# *Giuseppe Pellizzi Prize 2018*

## [F] PhD Extended Abstract Form *(Please select the Calibri 10 typeface)*

**Application and enhancement of Life Cycle Assessment and Water Footprint approaches to agricultural machinery and cultivation**

by *Daniela Lovarelli*
University of Milan – ITALY; daniela.lovarelli@unimi.it

**Extended Abstract**

*[10000 characters max, spaces included]*

### 1. Chapter 1 - Introduction

The environmental sustainability of agricultural productions has gained wide interest worldwide. For the scientific community, understanding the behaviour of agricultural production systems on the environmental impact perspective and quantifying the environmental benefits arising from the selection of a sequence of field operations permits to identify and suggest beneficial improvements for society and future generations. Commonly, the Life Cycle Assessment (LCA) method is adopted to carry out an environmental sustainability assessment.

Although this method is widely recognised and applied to different production sectors, not much attention has been paid yet on the environmental impact assessment of agricultural mechanisation. In particular, this lack is mostly due to the difficulties in data collection of inputs and outputs. In fact, average data are usually available in the databases for environmental assessments, but few of them are present about alternative tractors and machines (i.e. commonly, only an average tractor and an average implement are given). Therefore, site specificity cannot be investigated and the resulting environmental impacts could underestimate or overestimate the effective processes. The most important variables linked to site specificity of agricultural mechanisation are pedo-climatic (e.g., soil texture and moisture, field shape and slope), logistic and work-specific (e.g., availability of tractors and implements, their dimension and mechanical characteristics, working speed, annual working time). All of them affect the environmental sustainability of agricultural machinery operations and their effect should be investigated in detail to achieve reliable assessments.

### 2. Chapter 2 – Objective

This PhD Thesis aimed to study how to make adequately reliable the life cycle inventories for performing trustworthy environmental sustainability assessments about agricultural machinery production systems. Local pedo-climatic and work-specific characteristics affect considerably both the completion of inventories and the outcomes of Life Cycle Assessment (LCA) studies. The specific aims are:

- studying the environmental impact of crops production paying attention to local pedo-climatic conditions, operating features, temporal and geographical variability and alternative mechanical solutions. This permits to quantify the environmental impact of agricultural productions and to identify the process hotspots with specific local information;
- understanding how important is the effect of local data on the environmental impact assessment compared with database average data applied in the same contexts in order to identify and try to close the gap among different data sources and to quantify correctly the environmental loads;
- improving the methodological framework for reliable modelling and data collection about field operations, in view of efficiency improvements and of the consideration of technological innovations (e.g., tractors that belong to different Emission Stages);
- developing a modelling tool that works with local pedo-climatic, temporal, geographical and mechanical variables that mostly affect the systems. In particular, a tool formerly developed is improved from its original version and the modelling of fuel consumption and engine exhaust gases emissions was performed within a specific study in which primary data were collected on field.

**3. Chapter 3 - Structure of the Thesis**

The structure of the PhD Thesis is described introducing the aims of the scientific contributions that are related to the project, and their relation. In particular, scientific papers focus on:

- the description of a tool (ENVIAM, ENVironmental Inventory of Agricultural Machinery operations) that quantifies site-specific variables for field operations to be selected,
- the application of this tool to different ploughs (i.e. mouldboard, slatted, with different number of furrows) working on fields with different soil texture and coupled with tractors of different engine power,
- the comparison of different sequences of field operations (primary plus secondary soil tillage) for seedbed preparation distinguishing soil textures and more or less refined soils in accordance with the crop to cultivate,
- the comparison on the environmental perspective of different techniques for spreading organic fertilisers, identifying the advantages and drawbacks in distributing slurry or digestate on field with superficial spreading and subsequent incorporation or with direct injection,
- the evaluation of variables collected during experimental field measurements using CANbus, GPS, data logger and exhaust gases analyser on board of a tractor during several field operations, by distinguishing each operation in effective work, turns on headlands, stops for maintenance or refilling, and transport.

**4. Chapter 4 – Background**

Specific information about the LCA approach and the methodological limits and advantages are described and discussed mainly focusing on data collection for inventory fulfilment and on the applicability of LCA results of agricultural operations. For environmental assessments about agricultural mechanisation, fuel consumption and exhaust gases emissions are prominent and, consequently, represented the focus of the PhD Thesis. Moreover, measuring emissions can be quite complex.

