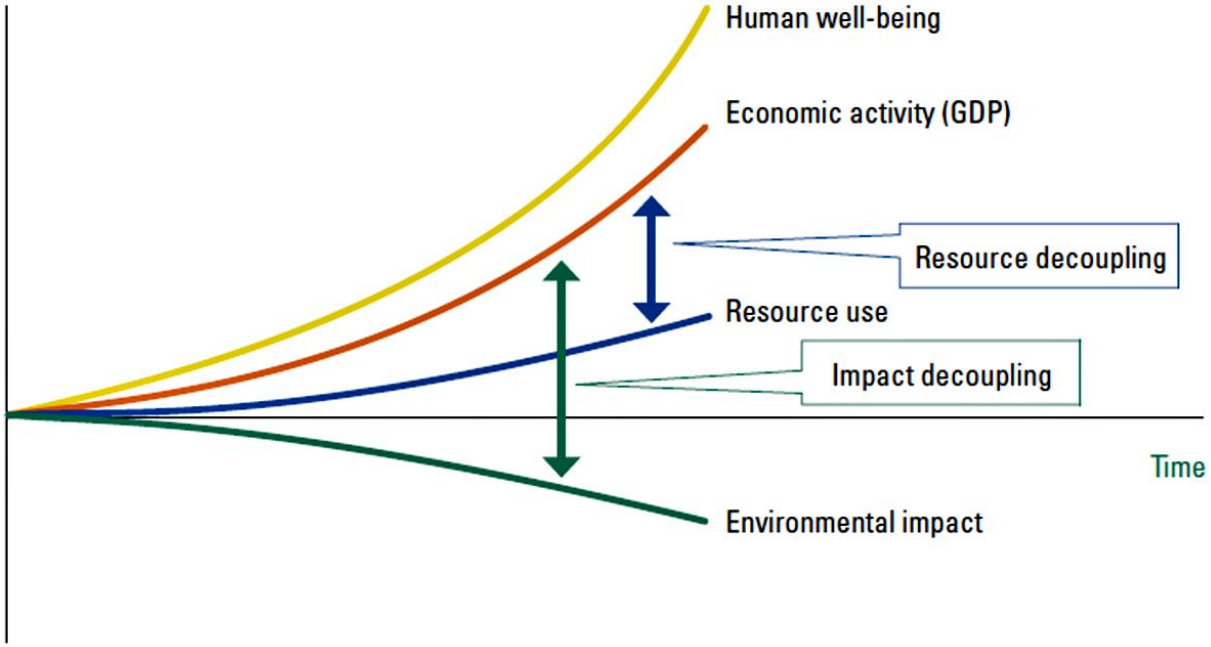
Ibimet
ISTITUTO DI BIOMETEOROLOGIA
Consiglio Nazionale delle Ricerche

DEALING WITH THE ENVIRONMENTAL CHARACTERISATION OF THE MEDITERRANEAN AGRI-FOOD SUPPLY CHAINS: THE CNR-IBIMET EXPERIENCE IN LCA APPLICATIONS

Enrico Vagnoni, Laura Sanna,
Pasquale Arca, Elena Campus and Pierpaolo Duce

Workshop "Area della Ricerca di Sassari: Ricerca Scientifica e Sviluppo del Territorio"
20 settembre 2018

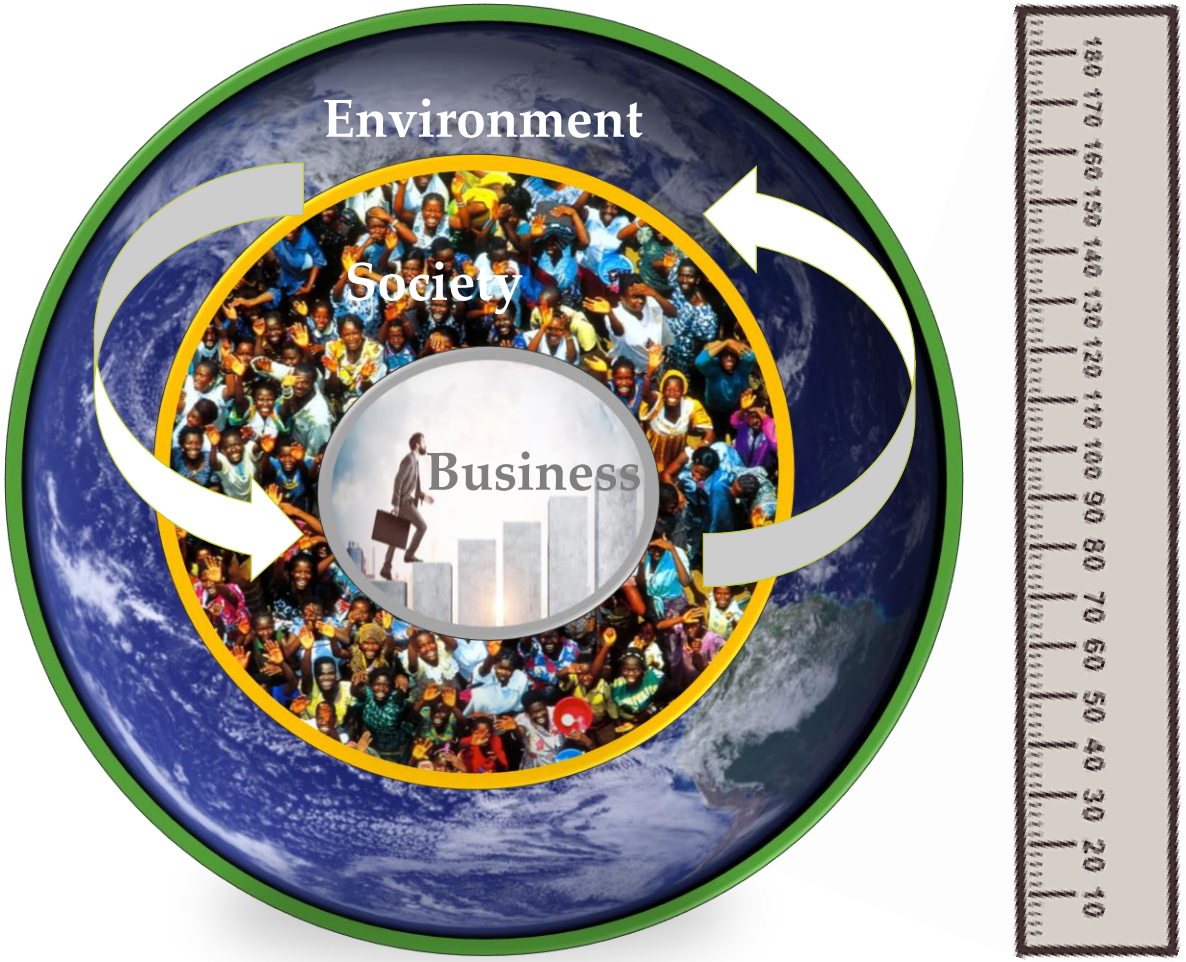
Why an LCA approach?



