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Life Cycle Assessment Interpretation and Improvement of the Sicilian Artichokes Production

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ABSTRACT: This paper presents the results obtained from the Life Cycle Assessment (LCA) of the production of Sicilian artichokes (Cynara scolymus) with the aim of reducing impacts, interpreting the results, suggesting possible improvements and enriching the sustainability knowledge already existing in the agro food field. Artichokes represent one of the excellent Italian agricultural products even if still not well-known and not appreciated despite their nutritional and functional quality. According to FAOSTAT (2013) data, Italy is the world leader in artichokes production, grown mainly in the central and southern regions of Italy, in particular in Sicily, Apulia and Sardinia. In particular, among all the Italian regions, Sicily, which is highly suited for this type of cultivation, is ranked first in terms of quantity produced: the reason for this lies in the excellent combination of climate and geological conformation of the soils. The study was conducted in accordance with the ISO standards 14040 and 14044 (2006), with the functional unit of 1 ha of land and, as the system boundaries being the phases of: pre-implantation preparation of the field; artichoke implantation; and harvesting. The most impacting phases are those related with the consumption of fuel and fertilizers as well as with the use of the PVC pipes for irrigation. Possible improvements could be the use of methanol instead of the naphtha (reduction of the total damage of about 13%) and the possibility of recycling the PVC pipes once the field is dismantled (furthermore reduction of the damage of about 3%).

Key words: Artichokes, Environmental hotspots, Life cycle assessment, Agri-food field, Sicily

INTRODUCTION

Over the last few years, increasing concern has been raised by the industry and all the related stakeholders regarding food safety and quality as well as its sustainable production and distribution and the environmental risks and impacts due to agricultural production process (Menpel & Meyers, 2004, Roy *et al.*, 2008). In the past, traditional crop production strategies had the main goal of only realizing maximum production, paying little or no attention to the associated environmental impacts. On the contrary, modern crop production system must take into account new issues, redefining new strategies for environmental friendly consumer-oriented production. Furthermore, there is an increasing demand arising from the consumers to be informed about the environmental impacts of the agricultural production systems and activities (Menpel & Meyers, 2004).

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In the last decade, the European community has made efforts for identifying instruments useful for preventing, managing and improving the impacts related to the product's life cycle.

The Life Cycle Assessment (LCA) methodology is one of the fundamental tools for the Integrated Product Policies (IPP) and, at the same time, the main operative instrument of the "Life Cycle Thinking" (LCT) (Lo Giudice & Clasadonte 2010): it can be defined, according to the ISO standard 14040:2006, as a systematic set of procedures for identifying, quantifying and assessing the impact of the utilized materials, energy and waste released to the environmental to evaluate the impacts directly attributable to the functioning of a product, process, activity throughout its life cycle (Uvsa *et al.*, 2009, Shams Fallah *et al.*, 2013). Taking into account the food-processing field, in particular, the applications of LCA have increased because this methodology represents an appropriate tool for finding new and alternative methods of agricultural production which can reduce environmental impacts, thus increasing products sustainability (FFTC, 2007; Milà i Canals *et al.*, 2006; Lo Giudice & Mbohwa, 2012; Lo Giudice *et al.*, 2013). Furthermore it can be useful in the decision-making process for the definition of a product environmental strategy enhancing the main gaps on which a firm should concentrate on in order to add value to its future sustainability improvement and commitment regarding agriculture and food production technologies (Ruviaro *et al.*, 2012).

The extensive literature review done highlighted four main studies (FFTC 2007, Meissner Schau & Magerholm Fet, 2008, Roy *et al.*, 2009, Ruviaro *et al.*, 2012) which summarize the principal LCA studies concerning agricultural and food products realized from 1998 to 2011.

Regarding horticulture, in particular, it is important to highlight the paper of Antón (Antón, 2008) about the utility of LCA in this sector, including its achievements and constraints. Besides it:

- Mempel & Meyers (2004) used a simplified LCA for the evaluation of the environmental impacts of horticultural production system. Two production systems with different production intensities (outdoor cropping-bunched onions and radish; protected cultivation in greenhouses-tomatoes) were investigated;
- Milà i Canals et al. (2008) have developed a study concerning the application of LCA for comparing domestic vs. imported vegetables (broccoli, salad crops and green beans);
- Yoshikawa et al. (2008), whose paper, focusing on the Japanese fruit and vegetables industry (green pepper, tomato, onion, potato, lettuce, spinach, cabbage), shows that the most environmental impacts can be recognize in the production phase of the products' life cycle;
- Hofer (2009) discusses about the reduction of the environmental footprint of consumer goods by developing a series of LCA studies on fruits and vegetables (asparagus, tomato, zucchini);
- Cellura et al. (2012) evaluated the energy consumption and environmental burdens associated with the production of protected crops (tomato and cherry tomato, zucchini, pepper and melon).

The literature review has shown, also, the absence of LCA studies about the artichokes sector. In this context, the present study arises with the aim of assessing the artichokes cultivation from an environmental point of view applying the LCA methodology.

