ASSOCIAZIONE
RETE ITALIANA LCA

ATTI

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INNOVAZIONE E CIRCOLARITÀ

Il contributo del *Life Cycle Thinking* nel Green Deal per la neutralità climatica

22-24 settembre 2021

Università Mediterranea di Reggio Calabria

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Environmental life cycle assessment of typical organic carrot in central Italy

Francesco Pacchera[1*], Gabriella Arcese[2], Stefano Poponi[3], Alessandro Ruggieri[4]

Abstract: The agri-food sector plays a key role in transforming the current system into a more sustainable, resilient, and inclusive one. At the forefront of European policies that will guide economic and social development in the coming years, it needs tools that can steer production towards sustainability. The LCA method is one of the key tools to achieve this goal. The study aims to analyse the environmental impacts of the production of the Fiumicino Carrot. This product is a characteristic element of the territory of Fiumicino, a municipality in central Italy. The CML 2001 and ReCIPE 2008 methods were used to assess impacts. The assessment result show that GWP is the greatest impact, followed by Marine sediment ecotoxicity and Marine aquatic ecotoxicity. These impacts are mainly caused by the use of fertilisers, particularly nitrates. The main impact is on Resources also due to the use of fertilisers.

1. Introduction

The agri-food industry is one of the key emerging industries of New European Circular Economy Action Plan, where a shift to a sustainable food system is a necessary condition (European Commission, 2020a). Pillar of the Green Deal (European Commission, 2019), sustainable development of the agri-food sector can be achieved through different production and consumption models, including organic farming (European Commission, 2020b). In Italy over the last ten years, has emerged a governance model that can help achieve this goal (European Committee of the Regions, 2020). This model, called Bio-district, is characterized by innovative multi-actor governance (Poponi et al., 2021), where companies cooperate with the local administration for the development of the territory and the economy in a sustainable direction. In this paper, a Biodistrict is defined as "*a territory naturally devoted to organic, where farmers, citizens, public authorities, realize an agreement aimed at the sustainable management of local resources, based on the principles of organic farming and agroecology*" (Eco-Region's, 2021). This study takes as a reference a biodistrict, Etruscan Roman Biodistrict, located in the municipality of Fiumicino, in the Lazio Region, composed of six enterprises. This covers an area of around one hundred hectares with around 70 employees and an annual turnover of 4.5 million euros. Its member companies are all certified organic and carry out vastly different activities (fruit and vegetable growing, wheat and fodder cultivation, wine production, livestock breeding, catering, and ac-

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commodation). This study aims to assess the impact of a typical local product, the "Fiumicino Carrot", produced within one of the biodistrict companies.

This study, therefore, aims to analyse the environmental impacts of this organic production using LCA method. As reported in the literature (Ingrao et al., 2019; Notarnicola et al., 2017, 2012), the agri-food sector has a very complex value chain and the use of an LCA method can allow the identification of different impacts throughout the life cycle in a systemic way.

The section 2 presents the reference context; the section 3 explains the methodology and assumptions used for the analysis. In the next section, data and results are presented. Some final remarks conclude the paper.