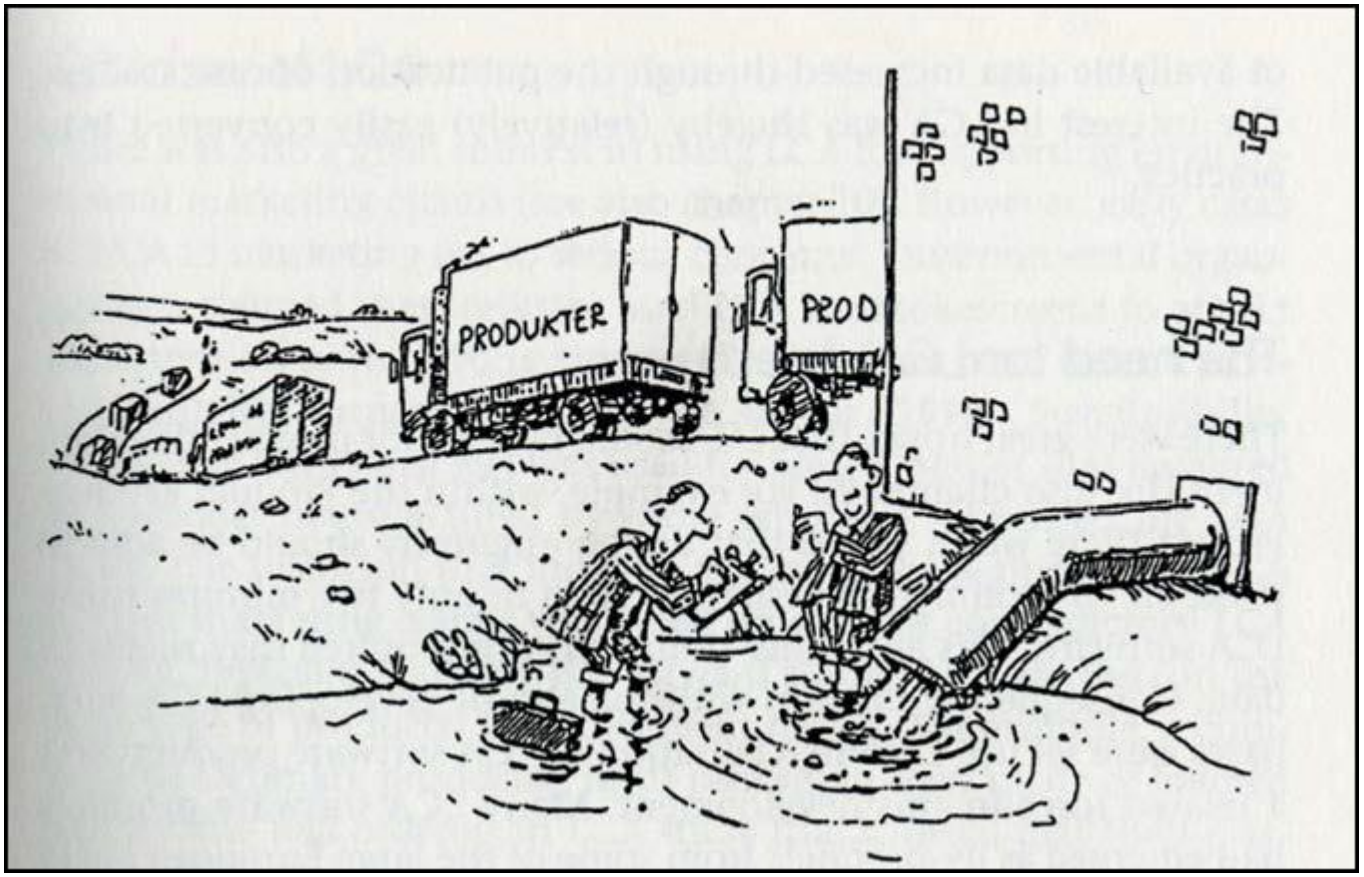
from: Decoupling Natural Resource Use and Environmental Impacts from Economic Growth
2011 UNEP International Resource Panel Report

Decoupling economic growth from resource consumption and environmental impacts

Sustainability: how much?