The global artichokes cultivation has a primary role in the Italian economy context, since it is, by value, the second open field horticultural crop after tomatoes (INEA, 2012). Considering the FAOSTAT data (FAOSTAT, 2013), in 2011 the world artichokes production was 1,550,000 tons: Mediterranean countries were the world leaders, accounting for almost 60% of the overall world production. In particular, for the same year, Italy, with an annual production of 500,000 tons, was ranked first, followed by Egypt and Spain. In Italy, artichokes are grown mainly in the central and southern Regions, mostly in Sicily, Apulia and Sardinia. In 2011, Sicily was the second largest Region in terms of total cultivated area (14,800 ha) after Apulia (16,530 ha). However, during the same year, artichokes production in Sicily amounted to 166,000 tons, while Apulia had a production of about 20,000 tons less than that of Sicily (ISTAT, 2013). Sicily, because of its climatic characteristics, is particularly suited to this type of cultivation. The largest productive district is located in the province of Caltanissetta (towns of Gela, Niscemi and Butera), followed by the district of the province of Agrigento (mainly in Menfi and Licata), the district of the province of Catania (mainly in Ramacca) and the district of the province of Palermo (Cerda is the most productive town) (Fig. 1). It is important to highlight that artichokes production in the triangle area of "Niscemi – Gela – Butera", because of the geology of the soil and of the climatic conditions, is considered the best in terms of quality and quantity.

Artichokes are one of the excellent Italian products even though not well appreciated by the consumers and not yet fully available on the international market due, above all, to a production chain that is not well organised when compared to other commodities. Italy boats of four varieties of this commodity which are certificated according to the European product quality scheme. In particular, there are the POD (Protected Designed Origin) variety (Carciofo spinoso di Sardegna) and the three PGI (Protected Geographical Indication) varieties (Cariofo romanesco, Carciofo tondo di Pestum and Carciofo brindisino). Furthermore, the Sicilian ones (Verde di Palermo and Violetto catanese) are worth of mention. The excellence and uniqueness of artichokes is, also, linked to their nutritional and functional qualities. In ancient times, the artichokes were renowned for medicinal properties, with activity against cholesterol, with an antineoplasica hepatoprotective function as well as diuretic and laxative action (ALSIA, 2012). The artichokes leaves, representing 10% to 20% of the whole plant's fresh weight, are chosen for medicine use because the concentration of the biologically active compounds is higher here than in the rest of the plant. The most

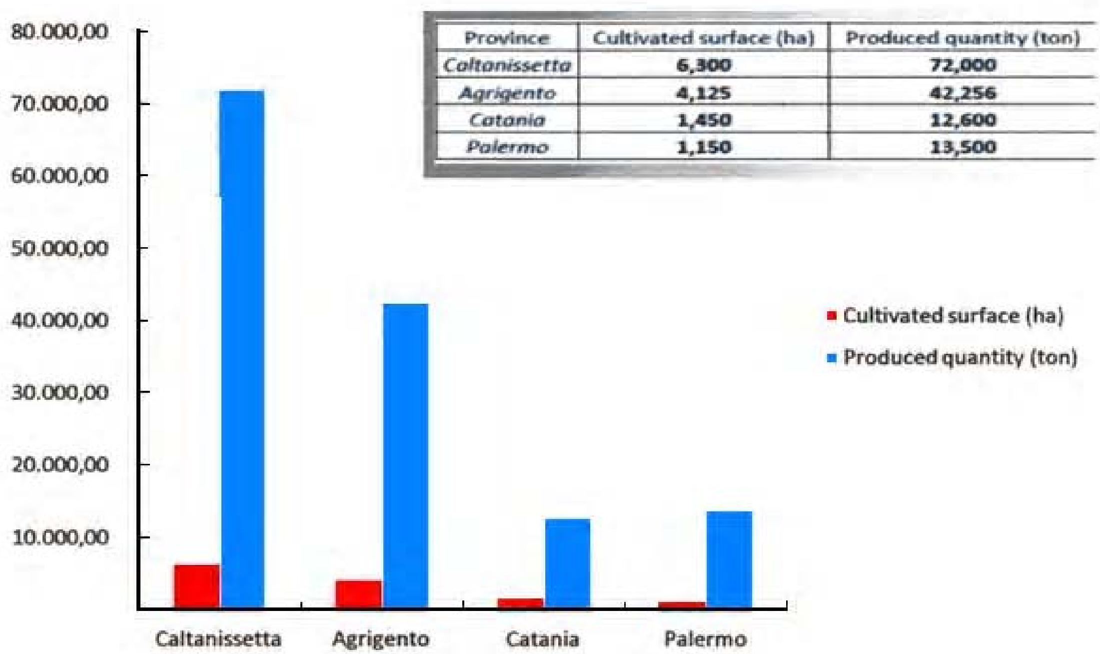

Fig. 1. Sicilian artichokes production (2011)

Table 1. Artichokes chemical composition (per 100 g)