2. Production of carrots

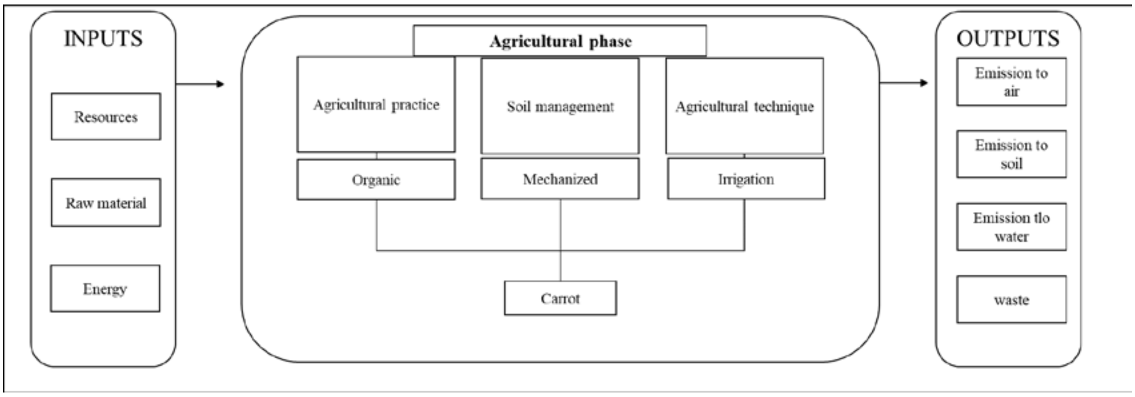
The carrot is a vegetable with high nutritional values and has a positive impact on human health (Arscott and Tanumihardjo, 2010; Leja et al., 2013). Worldwide, the hectares dedicated to the cultivation of carrots, and especially its production, have steadily increased over the last twenty-five years (Faostat, 2021). In 2019, 44,762,859 tonnes of carrots were produced in the world, of which 5,500,640 tonnes were produced in the European Union (12.3%) (Eurostat, 2021; Faostat, 2021). Regarding the extent of land cultivated with carrots in the world are 1,128,695 hectares of which 119,990 hectares in Europe (10.6%) (Eurostat, 2021; Faostat, 2021). Italy, with an extension of 11,080 hectares and a production of 492,220, ranks seventh in Europe. Organic carrot production in Italy is still marginal, in 2019 only 943 hectares were dedicated to organic carrot cultivation (8.5% of the total) (SINAB, 2020). The Lazio Region ranks second in Italy for organic dedicated area (2,064 hectares) and third for production (93,700 tonnes) (ISTAT, 2021). The municipalities of Fiumicino and Maccarese are the most suitable areas within the Lazio Region for growing carrots, due to the characteristics of the soil (sandy). The type of carrot produced here in fact requires soil with a high percentage of sand (more than 80%), well-drained and deep sunshine.

This product is analysed because it is a traditional product of this geographical area (it has been cultivated for more than 50 years). The recognition of the typicality that links this product to the area is given by its inclusion in the national list of typical food products under the name of 'Carota di Fiumicino' (Ministry of Agricultural Food and Forestry Policies, 2020). This recognition is only a first step, in fact the 'Carota di Fiumicino' is waiting for acceptance of the request for Protected Geographical Indication (PGI) certification submitted to the European Commission. The characteristics that make it a typical product, in addition to its territoriality and tradition, are its bright and intense orange colour, its crunchiness, its high content of vitamins (A (beta-carotene), B, C, K) and mineral salts (sodium, potassium, calcium, phosphorus).

3. Methodology and assumptions

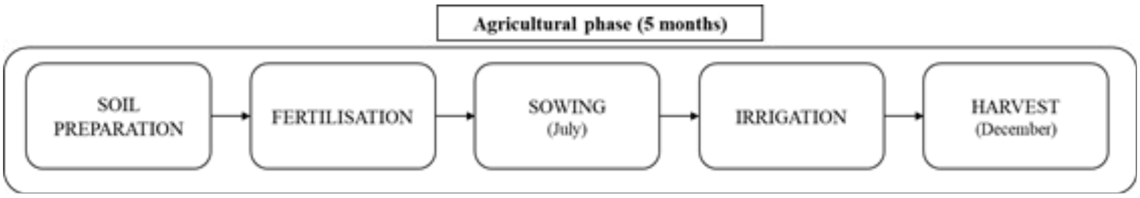
This study was carried out according to the requirements of the ISO standards 14040 and 14044 (International Standard Organisation (ISO), 2006a, 2006b) and it was developed with the aim of assessing, with a "cradle to gate" approach, the environmental hotspots linked to the central Italy carrot production and trasport. The functional unit chosen is 1 kg of carrot producted. The system boundaries cover the agricultural stage, including agricultural phase and the transports (figure 1). Transport concerns the use of agricultural machinery (tractors) within the field, used to transport the product. The distance covered is approximately 2 km from the field to the sales access point (directly in the fields). In the analysed farm there is no storage of the products, the sale takes place at field level right after the harvest. The Agricultural phase is characterised by the sub-processes shown in Figure 2 and has a duration of 5 months (from sowing to harvesting). The processes considered are soil preparation, fertilisation, sowing, irrigation, and harvesting. The processes of preparation for sale and external transport were not considered in this study. The preparation of the soil for sowing is done mechanically and the crop requires water for its growth. The cultivation method used is organic. The waste is obtained at harvest time and is made up of leaves and a small part of roots (10% of the product). There is also a percentage of unsold product (10% of total production), which, like the harvest waste, remains on the field to fertilise the soil. SimaPro 9.1.1. software was used for the analyses. Ecoinvent is the database used.

