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Energy-environmental assessment of the UIA-OpenAgri case study as urban regeneration project through agriculture

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1 **Energy-environmental assessment of the UIA-OpenAgri case study as urban** 2 **regeneration project through agriculture.**

3

4 **ABSTRACT**

5 Sustainable agriculture is strongly promoted by Agenda 2030 and peri-urban agriculture is considered strategic
6 for agri-food sustainability. Although, innovative farming practices are being implemented, the analysis of
7 their impacts often does not reach the required depth. Within the EU project ‘UIA-OpenAgri - New Skills for
8 new Jobs in Peri-urban Agriculture’, a regeneration process of a peri-urban area in Milan (Italy) was started,
9 through the development of an innovative food hub. 28 innovative foodchains are assessed by a Life Cycle
10 Assessment approach based on primary data collected from the involved start-ups. Non-Renewable
11 Cumulative Energy Demand and the Global Warming Potential indicators are assessed and coupled with the
12 productive land indicator. To effectively support involved operators in planning sustainable agriculture
13 practices, the results are presented with GIS maps and insights for improving economic sustainability of
14 involved start-ups are presented.

15 The study shows that the impacts related to the practices implemented (i.e. organic agriculture, including
16 intercropping, agroforestry, ancient grains, etc.) decrease by an average of 55% in energy consumption and
17 65% on Global Warming Potential if compared to conventional ones. Then, these practices can provide a
18 positive contribution to the Agenda 2030 goal of ensuring sustainable farm production practices.

19

20 **KEYWORDS**

21 Peri-urban agriculture; Urban regeneration; Cumulative energy demand; Global Warming Potential; Life
22 Cycle Assessment; Geographic Information System

23 **1 Introduction**

24 The agri-food sector is acknowledged as a relevant contributor to greenhouse gas (GHG) emissions, with
25 relevant implications on economy, culture, health, territory and resources deployment (BCFN, 2018). Ensuring
26 sufficient food supply for a growing urban population (UN, 2019) and, at the same time, improving the

27 environmental sustainability of the food production systems are significant challenges pointed out by the
28 United Nations (UN) in the Agenda 2030 for sustainable development (UN, 2015). The main goals of Agenda
29 2030 are to eradicate poverty and achieve sustainable development by 2030 worldwide and it includes 17
30 Sustainable Development Goals (SDGs). Among these, the SDG2 aims at ending hunger, achieving food
31 security and promoting sustainable agriculture. This goal should be achieved through many sub-targets, i.e. to
32 increase the productivity while at the same time maintaining ecosystems, adapting to climate change,
33 improving the quality of soil and maintaining the genetic diversity of plants. Achieving this goal requires better
34 access to food and the widespread promotion of sustainable agriculture.

35 In this context, reducing the community's reliance on distant food markets through the development of
36 local food systems is strengthened priority advocated by the Food and Agriculture Organization of the United
37 Nations (FAO, 2018). Small-scale food production would also ensure equal access to productive resources,
38 knowledge, and market opportunities and require the distribution of responsibilities between national and local
39 levels of government (Sachs et al., 2019).

40 To face these challenges, urban and peri-urban agriculture¹ may assume a strategic importance in ensuring
41 the sustainability of food supply and distribution in urban areas (Duvernoy et al., 2018). In addition, urban and
42 peri-urban agriculture is considered strategic for driving urban transition to a sustainable future by the Joint
43 Programming Initiative Urban Europe (Urban Europe, 2019). Indeed, urban and peri-urban agriculture is
44 interesting due to the promotion of local food procurement, biodiversity, carbon sequestration (Pérez-Neira
45 and Grollmus-Venegas, 2018), reduction of wastes produced (Kulak et al., 2013), more attractiveness for new
46 employers, participated agriculture (i.e. agricultural cooperatives) and social cohesion (Opitz et al., 2016).
47 However, results from literature indicate that the economic profitability is controversial, therefore peri-urban
48 agriculture should be sustained by municipal authorities and integrated into land use planning (Azunre et al.,
49 2019). Furthermore, the assessment of these practices should involve not only the economic dimension but
50 also the social and environmental ones (Yingjie, et al., 2019; Ardente et al. 2003).

¹ According to the comprehensive study of Opitz et al. (2016), peri-urban agriculture is here intended as a 'small- to large-scale agriculture that cultivates agricultural land predominantly at the fringes of cities. It is first and foremost economically motivated and is operated by professionals with medium to large distribution pathways from direct marketing up to global value chains.'

51 The quantitative assessment of the urban and peri-urban agriculture role at the urban scale in mitigating the
52 environmental impacts of food systems has not been addressed until very recently (Benis and Ferrão, 2017).
53 In this context, the Life Cycle Assessment (LCA) is a methodology widely adopted by the scientific community
54 in the quantification of the environmental impacts associated to the whole food supply chain (Nemecek et al.,
55 2016). In fact, the systemic and scientific approach of LCA, internationally standardized by the ISO 14040
56 (ISO, 2006a; ISO, 2006b), ensures the robustness of the results obtained and the comparability between
57 different options. LCA is a useful support for assessing the environmental sustainability of different agriculture
58 practices and for identifying options aimed at improving the global environmental performance of agricultural
59 products (Castellani et al., 2017; Cellura et al., 2018; Cerutti et al., 2018; Longo et al., 2017).

60 For instance, in the study of Roy et al. (2009) the LCAs of both processed (bread, beer and tomato ketchup)
61 and agricultural (dairy, meat, rice, sugar beet, potatoes, and tomatoes) food products, were reviewed. The
62 authors pointed out that organic agriculture causes lower GHG emissions but higher land demand.

63 In the study of Borsato et al. (2018), authors reported values of carbon footprint, water footprint and energy
64 ratio between the nutritional intake and the energy consumption for seven food categories (fruits, dry fruits,
65 vegetables, pulses, cereals, oil crops, and animal products) based on reviewed studies. Results highlighted that
66 higher environmental impacts are due to animal products while lower ones are due to vegetable ones. This is
67 in accordance with the results from Clune et al. (2017), who elaborated a database with mean values of Global
68 Warming Potential (GWP) for five food categories (fresh vegetables, fresh fruits, staples, dairy, ruminant
69 livestock and non-ruminant livestock) and founded that a clear hierarchy emerges across them, with lowest
70 impact for plants while highest for meat from ruminants.

71 Moreover, LCA can be used to identify the most environmentally impactful stages of a productive chain.
72 Cellura et al. (2012) assessed five vegetables (peppers, melons, tomatoes, cherry tomatoes, and zucchini)
73 cultivated in Southern Italy and observed that the use of materials for the packaging and the greenhouses
74 construction were the most impactful stages for most of indicators, while cultivation activities accounted for
75 the 20-46% of energy consumptions. In the study of Mistretta et al. (2019), an analysis of eight conventional
76 and organic food chains (bread, potatoes, lettuce, yogurt, rice, milk, tomatoes, flour in an institutional catering
77 in Northern Italy is developed. Results show that cultivation activities generate 66% of life cycle energy
78 consumption and 69% of GWP.

79 Fewer studies are found in literature concerning urban and peri-urban agriculture. Among them, Pérez-
80 Neira and Grollmus-Venegas (2018) use the LCA methodology in order to analyse the energy metabolism,
81 carbon footprint and economic profitability of three small family farms in Seville, featured by different models
82 of production and distribution. Authors adopt a cradle-to-consumption boundary and assume both hectares and
83 kilograms of production as functional unit (FU). The Community Supporting Agriculture initiative shows the
84 best results among the three case studies. Yingjie et al. (2019) perform an LCA in order to compare the carbon
85 footprint of two farms for conventional vegetables production in Beijing. They assume a cradle-to-
86 consumption system boundary and selected the amount produced in a specific year as FU. The results show
87 better environmental performances for a small family farm, while for a large-scale one the best performances
88 are traced when taking economic profitability into consideration. An urban community farm in London,
89 organically producing vegetables and fruits, is assessed by Kulak et al. (2013) through an LCA approach.
90 Results show that adopting organic and local food chains may reduce largely GHG emissions, compared to
91 conventional food-chains, although they cannot satisfy the entire annual food demand. In the study of Rothwell
92 et al. (2016), the supply chains of fresh vegetables are assessed in case of peri-urban farms in Sydney as
93 opposed to a larger farm placed in Victoria State (Australia). Authors conclude that larger impacts occur for
94 the delocalised production due to transportations, which further increases if combined with synthetic
95 packaging. Benis and Ferrão (2017) apply the LCA methodology to evaluate to what extent urban and peri-
96 urban agriculture in Lisbon metropolitan area would play a role in mitigating the environmental impacts of
97 entire urban food systems in terms of greenhouse gases emissions and land use. Specifically, the authors
98 assessed the potential benefits related to the transition toward healthy diet characterized by a higher share of
99 vegetables and fruits compared to the current diet. Further, they assess the benefits which can be derived from
100 the elimination of loss and wastage and from the reduction of transportation distances due to an increased
101 efficiency of the food supply chain. The scenarios are compared based on the same diet energy content assumed
102 as functional unit. The system boundaries include all the steps from cultivation to distribution. The study shows
103 that higher environmental benefits are related to the adoption of the healthier diet. However, urban and peri-
104 urban agriculture strategies enhancing the efficiency of the food supply chain, reducing losses and wastage
105 and shortening transportation distances can further increase the mitigation potential.