Chemical Composition	Unit of measurement	Value in 100 g	Chemical Composition	Unit of measurement	Value in 100 g
Water	g	91.3	Iron	mg	1
Proteins	g	2.7	Calcium	mg	86
Lipids	G	0.2	Phosphorus	mg	67
Cholesterol	Mg	--	Magnesium	mg	45
Carbohydrates	G	2.5	Zinc	mg	0.95
Starch	G	0.5	Copper	mg	0.24
Soluble sugars	G	1.9	Selenium	g	--
Total fiber	G	5.5	Potassium	mg	376
Alchohol	G	--	Vitamin A (retinol eq)	g	18
Energy content	kcal	22	Vitamin C	mg	12
Sodium	Mg	133	Vitamin E	mg	0.19

active of these compounds have been discovered to be the flavonoids and caffeoylquinic acids. These substances belong to the polyphenol group and include chorogenic acid, caffeoylquinic acid derivates (cynarin is one of them), luteonin, scolymoside, and cynaroside. The plant's bud (the elongated globe shape surrounded by a series of overlapping, thick, leathery, green scales) contains an appreciable amount of proteins, minerals and vitamins. Artichokes are, also, rich in nitrogen, lipids, and carbohydrates qualifying them as a main source of energy (Table 1). They contain inulin which does not contribute to the glucose enhancement, making the artichokes a suitable food for diabetics. In addition, this crop helps to improve digestion and reduce gas formation in the intestine. They have high fibre content, which is very useful for the prevention of bowl cancer. Finally, the presence of cynarin, which characterises the flavour of the artichokes, triggers choleretic and cholagogue activity: the first stimulates the bilirubin production, whereas the second favours the elimination of bilirubin into the intestine being useful for digestive, gallbladder, and liver disorders (Lutz *et al.*, 2011).

MATERIALS & METHODS

LCA methodology is based on the requirements of the ISO standards 14040:2006 and 14044:2006 (ISO, 2006a and b) and it is divided in the following four main phases:

1.Goal and scope definition, defining the purpose of the study, the expected product of the study, system boundaries, Functional Unit (FU), and assumptions.

2.Life Cycle Inventory (LCI) analysis: this phase involves the compilation and quantification of inputs and outputs comprising data (on raw materials and energy consumption, emissions to air, water and soil, and generation of solid waste) collection and calculation. Data collection consists of the identification and quantification of the relevant input and output flows for the whole life cycle of a product;

3.Life Cycle Impact Assessment (LCIA): this is carried out on the basis of the inventory analysis results. It aims to understand and evaluate the environmental impacts based on the inventory analysis within the framework of the goal and scope of the study. In this phase, the inventory results are assigned to different impact categories based on the expected types of impact on the environment;

4.Life Cycle Interpretation (LCI): in this phase, the results from the impact assessment and the inventory analysis are analyzed. Conclusions and recommendations are established so as to be consistent with the goal and scope of the study.

The impact assessment phase was carried out including both the mandatory elements (Classification, Characterization and Damages Evaluation) and the optional ones (Normalization and Weighing), as established by the standards, in order to express the results with equivalent numerical parameters so as to be able to represent quantitatively the environmental effects of the system analysed. The environmental effects were given in quantitative measure and all the collected data, both the primary and secondary one, has been processed by the Simapro 7.1 software (SimaPro, 2006). In order to carry out the impact assessment stage, the Impact 2002+ method has been chosen for the following reasons: the set-up is more comprehensible for insiders and it is also more accessible compared to other methods. It also presents the following advantages: it calculates the non-renewable energy consumption which, in the agricultural sector, represents a fundamental aspect to be considered. It recognizes the carbon dioxide as having the greatest responsibility for the greenhouse effect and climate change, during characterization (Jolliet *et al.*, 2003). Impact 2002+, as any of the methods most commonly used for the LCIA phase, provides also the distinction between impact and damage categories: the first ones represent the negative effects to the environment, through which the damage, due to an emitted substance or an used resource, occurs., while the second ones are obtained by grouping the impact categories in major ones and represent the environmental compartments suffering the damage (Jolliet *et al.*, 2003).

RESULTS & DISCUSSIONS

LCA study must, necessarily, be preceded by an explicit statement of the study's aim and scope which, in accordance with the ISO Standard 14040 :2006, must be clearly defined and be consistent with the intended application (Baldo *et al.*, 2008). The goal of LCA must state unambiguously what the intended application, the motivation to conduct the study and the type of audience that is targeted are. In this context, the present work arises with the aim of applying the LCA methodology for identifying and analysing the main environmental impacts associated to the artichokes cultivation. Also, possible improvement solutions for reducing the total damage have been proposed. Although it regards a specific case, this study is intended to be of sufficient detail and quality to provide a useful contribution to the LCA approach. Its results as well as the input data, can be used for developing comparisons with any similar cases and studies.

Once analyzed in details the examined production system, a flow chart, indicating how processes of the product system are interconnected through commodity flows, was created (Fig. 2).

The chosen system boundaries include the following phases: pre-plant field preparation; artichoke planting; artichoke harvesting. Furthermore, in order to provide a reference for linking all input and output data and assuring the results comparability, a functional unit of the study has been identified: in particular, in this case, 1 ha of cultivated land has been chosen.

