Balance Sheet. 2022. Available online: https://www.ismeamercati.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/4546 (accessed on 23 February 2022).
27. Zingale, S.; Guarnaccia, P.; Timpanaro, G.; Scuderi, A.; Matarazzo, A.; Bacenetti, J.; Ingrao, C. Environmental life cycle assessment for improved management of agri-food companies: The case of organic whole-grain durum wheat pasta in Sicily. *Int. J. Life Cycle Assess.* **2022**, *27*, 205–226. [CrossRef]
28. Todorović, M.; Mehmeti, A.; Cantore, V. Impact of different water and nitrogen inputs on the eco-efficiency of durum wheat cultivation in Mediterranean environments. *J. Clean. Prod.* **2018**, *183*, 1276–1288. [CrossRef]
29. Alhajj Ali, S.; Tedone, L.; Verdini, L.; De Mastro, G. Effect of different crop management systems on rainfed durum wheat greenhouse gas emissions and carbon footprint under Mediterranean conditions. *J. Clean. Prod.* **2017**, *140*, 608–621. [CrossRef]
30. Casolani, N.; Pattara, C.; Liberatore, L. Water and Carbon footprint perspective in Italian durum wheat production. *Land Use Policy* **2016**, *58*, 394–402. [CrossRef]
31. Ababaei, B.; Etedali, H.R. Estimation of water footprint components of Iran's wheat production: Comparison of global and national scale estimates. *Environ. Process.* **2014**, *1*, 193–205. [CrossRef]

32. Bouatrous, A.; Harbaoui, K.; Karmous, C.; Gargouri, S.; Souissi, A.; Belguesmi, K.; Cheikh Mhamed, H.; Gharbi, M.S.; Annabi, M. Effect of Wheat Monoculture on Durum Wheat Yield under Rainfed Sub-Humid Mediterranean Climate of Tunisia. *Agronomy* **2022**, *12*, 1453. [CrossRef]
33. Kourat, T.; Smadhi, D.; Madani, A. Modeling the Impact of Future Climate Change Impacts on Rainfed Durum Wheat Production in Algeria. *Climate* **2022**, *10*, 50. [CrossRef]
34. Drugova, T.; Curtis, K.R.; Akhundjanov, S.B. Organic wheat products and consumer choice: A market segmentation analysis. *Br. Food J.* **2020**, *122*, 2341–2358. [CrossRef]
35. Draghici, M.; Niculita, P.; Popa, M.; Duta, D. Organic Wheat Grains and Flour Quality versus Conventional Ones—Consumer versus Industry Expectations. *Rom. Biotechnol. Lett.* **2011**, *16*, 6572–6579.
36. Montemurro, F.; Maiorana, M. Agronomic Practices at Low Environmental Impacts for Durum Wheat in Mediterranean Conditions. *J. Plant Nutr.* **2016**, *38*, 624–638. [CrossRef]
37. Tudisca, S.; di Trapani, A.M.; Sgroi, F.; Testa, R. Organic farming and economic sustainability: The case of Sicilian durum wheat. *Qual.-Access Success* **2014**, *15*, 93–96.