106 The examined LCA studies reveal that the potential contribution of urban and peri-urban agriculture in
107 reducing the energy and environmental impacts of food provision requires further analysis and scientific
108 assessments. In this framework, this study aims at assessing the sustainability of an urban regeneration project
109 through peri-urban agriculture in Milan (Northern Italy) and at providing a useful support towards the
110 implementation of sustainable practices for the involved start-ups in compliance with some strategies of the
111 “Driving urban transitions to a sustainable future” (Urban Europe, 2019). The assessment involves both
112 environmental and economic dimensions of the sustainability concept. In detail, the environmental dimension
113 is investigated by applying the LCA approach and the economic one by evaluating the food production costs.
114 Different scenarios are investigated in order to provide a set of energy and environmental data that can
115 represent a useful support in peri-urban agriculture planning and, in general, to regeneration process of
116 deprived urban area. For spatially analysing the energy-environmental impacts of the farming practices, the
117 representation of results through Geographic Information System (GIS) makes the information more accessible
118 and understandable for stakeholders.

119 **2 Methods**

120 The examined peri-urban area is involved in the European Urban Innovation Actions (UIA) project
121 ‘OpenAgri - New Skills for new Jobs in Peri-urban Agriculture’ (OA) (UIA-OpenAgri website). Such a project
122 is particularly interesting as it proposes the creation of a coherent urban-rural food governance system, towards
123 the implementation of a circular economy along the whole chain. At the core of the project, there is the
124 settlement of a so-called ‘Open Innovation Hub on Peri-Urban Agriculture’ in a peri-urban area of Milan (Italy)
125 to deliver innovation in the agri-food chain and focusing on new skills and jobs. The project site includes the
126 agricultural area of ‘Vaiano Valle’, in which start-ups, selected through a public call, are beginning agricultural

127 activities based on organic² and innovative farming practices, such as intercropping³ and agroforestry⁴, and
128 mainly local chains⁵. Within the OA project, the analysis of the main impacts, related to energy and matter
129 main flows of food production has been carried out, and pertinent indicators and indexes to quantify and
130 monitor them have been defined and calculated.

131 The methodology proposed in this paper is illustrated in Figure 1. More in detail, it is based on primary
132 data collected through extended experimental studies carried out in the period April-July 2019, including
133 meetings, on-site visits, interviews and follow-up activities with farmers involved in the OA project. In detail,
134 semi-structured interviews, including both qualitative and quantitative questions on crops cultivation planning
135 and the food chains stages, have been carried out. Data on raw materials, farm machines and related fuels,
136 routes and related transport consumptions, as well as harvest yields, have been collected and periodically
137 updated by means of phone calls with the representatives of the start-ups.

138 The environmental assessment of the agri-food items produced in the examined peri-urban food hub has
139 been carried out through a Life Cycle Assessment approach according to the ISO 14040 series of standards
140 (ISO, 2006a; ISO, 2006b). The non-renewable primary energy consumption and the global warming potential
141 are provided as results. In addition, also the productive land (PL) needed for the different productions is
142 assessed. These three indicators are selected following a debate involving the partners of the OA project and
143 other local stakeholders in order to provide understandable and ‘ready to use’ metrics on the environmental
144 burden of food production. In order to provide decision makers with a synoptic view of the aspects analysed,
145 the results obtained are represented through a spatial analysis accomplished through GIS tool. Moreover,

² Organic agriculture: crop management able to produce food obtained with organic methods in accordance with the 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 and subsequent amendments and additions (Caputo et al., 2017).

³ Intercropping: farming practice involving two or more crop species growing together and coexisting for a time, which can provide several advantages versus the monocrop system including better land use efficiency, maintenance of soil fertility, reduction of disease and pest incidence (Monti et al., 2019).

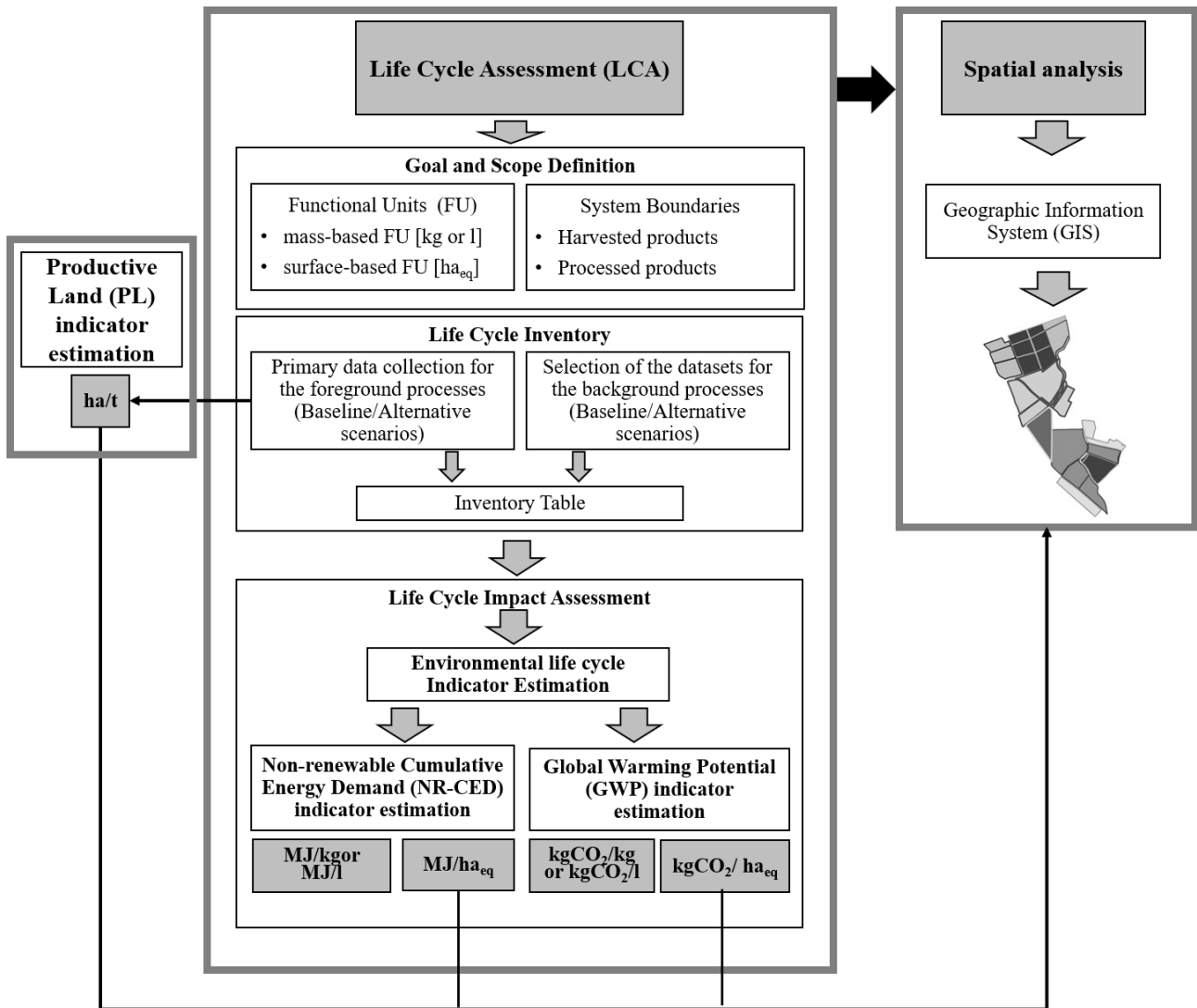
⁴ Agroforestry: farming management practice characterized by the deliberate inclusion of woody perennials on farms, which usually leads to significant economic and/or ecological benefits between woody and non-woody system components (UNEP, 2017).

⁵ Local agriculture: crop management able to produce food whose main ingredient is produced within a defined area (geographic area, distance in km, etc.), indicated by the client. In this case, a distance of 50/60 km is considered as in (Caputo et al., 2017).

146 according to the cash flows of the involved start-ups and on available statistics on the food market, some
 147 economic feasibility insights are provided.

148 The methodology is applied to five scenarios, described in Section 2.3.

149



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151

Figure 1. Flow-chart of the methodological approach adopted.

152 2.1 Goal definition

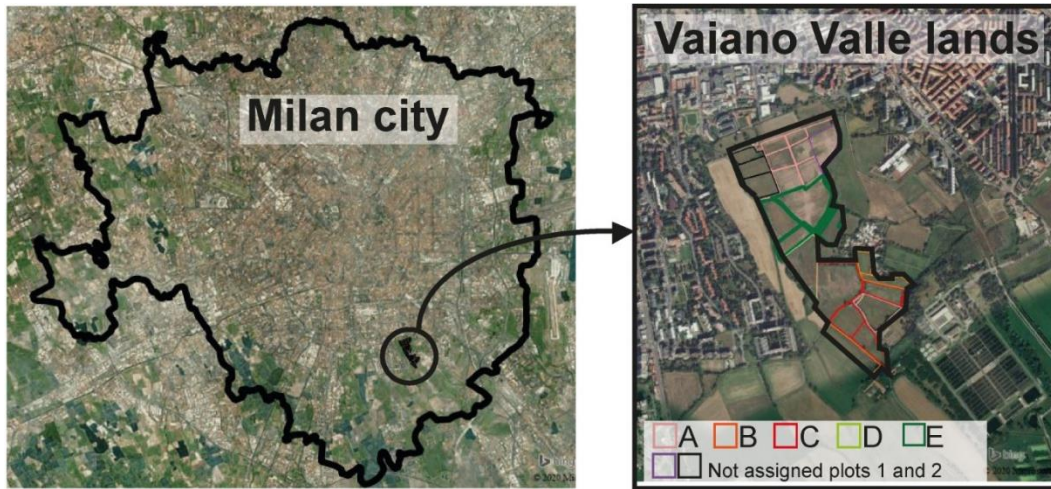
153 The goals of the Life Cycle Assessment study are:

- 154 • to assess the life cycle energy and environmental impacts related to the peri-urban agriculture area,
 155 considering the dual perspective of ‘sustainable food production’ and ‘sustainable planning and
 156 management of the territory’;
- 157 • to identify the hot-spots along the agri-food supply chain;

- 158 • to identify potential environmental improvements related to different agricultural practices and
159 different selected crops.