The Life Cycle Inventory (LCI) analysis phase, in which the degree of detail affects the reliability of the final results and the relevance of any proposal of environmental performance improvement, quantifies the use of resources and energy and environmental releases associated with the system being evaluated. An inventory should provide sufficient guarantees of reliability by performing data collection in accordance with a well-defined code, in order to allow comparisons with the existing literature data. This procedure leads to the time optimization in the later phases, as it avoids continuous addictions of data and corrections of the already collected one (Rebitzer *et al.*, 2004). Below, the main processes associated with the cultivation of artichokes have been described concisely but as comprehensively as possible.

The "Pre-plant field preparation" phase needs, first of all, of "stumping" which consists in the elimination

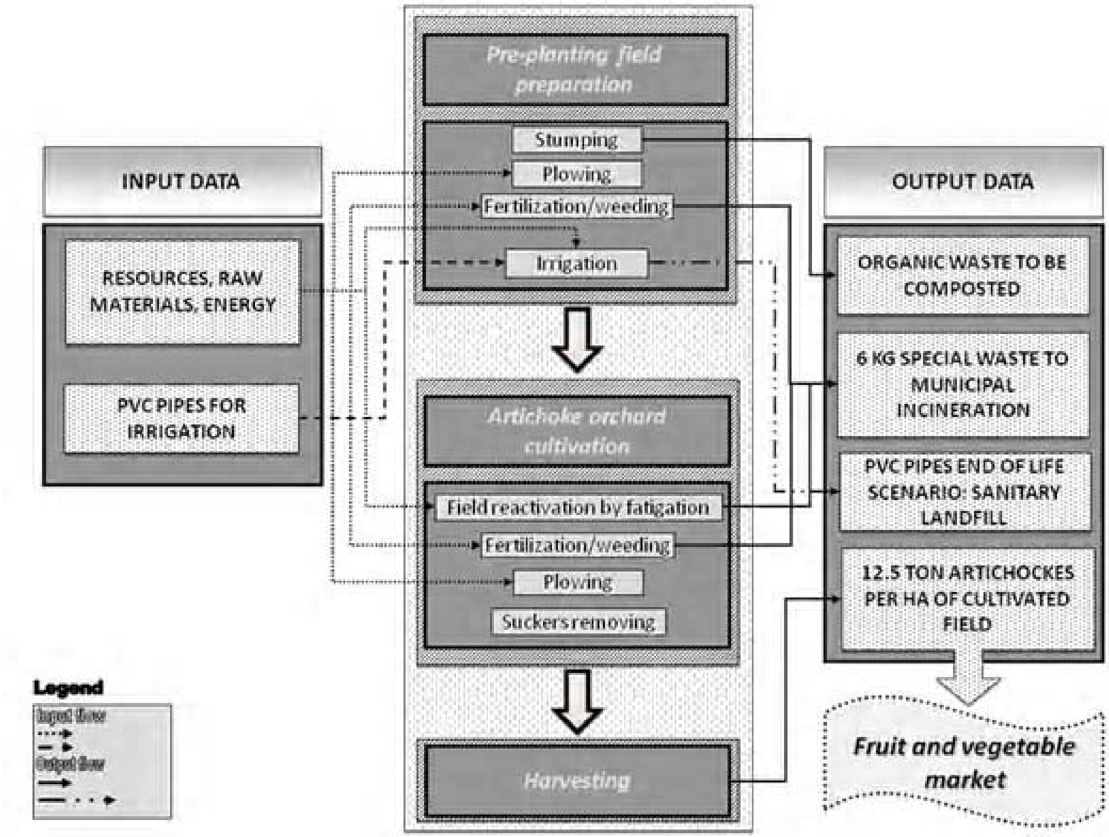

Fig. 2. System boundaries

of the stems that have produced the buds: the collected bulbs are, so, cleaned, stratified in the sand and let to pre-sprout in warm humidity, watering them for 4-5 days, 1-2 times a day.

In July, after an organic fertilizing treatment done with a cultivator, it is necessary to plant into the soil (30 - 40 cm of depth) the bulbs along the rows, together with the shredded above - ground parts of the plants obtained during the stumping phase. Irrigation is done with PVC tubes distributed along the rows. The "Artichokes planting" phase includes the phases of reactivation of the field by fertigation, fertilization, weed management, irrigation and "suckers removing" which is done till the first harvest because, after it, suckers do not grow anymore. The "Harvesting" phase, which occurs between November and April, is done by hand for 20-25 times; then it will be necessary to transport the harvest to the fresh market. After the last harvest, the field is cleared, the irrigation system is dismantled and the waste materials are taken to an adequate waste plant.

For this study, the inventory data were collected from various sources, trying to guarantee the same quality and are listed in Table 2 and Table 3. The most of the data were collected from people working in the sector. It was thus possible to measure the quantity of fertilizers, water and plant protection products used and to know exactly which methods of cultivation were used. Furthermore, it was possible to estimate the consumption of fuel and electricity. Ecoinvent database was also used for assessing the impact of fertilizers and pesticides-production and fuel production and it was necessary to create data for the PVC pipes life cycle because it does not exist in the software used for the analysis, choosing 1 kg of PVC pipes as the functional unit.

Inventory data on the amount of energy and materials entering the system under examination were verified by expertise in terms of quality and reliability. The data which were not possible to be directly collected were integrated from with literature or collected from databases of recognized scientific value and importance. This type of data were first evaluated by experts in terms of quality and reliability and then appropriately matched to the data collected in the field.