38. Fagnano, M.; Fiorentino, N.; D'Egidio, M.G.; Quaranta, F.; Ritieni, A.; Ferracane, R.; Raimondi, G. Durum Wheat in Conventional and Organic Farming: Yield Amount and Pasta Quality in Southern Italy. *Sci. World J.* **2012**, *2012*, 973058. [CrossRef] [PubMed]
39. Ruini, L.; Marino, M.; Pignatelli, S.; Laio, F.; Ridolfi, L. Water footprint of a large-sized food company: The case of Barilla pasta production. *Water Resour. Ind.* **2013**, *1–2*, 7–24. [CrossRef]
40. Amicarelli, V.; Lagioia, G.; Gallucci, T.; Dimitrova, V. The water footprint as an indicator for managing water resources. The case of Italian olive oil. *Int. J. Sustain. Econ.* **2011**, *3*, 425–439. [CrossRef]
41. Finco, A.; Bucci, G.; Belletti, M.; Bentivoglio, D. The Economic Results of Investing in Precision Agriculture in Durum Wheat Production: A Case Study in Central Italy. *Agronomy* **2021**, *11*, 1520. [CrossRef]
42. Frascarelli, A.; Ciliberti, S.; Magalhães de Oliveira, G.; Chiodini, G.; Martino, G. Production Contracts and Food Quality: A Transaction Cost Analysis for the Italian Durum Wheat Sector. *Sustainability* **2021**, *13*, 2921. [CrossRef]
43. Ciliberti, S.; Del Sarto, S.; Frascarelli, A.; Pastorelli, G.; Martino, G. Contracts to Govern the Transition towards Sustainable Production: Evidence from a Discrete Choice Analysis in the Durum Wheat Sector in Italy. *Sustainability* **2020**, *12*, 9441. [CrossRef]
44. Bux, C.; Amicarelli, V. Separate collection and bio waste valorization in the Italian poultry sector by material flow analysis. *J. Mater. Cycles Waste Manag.* **2022**, *24*, 811–823. [CrossRef] [PubMed]
45. Hendriks, C.R.; Obernosterer, D.; Müller, S.; Kytzia, P.; Brunner, B.P.H. Material flow analysis: A tool to support environmental policy decision making Case-studies on the city of Vienna and the Swiss lowlands. *Int. J. Justice Sustain.* **2000**, *5*, 311–328. [CrossRef]
46. Yildiz, T. An Input-Output Energy Analysis of Wheat Production in Çarşamba District of Samsun Province. *J. Agric. Fac. Gaziosmanpasa Univ.* **2016**, *33*, 10–20. [CrossRef]
47. Brunner, P.H.; Rechberger, H. *Handbook of Material Flow Analysis. For Environmental, Resource and Waste Engineers*, 2nd ed.; CRC Press: Boca Raton, FL, USA; Taylor & Francis Group: London, UK; LLC: New York, NY, USA, 2017.
48. Camana, D.; Manzardo, A.; Toniolo, S.; Gallo, F.; Scipioni, A. Assessing environmental sustainability of local waste management policies in Italy from a circular economy perspective. An overview of existing tools. *Sustain. Prod. Consum.* **2021**, *27*, 613–629. [CrossRef]
49. Courtonne, J.-Y.; Alapetite, J.; Longaretti, P.-Y.; Dupré, D.; Prados, E. Downscaling material flow analysis: The case of the cereal supply chain in France. *Ecol. Econ.* **2015**, *118*, 67–80. [CrossRef]
50. Courtonne, J.-Y.; Longaretti, P.-Y.; Alapetite, J.-Y.; Dupré, D. Environmental Pressures Embodied in the French Cereals Supply Chain. *J. Ind. Ecol.* **2016**, *20*, 423–434. [CrossRef]
51. Brock, P.; Madden, P.; Schwenke, G.; Herridge, D. Greenhouse gas emissions profile for 1 tonne of wheat produced in Central Zone (East) New South Wales: A life cycle assessment approach. *Crop Pasture Sci.* **2012**, *63*, 319–329. [CrossRef]
52. Holka, M.; Jankowiak, J.; Bienkowski, J.F.; Dabrowicz, R. Life Cycle Assessment (LCA) of winter wheat in an intensive crop production system in Wielkopolska Region (Poland). *Appl. Ecol. Environ. Res.* **2016**, *14*, 535–545. [CrossRef]
53. McAuliffe, G.A.; Takahashi, T.; Lee, M. Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food systems. *Int. J. Life Cycle Assess.* **2020**, *25*, 208–221. [CrossRef]
54. Tamburini, E.; Pedrini, P.; Marchetti, M.G.; Fano, E.A.; Castaldelli, G. Life Cycle Based Evaluation of Environmental and Economic Impacts of Agricultural Productions in the Mediterranean Area. *Sustainability* **2015**, *7*, 2915–2935. [CrossRef]
55. Fischer-Kowalski, M.; Krausmann, F.; Giljum, S.; Lutter, S.; Mayer, A.; Bringezu, S.; Moriguchi, Y.; Schutz, H.; Schandl, H.; Weisz, H. Methodology and Indicators of Economy-wide Material Flow Accounting. State of the Art and Reliability Across Sources. *J. Ind. Ecol.* **2011**, *15*, 855–876. [CrossRef]
56. Official Journal of the European Commission. Council Regulation (EC) No 834/2007 of 28 June 2007 on Organic Production and Labelling of Organic Products and Repealing Regulation (EEC) No 2092/91. 2007. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32007R0834 (accessed on 25 February 2022).