160 **2.2 Study site**

161 The system examined is an innovative hub including 33 hectares of agricultural land. This is a peri-urban
162 land located in a flat area in the South-East of Milan (Lombardy Region, northern Italy). The land, named
163 ‘Vaiano Valle’, is undergoing an urban regeneration process because it belongs to a critical zone of the
164 metropolitan area due to social and economic deprivation (Figure 2). Since autumn 2018 5 start-ups have been
165 starting agricultural activities involving 26 different food chains and 2 processed products, mainly based on
166 sustainable farming practices, as summarized in Table 1. According to the nomenclature adopted in Table 1,
167 for sake of simplicity, the involved start-ups are identified hereafter with letters from A to E. Data for modelling
168 the activities of the considered start-ups are based on the following assumptions. All agricultural activities (i.e.
169 from the land preparation to the harvest) for start-ups A, B and C were accomplished between autumn 2018
170 and summer 2019. Activities related to the processed products of start-ups B and C are still at the planning
171 stage, thus data from technical literature are used. Regarding the start-up D, the agricultural activities are still
172 at the planning stage, therefore data estimated by entrepreneurs are used. Moreover, in this particular case,
173 which foresees the implementation of an agroforestry system, data on raw materials and transportations are
174 accounted only for the food products. Data on farm machineries are estimated by the farmers for both food
175 products and perennial trees, by weighting their impact on the cultivated surface of food crops. About the start-
176 up E, the agricultural activities are still at the early planning stage, thus data used are both estimated (in case
177 of farm machineries time of use) and from technical literature (in case of mass of seeds, transports and harvests
178 yields). Moreover, even if most of the area is dedicated to polifita grass while only a smallest share to the
179 cultivation of peppers, the activities along the whole land have been considered.



180

181

182

183

Figure 2. Study site map.

Table 1. Features of the 5 start-ups.

START-UP	PLOT AREA [ha]	FORESEEN CULTIVATIONS	CULTIVATED NET AREA [ha]	FARMING PRACTICE	PROCESSED PRODUCTS
A	5.40	Barley	0.30	Intercropping - organic	-
		Lentils			-
B	2.38	Chickpeas	1.00	Organic	-
		Barley	2.00	Organic	Beer
C	6.40	Spelt	6.00	Organic	Bread
		Vegetables (black / kohlrabi / savoy cabbages, chards, Asparagus, artichokes, sweet potatoes, radishes,	0.88		-
D	2.20	maize, beans)		Agroforestry – organic	
		Fruits (cherries, apples, sorbs, plums, peaches, mulberries, pomegranates, figs and berries)	0.20		
E	6.60	Chili peppers	0.003	Organic	-

184

185 2.3 Scope definition

186 Based on the main goals of the study, two functional units are considered:

- 187 • a mass-based FU, i.e. per 'kg' of harvested products or 'kg' and 'l' of processed products for the
- 188 sustainable food production perspective;

189 • a surface-based FU, i.e. per equivalent hectare ‘ha_{eq}’ for the sustainable planning and management of
 190 the territory perspective.

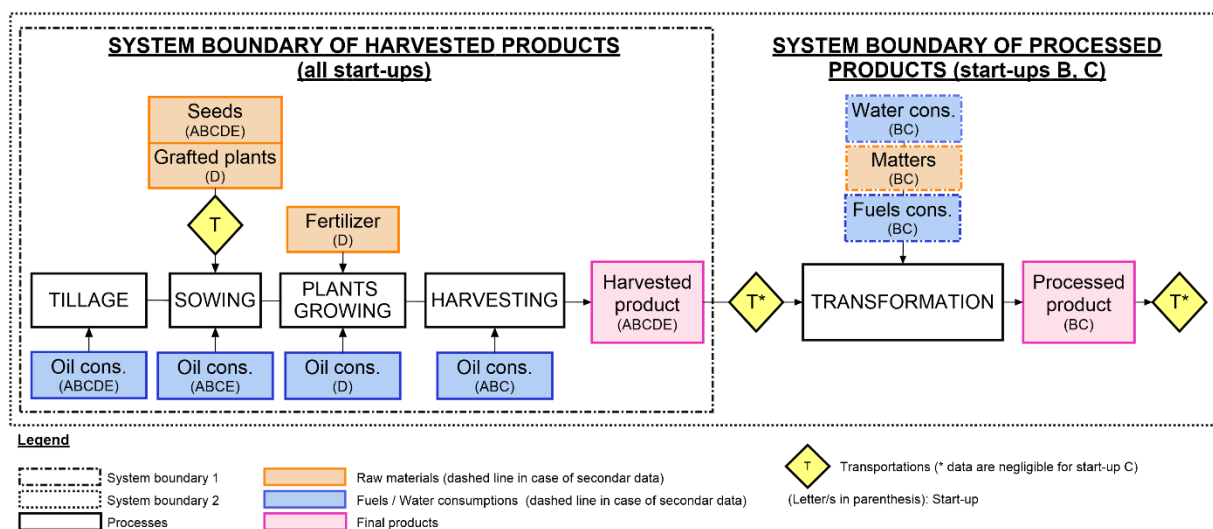
191 The system boundaries chosen are ‘from-cradle-to-farm gate’ and include the production of the seed/tree
 192 seedling, the production of fertilizers (if the case occurs), the preparation of soil through ploughing, swathing,
 193 mowing, harrowing, the mechanical sowing and harvesting (if the case occurs), the plants pruning and chipping
 194 (if the case occurs), and the transports.

195 In addition, for start-ups B and C, since the processed products are beer and bread, respectively, the
 196 transformation processes performed are also taken into account.

197 The eco-profiles of materials and energy sources used to model the agri-food supply chains are based on
 198 the Ecoinvent 3 database (Wernet et al., 2016) accessed through the SimaPro tool (SimaPro website).

199 The system boundaries are illustrated in Figure 3.

200



201

202

Figure 3. Adopted system boundaries.

203 Since this research group was committed to give suggestions about the definition of a set of indicators able
 204 to take into account the interests of the stakeholders involved in the OpenAgri project, three synthetic
 205 indicators, two of which determined through the Life Cycle Assessment methodology, were selected in order
 206 to provide a clear insight on the outcomes in terms non-renewable primary energy consumption, global
 207 warming potential and consumed land on the results of the project.

208 Cumulative Energy Demand model (Frischknecht et al., 2007) is applied to calculate the NR-CED
 209 indicator, and the IPCC 2013 model (IPCC, 2013) is used to estimate the GWP over a time horizon of 100
 210 years. Further, according to the aims of the overall project, another indicator is provided, i.e. the PL, which is
 211 calculated as inverse of the crops' yields [ha/t]. PL estimation is based on primary data or statistical data,
 212 depending on data availability (MIPAAF, 2016).

213 For each crop, to calculate the above three indicators per equivalent hectare, the produced masses, NR-
 214 CED and GWP per year are divided by the net area devoted to related crop. The calculation is carried out
 215 including doubled areas for both the intercropped and the rotational cultivations and excluding the areas
 216 devoted to other activities (e.g. maintenance), in order to avoid misleading information, as underestimating the
 217 impact of farms which use only a small area of the assigned plot. For the sake of comparability, such
 218 evaluations only regard the harvested products.

219 For each crop, to calculate the above three indicators per equivalent hectare, the produced masses, NR-CED
 220 and GWP per year are divided by the net area devoted to the related crop. The calculation is carried out
 221 including doubled areas for both the intercropped and the rotational cultivations and excluding the areas
 222 devoted to other activities (e.g. maintenance), in order to avoid misleading information, as underestimating the
 223 impact of farms which use only a small area of the assigned plot. For the sake of comparability, such
 224 evaluations only regard the harvested products.

225 The value of NR-CED, GWP and PL per equivalent hectare is calculated through the following Equations 1,
 226 2 and 3.

227

$$228 \quad I_{ha,NR-CED} = \frac{\sum_{i=1}^n (I_{NR-CED_{crop-i}})}{\sum_{i=1}^n (A_{crop-i})} \quad (1)$$

$$229 \quad I_{ha,GWP} = \frac{\sum_{i=1}^n (I_{GWP_{crop-i}})}{\sum_{i=1}^n (A_{crop-i})} \quad (2)$$

$$230 \quad PL = \frac{\sum_{i=1}^n (A_{crop-i})}{\sum_{i=1}^n (P_{crop-i})} \quad (3)$$

231 where:

232 $I_{ha,NR-CED}$ = indicator of annual NR-CED per equivalent hectare for the Vaiano Valle area [MJ/ha_{eq}]

233 $I_{NR-CED_{crop-i}}$ = indicator of annual NR-CED for the i^{th} crop [MJ]

234 A_{crop-i} = productive land area of the i^{th} crop [ha_{eq}]

235 $I_{ha,GWP}$ = indicator of annual GWP per equivalent hectare for the Vaiano Valle area [kgCO₂eq/ha_{eq}]

236 $I_{GWP_{crop-i}}$ = indicator of annual GWP for the i^{th} crop [kgCO₂eq]

237 PL = indicator of productive land per equivalent hectare for the Vaiano Valle area [ha_{eq}/t]

238 P_{crop-i} = annual food production for the i^{th} crop [t]

239 Furthermore, in order to provide each start up with a set of indicators useful for obtaining, for example, an
240 environmental certification or an environmental management system, the NR-CED, GWP and PL indicators
241 are calculated with reference to the individual start up. Specifically, the following Equation 4 is used for the
242 estimation of the NR-CED indicator of each start up. The same principle is applied for calculating GWP and
243 PL indicators of each start up.