Table 2. Input data LCA 1 ha of cultivated field

Functional Unit (F. U.)	**1**	ha	The F. U., 1 ha of cultivated field, which the following data is referred to, corresponds to 12.5 ton of produced and collected artichokes
Input flow	**Physic amount**	**Measure unit**	**Comment**
		Resources	
Water, process, well, in ground	**3,000**	ton	
Occupation, permanent crop	**1**	ha*a	
Transformation, from pasture and meadow	**1**	ha	
Transformation, to permanent crop	**1**	ha	
Manure	**13.33**	ton	
			Raw materials and fossil fuels
Ammonium nitrate, as N, at regional storehouse	**53**	kg	
Calcium nitrate, as N, at regional storehouse	**30**	kg	
Urea, as N, at regional storehouse	**92**	kg	
Potassium nitrate, as K_2O, at regional storehouse	**44**	kg	
Potassium nitrate, as N, at regional storehouse	**13**	kg	
Single superphosphate, as P_2O_5, at regional storehouse	**160**	kg	
Potassium sulphate, as K_2O, at regional storehouse	**100**	kg	
Glyphosate, at regional storehouse	**4**	kg	
Linuron, at regional storehouse	**1.5**	kg	
Pesticide unspecified, at regional storehouse	**50.70**	g	
Naphtha, at refinery	**875.65**	kg	All processes on the refinery site excluding the emissions from combustion facilities, including waste water treatment, process emissions and direct discharges to rivers.
PVC pipes	**107**	kg	The PVC pipes production has been represented in another file, choosing 1 kg of pipes as F.U. 5% of scrap has been taken into account. The value shown alongside, concerning every year amount of pipes, has been provided by those who works in the sector, while the data, used for the pipes production implementation, has been taken from literature
		Transports	
Transport, lorry 7,5-16 ton, EURO 3	**13.73**	ton*km	Transport of all the raw materials used for the artichokes cultivation (Distance = 10 km)
Transport, lorry > 32 ton, EURO 3	**400**	ton*km	Transport of the manure used for the organic fertilization of the field. Distance = 30 km
Transport, lorry 16-32 ton, EURO 3	**875**	ton*km	Once collected, the artichokes are transported to the market (70 km)
	Main processes		
Solid manure loading and spreading, by hydraulic loader and spreader	**13.33**	ton	In this case, the following activities where considered part of the work process: preliminary work at the farm, like attaching the adequate machine to the tractor; transfer to field; field work; transfer to farm and concluding work, like uncoupling the machine. The diesel fuel consumption and the amount of agricultural machinery and of the shed, attributed to the manure loading and spreading, have been taken into account. In this case, literature data has been used.
Fertilization	**1**	ha	The fertilizing process has been separately represented, choosing 1 ha of field as F. U. and including, not only the tractor and the agricultural machinery, in terms of life cycle, but also the emissions in air and soil due to the cultivation phase. Average data from literature.
Pump station for irrigation	**0.000065**	p	In this case materials, transports, disposal for the infrastructure, estimation for land use have been considered
	Waste treatments		
Disposal, hazardous waste, 25% water, to hazardous waste incineration	**12**	kg	
Disposal, polyvinylchloride, 0,2% water, to sanitary landfill	**107**	g	PVC pipes end of life

Table 3. Input data LCA 1 kg PVC pipes

Functional Unit	**1**	kg	PVC pipes production
Input flow	**Physic amount**	**Measure unit**	**Comment**
Raw materials			
Polyvinylchloride, at regional storage	**1.05**	kg	Granules amount for pipes production, considering a scrap of 5%
Main processes and transports			
Extrusion PVC	**1.05**	kg	
Transport, lorry 16-32 ton, EURO 4	**1,800**	kg*Km	Transport of the granule to the extrusion plant.
Waste treatments			
PVC scrap	**0.05**	kg	This scrap material is treated in a recycling plant.

Inventory data on the amount of energy and materials entering the system under examination were verified by expertise in terms of quality and reliability. The data which were not possible to be directly collected were integrated from with literature or collected from databases of recognized scientific value and importance. This type of data were first evaluated by experts in terms of quality and reliability and then appropriately matched to the data collected in the field.
Life Cycle Impact Assessment (LCIA)
It was found that the total damage corresponds to 1.29 pt and it can be attributed to the following phases:

- 32.6 % to the Naphtha consumption;
- 16.2 % to the use of P_2O_5 as fertilizer;
- 14.5 % to the use of PVC pipes for irrigation;
- 7.92 % to the use of urea;
- 6.34 % to the use of ammonium nitrate,

These were found to have the most impacts along the artichokes production life cycle. In terms of damage categories, the total damage is divided as follows:

- 43.2 % Resources;
- 33.6 % Human Health;
- 19.3 % Climate Change;
- 3.9 % Ecosystem Quality

In Table 4 each environmental damage category has been allocated a corresponding weighing point, the damages assessment value and the percentage due to the most impacting phases, while in Tables 5-8 the most impacting substances and resources have been listed for each damage category.