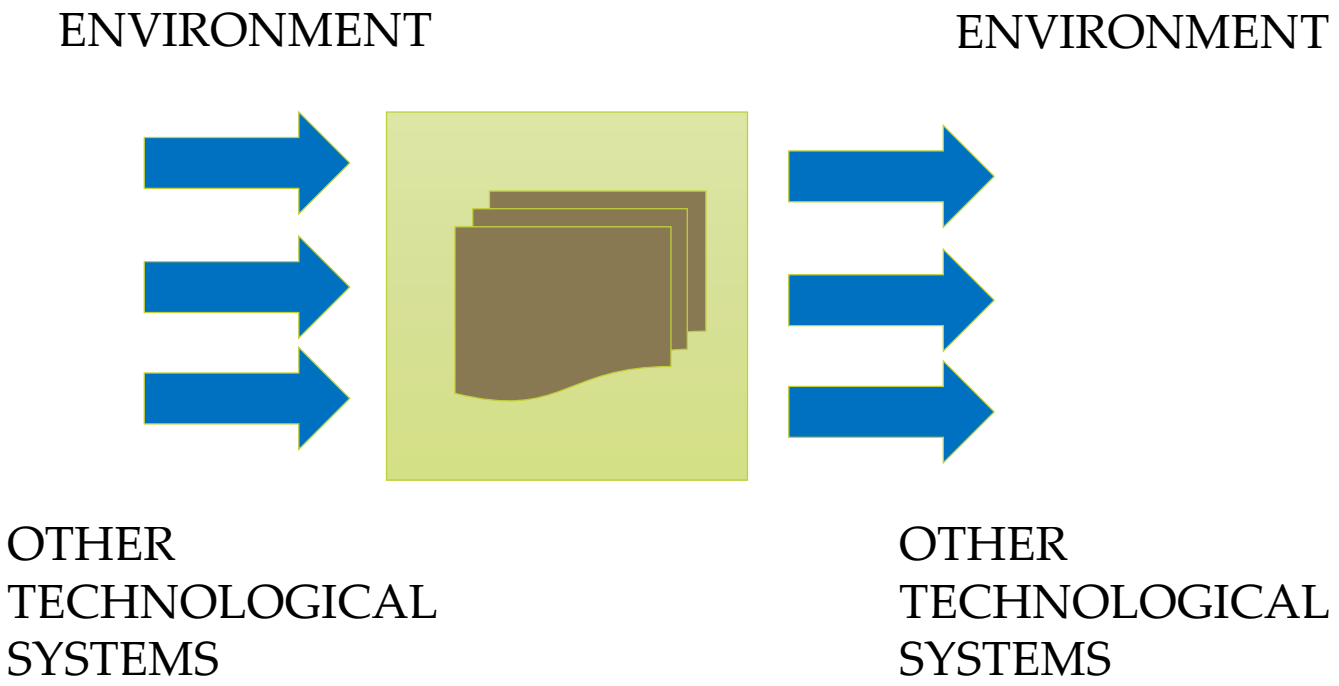


The «traditional» point of view

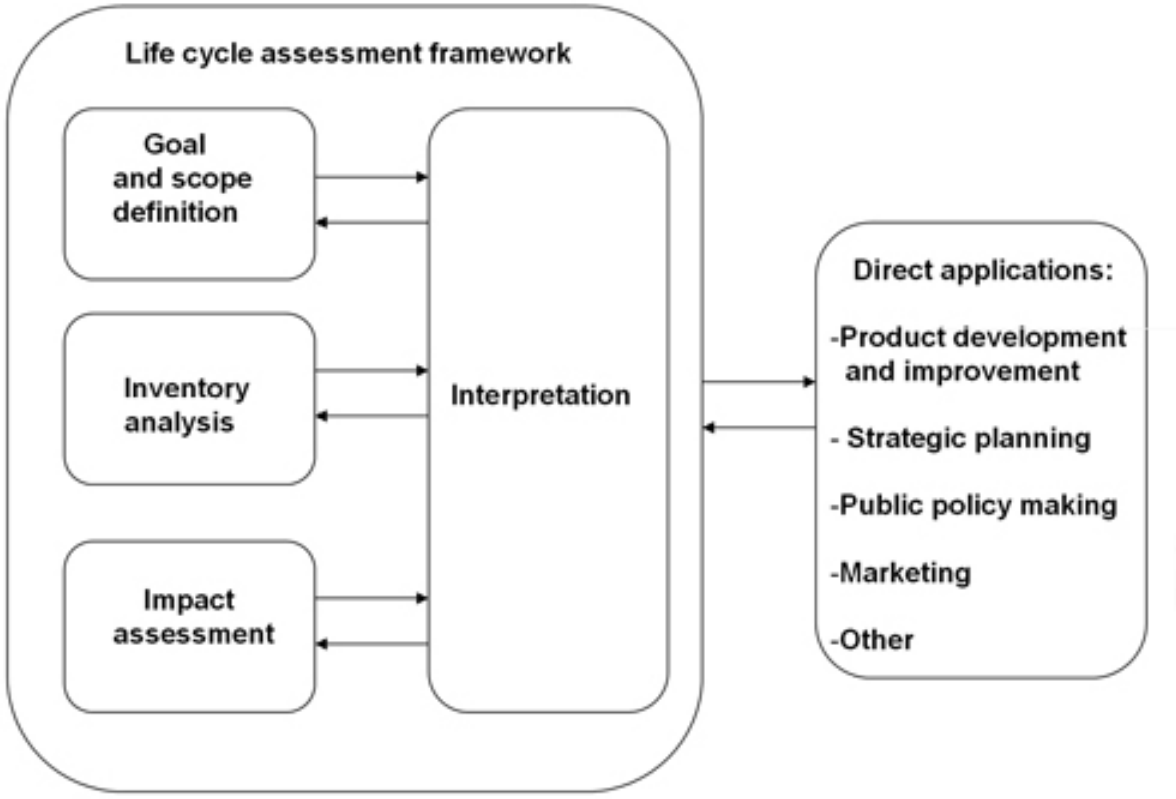


Life Cycle Assessment (LCA)

Modelling and interpreting the effect on the environment of a technological system along its whole life cycle ("from cradle to grave")



How? The ISO framework



ISO 14040/44 (2006)

Straightness

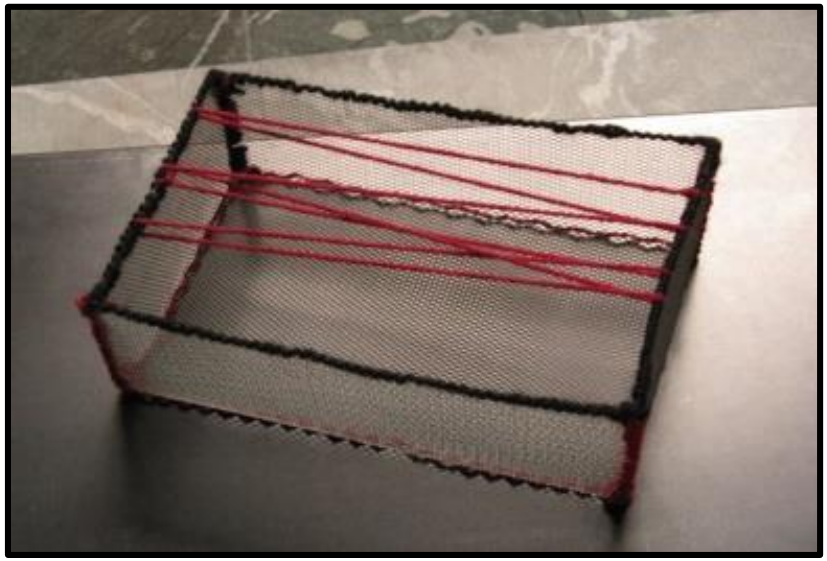
- Avoiding problems' shift among different phases/systems
- Avoiding the shift of the problems among different impact categories
- Considering the complexity
- Comparing systems with similar function

Weakness

- Space and time not modelled
- Linear model: several simplifications, not dynamic
- No experimental control of LCA results
- Time consuming

The CNR-IBIMET experience

Dealing with the sustainability web…



Medl@ine

in collaboration with

Consiglio Nazionale delle Ricerche
Istituto di Chimica Biomolecolare

ISE
Istituto per lo Studio degli Ecosistemi

The CNR-IBIMET experience

From SHEEP to SHEEP

PECUS – Pecorino Romano cheese scenario of production: qualitative, management and environmental implications

ECO-INNOVATION

CISIA – project "**Integrated knowledge for sustainability and innovation of Italian agri-food sector**" (partially funded by MEF —Ministry of Economy and Finance of Italy, Act no. 191/2009)

In collaboration with ISPAAM

LCA of the Sardinian dairy sheep supply chain

SARDINIA (Italy) is the most important EU region for sheep milk production:

- 13,000 sheep farms
- 3,2 million ewes (3.5% of EU total)
- 330,000 t year^{-1} of milk (~12% EU)

(EUROSTAT, 2012)