244

$$245 \quad I_{ha,NR-CED,su_j} = \frac{\sum_{i=1}^n (I_{NR-CED_{crop-i}})_{su_j}}{\sum_{i=1}^n (A_{crop-i})_{su_j}} \quad (4)$$

246

247 where

248 $I_{ha,NR-CED,su_j}$ = indicator of annual NR-CED per equivalent hectare for the j^{th} start-up [MJ/ha_{eq}]

249 $I_{NR-CED_{crop-i}}$ = indicator of annual NR-CED for the j^{th} start-up [MJ]

250 A_{crop-i} = productive land area of the j^{th} start-up [ha_{eq}].

251 **2.4 Life Cycle Inventory: Baseline and alternative scenarios**

252 First, a baseline scenario (S1) is defined to assess the designed organic farming practices based on the
253 current state of progress of the activities planned as described in Section 2.2.

254 Concerning start-up A, an organic agricultural practice is considered for chickpeas, lentils and barley. The
255 cultivation processes involve the employment of a plough and a harrow for the tillage processes. Sowing takes
256 place mechanically through a sowing machine fuelled with diesel. Finally, the transport process related to the
257 seeds supply is considered. In detail, chickpeas and lentils come from Central Italy, while barley is local.

258 With reference to start-up B, the organic cultivation of barley and the brewery are assessed. The tillage
259 processes are accomplished with a plough and harrow, followed by mechanical sowing and mechanical
260 harvesting. The barley seeds are shipped from a distance of 60 km; thus, the harvest is considered to be shipped
261 to a local storage, the malt to a factory placed in a neighbouring region and, lastly, the produced beer to a town
262 near Milan to be sold to consumers. The beer production from barley in start-up B is modelled based on a study
263 referred to brewery in UK (Amienyo and Azapagic, 2016). Based on the data reported in that study, a
264 productivity of 13.7 litres of beer from 1 kilogram of barley is considered. The production process also requires
265 water, hops, yeast, diatomaceous earth, sodium hydroxide, phosphoric acid, sulphuric acid, carbon dioxide and
266 heat. The water consumption is assessed by means of the European dataset of tap water production. Dataset
267 for modelling the production of hops and the yeast were not available. Then, according to Amienyo and
268 Azapagic (2016), they have been assimilated to the barley. The diatomite for beer filtering has been neglected,
269 since the dataset was lacking. The sodium hydroxide, the phosphoric acid, the sulfuric acid and the carbon
270 dioxide are modelled with the proper datasets.

271 Concerning start-up C, the organic cultivations of spelt and the baking are assessed. In detail, plough and a
272 harrow for the tillage processes, seeder and, the harvester are considered in the analysis. For start-up C, both
273 spelt seeds and baking are local. The baking is split into the flour production phase, which is modelled on the
274 basis of the LCA food dataset (LCA food website) and the bread production one, which is modelled based on
275 field report (Caputo et al., 2015).

276 For start-up D, first land preparation is considered as performed with a mower and a swather, then an auger
277 for perennial trees planting, a chainsaw for trees pruning and a chipper for woodchips production towards soil
278 protection, while both manual sowing and harvesting are planned within a Community Supported Agriculture.
279 About transports, the shipment of grafted plants from a neighbouring region is considered.

280 Regarding start-up E, a tractor and a shredder have been considered for tillage and a seeder for mechanical
281 sowing. Seeds is assumed as local.

282 The routes travelled for the provision of seeds to the agricultural lands and, in case of processed products,
283 in the next steps of the food chains are accounted for by considering a lorry with a weight of 16-32 tons and
284 Euro 5 emission class.

285 Three alternative scenarios are defined for assessing the effect of possible changes in terms of the farming
286 practices. Additionally, a scenario regarding the delocalized and conventional production of the foreseen food
287 chains is assessed. The assessed scenarios are the following:

288 – an ‘upgraded’ scenario (S2) is defined to assess the effects of possible improvements compared to the
289 current practices. In detail:

- 290 • for start-up A, an increment of productivity is forecasted according to MIPAAF decree (MIPAAF,
291 2016); in particular, for legumes an opportune irrigation technique is accounted to this end;
- 292 • for start-up B, an increment of productivity according to MIPAAF decree (MIPAAF, 2016) due to
293 use of fertilizer (i.e. urea) and localization of the brewing into a closed building whose
294 refurbishment is one of the tasks of the OpenAgri project are considered;
- 295 • for start-up C, an increment of productivity was taken into account according to MIPAAF decree
296 (MIPAAF, 2016);
- 297 • for start-up D, an increment of productivity according to start-ups estimates and MIPAAF decree
298 (MIPAAF, 2016) and due to vegetables irrigation is considered;
- 299 • for start-up E, the addition of cabbage cultivation on a 1 ha land, productivities according to
300 MIPAAF decree (MIPAAF, 2016) and additional consumptions due to irrigation are considered

301 As prior assumption valid for all interested start-ups activities, it should be pointed out that the accurate
302 assessment of water consumptions and related energy-environmental impact has been a hard task,
303 because it depends on many climate and agronomic factors (rainfall, crops characteristics and growing
304 period and the related mismatch). Furthermore, in the project OA, the irrigation system has to be
305 realized yet and, as such, there is a large degree of uncertainty on its final design and features. Hence,
306 considering such uncertainty, it has been decided to model the irrigation system considering a range
307 of possible values. In detail, a dataset including electricity and oil consumptions, machinery and
308 additional infrastructure such as pump or water pipe, is considered;

309 – an ‘organic monoculture’ scenario (S3) is defined in order to minimize the energy-environmental
310 impacts. To that end, the least energy-environmental impacting food chain, chosen among the ones
311 already operating due to higher quality of primary data, i.e. the cultivation of spelt towards baking
312 (start-up C), has been extended to the entire project area;

- 313 – a ‘conventional monoculture’ scenario (S0b) is defined in order to assess the use of lands for the
 314 cultivation of silage maize as animal feed. Maize grains are assumed locally supplied and are modelled
 315 with the Swiss maize grain dataset towards production of animal feed;
- 316 – a ‘conventional delocalized’ scenario (S0a) is defined in order to assess the effects of producing the
 317 same food products with conventional practices (including consumption of agrochemicals, larger use
 318 of farm machineries, orchards facilities realization) and importing them from other Italian regions or
 319 even European countries (legumes from Tuscany, cereals from France, except for maize assumed as
 320 local, chards, radish and asparagus from central Italy, cabbages, artichokes and chili peppers from
 321 south Italy, potatoes from France, apples, prunes, sorbs, peaches and strawberries from different
 322 regions in northern Italy, cherries, pomegranates and figs from south Italy).

323 Table 2 summarizes the scenarios features while Table 3 the related input data.

324 Table 2. Scenarios features.

Land plot of start-up	S1	S2	S3	S0a	S0b
A	Organic chickpeas, intercropped lentils and local barley	As S1a with greater yields		Conventional not local chickpeas, lentils and barley	
B	Organic local barley + not local brewing	Local fertilized barley with greater yields + local brewing	Organic	Conventional not local barley + brewing	
C	Organic local spelt + local bakery Agroforestry -	As S1a with greater yields	monoculture of spelt (i.e. the least impacting	Conventional not local spelt + bakery	Conventional monoculture of local silage
D	Organic local fertilized vegetables and fruits	As S1b with greater yields	food chain in S2)	Conventional not local vegetables and fruits	maize (as animal feed)
E	Organic local chili peppers	Organic local irrigated chili peppers and fertilized cabbages		Conventional not local chili peppers and cabbages	

325

Table 3. Input data for the assessed start-ups with reference to defined scenarios⁶.

START-UP	CROPS	CROPS YIELD			FERTILIZERS [kg/FU]		FARM MACHINERY		WATER DEMAND	TRAVELLED		
		[t/ha]					TIME OF USE [s/FU]		[m ³ /FU]	DISTANCES [km]		
		S1	S2	S0a	S1	S2	S1	S2	S2	S1	S2	S0a
A	Chickpeas ^{PR}	0.50 ^{PR}	2.03 ^T	2.53 ^T					0-0.25 ^T	400 ^C	400 ^C	300 ^T
	Barley ^{PR}		4.59 ^T	5.74 ^T	0 ^{PE}	0 ^{PE}	50.6 ^{PE}	33.8 ^C	0	35 ^C	35 ^C	1000 ^T
	Lentils ^{PR}	0.57 ^{PR}	1.22 ^T	1.52 ^T					0-0.25 ^T	400 ^C	400 ^C	300 ^T
B	Barley for brewing ^{PR}	3.50 ^{PR}	5.74 ^T	5.74 ^T	0 ^{PE}	0.02	11.7 ^{PE}	10.5 ^C	0	338 ^C	60 ^C	1150 ^T
C	Spelt for baking ^{7PR}	3.48 ^{PR}	4.17 ^{PE}	3.91 ^T	0 ^{PE}	0 ^{PE}	4.3 ^{PE}	4.3 ^{PE}	0	35 ^C	35 ^C	1146 ^T
D	Black cabbages ^{PE}		24 ^T	30 ^T					0-0.08 ^T			
	Kohlrabi cabbages ^{PE}						7.6 ^{PE}	6.2 ^C				850 ^T
	Savoy cabbages ^{PE}		34 ^T	43 ^T					0-0.06 ^T			
	Chards ^{PE}		20.6 ^T	25.8 ^T					0-0.10 ^T			200 ^T
	Asparagus ^{PE}	10 ^{PE}	20 ^{PE}	9 ^T	6 ^{PE}		10.4 ^{PE}	7.6 ^C	0-0.07 ^T			
	Artichokes ^{PE}		15.5 ^T	43 ^T					0-0.10 ^T	150 ^C	150 ^C	
	Potatoes ^{PE}		36.6 ^T	46 ^T					0			1000 ^T
	Maize ^{8PE}			12 ^T			7.6 ^{PE}	6.2 ^C	0-0.10 ^T			50 ^T
	Beans ^{PE}		20 ^{PE}	29 ^T					0			300 ^T
Radishes ^{PE}			25.8 ^T					0-0.07 ^T			200 ^T	

⁶ PR: primary and real data – PE: primary data based on entrepreneurs' estimates – T: tertiary data – T: tertiary data that are used in S2 for the estimation of the maximum impacts related to irrigation - C: calculated data by the research group.