Figure 1: System Boundaries for LCA analysis.



The system boundaries cover the agricultural stage to produce carrot. The system analysed is shown in Figure 1. The data collected allows the analysis of all life cycle phases. The foreground is located in the municipality of Fiumicino in Italy. The extension of the land is 1 ha. The production yield is 30 tonnes/ha. Cultivation is carried out organically, with mechanised soil treatment and a crop that requires irrigation. The cultivar examined is Carrot of Fiumicino, distinctive crop in the area. The primary data were collected in the field through an in-depth interview with the production manager. The advice and recommendations on production activities given by the manager were qualitatively analysed and used to construct the foreground. The data background is derived from literature.

Figure 2: The agricultural phase.



4. Life Cycle Inventory

In this study, the Life Cycle Inventory analysis was developed by collecting available and suitable data for carrot production. In the agri-food sector it is considered a fundamental point to use data that are specific and regionalised to carry out a LCA (Ruviaro et al., 2012) so we used primary data as much as possible. These data were collected through an in-depth interview with the production manager. From this interview we collected data on the quantity produced, the use of water, fertilisers, fuel, waste, and people employed. Data from the literature were used to complete the analysis. Ecoinvent was the database used for the study.

Data for all inputs and outputs of the agricultural phase were estimated for 1 kg of carrots. Inputs included the amount of irrigated water, seeds used, fertilisers and use of agricultural equipment. Emissions to water, air and land were considered in the outputs (Table 1).

Table 1: Inventory of the agricultural step referred to 1 kg of carrot

Inputs from technosphere	**Amount**	**Unit**
ammonium nitrate, as N	3.57E-04	kg
irrigation	1.11E-01	m^3
carrot seed, for sowing	1.18E-04	kg
nitrogen fertiliser, as N	8.61E-05	kg
Manure	1.38E-01	kg
phosphate fertiliser, as P_2O_5	1.12E-03	kg
K_2O	1.25E-03	kg
transport, tractor, and trailer, agricultural	2.00E-03	ton*km
OUTPUT		
Product		
Carrot	1.00	kg

5. Impact assessment

The quantity of materials and energy for each process and selection of data were compared according to the provisions of ISO 14044 with due diligence.

A problem-oriented approach (Guinèe et al., 2002) was used by applying the CML 2001 characterisation method (figure 3). The detailed results, including the influence of the respective substances, are presented in figure 4.

The ReCiPe Endpoint is also applied to assess environmental impacts (figure 5). This was used to represent in the three aggregate levels the impacts on the environment effect on human health, biodiversity and ecosystem, and resource scarcity (Goedkoop et al., 2009). Figure 3 shows the environmental impacts generated in the agricultural phase of carrot production. The graph shows that Global warming is the main impact followed by Marine sediment ecotoxicity and Marine aquatic ecotoxicity. These impacts are mostly related to the use of fertilisers (nitrates) as can be seen in figure 4. Figure 5 confirms that the biggest impact is on resources, given the massive use of these resources (fertilisers).

Figure 3: Characterisation of the agricultural phase CML 2001, our elaboration.