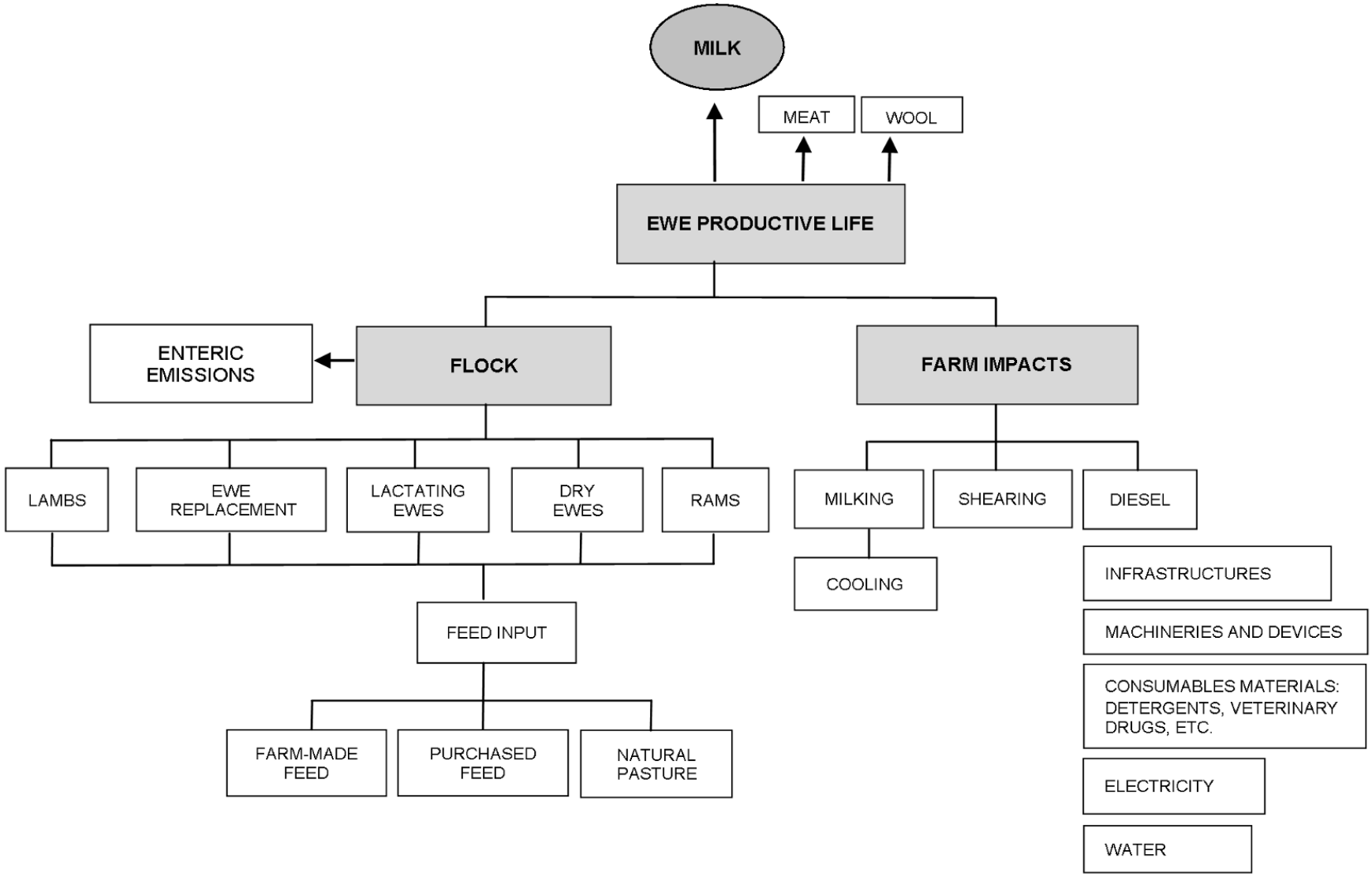


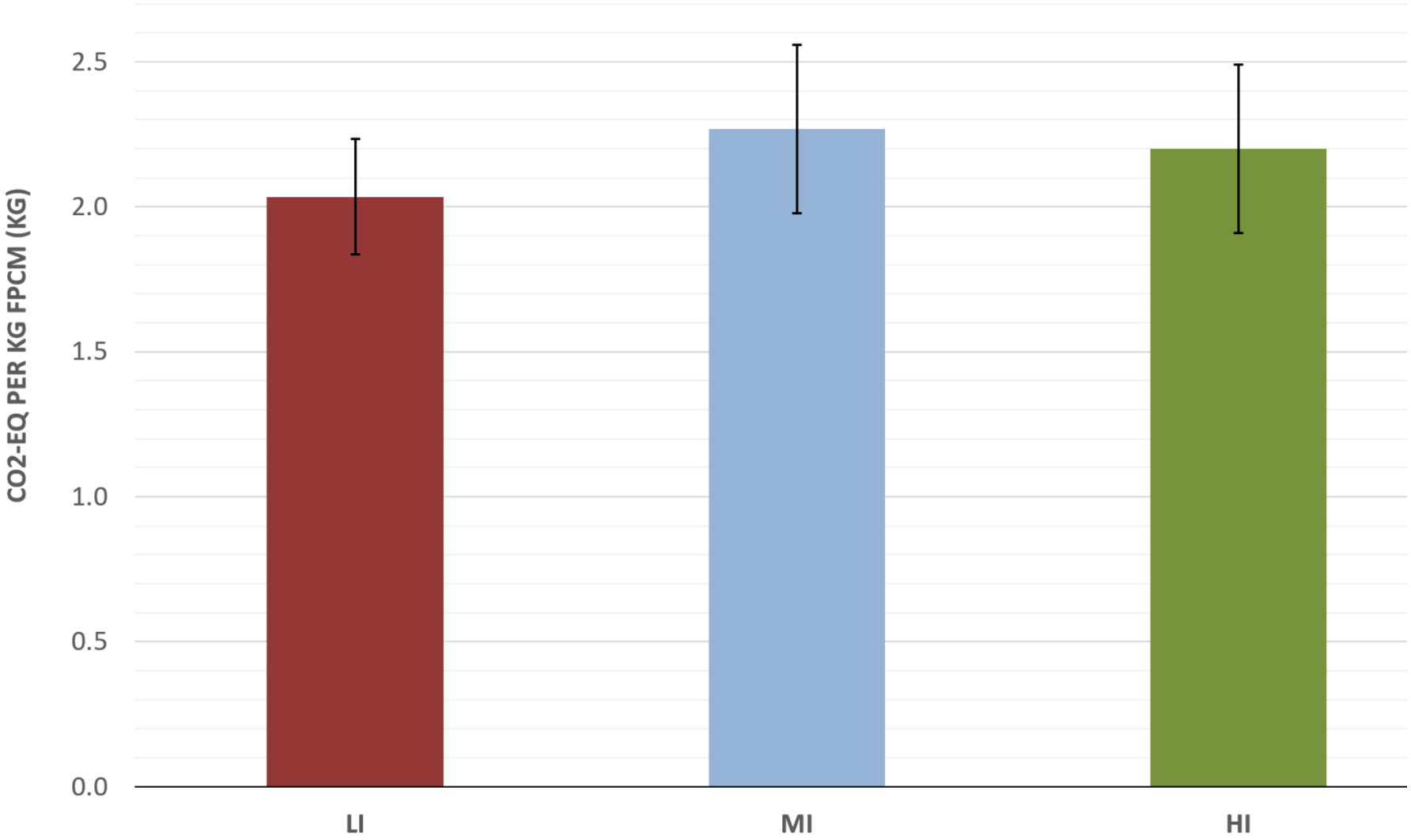
Objectives

I. Characterizing the **environmental profile** of the Sardinian dairy sheep supply chain

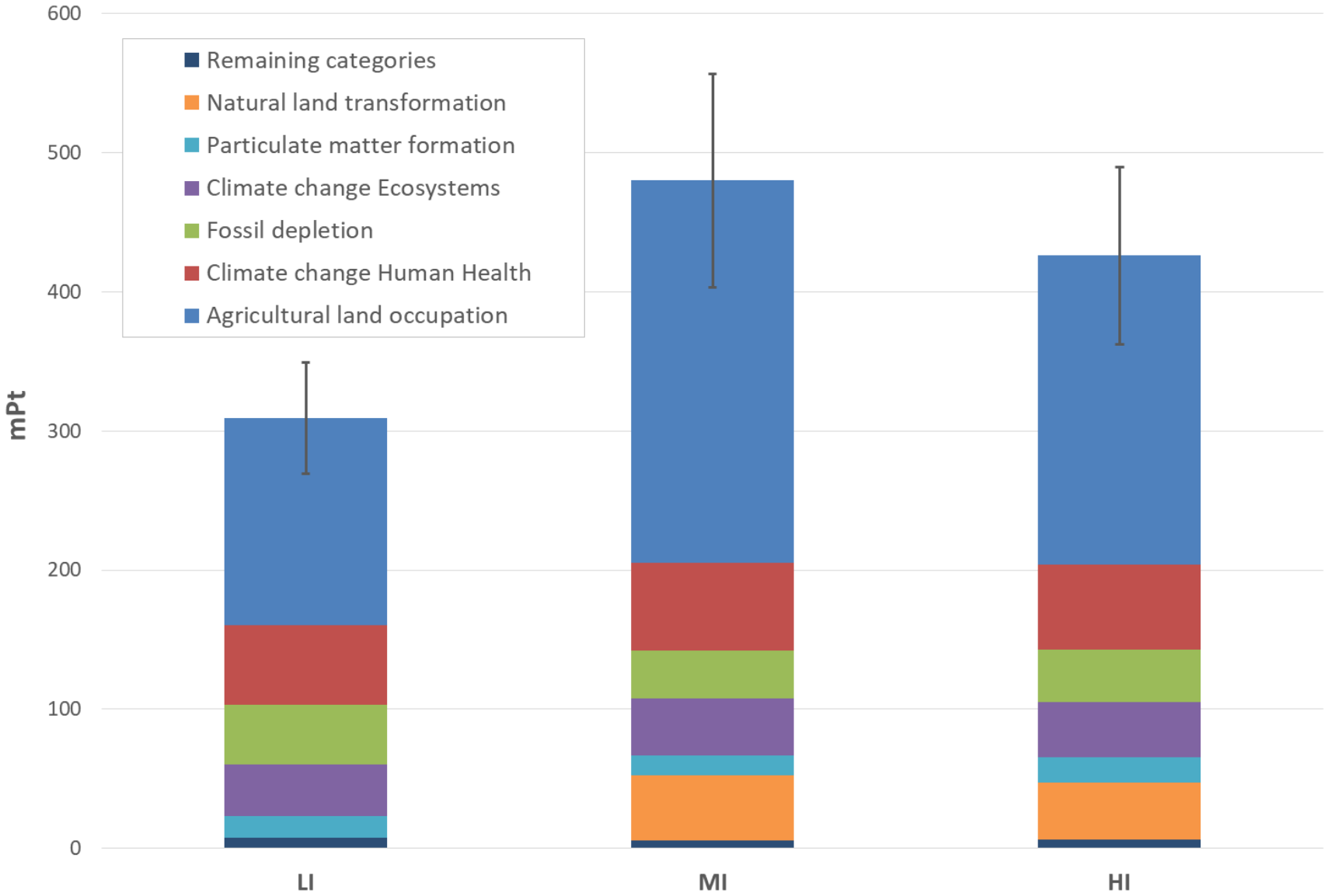
II. Evaluating the effectiveness and efficacy of **climate change mitigation actions**

Sheep milk LCA





Mean values and standard errors of the **Carbon Footprint** (IPCC, 2006) of low- (LI), mid- (MI), and high-input level (HI) farms. The functional unit (FU) is 1 kg of FPCM (Fat and Protein Corrected Milk).