⁷ The values for spelt adopted in scenario S2 have been also adopted for the scenario S3 (organic monoculture).

⁸ The values of 59.37 t/ha and 50 km have been adopted for the scenario S0b (monoculture of silage maize).

	Cherries ^{PE}	10 ^{PE}	8.3 ^T	0.04 ^{PE}	0.04 ^{PE}	17.6 ^{PE}	17.6 ^C				850 ^T	
	Apples ^{PE}	20 ^{PE}	25.7 ^T	32 ^T	0.03 ^{PE}	0.03 ^{PE}	8.8 ^{PE}	8.0 ^C			300 ^T	
	Sorbs ^{PE}	20 ^{PE}	21.3 ^T					8.8 ^C				
	Plums ^{PE}	16 ^{PE}	17 ^T		0.04 ^{PE}	0.04 ^{PE}	11.0 ^{PE}	10.7 ^C			200 ^T	
	Peaches ^{PE}	16 ^{PE}	16 ^{PE}	15.1 ^T				11.0 ^C	0			
	Mulberries ^{PE}	10 ^{PE}	10 ^{PE}	10 ^T			17.6 ^{PE}	17.6 ^C				
	Pomegranates ^{PE}	20 ^{PE}	20 ^{PE}	25 ^T	0.03 ^{PE}	0.03 ^{PE}	8.8 ^{PE}	8.8 ^C			1000 ^T	
	Figs ^{PE}	16 ^{PE}	16 ^{PE}	10 ^T	0.04 ^{PE}	0.04 ^{PE}	11.0 ^{PE}	11.0 ^C				
	Berries ^{PE}	12 ^{PE}	12 ^{PE}	3.35 ^T	1.08 ^{PE}	1.08 ^{PE}	14.7 ^{PE}	14.7 ^C			200 ^T	
E	Chili peppers ^{PE}	12 ^T	12 ^T	15 ^T	0 ^{PE}	0 ^{PE}	2.6 ^{PE}	2.6 ^{PE}	0-0.07 ^T	0 ^C	0 ^C	1000 ^T
	Cabbages ^C	ND	24 ^T	30 ^T	ND	6 ^C	ND	13.0 ^{PE}	0-0.08 ^T	ND	0 ^C	850 ^T

328 **3 Results**

329 In the following subsections, the impacts assessed in the study are reported while referring to both the mass-
330 based and the surface-based functional units as well as in terms of spatial analysis of the area.

331 **3.1 Energy-environmental impacts per mass of food**

332 In the following, the Non-Renewable Cumulative Energy Demand, Global Warming Potential for one year
333 referred to a mass unit of food (kilogram or litre) are reported for each of the 26 harvested products and the 2
334 processed products for the baseline scenario S1 (Figure 4).

335 In detail, the start-up A food chains returned the largest impacts due to low productivity, with one of the
336 most relevant contributions being due to raw material production, mainly to GWP. More in detail, the results
337 show the highest NR-CED and GWP for chickpeas, mean for lentils and lowest for barley because the former
338 require the largest amount of seeds but returned the lowest yield, and vice versa. It can be noted that, usually,
339 the largest responsibility to the NR-CED is due to farm machineries, which account for the 76-94% of the total
340 impacts, while the contribution of transports is not particularly relevant since goes from a negligible value for
341 the local barley to 5% for chickpeas.

342 Better results are reported for the other cereals, whose impacts are dominated by farm machineries (94% in
343 start-up B foodchain and 82% in start-up C foodchain). Regarding the brewing, the larger contribution to the
344 assessed impact categories is due to raw materials (i.e., in decreasing order, yeast, hops and water) and
345 chemical compounds production (i.e. carbon dioxide, sodium hydroxide, phosphoric and sulfuric acids)
346 processes (71% of NR-CED), while the transportation is only the 7% of NR-CED, although not-local routes
347 are included. Considering a productivity of 13.7 litres from 1 kg of barley mentioned in section 2.3, the NR-
348 CED would increase up to 8.5 MJ/l and 0.63 kgCO₂eq/l. Regarding the baking, the spelt cultivation represents
349 the 35% of NR-CED, while the processes are responsible for the 64%.

350 In the case of start-up D, the impacts of vegetables and fruits are very low if compared to the other food
351 products assessed so far, i.e. below 1.0 MJ/kg and 0.1 kgCO₂eq/kg, except for berries. The largest contribution
352 comes from farm machineries for all products, although with quite variable values (49-83% for vegetables and
353 75-86% for fruits). Conversely, the berries impacts are affected by a probably overestimated fertilizers mass
354 (61% of NR-CED).

355 In case of start-up E, very low impact is for peppers, due to adopted techniques and to the considered yield.
356 Anyway, also in this case the most important contribution comes from the machineries (72%).

357 In addition to the Life Cycle Assessment based indicators above described, also productive land , calculated
358 as inverse of the crops' yields as mentioned in Section 2.3, is evaluated and reported together with GWP and
359 NR-CED in the following Figure 4. The activity of start-up A requires the highest surface among the start-ups
360 due to low productivity; start-ups B, C and E present low PL values due to good yields; in case of start-up D,
361 low PL indicators indicate the use of greater intensive and productive agriculture.

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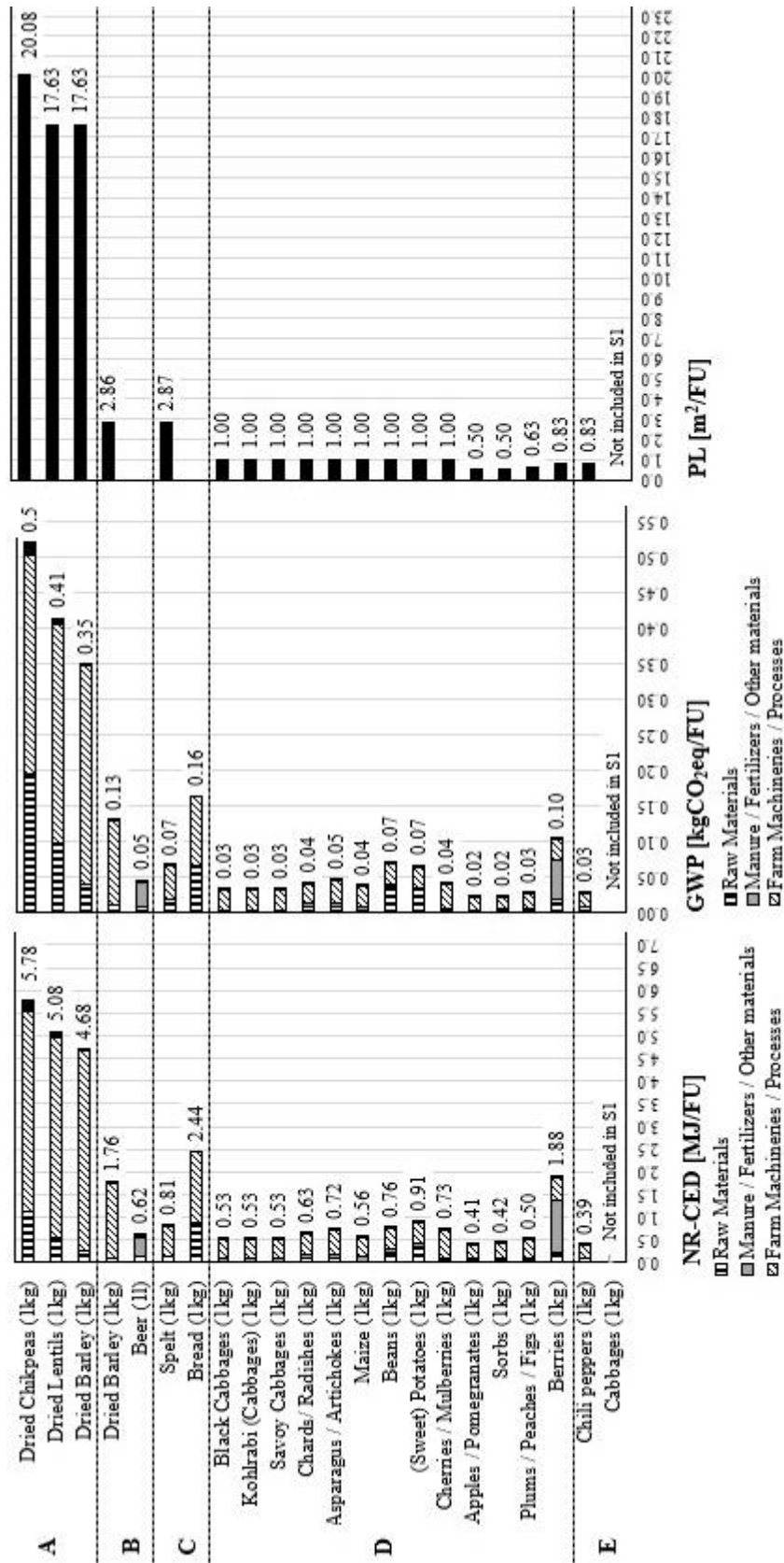


Figure 4. NR-CED, GWP and PL per mass unit of food in scenario S1.

The results of the other scenarios investigated are reported in Table 4 and compared with S1 following.

366 In case of start-up A, 'upgraded scenario' (S2), if compared with S1, show a reduction of NR-CED due to
367 higher productivity. Comparable NR-CED occurs in the 'conventional delocalized' scenario (S0a), due to
368 greater yields, while larger GWP occur due to greater use of agrochemicals and machineries. Relevant
369 contributions in both NR-CED and GWP are also from irrigation in both scenarios.