Fig. 3 shows a histogram in which all the artichokes life cycle phases have been associated to each impact categories. In Table 9 those with the highest damage values have been given a weighing score, a characterization value and a damage percentage due to each artichokes life cycle phase. In order to give a greater rank of detail to the developed work, a flow chart of the damages arising from all the processes characterizing the artichokes cultivation is reported in Fig. 4.

Table 4. Damage evaluation, weighing, total damage distribution (%) for each damage categories

Damage category	**Wieghing (pt)**	**Damages evaluation**		**Artichokes cultivation – Most impacting phases**				
		Value	Measure Unit	**Naphtha consumption**	**Use of single superphosphate as P_2O_5**	**Use of PVC pipes**	**Urea**	**Ammonium nitrate as N**
				Total damage distribution (%)				
Resources	0.557	8.47E4	MJ primary	54.80	9.22	9.21	7.51	3.89
Human health	0.432	0.00307	DALY	14.80	24.60	24.30	6.36	6.00
Climate change	0.248	2.46E3	Kg CO_2 eq	13.90	17.20	11.40	12.10	12.70
Ecosystem quality	0.0510	699	PDF*m^2*yr	31.90	15.60	2.87	5.24	4.82

Table 5. Most impacting output substances for Damage Category: Human Heath

HUMAN HEALTH			
Substance	Emission sector	Quantity	Measure Unit
Nitrogen oxides	Air	**8.688**	kg
Particulates <2.5 micron	Air	**962**	g
Aromatic hydrocarbons	Air	**4.84**	g
Sulphur dioxide	Air	**12.848**	g

Table 6. Most impacting output substances for Damage Category: Resources

RESOURCES		
Raw material	Quantity	Measure Unit
Oil, crude, in ground	**1.24E3**	kg
Uranium, in ground	**9.89**	g
Gas, natural, in ground	**410.268**	m^3

Table 7. Most impacting output substances for Damage Category: Climate Change

ECOSYSTEM QUALITY			
Substance	Emission sector	Quantity	Measure Unit
Zinc	Soil	**4.41**	g

Table 8. Most impacting output substances for Damage Category: Ecosystem Quality

CLIMATE CHANGE			
Substance	Emission sector	Quantity	Measure Unit
Carbon dioxide, fossil	air	**2.12E3**	kg

Table 9. Characterization, weighing and total damage distribution (%) for the most relevant impact categories

Impact category	**Weighing (pt)**	**Characterization**		**Artichokes cultivation – Most impacting phases**				
		Value	Measure Unit	**Naphtha consumption**	**Single superphosphate as P_2O_5**	**PVC pipes**	**Urea**	**Ammonium Nitrate as N**
				Total damage distribution (%)				
Non-renewable energy	0.557	8.46 E4	MJ primary	54.90	9.20	9.22	7.51	3.89
Respiratory Inorganics	0.316	3.21	$kg_{eq}PM_{2.5}$	18.60	30.7	5.90	7.89	7.61
Global Warmimg	0.248	2.46 E3	kg_{eq} CO_2	13.90	17.20	11.40	12.1	12.70

This paper analyzes the environmental profile of the production of about 13 ton of artichokes and focuses on the critical points of the considered system. The study has pointed out that:

- the most impacting phases are those related with the consumption of fuel and fertilizers and with the use of the PVC pipes for the field irrigation;
- the most impacted damage category is the one called "Resources";
- The most significant impact categories for the environmental assessment are: Non Renewable Energy (NRE), Respiratory Inorganics (RI) e Global Warming (GW);
- In the category NRE, the main contribution (56%) is due to the Naphtha consumption phase, while, in the other two categories, the most impacting phase along the whole life cycle is the one related to the Use of