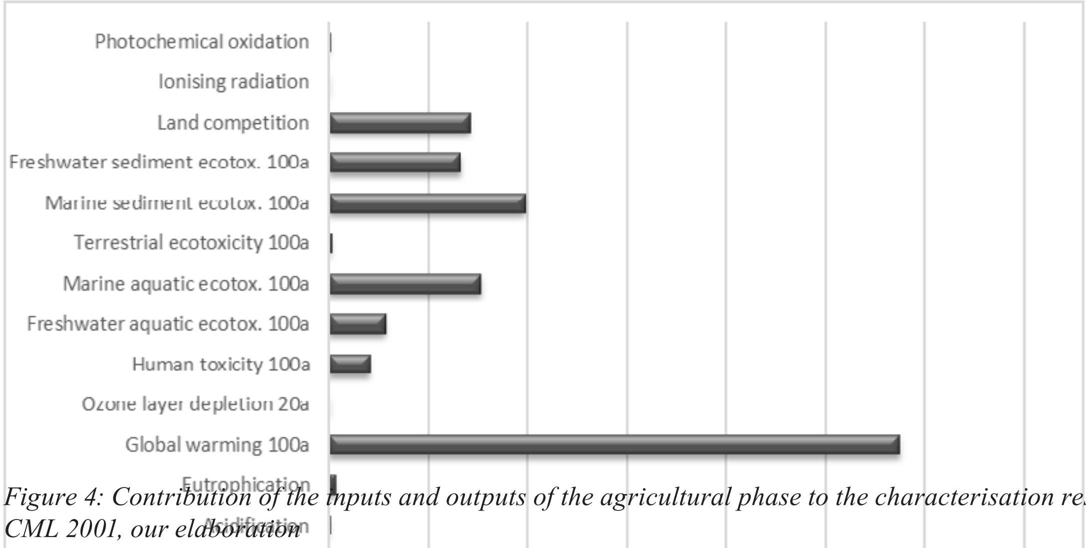


Figure 4: Contribution of the inputs and outputs of the agricultural phase to the characterisation results CML 2001, our elaboration

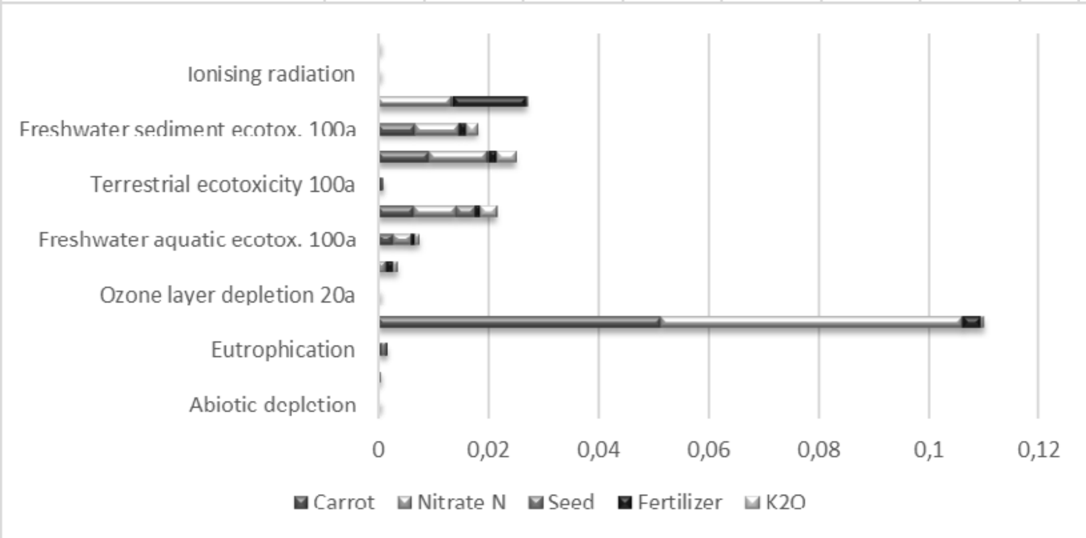
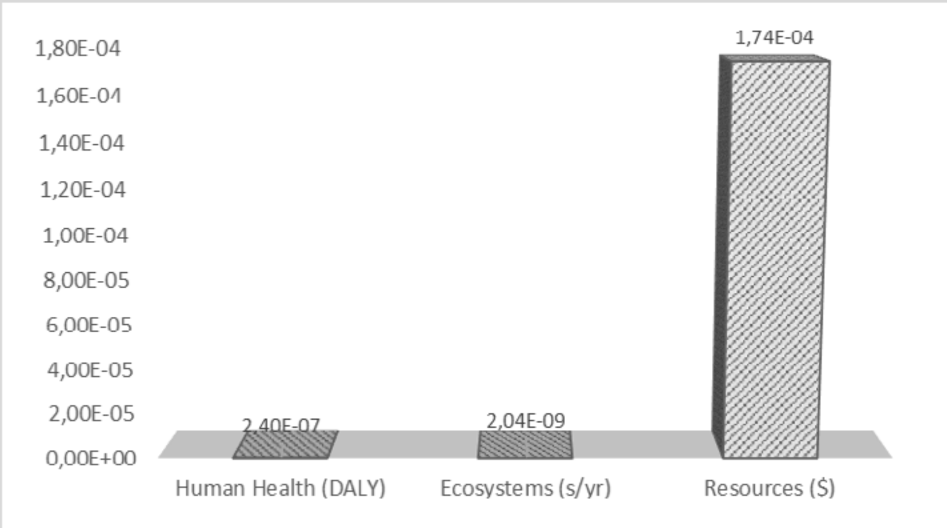


Figure 5: Environmental impact of Carrot of Fiumicino based on Recipe Method, our elaboration.