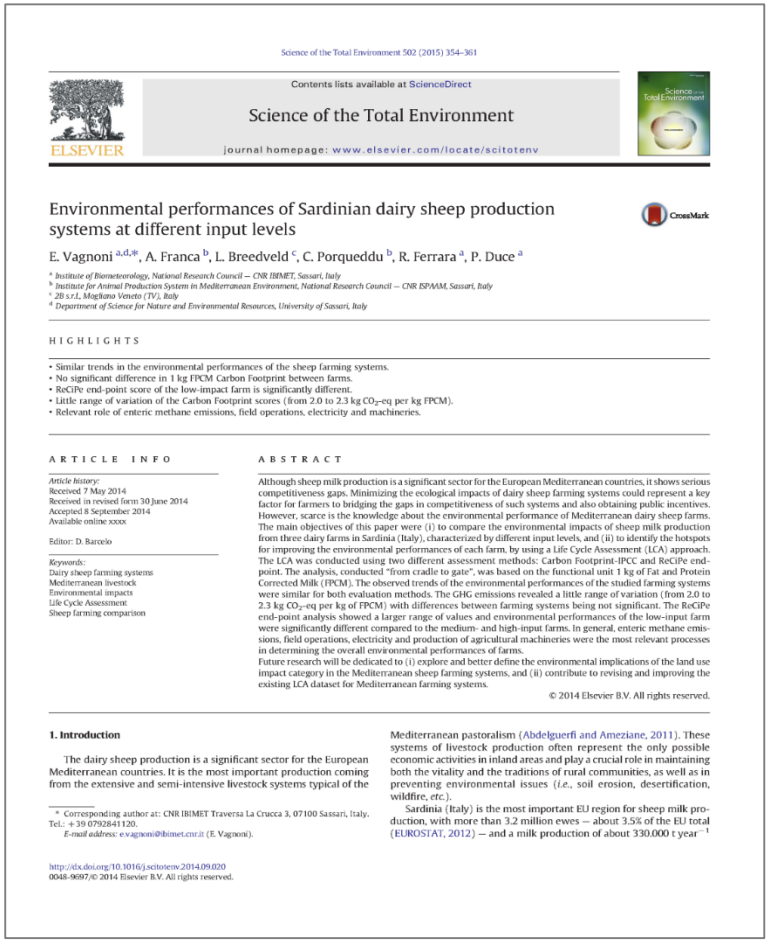


Mean values and standard errors obtained using the **ReCiPe end-point** impact assessment method for the functional unit 1 kg of FPCM for low- (LI), mid- (MI), and high-input level (HI) farms. Impact effects are expressed in milli-ecopoints (mPt). Impact categories with scores lower than 10 mPt are included in the group 'Remaining categories'.

	C_{seq} excluded		C_{seq} included	
Carbon Footrpint	SI	SE	SI	SE
kg CO_2-eq per kg FPCM	3.18	3.33	2.92	2.69
kg CO_2-eq per ha UAA	5,903	3,797	5,415	3,064
Processes contribution (%)				
Enteric CH_4 emissions	48	55	52	69
Purchased feeds	23	29	25	36
On-farm feeds	14	1	15	1
Generator (diesel)	7	2	7	2
Transport (lorry and/or transoceanic freight ship)	3	6	4	7
Infrastructures	1	0	1	0
Tractor and agricultural machinery production	0	3	1	4
C sequestration	0	0	-9	-24
Remaining processes	4	4	4	5

Carbon Footprint and percentage of contribution processes to the total GHG emissions of semi-intensive (SI) and semi-extensive (SE) production systems, calculated including and excluding **soil C sequestration** (Cseq), for both 1 kg of Fat and Protein Corrected Milk (FPCM) and 1 ha of Utilised Agricultural Area (UAA) as functional units. "Remaining processes" all processes with a percentage contribution lower than 0.35%.

For more information



Science of the Total Environment 502 (2015) 354–361

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Environmental performances of Sardinian dairy sheep production systems at different input levels

E. Vagnoni [a,d,*], A. Franca [b], L. Breedveld [c], C. Porqueddu [b], R. Ferrara [a], P. Duce [a]

[a] Institute of Biometeorology, National Research Council – CNR IBIMET, Sassari, Italy
[b] Institute for Animal Production System in Mediterranean Environment, National Research Council – CNR ISPAAM, Sassari, Italy
[c] 2B s.r.l., Magliano Veneto (TV), Italy
[d] Department of Science for Nature and Environmental Resources, University of Sassari, Italy

HIGHLIGHTS

- Similar trends in the environmental performances of the sheep farming systems.
- No significant difference in 1 kg FPCM Carbon Footprint between farms.
- ReCiPe end-point score of the low-impact farm is significantly different.
- Little range of variation of the Carbon Footprint scores (from 2.0 to 2.3 kg CO_2-eq per kg FPCM).
- Relevant role of enteric methane emissions, field operations, electricity and machineries.

ARTICLE INFO

Article history:
Received 7 May 2014
Received in revised form 30 June 2014
Accepted 8 September 2014
Available online xxxx

Editor: D. Barceló

Keywords:
Dairy sheep farming systems
Mediterranean livestock
Environmental impacts
Life Cycle Assessment
Sheep farming comparison

ABSTRACT

Although sheep milk production is a significant sector for the European Mediterranean countries, it shows serious competitiveness gaps. Minimizing the ecological impacts of dairy sheep farming systems could represent a key factor for farmers to bridging the gaps in competitiveness of such systems and also obtaining public incentives. However, scarce is the knowledge about the environmental performance of Mediterranean dairy sheep farms. The main objectives of this paper were (i) to compare the environmental impacts of sheep milk production from three dairy farms in Sardinia (Italy), characterized by different input levels, and (ii) to identify the hotspots for improving the environmental performances of each farm, by using a Life Cycle Assessment (LCA) approach. The LCA was conducted using two different assessment methods: Carbon Footprint-IPCC and ReCiPe end-point. The analysis, conducted "from cradle to gate", was based on the functional unit 1 kg of Fat and Protein Corrected Milk (FPCM). The observed trends of the environmental performances of the studied farming systems were similar for both evaluation methods. The GHG emissions revealed a little range of variation (from 2.0 to 2.3 kg CO_2-eq per kg of FPCM) with differences between farming systems being not significant. The ReCiPe end-point analysis showed a larger range of values and environmental performances of the low-input farm were significantly different compared to the medium- and high-input farms. In general, enteric methane emissions, field operations, electricity and production of agricultural machineries were the most relevant processes in determining the overall environmental performances of farms.
Future research will be dedicated to (i) explore and better define the environmental implications of the land use impact category in the Mediterranean sheep farming systems, and (ii) contribute to revising and improving the existing LCA dataset for Mediterranean farming systems.

1. Introduction

The dairy sheep production is a significant sector for the European Mediterranean countries. It is the most important production coming from the extensive and semi-intensive livestock systems typical of the Mediterranean pastoralism (Abdelguerfi and Ameziane, 2011). These systems of livestock production often represent the only possible economic activities in inland areas and play a crucial role in maintaining both the vitality and the traditions of rural communities, as well as in preventing environmental issues (*i.e.*, soil erosion, desertification, wildfire, *etc.*).