57. Protezione Civile Puglia. Annali Idrologici—Parte I—Download dal 1921 al 2020. 2022. Available online: https://protezionecivile.puglia.it/centro-funzionale-decentrato/rete-di-monitoraggio/annali-e-dati-idrologici-elaborati/annali-idrologici-parte-i-download/ (accessed on 17 February 2022).

58. Longobardi, A.; Buttafuoco, G.; Caloiero, T.; Coscarelli, R. Spatial and temporal distribution of precipitation in a Mediterranean area (southern Italy). *Environ. Earth Sci.* **2016**, *75*, 189. [CrossRef]
59. Caporali, E.; Lompi, M.; Pacetti, T.; Chiarello, V.; Fatichi, S. A review of studies on observed precipitation trends in Italy. *Int. J. Climatol.* **2020**, *41*, E1–E25. [CrossRef]
60. Golova, E.E.; Baranova, I.V.; Gapon, M.N. Crop Production Cost Accounting Audit. In *Land Economy and Rural Studies Essentials*; Nardin, D.S., Stepanova, O.V., Kuznetsova, V.V., Eds.; European Publisher: London, UK, 2021; Volume 113, pp. 72–78. [CrossRef]
61. Rahman, S.M.M.; Kim, J. Circular economy, proximity, and shipbreaking: A material flow and environmental impact analysis. *J. Clean. Prod.* **2020**, *259*, 120681. [CrossRef]
62. European Union. *Agriculture and Food Security in Climate Sensitive Areas in the Mediterranean*; Commission for Citizenship, Governance, Institutional and External Affairs: Bruxelles, Belgium, 2020. [CrossRef]
63. Schiller, G.; Gruhler, K.; Ortlepp, R. Continuous Material Flow Analysis Approach for Bulk Nonmetallic Mineral Construction Materials Applied to the German Building Sector. *J. Ind. Ecol.* **2017**, *21*, 673–688. [CrossRef]
64. Eisenhardt, K.M. Building theories from case study research. In *The Qualitative Researchers' Companion*; Huberman, A.M., Miles, M.B., Eds.; Sage Publications: Thousand Oaks, CA, USA, 2002.