**5. Chapter 5 – Materials and methods**

LCA is a standardised and widely recognised approach (ISO Standards, ISO 14040-14044) through which materials and energy inputs (e.g., fuel, lubricants, fertilisers, water) and outputs (emissions of pollutants to air, soil and water) of a production system are translated into environmental impacts by means of characterisation factors. The analysis is performed from cradle-to-grave, so that the complete system is studied. In order to take into account the several effects on the environment and obtain a holistic view of the environmental impact, numerous impact categories exist, among which are included Global Warming Potential, Acidification, Marine and Freshwater Eutrophication, Ozone Layer Depletion, Mineral and Fossil Resources Depletion, etc. (ILCD Handbook, 2012).

In this context, with LCA were quantified the environmental impacts of agricultural field operations for seedbed preparation (i.e. primary and secondary soil tillage) and for organic fertilisers spreading techniques. This was done by studying the use of different machinery in different working conditions and, consequently, highlighting how different environmental outcomes can be obtained when average inventory data are used uncritically. In particular, functional units, system boundaries, life cycle inventories and characterisation methods are declared.

The alternative operations that were studied as representative of the Italian Po Valley were analysed with the tool ENVIAM (ENVironmental Inventory of Agricultural Machinery operations) and with the Simapro® software for the LCA outcomes. ENVIAM was developed to quantify inventory data considering the mechanical variability of machinery (i.e. tractors and implements), the coupling choices between tractor and implement, the organisation of working time and the local pedo-climatic variables. To deepen knowledge and improve the reliability of the inventory calculation tool, field tests on several field operations were carried out using a tractor equipped with GPS, CAN-bus, Dewesoft® data logger and Testo® emissions analyser. This allowed collecting data directly during field operations (i.e. ploughing, rotary harrowing, spring tine harrowing, sowing and rolling) and processing them within the identified work states (i.e. effective work, turns at the headlands, stops and transport).

**6. Chapter 6 – Results and discussion**

The results got from the LCA analyses of agricultural machinery operations have permitted to identify the alternatives with a more restrained environmental impact respect to others. Suggestions are made about the choice of implements with or without Power-Take-Off, type of ploughs, type of slurry tankers, best combination of engine speed and torque and their effect on fuel consumption and exhaust gases emissions for achieving environmental benefits in the defined work conditions. In particular, the machinery choice greatly influences the environmental sustainability of agricultural productions, showing that farmers play a very important role on these performances. Specifically, type of machinery, mass, annual working time, fuel and lubricating oil consumptions as well as emissions of engine exhaust gases must be carefully analysed with local variability instead of average database data. The same occurs for nutrients to air, soil and water (nitrogen and phosphorous compounds) that are deeply affected by weather and type of implements used. Moreover, considering the activity on field, the effective work resulted quite homogeneous in terms of fuel consumption and exhausts emissions, whereas turns at headlands and stops achieved the worst and unstable results. Five headlands strategies were studied, which showed different behaviours for fuel and exhausts, thus giving importance to the strategy selected by farmers during the operation.

**7. Chapter 7 – Conclusions and future research**

In conclusion, the outcomes of this PhD Thesis bring to a methodology for analysing local production systems. Assessing local variability and achieving greater reliability in the results is fundamental, especially with the huge potentiality enclosed in the LCA method that can be supported by technological instrumentation for data collection. Moreover, the achieved results can be helpful for policy makers and stakeholders to introduce policies, incentive systems and knowledge appropriate to support the environmental sustainability of agri-food systems and to spread the life cycle thinking approach.

**Final remarks concerning the competition benchmarks and strength points**

*[compulsory chapter to fill with 500 characters max, spaces included]*

The PhD Thesis is also dedicated to the Water Footprint indicator, and includes in total 7 scientific papers already published on scientific peer-reviewed journals.

A strength of this project is linked to direct field measurements for several operations, analysis of big data that gives secondary role to database, and the fact that attributing every variable to a geographical coordinate on field is very promising for identifying the most environmentally sustainable driving schemes and work issues.