Sardinia (Italy) is the most important EU region for sheep milk production, with more than 3.2 million ewes – about 3.5% of the EU total (EUROSTAT, 2012) – and a milk production of about 330.000 t year^{-1}

* Corresponding author at: CNR IBIMET Traversa La Crucca 3, 07100 Sassari, Italy. Tel.: +39 079284120.
E-mail address: e.vagnoni@ibimet.cnr.it (E. Vagnoni).

http://dx.doi.org/10.1016/j.scitotenv.2014.09.020
0048-9697/

Vagnoni et al., 2015 - Science of The Total Environment 502, 354–361

Small Ruminant Research 159 (2018) 62–68

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Transition among different production systems in a Sardinian dairy sheep farm: Environmental implications

Enrico Vagnoni[a], Antonello Franca[b,*]

[a] CNR—IBIMET, Institute of Biometeorology, National Research Council, Trav. La Crucca 3, Reg. Baldinca, 07100 Sassari, Italy
[b] CNR—ISPAAM, Institute for Animal Production System in Mediterranean Environment, National Research Council, Trav. La Crucca 3, Reg. Baldinca, 07100 Sassari, Italy

ARTICLE INFO

Keywords:
Dairy sheep farming systems
Environmental impacts
Life Cycle Assessment
Semi-extensive production systems

ABSTRACT

Sardinia (Italy) plays a relevant role on EU sheep milk production. In Sardinia, as well as in other Mediterranean regions, there is a range of different dairy sheep farming systems and an effective renovation process is needed to tackle the deep structural crisis of the sector. The eco-innovation of production processes and the valorisation of pasture-based livestock systems can be a key strategy to improve the farms competitiveness and to promote the environmental sustainability of the typical Mediterranean dairy sheep products. For these reasons, research studies based on holistic and site-specific approaches are needed to assess the environmental implications of Mediterranean sheep systems. The main objective of this study was to compare the environmental performances of two contrasting sheep milk production systems through a Life Cycle Assessment (LCA) approach. The LCA was carried out on a farm where changes in land use (from arable and irrigated crops to native and artificial pastures) occurred over a 10-year period, in conjunction with a reduction of total supply of mineral fertilizers. The analysis was performed using IPCC and ReCiPe methodologies, and a functional unit of 1 kg of Fat and Protein Corrected Milk (FPCM). The LCA analysis showed that the change from semi-intensive to semi-extensive production system had only a slight effect on the overall environmental performances of 1 kg FPCM, due to the dominant impact of enteric fermentation in both systems. The Carbon Footprint was on average 3.12 kg CO_2-eq per kg FPCM and the average score of the ReCiPe Endpoint was 461 mPt per kg FPCM. Methane enteric emissions and the use of imported soybean meal were identified as the main environmental hotspots.

1. Introduction

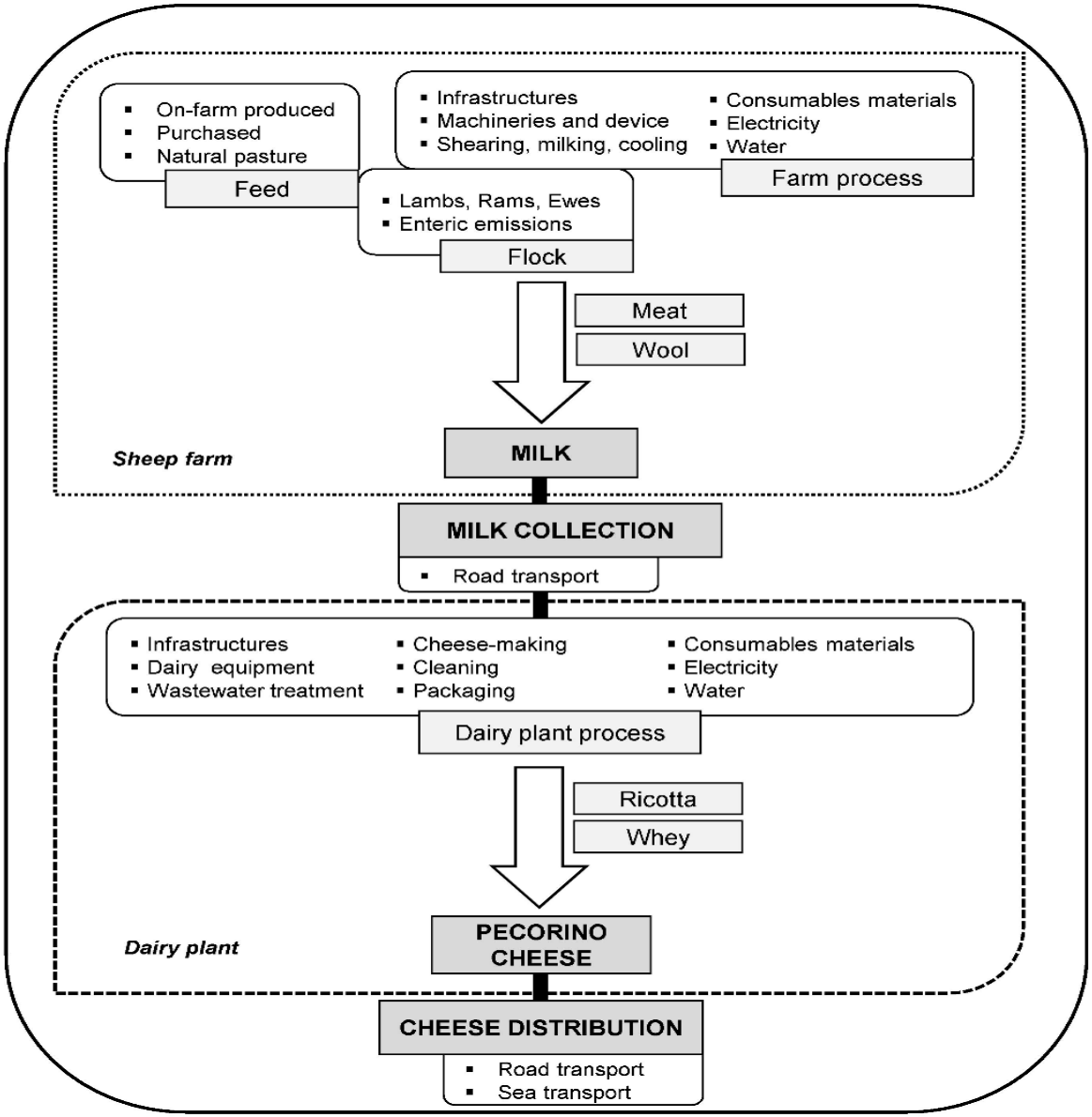
The dairy products scenario described by the last OECD-FAO (2015) baseline projection attributes to the sheep sector the most dynamic trend with an expected production increase of 23% during the period 2014–2024. Europe, with a contribution of about 35%, is the second continent in the world for sheep milk production, after Asia that contributes for about 44%. Considering the annual production of sheep milk per inhabitant in the mid-2000s, Europe is by far the world's biggest producer: 4.1 kg per inhabitant compared to an average worldwide production of 1.4 kg per inhabitant (FAOSTAT, 2014). The European sheep milk production is concentrated in Central and Southern regions (Czech and Slovak Republics, Hungary, Romania, Greece, France, Spain and Italy) where the dairy sheep farming plays a crucial role in cultural, economic and ecological terms, mainly in marginal rural areas. Structural data indicate that Sardinia (Italy) is among the leading regions for the sheep milk production: 3.2 million ewes and 14,000 dairy sheep farms (Anagrafe Nazionale Zootecnica, 2016) provide about 330,000 t year^{-1} of milk, and 201.2 kg of milk per capita (ISTAT, 2012). In fact, 25% of total EU-27 sheep milk production came from Sardinia (Rural Development Programme of Sardinia – RDP, 2014–2020). These numbers explain why the dairy sheep breeding, driven by the export of Pecorino Romano PDO cheese, represents one of the main economic sectors of Sardinia. In Sardinia, as well as in other Mediterranean regions, there is a range of different dairy sheep farming systems, with differences in land use and input and intensification levels. These differences depend on a number of factors ranging from geographical location and specific market conditions to public incentive policies and local or global market trends (Biala et al., 2007). In the 80s, programs and actions for increasing farm productivity led to the development of intensified production systems in Sardinian lowlands, where the availability of irrigation water contributed to the spread of highly-yield forage crops like maize (for silage), lucerne and hybrid forage sorghum (Fois et al., 2001). Later, when the Sardinian dairy sheep farming sector suffered a deep structural crisis due to the collapse of Pecorino Romano PDO cheese price in the early 2000s, many