370 In case of start-up B, the 'upgraded scenario' (S2) does not imply a greater change in both NR-CED and
371 GWP, since the larger yield mitigates the effects of the use of fertilizer. Conversely, the conventional
372 production of barley could imply about double NR-CED, whose responsibility is almost equally shared
373 between machineries and chemical compounds, and larger GWP. In case of brewing, the localization of the
374 foodchain reduced the transportation contribution to 0.05%, while in the 'conventional delocalized' scenario
375 (S0a), transportations are the 23%.

376 In case of start-up C, regarding spelt cultivation, the assumption on increased yield (S2) implies a slight
377 improvement in NR-CED and in GWP compared to S1. Looking at the baking, a similar NR-CED is in both
378 scenarios. Clearly, a conventional scenario would return in significantly greater energy-environmental impacts,
379 due to both more impactful agronomic practices (use of compounds, more machines, etc.) and higher distances
380 for the raw materials supply. Regarding the single contributions to the NR-CED in S1 and S2, the energy
381 consumption for spelt cultivation is dominated by farm machineries (82%). In case of baking, the spelt
382 cultivation phase accounts for the 33-35% of the energy consumption in S1 and S2. Clearly, since it is a fully
383 local food chain, transportation consumptions are not relevant in both system boundaries. In S0a, the role of
384 raw material and chemical compounds production is relevant, and transportations could increase up to 6%.

385 In case of start-up D, a slight decrease of both energy consumptions and GWP of vegetables is generally
386 implied if considering null impacts due to irrigation, while a significant increase is to be expected if considering
387 the maximum impact due to irrigation. In case of fruits, values of NR-CED and GWP in the upgraded scenario
388 (S2) are comparable, due to absence of irrigation. For fruits, the largest responsibility in energy consumption
389 lies in machineries (28-86%). Much larger energy consumptions and emissions would be implied in most cases
390 in the conventional scenario, mainly due to machineries and manure / agrochemicals but also calculation
391 assumptions.

392 In case of start-up E, the peppers impact increases in the upgraded scenario (S2) due to water demand. The
 393 new cultivation, i.e. cabbages, returns energy-environmental impacts lower than peppers, even in case of
 394 maximum impact due to irrigation. Larger impacts occur in case of conventional food chains.

395 With regard to the monoculture scenarios, the organic one implies minimization of the impacts, while the
 396 conventional one is based on impacts lower on average than the ‘conventional delocalized’ one. However, it
 397 is worth noting that a strong reduction in biodiversity and other environmental benefits is expected in both
 398 cases.

399 Table 4. Results obtained for the alternative scenarios.

START-UP	CULTIVATIONS	NR-CED [MJ/FU]				GWP [kgCO _{2eq} /FU]				PL [m ² /FU]			
		S2	S3	S0a	S0b	S2	S3	S0a	S0b	S2	S3	S0a	S0b
A	Chikpeas	3.24		2.70		0.25		0.72		4.93		3.95	
	Lentils	3.24		4.47		0.21		1.19		8.20		6.56	
	Barley	4.41		4.49		0.31		0.56		2.18		1.74	
B	Barley	3.18		4.49		0.20		0.56		1.74		1.74	
	Beer (1l)	0.58		1.49		0.04		0.15		ND		ND	
C	Spelt	0.68		6.57		0.05		0.82		2.40		2.56	
	Bread	2.36		6.27		0.16		0.65		ND		ND	
	Black Cabbages	0.49		4.63		0.03		0.42		0.42		0.33	
	Kohlrabi (Cabbages)	0.49		4.63		0.03		0.42		0.42		0.33	
	Savoy Cabbages	0.37		3.23		0.02		0.30		0.29		0.23	
	Chards	0.59		1.15		0.04		0.10		0.48		0.39	
	Asparagus	0.73		3.28		0.05		0.28		0.50		1.11	
	Artichokes	0.71	0.68	0.74	1.91	0.05	0.05	0.06	0.29	0.64	2.40	0.23	0.17
	Maize	0.52		3.42		0.04		0.37		0.50		0.83	
	Fresh Beans	0.97		2.53		0.09		0.11		0.50		2.88	
D	(Sweet) Potatoes	0.86		1.55		0.06		0.14		0.27		0.22	
	Radishes	0.59		7.02		0.04		0.60		0.50		0.39	
	Cherries	0.73		2.90		0.04		0.26		1.00		1.21	
	Apples	0.40		1.94		0.02		0.06		0.39		0.31	
	Sorbs	0.43		1.12		0.02		0.03		0.50		0.47	
	Plums	0.51		1.12		0.03		0.03		0.59		0.47	
	Peaches	0.51		1.58		0.03		0.14		0.63		0.66	
	Mulberries	0.74		2.39		0.04		0.21		1.00		1.00	
	Pomegranates	0.43		0.86		0.02		0.07		0.50		0.40	

	Figs	0.51	2.39	0.03	0.21	0.63	1.00
	Berries	1.88	13.32	0.10	1.34	0.83	2.99
E	Chili peppers	0.39	2.02	0.03	0.17	0.83	0.67
	Cabbages	0.24	4.63	0.01	0.42	0.42	0.33

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401 3.2 Energy-environmental impacts per equivalent hectare

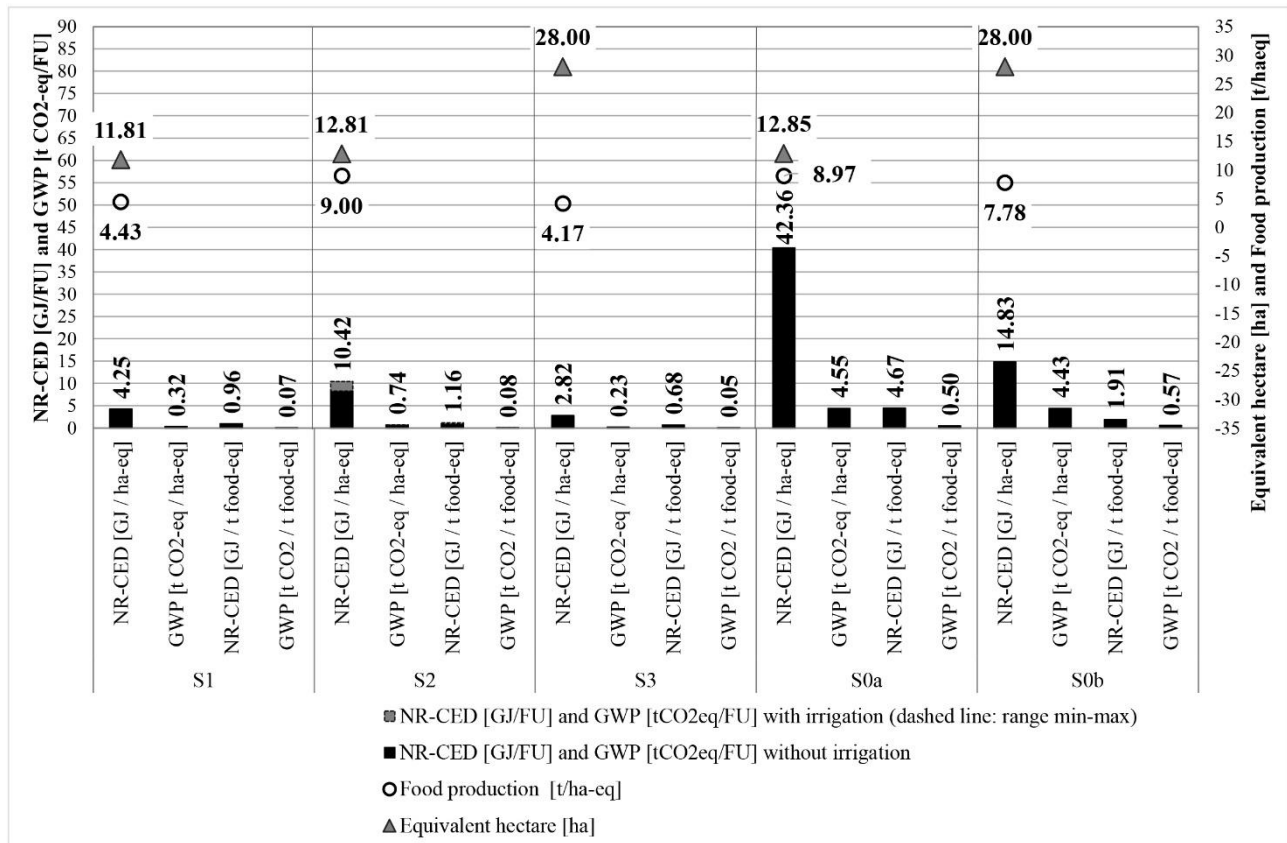
402 Figure 5 reports food production, Non-Renewable Cumulative Energy Demand, and Global Warming
 403 Potential per surface unit of cultivated land and the cultivated land surfaced along scenarios and based on
 404 equations (1) and (2) in Section 2.3. Noteworthy, the values of NR-CED and GWP indicated over the black
 405 bars in S2 refer to the maximum impact for irrigation. It can be noted that, ranging from scenario S1 to S2,
 406 both the equivalent hectares and the production of food increase. This implies an increase also in energy
 407 consumptions and greenhouse gas emissions per land surface unit but a decrease per mass unit of food because
 408 the relevant increase of food production is not proportional to the increment in land use.

409 In S3, the lowest impacting scenario could be achieved by adopting an organic monoculture, although it
 410 would decrease the agricultural biodiversity and the types of food produced.

411 A scenario based on conventional and delocalized food production (S0a) would imply a dramatic increase
 412 of the energy consumptions and GHG emissions. In detail, comparing its results with the ones for S2 with
 413 maximum impacts due to irrigation, each year about 30 GJ/ha and 3.8 tCO₂eq/ha would be saved, while having
 414 a comparable productivity.