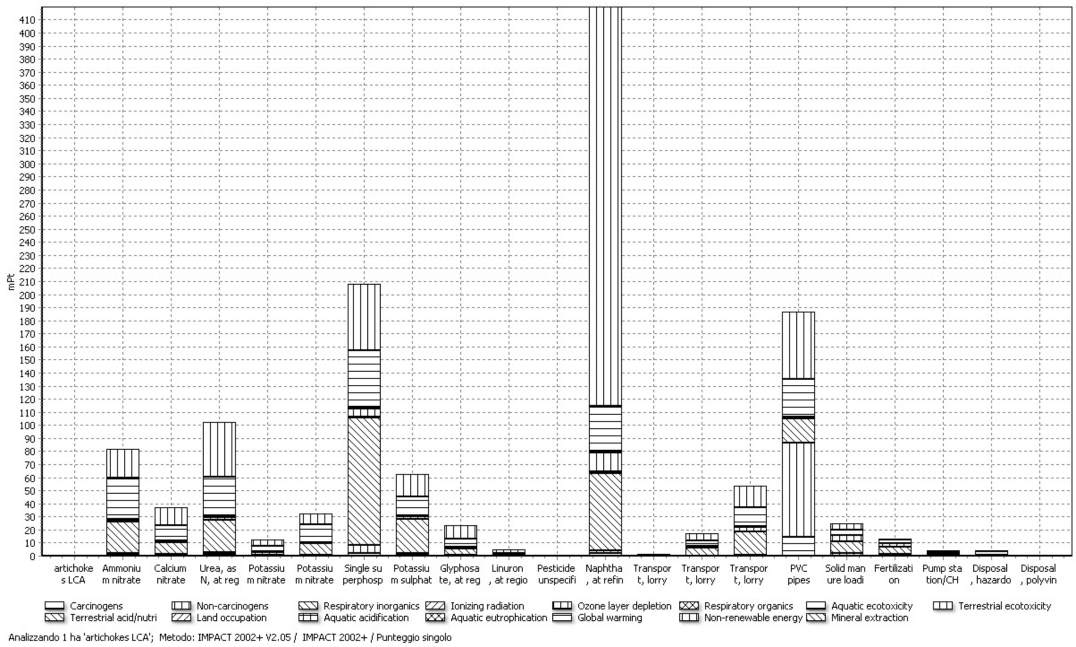

Fig. 3. Single score evaluation per Impact categories

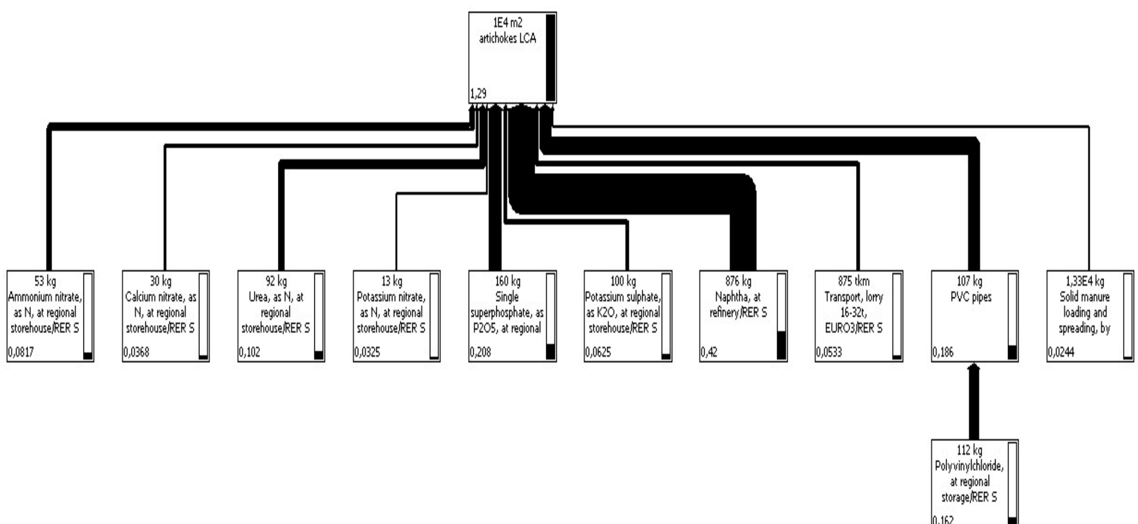

Fig. 4. Damage flows in the artichokes cultivation

single superphosphate as P2O5, contributing for 17% e 33% respectively.

It has to be noted that along the whole life cycle there is no electric energy consumption (there is no electric energy service in the area where the examined field is placed): this is the reason of the huge fuel consumption, required to operate all the mechanical equipment, including the hydraulic pump used for the irrigation phase.

Efforts to reduce the environmental impact which results from the huge naphtha consumption should concentrate on finding alternative way of powering the pump station, for example, through the use of biofuels. Efforts to reduce the environmental impact arising from the use of the PVC pipes should concentrate on the possibility of the PVC tubes recycling once the irrigation system is dismantled.

Regarding the first improvement solution, if technically possible, methanol from biogas could be used for fuelling the pump station used for the artichokes irrigation, as well as the other agriculture machineries for fertilizing and weeding As shown in Fig. 5, this solution would allow a reduction of the total damage of about 13% (from the value of 1.29 pt to 1.12 pt). The comparison has been developed considering that methanol, if compared to naphtha, has a lower calorific value (22.7 MJ/kg vs. 40.2 MJ/kg): this means that, on equal energy consumption, the amount of methanol required is greater (1.550 kg). Nevertheless, methanol can be more sustainable than naphtha.

Considering the second improvement hypothesis, the total damage is further reduced from 1.12 pt to 1.08 pt. By a proper interpretation of the graph reported in Fig. 6 it is clearly evident that the environmental impacts associated to the recycling process, from the shredding and sorting phases to the extrusion, purification and granulating are justified by the regenerated granule itself which, due to its quality, can find many applications in various sectors of the plastic industry. The process of recycling allows, in fact, avoiding not only the use, when possible, of primary raw materials, but also the environmental impact due to their production.