65. Amicarelli, V.; Fiore, M.; Bux, C. Hidden flows assessment in the agri-food sector: Evidence from the Italian beef system. *Br. Food J.* **2021**, *123*, 384–403. [CrossRef]
66. Noble, H.; Heale, R. Triangulation in research, with examples. *Evid.-Based Nurs.* **2019**, *22*, 67–68. [CrossRef]
67. Patrício, J.; Kalmykova, Y.; Rosado, L.; Lisovskaja, V. Uncertainty in Material Flow Analysis Indicators at Different Spatial Levels. *J. Ind. Ecol.* **2015**, *19*, 837–852. [CrossRef]
68. da Silva, V.P.R.; da Silva, B.B.; Albuquerque, W.G.; Borges, C.J.R.; de Sousa, I.F.; Neto, J.D. Crop coefficient, water requirements, yield and water use efficiency of sugarcane growth in Brazil. *Agric. Water Manag.* **2013**, *128*, 102–109. [CrossRef]
69. Nielsen, K.M. Organic Farming. In *Encyclopedia of Ecology*, 2nd ed.; Fath, B., Ed.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 550–558. [CrossRef]
70. Yadav, S.K.; Subhash Babu, M.K.; Yadav, K.S.; Yadav, G.S.; Pal, S. A Review of Organic Farming for Sustainable Agriculture in Northern India. *Int. J. Agron.* **2013**, *2013*, 718145. [CrossRef]
71. Liu, H.; Meng, J.; Bo, W.; Cheng, D.; Li, Y.; Guo, L.; Li, C.; Zheng, C.; Liu, M.; Ning, T.; et al. Biodiversity management of organic farming enhances agricultural sustainability. *Sci. Rep.* **2016**, *6*, 23816. [CrossRef] [PubMed]
72. Jouzi, Z.; Azadi, H.; Taheri, F.; Zarafshani, K.; Gebrehiw, K.; Van Passel, S.; Lebailly, P. Organic farming and small-scale farmers: Main opportunities and challenges. *Ecol. Econ.* **2017**, *132*, 144–154. [CrossRef]
73. Joshi, N.; Prasad Parewa, H.; Joshi, S.; Sharma, J.K.; Shukla, U.N.; Paliwal, A.; Gupta, V. Chapter 5—Use of microbial biostimulants in organic farming. In *Advances in Organic Farming*; Meena, V.S., Meena, S.K., Rakshit, A., Stanley, J., Srinivasarao, C., Eds.; Woodhead Publishing: Sawston, UK, 2021; pp. 59–73. [CrossRef]
74. Post, E.; Schahczenksi, J. Understanding Organic Pricing and Costs of Production. In *National Sustainable Agriculture Information Service*; ATTRA: Butte, MT, USA, 2012; pp. 1–12.
75. Durham, T.C.; Tamás, M. Comparative Economics of Conventional, Organic, and Alternative Agricultural Production Systems. *Economies* **2021**, *9*, 64. [CrossRef]
76. Slorach, P.C.; Jeswani, H.K.; Cuéllar-Franca, R.; Azapagic, A. Environmental sustainability in the food-energy-water-health nexus: A new methodology and an application to food waste in a circular economy. *Waste Manag.* **2020**, *113*, 359–368. [CrossRef]
77. Karamian, F.; Mirakzadeh, A.A.; Azari, A. The water-energy-food nexus in farming: Managerial insights for a more efficient consumption of agricultural inputs. *Sustain. Prod. Consum.* **2021**, *27*, 1357–1371. [CrossRef]
78. Sidhoum, A.A.; Dakpo, K.H.; Latruffe, L. Trade-offs between economic, environmental and social sustainability on farms using a latent class frontier efficiency model: Evidence for Spanish crop farms. *PLoS ONE* **2022**, *17*, e0261190. [CrossRef]
79. Viganò, E.; Maccaroni, M.; Righi, S. Finding the right price: Supply chain contracts as a tool to guarantee sustainable economic viability of organic farms. *Int. Food Agribus. Manag. Rev.* **2022**, *23*, 411–426. [CrossRef]
80. European Commission. Organic Action Plan. 2022. Available online: https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming/organic-action-plan_it (accessed on 29 June 2022).
81. Solfanelli, F.; Ozturk, E.; Pugliese, P.; Zanoli, R. Potential outcomes and impacts of organic certification in Italy: An evaluative case study. *Ecol. Econ.* **2021**, *187*, 107107. [CrossRef]
82. Saber, Z.; van Zelm, R.; Pirdashti, H.; Schipper, A.M.; Esmaeili, M.; Motevali, A.; Nabavi-Pelesaraei, A.; Huijbregts, M.A.J. Understanding farm-level differences in environmental impact and eco-efficiency: The case of rice production in Iran. *Sustain. Prod. Consum.* **2021**, *27*, 1021–1029. [CrossRef]
83. *ST/ESCAP/2561*; Eco-Efficiency Indicators: Measuring Resource-Use Efficiency and the Impact of Economic Activities on the Environment. United Nations: New York, NY, USA, 2009.