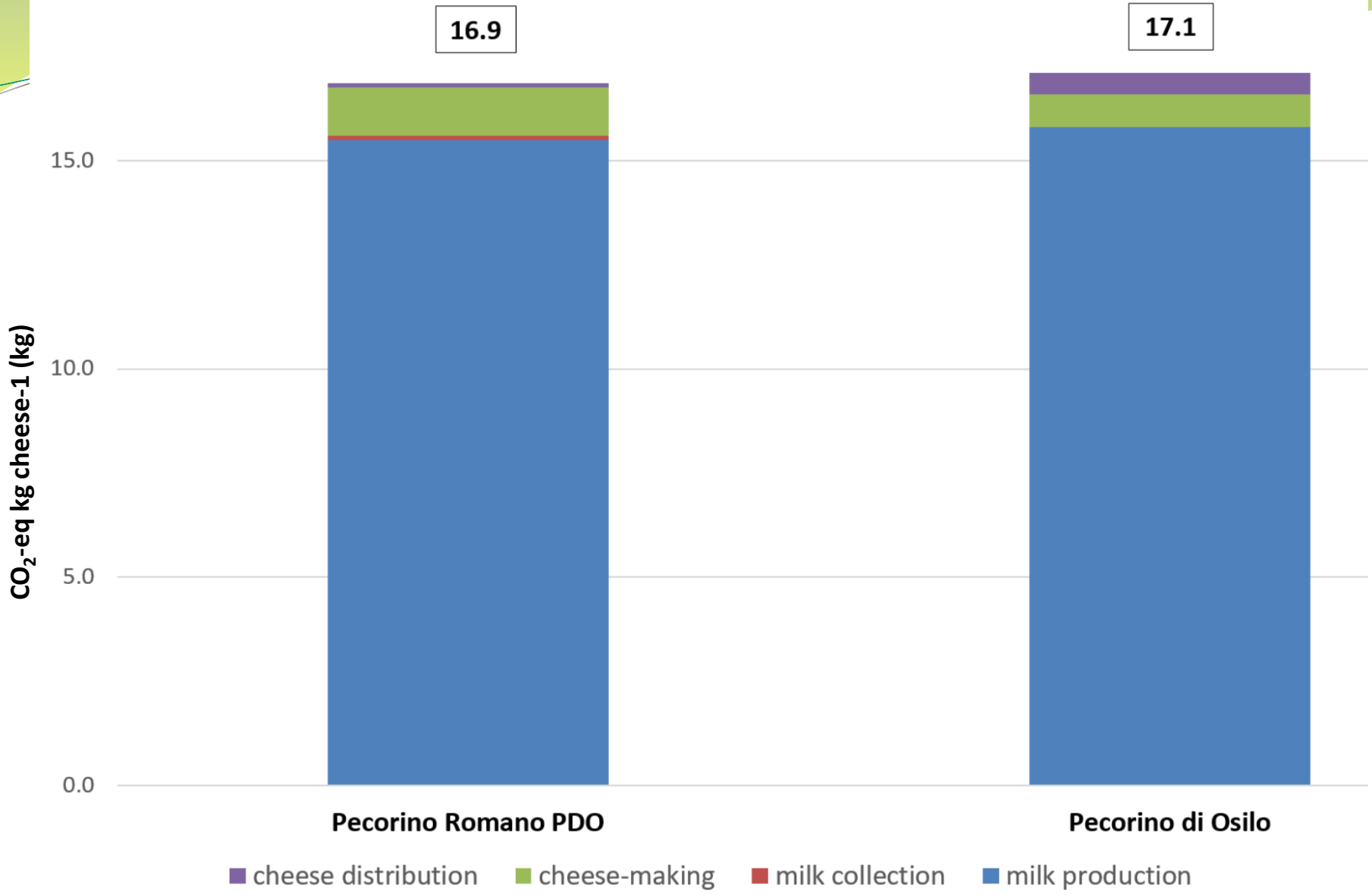
* Corresponding author.
E-mail addresses: e.vagnoni@ibimet.cnr.it (E. Vagnoni), antonio.franca@cnr.it (A. Franca).

https://doi.org/10.1016/j.smallrumres.2017.12.002
Received 28 February 2017; Received in revised form 4 December 2017; Accepted 5 December 2017
Available online 06 December 2017
0921-4488/

Vagnoni and Franca, 2018 – Small Ruminant Research 159, 62–68

Sheep cheese LCA





Carbon Footprint (kg CO_2-eq) for 1 kg of Pecorino Romano PDO and Pecorino di Osilo life cycle.

Impact category	Unit	PR	PO
Abiotic depletion (minerals)	kg Sb eq	$5.64 \cdot 10^{-5}$	$5.24 \cdot 10^{-5}$
Abiotic depletion (fossil fuels)	MJ	73.06	73.73
Ozone layer depletion (ODP)	kg CFC-11 eq	$8.41 \cdot 10^{-7}$	$7.22 \cdot 10^{-7}$
Human toxicity	kg 1,4-DB eq	10.74	4.14
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	3.59	2.58
Marine aquatic ecotoxicity	kg 1,4-DB eq	5,928	4,876
Terrestrial ecotoxicity	kg 1,4-DB eq	0.05	0.03
Photochemical oxidation	kg C_2H_4 eq	0.005	0.005
Acidification	kg SO_2 eq	0.05	0.04
Eutrophication	kg PO_4--- eq	0.04	0.05

Environmental impact results associated to the production of 1 kg of Pecorino Romano PDO (PR) and Pecorino di Osilo (PO), using the **CML-IA** evaluation method.

For more information

Journal of Cleaner Production 165 (2017) 1078–1089

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Environmental profile of Sardinian sheep milk cheese supply chain: A comparison between two contrasting dairy systems

Enrico Vagnoni [a, *], Antonello Franca [b], Claudio Porqueddu [b], Pierpaolo Duce [a]

[a] CNR - IBIMET, Institute of Biometeorology, National Research Council, Trav. La Crucca 3, 07100 Sassari, Italy
[b] CNR - ISPAAM, Institute for Animal Production System in Mediterranean Environment, National Research Council, Trav. La Crucca 3, 07100 Sassari, Italy

ARTICLE INFO

Article history:
Received 7 March 2017
Received in revised form
20 June 2017
Accepted 15 July 2017
Available online 17 July 2017

Keywords:
Sheep milk cheese
LCA
Environmental improvements
Dairy supply chain
Sheep farming systems

ABSTRACT

Despite the significant role of small ruminant sector in the global trends of livestock productions, little research has been conducted on the environmental implications of dairy sheep production systems. Dairy sheep systems are relevant for the economy of many areas of the Mediterranean Basin and the environmental and economic optimization of their productive factors is considered an effective strategy for promoting the innovation and increasing the competitiveness of Mediterranean dairy sheep systems. Therefore, scientific studies are needed in order to propose specific greening strategies and to improve the environmental performances of dairy sheep systems. The main objective of this study was to define a preliminary characterization of the environmental profile of sheep milk ("Pecorino") cheese chain in Sardinia (Italy), using a Life Cycle Assessment (LCA) approach, with the following specific goals: i) comparing the environmental impacts caused by both the artisanal and the industrial manufacturing processes of "Pecorino" cheese and ii) identifying the hotspots to reduce the environmental impacts of the Sardinian dairy sheep sector. The analysis was based on the functional unit of 1 kg of artisanal "Pecorino di Osilo" cheese, and 1 kg of the industrial manufacturing cheese "Pecorino Romano PDO" cheese. The LCA highlighted that the GHG emissions of the two cheeses were similar, with an average value equal to 17 kg CO_2-eq, largely due to enteric fermentation. The main differences between the two environmental profiles were found for human toxicity, ecotoxicity and eutrophication potential impact categories. Enteric methane emissions, feed supply chain, electricity, equipment and wastewater management seemed to be the hotspots where the environmental performances can be improved.