6. Discussion and conclusions

In this study, the environmental impact of the agricultural phase in organic carrot production was analysed. As reported in the literature, this phase has the highest environmental impact due to the use of fertilisers and pesticides (Ilari A., Duca D., Toscano G., Vecchiarelli V., 2020; Tassielli et. al., 2018). At the Italian level, the only study found on the environmental impact of carrots aims to assess the impact of different packaging solutions used to sell carrots produced in central Italy (Ilari A., Duca D., Toscano G., Vecchiarelli V., 2020). As the goal of our study is to evaluate the agricultural phase of carrot production and no similar studies were found in Italy, studies with the same purpose from geographical areas outside Italy were examined for comparison. The results of the analysis showed that GWP (Global Warming Potential) is the most significant impact. This is in line with other studies in the literature on the agricultural production stage of carrots (Lopes et al., 2018). With the aim of assessing economically and environmentally the impact of conventional carrot production in Brazil, the authors demonstrated how by acting on a few points it is possible to reduce the highest environmental impact (GWP to 0.07 kg C02 eq/kg) (Lopes et al., 2018). This value is close to our result of 0.0575 kg C02 eq/kg, this is similar to other studies on organic production (e.g. 0.060 kg C02 eq/kg (Koch and Salou, 2016)). Our result, however, differs from the result (0.004 kg C02 eq/kg) of the study that Raghu, 2014 conduct on different methods of carrot production in Finland. This difference depends on the use of only manure to fertilise the crop. Organic carrot production has a lower environmental impact than conventional production (Raghu, 2014). This result also emerges in a comparative study between conventional and organic carrot production in Poland (Kowalczyk and Cupiał, 2020). The lower environmental impact is due to the non-use of pesticides and the limited use of fertilisers. The study also analyses the transport of the carrot off the farm, which implies a high use of diesel. For this reason, our results differ from theirs. In our study, the biggest impact is from the use of fertilisers (especially nitrate). Kowalczyk and Cupiał, 2020 highlights that for both methods the most significant impact is Human Health and Resources and residually Ecosystem Quality. Their results are different from ours. While yet for our study one of the biggest impacts is on Resources, Human Health does not have the same result. This happens because in their case there is a large amount of diesel related to the transport of the product outside the company. The impact on Resources is much greater in our case, as there is a high use of fertilisers (nitrate), which is absent in their study (Kowalczyk and Cupiał, 2020).

7. References

Arscott, S.A., Tanumihardjo, S.A., 2010. Carrots of Many Colors Provide Basic Nutrition and Bioavailable Phytochemicals Acting as a Functional Food. Compr. Rev. Food Sci. Food Saf. 9, 223–239. https://doi.org/10.1111/j.1541-4337.2009.00103.x

Eco-Region’s, 2021. Eco-Region – Eco-Region’s Portal [WWW Document]. URL https://www.ecoregion.info/ (accessed 3.3.21).

European Commission, 2020a. Circular Economy Action Plan: For a cleaner and more competitive Europe. Brussels, Belgium.

European Commission, 2020b. Farm to Fork Strategy [WWW Document]. URL https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/farm-fork_en (accessed 3.3.21).

European Commission, 2019. The European Green Deal COM/2019/640.

European Committee of the Regions, 2020. The role of local and regional authorities in making food systems more sustainable. Brussels, Belgium. https://doi.org/10.2863/72792

Eurostat, 2021. Eurostat [WWW Document]. URL https://ec.europa.eu/eurostat/databrowser/view/APRO_CPNH1__custom_874413/default/table?lang=en (accessed 3.3.21).

Faostat, 2021. Faostat [WWW Document]. URL http://www.fao.org/faostat/en/#data (accessed 3.3.21).

Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., 2009. ReCiPe 2008-A Life Cycle Impact Assessment Method Which Comprises Harmonised Category Indicators at the Midpoint and the Endpoint Level.

Guinèe, J.B., Gorrèe, M., Heijungs, R., Huppes, G., Kleijin, R., Koning, A., de Oers, L., van Wegner Sleeswijk, A., Suh, S., Udo de Haes, H.A., Bruijin, H., de Duin, R., van Huijbregts, M.A.J., 2002. Handbook on Life Cycle Assessment. Operational Guide to the ISO Standards. I: LCA in Perspective. IIa: Guide. IIb: Operational Annex. III: Scientific Background. Kluwer Academic Publishers, Dordrecht.