415 Relevant impacts are achieved also by supposing the settlement of a conventional monoculture of silage maize
 416 (S0b). Again, by comparing its results with the S2 with the greatest conservative assumptions, interesting
 417 annual savings (4.1 GJ/ha for NR-CED and 3.8 tCO₂eq/ha for GWP) would be reported.

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Figure 5 . Energy-environmental impacts per equivalent hectare.

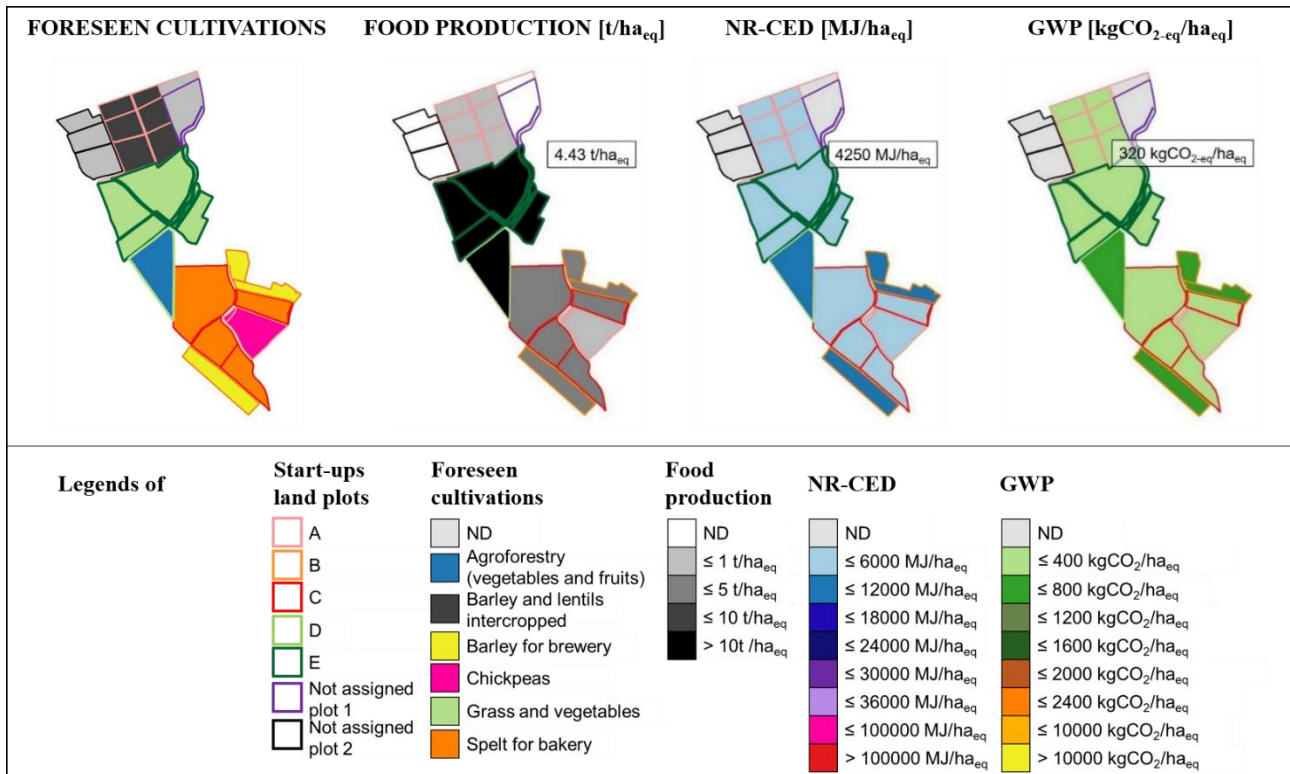
421 3.3 Development of a set of GIS maps

422 As an innovative contribution to the representation of the results obtained through the Life Cycle
 423 Assessment, a set of a Geographic Information System maps of the cultivated area has been developed, as a
 424 support for the involved operators in spatially analysing and representing the effects on the energy and
 425 environment of peri-urban agriculture. More in detail, this representation consists of four types of maps
 426 showing the foreseen cultivations, the food production, the Non-Renewable Cumulative Eergy Demand and
 427 the Global Warming Potential, per unit surface of cultivated land, along all scenarios.

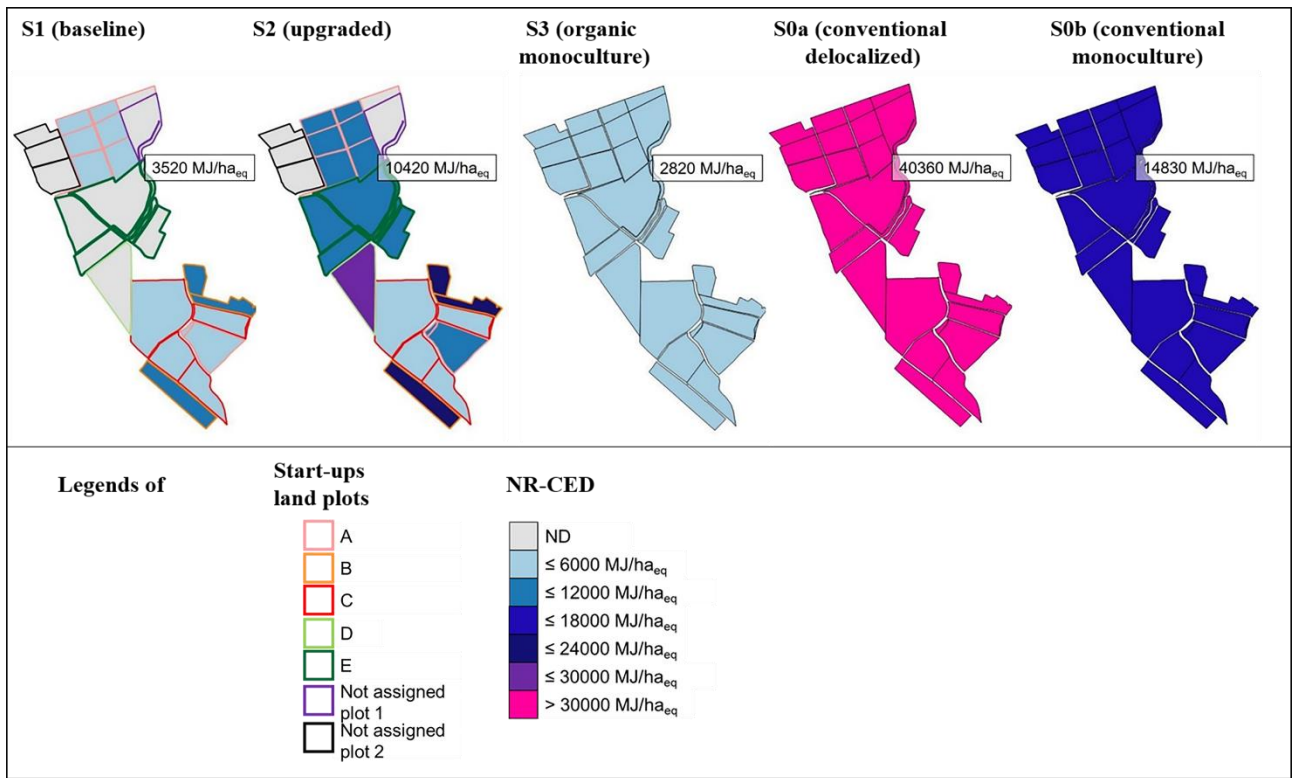
428 Hence, the approach allows to assess the behaviour of a start-up, either according to one indicator along all
 429 scenarios or according to more indicators in one scenario, as well as to compare different start-ups behaviours.
 430 As an example, Figure 6 shows the four maps with reference to scenario S2⁹, Figure 7 and Figure 8 show a set
 431 of maps regarding the same indicator (NR-CED and GWP, respectively) along selected scenarios.

⁹ Noteworthy, the metrics of S2 refer to the most conservative conditions with greatest impact attributed to irrigation.

432 Summarizing, the maps clearly visualize the enrichment achievable in terms of biodiversity and lower
 433 energy-environmental impacts from the forecast agri-food activities. Accordingly, the project offers the
 434 opportunity of valorising an abandoned area with activities that allow boosting new skills and jobs in the
 435 district, through the cultivation of sustainable products which also feed a local market, both in terms of
 436 suppliers and customers.
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 439 Figure 6. GIS maps obtained for scenario S2.