1. Introduction

The significant role of the animal production in the global climate change scenario has been clearly assessed by international organizations and environmental advocacy groups oriented by several scientific research on greenhouse gas (GHG) emissions of livestock sector (FAO, 2006; Galloway et al., 2010; Garnett, 2009; Gerber et al., 2013; O'Mara, 2011). In particular, the main studies have been concentrated in beef and dairy cattle systems (de Boer, 2003; de Vries et al., 2015; Soteriades et al., 2016) because of their essential function as protein food source and for their relevant contribution in global methane and nitrogen dioxide emissions. Less attention has been dedicated to the analysis of the environmental implications of sheep and goat systems despite their increasingly significance in the current and near future environmental and socio-economic dynamics. At global level, the GHG emissions of small ruminant sector account around 0.5 Gt CO_2-eq, representing 6.5% of overall livestock emissions. In particular, the enteric methane emissions from the entire world sheep population represent over 6.5% of the whole livestock sector. Moreover, correlating the total emission of CO_2-eq to the unit of protein produced, the milk and the meat produced by small ruminants (with 165 and 112 kg CO_2-eq kg^{-1} protein, respectively) represent the second and third animal products, respectively, for emission intensity (amount of GHG emitted per unit of product) (Gerber et al., 2013; Opio et al., 2013). On the other hand, the world goats and sheep population is increasing since 2001 and exceeded 2200 million heads in 2014 (+22% compared to 2000) (FAOSTAT, 2017). In addition, within the positive trend of livestock productions estimated by OECD-FAO in the Agricultural Outlook 2015-2024 (OECD-FAO, 2015), the sheep sector occupies a key position with an increase in production larger than 20% compared to the previous

* Corresponding author.
E-mail address: e.vagnoni@ibimet.cnr.it (E. Vagnoni).

http://dx.doi.org/10.1016/j.jclepro.2017.07.115
0959-6526/

Vagnoni et al., 2017 - Journal of Cleaner Production 165, 1078-1089

Feeding meta-analysis

Poore et al., 2018. **Reducing food's environmental impacts through producers and consumers**. **Science** 360, 987-992

1,530 studies, 139 authors
40,000 farms, 1,600 plants

- **-73% of GHG = consuming LI livestock products = vegetarian diet**
- **-43% of GHG = -20% consumption of oil, alcohol, sugar, supplements**
- **Clear and complete communication [PEF/OEF, 2013]**

Looking for an eco-sustainable sheep supply chain: environmental benefits and implications

With the contribution of the LIFE financial instrument of the European Union
LIFE15 CCM/IT/000123

Area of intervention: *Sardinia*

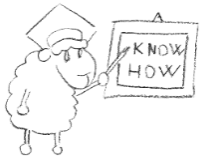
Budget: *2.610.043 € (EU contribution = 1.533.561 €)*

Duration: *4 years, from 01/07/2016 to 30/06/2020*

SheepToShip LIFE: *reducing GHG emissions improving efficiency*

Environmental impacts assessment farms and dairy plants

Guidelines/Best practices for the sheep sector



Demonstrative farms: from theory to field

Environmental Action Plan
(-20% CO_2 in 10 years)

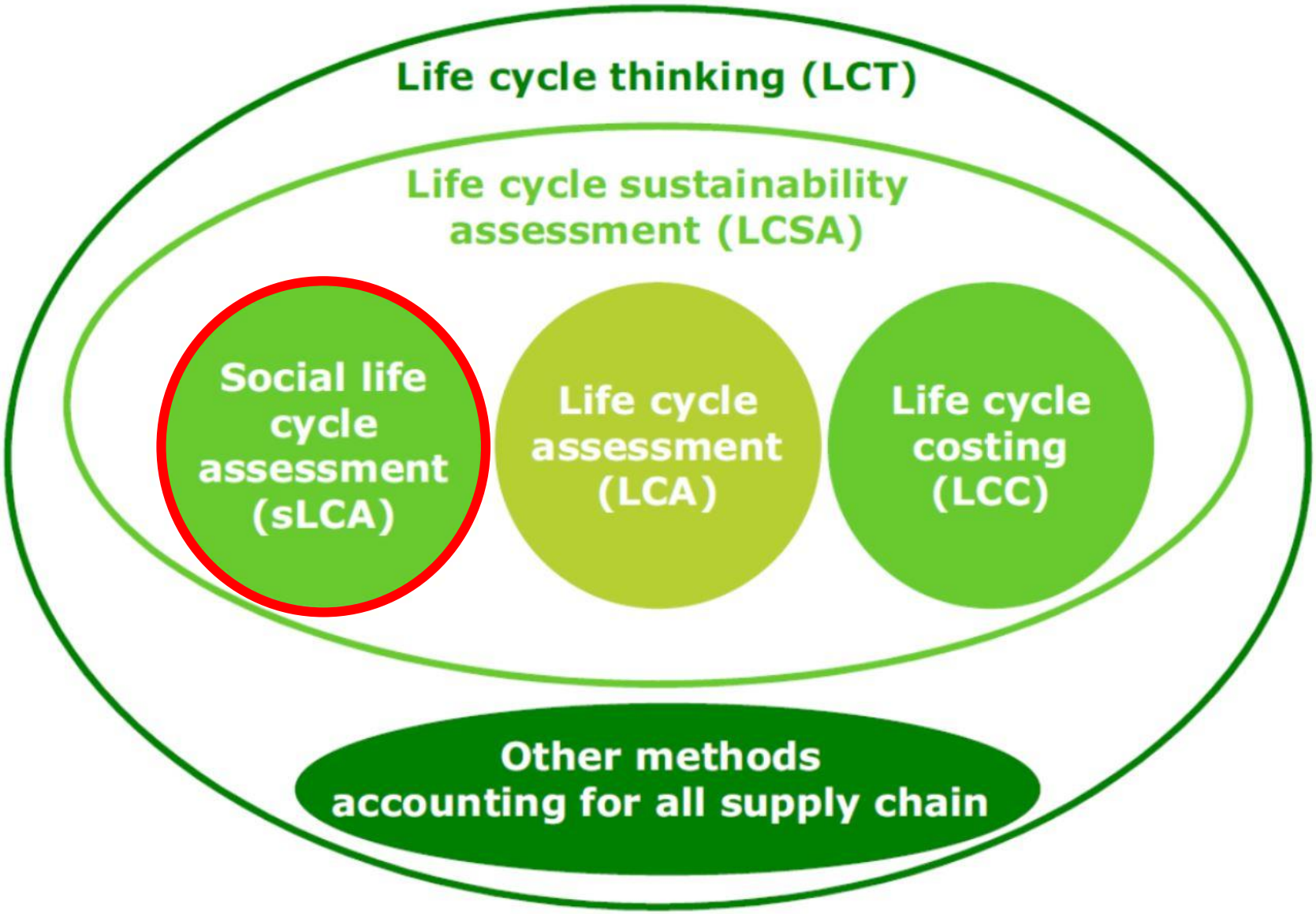
+ COMMUNICATION

The CNR-IBIMET experience

From SHEEP to WINE

GA-VINO - Methods and technologies for innovative and sustainable management of water resources in the vineyard (co-founded by POR-FESR, Sardinia 2014-2020)

The CNR-IBIMET experience



Thank you for your attention

Ibimet
ISTITUTO DI BIOMETEOROLOGIA
Consiglio Nazionale delle Ricerche