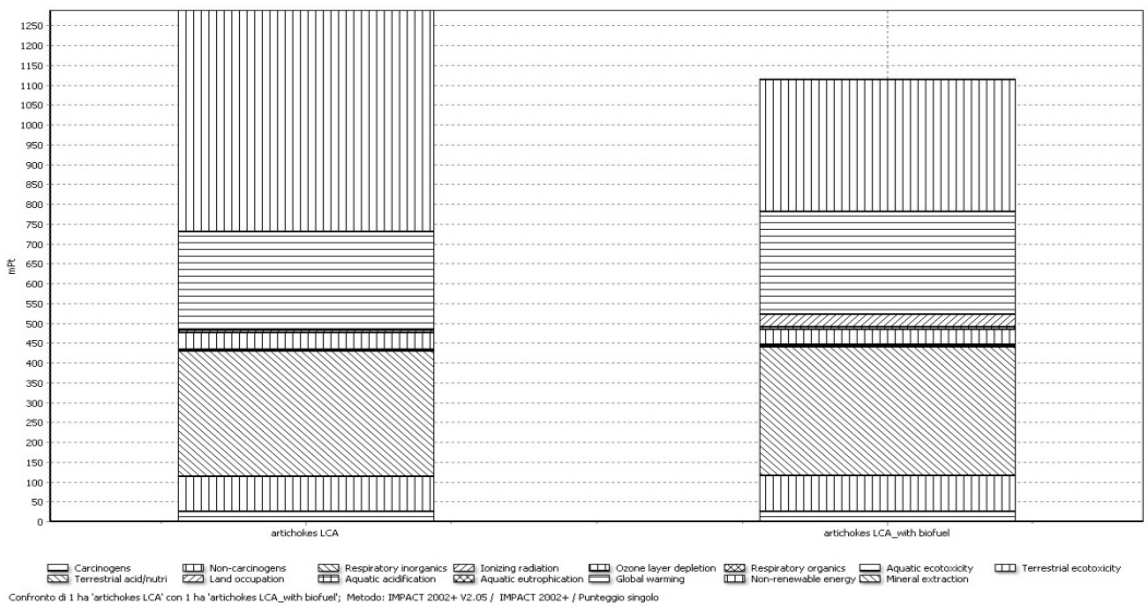

Fig. 5. Single score evaluation artichokes LCA: fuel vs. biofuel

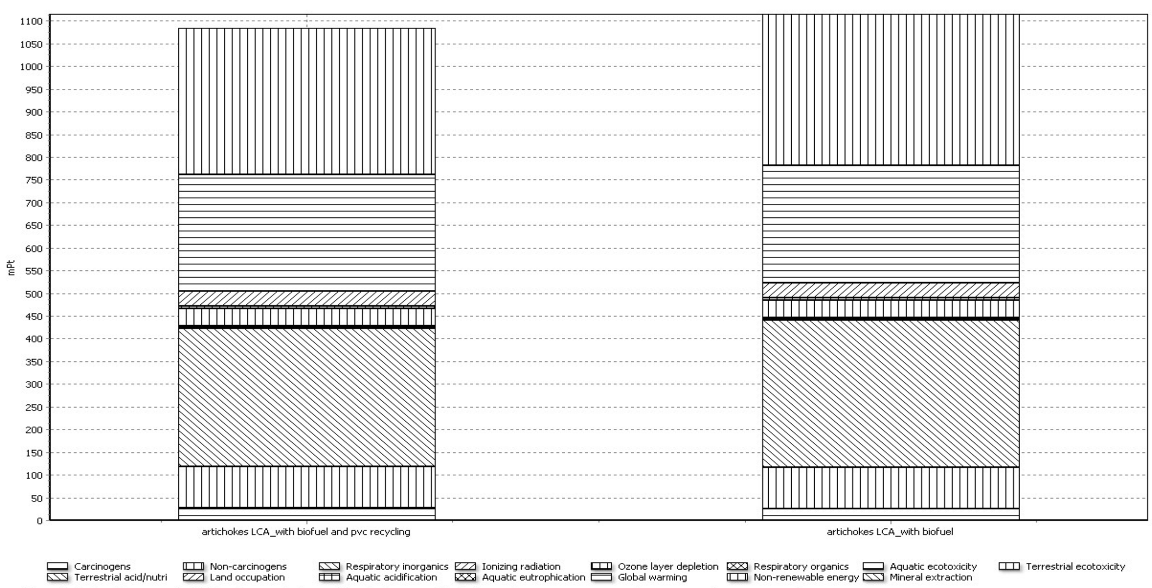

Fig. 6. Single score evaluation artichokes LCA: biofuel and PVC recycling vs. biofuel

CONCLUSION

LCA represents a popular tool for evaluating the environmental impact and the use of resources in food production and distribution systems; furthermore, on the basis of the obtained results it allows to evaluate possible improvements in the production methodology. In this context, the analysis presented has highlighted the environmental hot spots, linked to the artichokes production life cycle, painting a picture of their environmental performance. Following a life cycle approach, it was assessed the environmental impacts deriving from the artichokes production, in order to identify the most significant issues and to suggest suitable options that reduce the environmental impacts of the production system. The study highlighted that the most of the environmental impacts can be attributed to the consumption of naphtha and fertilizers and to the use of PVC pipes. Considering these results, improvement hypothesis were done: efforts to reduce the environmental impact which results from the huge naphtha consumption should concentrate on finding alternative way of powering the pump station, for example, through the use of biofuels. Efforts to reduce the environmental impact arising from the use of the PVC pipes should concentrate on the possibility of the PVC tubes recycling once the irrigation system is dismantled. In both cases, new assessments were done to quantify the reduction of the environmental impact.

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