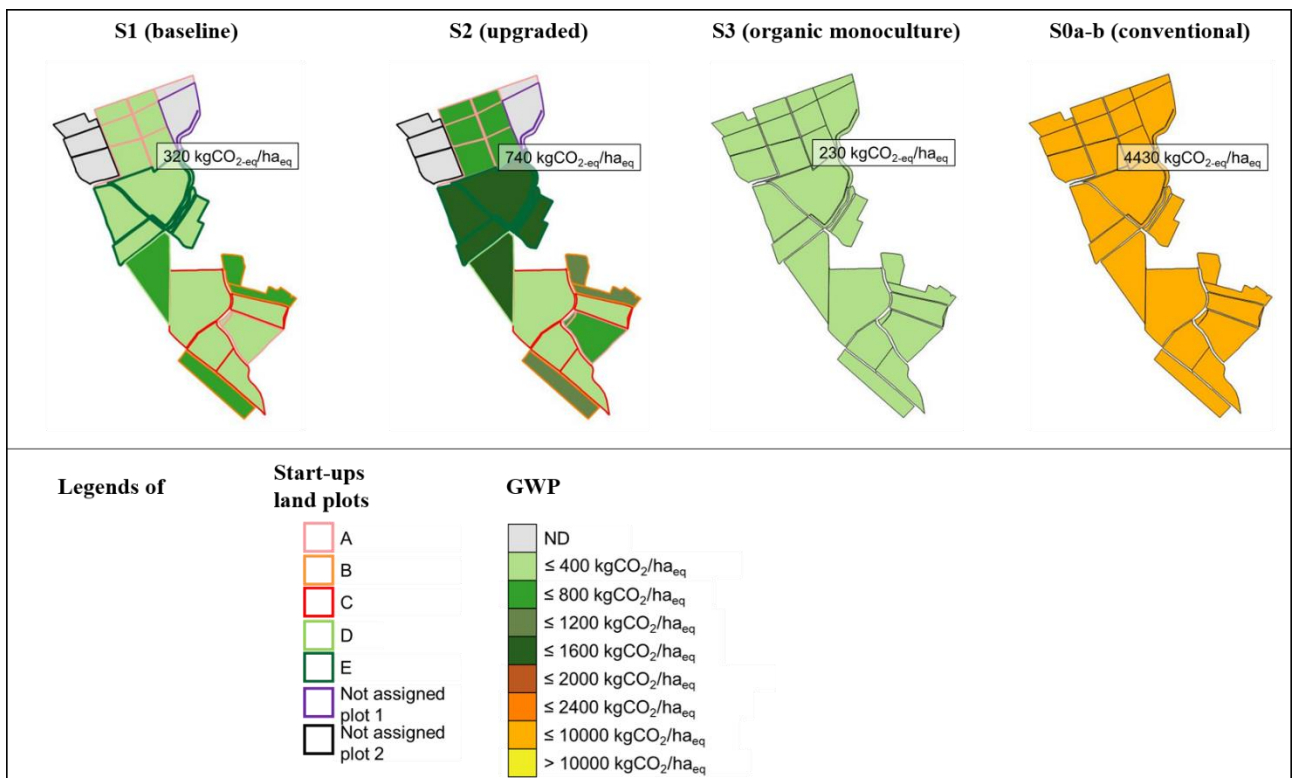


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Figure 7. GIS maps of NR-CED along scenarios.

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Figure 8. GIS maps of GWP along scenarios.

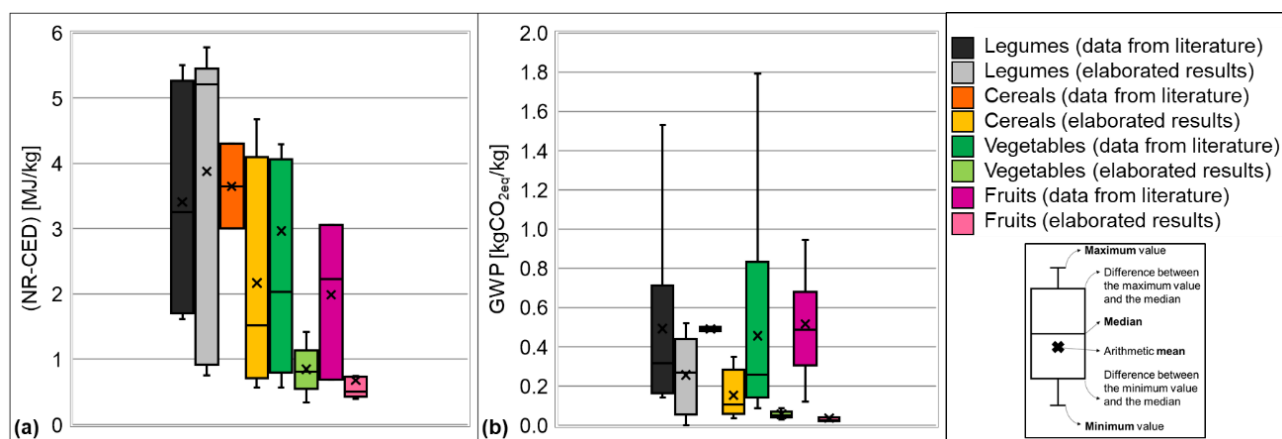
445 **4 Discussion**

446 From the previous subsection on the Life Cycle Assessment evaluated impacts per mass unit, interesting
447 results for the foreseen food chains compared with the conventional agriculture practices emerged. These
448 results are in line with previous researches, as discussed in subsection 4.1. Moreover, the results from the GIS
449 analysis of the energy-environmental impacts show that the whole experience is promising since it has the
450 potential to increase the local production of healthy food (e.g. organic agrochemicals free) and at the same
451 time give new value to an abandoned urban area. However, during the project several issues in terms of
452 available resources and facilities were raised, affecting also its replicability in other contexts. Therefore, to
453 preliminarily assess the economic profitability of these foodchains, start-ups' productive costs are provided in
454 subsection 4.2.

455 **4.1 Comparison with evaluations from technical literature**

456 From the examined technical literature (Borsato et al., 2018; Caputo et al., 2017; Cellura et al., 2012; Clune
457 et al., 2017; Del Borghi et al., 2018; Kulak et al., 2013; Köpke & Nemecek, 2010; Mistretta et al., 2019;
458 Nemecek et al., 2008; Quirós et al., 2014), provided values on the energy-environmental impacts of food chains
459 similar to the ones analyzed in this study have been elaborated in order to obtain the share attributable only to
460 the cultivation phase. Although literature data in some cases refer to either different case studies or average
461 values, the related energy consumptions and greenhouse gas emissions were compared with the results of the
462 study, in Figure 9. It can be noted that, in literature, cereals and legumes have the highest Non-Renewable
463 Cumulative Energy Demand values among food products. Conversely, vegetables and fruits can have Global
464 Warming Potential values greater than cereals and fruits, probably because of larger variability in the reported
465 agricultural practices. Concerning the results from this study, NR-CED of legumes are similar to literature,
466 while lower values are traced in the case of cereals, followed by vegetables and fruits. In terms of GWP, data
467 from literature are significantly higher than the data estimated in this study, possibly due to foreseen innovative
468 and low-impact food chains.

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Figure 9. Comparison among annual (NR-)CED (a) and GWP (b) by food category.

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4.2 Insights on economic feasibility of selected start-ups

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Despite the objective of the OpenAgri project is to promote the development of jobs and skills to globally improve the conditions of the involved area and not to develop activities strictly business-oriented, the analysis of the economic performances of the involved start-ups cannot be overlooked. In order to provide a first estimation of the economic feasibility of the process, costs of production for three of the five start-ups in case of scenario S1 have been collected. Costs of start-up B, which comprise all the activities on field, the transports and the processing of barley into malt, account for 1.40 €/kg; costs for start-up C for spelt, which comprises all the activities on field, accounts for 0.21 €/kg while for bread production, which comprises storage, transportation and baking, account for 4.34 €/kg; costs for start-up D, which comprise all activities required on field for setting the agroforestry system and raw transportations, accounts for 3.33 €/kg. Such costs are in some cases higher than statistics of prices at source of organic products in Italy. Average 2019 prices, from data provided by the national Institute of the agri-food trade services (ISMEA website), are: for barley of 0.23 €/kg, for spelt of 0.29 €/kg, for fruits of 1.35 €/kg and for vegetables of 0.75 €/kg. Moreover, from (Caputo et al., 2017) a wholesale price of bread of 1.01 €/kg was provided. Therefore, it can be noted that, on the one hand, the products obtained by innovative farming techniques in small farms are more targeted on highly conscious customers, while, on the other hand, methods and measures for an optimization of the food chains in order to make them more economically sustainable should be investigated.

Moreover, it is interesting to highlight that for the start-ups producing cereals (B, and C) the main expenditure is due to farm machineries and processes (93% for barley, 80% and 69% for spelt and bread, respectively), while in the agroforestry system (start-up D) another relevant expenditure, together with farm

492 machineries and processes (58%), is represented by the supply of raw materials, i.e. (perennials and fruit) trees
493 and vegetables (39%).

494 **5 Conclusions**

495 Urban community farms can contribute to regenerate deprived urban areas, providing citizens jobs, leisure,
496 healthier diets, food and environmental education, awareness and participation.

497 Furthermore, these initiatives can help to reduce both losses in biodiversity associated with conventional
498 food production and improve the global metabolism of cities by promoting recycle and reuse practices,
499 according to the new circular economy paradigms.

500 The OpenAgri project proposes the development of local food chains in order to give value to a peri-urban
501 area, otherwise occupied by abusive activities or massive building construction. In this frame, a sample of five
502 pilot start-ups is starting the farming activities targeted on production of sustainable food and on boosting a
503 local market, both in terms of suppliers and customers.

504 Hence, as an added value, the project has avoided further conventional agri-food production.

505 In this frame, this study has been intended at integrating the Life Cycle Assessment-based evaluations on
506 energy and environmental impacts of food production within the urban regeneration processes. To that end, it
507 has also been accomplished the spatial representation of provided indicators in Geographic Information
508 System. In this way, the impacts of the implemented practices have been compared against possible
509 improvements and also against common agricultural practices, highlighting, in this last case, relevant savings
510 even in most conservative conditions.

511 As lesson learnt, first it is recommended to select suitable areas in order to prevent possible criticalities
512 related to disadvantageous field conditions (e.g. water availability, urban pollution, etc.).

513 Additionally, it is quite difficult to achieve a local chain in all steps and the five start-ups have all dealt with
514 the issue in different ways, since the choice of local products is interesting only under determined conditions.
515 Hence, based on these study findings and on a long-term perspective, the actors of the start-ups could be
516 encouraged to improve the sustainability of their agricultural practices, through the choice of renewable
517 energies-based farm machineries or more efficient practices and digital tools for the monitoring of the field
518 conditions.

519 As another remark, for obtaining a more comprehensive assessment, elaborated information should be
520 interpreted together with the ones on agronomic features and produced food nutritional content, costs of
521 investment and operation, jobs opportunities and required skills.

522 Considering the limited availability of tertiary data on any food products and the not always geographic
523 representativeness of existing LCA databases, this study also contributes to enrich technical literature with
524 new information on the energy-environmental impacts of 26 crops plus two processed products for both
525 organic and conventional scenarios.

526 In conclusion, a monitoring campaign is under development in order to update primary data and enlarge
527 the adopted system boundaries.

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