Ilari A., Duca D., Toscano G., Vecchiarelli V., F.P.E., 2020. Life Cycle Impact Assessment of Carrot Cultivation and Processing: An Italian Case Study for a Small Family Company in the Marche Region, in: Innovative Biosystems Engineering for Sustainable Agriculture, Forestry and Food Production. MID-TERM AIIA 2019. Lecture Notes in Civil Engineering. Springer, Cham. https://doi.org/https://doi.org/10.1007/978-3-030-39299-4_63

Ingrao, C., Faccilongo, N., Valenti, F., De Pascale, G., Di Gioia, L., Messineo, A., Arcidiacono, C., 2019. Tomato puree in the Mediterranean region: An environmental Life Cycle Assessment, based upon data surveyed at the supply chain level. J. Clean. Prod. 233, 292–313. https://doi.org/10.1016/j.jclepro.2019.06.056

International Standard Organisation (ISO), 2006a. Environmental ManagementdLife Cycle Assessment: Requirements and Guidelines. ISO14044. Geneva.

International Standard Organisation (ISO), 2006b. Environmental management—Life cycle assessment Principles and framework. 14040:2006. Geneva.

ISTAT, 2021. ISTAT [WWW Document]. URL http://dati.istat.it/Index.aspx?DataSetCode=DCSP_COLTIVAZIONI# (accessed 3.10.21).

Koch, P., Salou, T., 2016. Agribalyse ® : Rapport Methodologique.

Kowalczyk, Z., Cupiał, M., 2020. Environmental analysis of the conventional and organic production of carrot in Poland. J. Clean. Prod. 269. https://doi.org/10.1016/j.jclepro.2020.122169

Leja, M., Kamińska, I., Kramer, M., Maksylewicz-Kaul, A., Kammerer, D., Carle, R., Baranski, R., 2013. The Content of Phenolic Compounds and Radical Scavenging Activity Varies with Carrot Origin and Root Color. Plant Foods Hum. Nutr. 68, 163–170. https://doi.org/10.1007/s11130-013-0351-3

Lopes, J., Medeiros, D.L., Kiperstok, A., 2018. Combining cleaner production and life cycle assessment for reducing the environmental impacts of irrigated carrot production in Brazilian semi-arid region. J. Clean. Prod. 170, 924–939. https://doi.org/10.1016/j.jclepro.2017.08.198

Ministry of Agricultural Food and Forestry Policies, 2020. Ministerial Decree - 10 February 2020. Update of the national list of traditional agri-food products pursuant to Article 12(1) of Law No 238 of 12 December 2016. Rome,Italy.

Notarnicola, B., Hayashi, K., Curran, M.A., Huisingh, D., 2012. Progress in working towards a more sustainable agri-food industry. J. Clean. Prod. 28, 1–8. https://doi.org/10.1016/j.jclepro.2012.02.007

Notarnicola, B., Sala, S., Anton, A., McLaren, S.J., Saouter, E., Sonesson, U., 2017. The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges. J. Clean. Prod. 140, 399–409. https://doi.org/10.1016/j.jclepro.2016.06.071

Poponi, S., Arcese, G., Mosconi, E.M., Pacchera, F., Martucci, O., Elmo, G.C., 2021. Multi-Actor Governance for a Circular Economy in the Agri-Food Sector : Bio-Districts. Sustainability 13. https://doi.org/https:// doi.org/10.3390/su13094718

Raghu, K.C., 2014. Comparative Lifecycle Assessment on organic and conventional carrots - case: Carrots from South - Savo and imported carrots from Italy.

Ruviaro, C.F., Gianezini, M., Brandão, F.S., Winck, C.A., Dewes, H., 2012. Life cycle assessment in Brazilian agriculture facing worldwide trends. J. Clean. Prod. 28, 9–24. https://doi.org/10.1016/j.jclepro.2011.10.015

SINAB, 2020. Bio in Cifre 2020 [WWW Document]. URL http://www.sinab.it/sites/default/files/share/BIO IN CIFRE 2020.pdf (accessed 3.3.21).

Tassielli, G., Notarnicola, B., Renzulli, P.A., Arcese, G., 2018. Environmental life cycle assessment of fresh and processed sweet cherries in southern Italy. J. Clean. Prod. 171, 184–197. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.09.227

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