EIP-AGRI Focus Group – Circular horticulture
Mini-paper – *Sustainability in circular in horticulture*

Thomas Bartzanas, Anna Vatsanidou

Introduction

Along with an increasing population, the world faces climate change, rising fossil fuel prices, ecosystem degradation, and water and land scarcity -- all of which are making today's food production methods increasingly unsustainable. The EU energy strategy (2030 Energy Strategy) calls for a 40% cut in greenhouse gas (GHG) emissions compared to 1990 levels and at least a 27% share of renewable energy consumption whereas the EU directive (EU No 406/2009/EC) for greenhouse gas emissions (GHG) forces for to at least 50 % reduction below 1990 levels by 2050. Agriculture contributes 10% of greenhouse gases, and 95% of the EU's ammonia emissions and nitrogen pollution, while agriculture practice costs the EU between 70 and 320 billion euros per year. The intensity of fertiliser use has implications for agricultural production and environmental impacts of nutrient run-off from farmland. Increased use of fertilisers concern nutrient volatilization and GHG emissions on one hand and nutrient and heavy metal leaching on the other, leading to various environmental impacts, such as climate change, air, soil and water pollution. Excessive use of nitrogen (N) and phosphorous (P) fertilisers can lead to increased nitrate and phosphate levels in water and hereby cause eutrophication (, which in turn can lead to toxic algal blooms and fish kills. N fertiliser application to crop land causes N based-emissions resulted in acidification and climate change. Mineral fertilisers are also energy and GHG intensive to produce, since their production and transport require significant amounts of fossil energy (Wood and Cowie, 2004). Limited water availability already poses a problems in many parts of Europe and the situation is likely to deteriorate further due to climate change, with Europe's high water stress areas expected to increase from 19% today to 35% by the 2070s. Although the Water Framework Directive (2000/60/EC) establishes a legal framework to protect and restore clean water across Europe and to ensure the long-term sustainable use of water the EU white paper on adaptation to climate change (COM2009 147/4) indicates that there is a need for further measures to enhance water efficiency in agriculture.

Modern agriculture has been successful in increasing food production, though it has done so at a cost of depleting the natural resources like soil, energy, water and nutrients. High- yielding crop production depends on high inputs of fertilisers, pesticides and water, and directly and

funded by European Commission

indirectly energy use which can lead in turn to increased direct and indirect on-arm and off-farm emissions into the environment as well as depletion of groundwater aquifers. Therefore, it could be argued that agricultural practices are related to several environmental issues, which impacts that can be grouped into the following categories:

- Impacts related to energy consumption (global warming, acid rain, resource depletion, etc.).
- Surface and groundwater pollution (NO_3^-, phosphates, pesticides, etc.)
- Toxicity impacts primarily related to agri-chemical use to humans and wildlife
- Decrease in soil quality (soil degradation, pollution, erosion, reduced organic carbon content, etc.)
- Water depletion
- Decrease of biodiversity in cultivated land, land use change (deforestation, etc.) and land management changes.

Given the pressure on natural resources, agriculture has to improve its environmental performance through more sustainable production methods maintaining its productivity to cover society needs. From the environmental point of view, an agricultural activity is sustainable if its polluting emissions and its use of natural resources can be supported in the long term by the natural environment. Diagnosis or assessment of the environmental impact of agriculture, therefore, constitutes the first step in the overall evaluation of agricultural sustainability. During the last years, high attention was paid on environmental impact assessment with multiple goals: quantifying environmental impacts of processes (in agriculture), identifying environmental hotspots and suggesting mitigation strategies to reduce the impact of anthropogenic activities on the environment. To evaluate the environmental performance of human activities and to identify improvement potential, a large number of assessment methodologies and corresponding indicators have been proposed.

The challenge for sustainable crop production is to achieve optimized yield (in quantity and quality) and farm income with a minimum of inputs (nutrients, water, energy, pesticides, herbicides, labor, money), while preserving and protecting the environment and social fabric. For this purpose, innovative mitigation technologies and practices has to be applied, resource saving alongside with recycling at farm level mustbe prioritized, and the interaction between the farm and the ecosystem taking into the account also the market and the society influence on the agricultural production has to be evaluated against sustainability criteria towards improving overall sustainability and innovation capacity of the farming systems and enhancing nutrient cycles in the farm.

Sustainability in circular horticultural should be based on the following aspects:

Farming practices: how to improve current practices to minimize greenhouse gas emissions, waste flows and resources investment, whilst keeping productivity (new technologies/machinery, mixing farming, green manure, etc)

Novel products and production systems in agriculture: we need to develop products to be used in the farm (e.g. bio-based fertilizer, plant growth promoting material, single cell protein, pesticides, water, etc.) based on biotechnological processes for waste recycling and valorisation. Most organic materials can be considered as raw materials for nutrient recovery and recycling purposes. **Consumer habits**: focuses on understanding consuming habits and how to change them to i) accept second generation food products (e.g. meat from animals feed with SCP grown on ammonia from manure) and ii) shift to more sustainable diets (e.g. increased consumption of vegetables).

Sustainability has somehow to be assessed and quantified. Many tools and indicators for assessing and benchmarking environmental impacts of different systems have been developed (e.g., Finnveden and Moberg, 2005; Ness et al., 2007). However, one of the most effective ways to assess sustainability of production systems is the use of Life Cycle approach and specifically the method of Life Cycle Assessment (LCA). LCA is a tool to assess the potential environmental impacts and resources used throughout a product's life cycle, i.e., from raw material acquisition, via production and use phases, to waste management (ISO, 2006). The waste management phase includes disposal as well as recycling. LCA is a comprehensive assessment and considers all attributes or aspects of the three Areas Of Protection (AsOP); the natural environment, the human health, and the natural resources (ISO, 2006). The unique feature of LCA is the focus on products in a life-cycle perspective. The comprehensive scope of LCA is useful in order to avoid problem-shifting, for example, from one phase of the life-cycle to another, from one region to another, or from one environmental problem to another (Finnveden, et al., 2009).

Sustainability Assessment

LCA has a proven to be a valuable tool for identifying, quantifying and, evaluating the environmental impacts of agricultural products in the context of different farming systems (Fig.1) and cultivation practices. Several recent developments have contributed to support the application of LCA to agro-products, where applying LCA appears to be more challenging than for other types of products (Ponsioen and van der Werf, 2017). To address these challenges a variety of methodological choices such as, ENVI-FOOD protocol, Leap guidelines, PCRs and labelling schemes, particularly the Single Market for Green Products initiative by the DG-ENV European Commission, along with a number of agricultural background inventory data have been developed, such as GaBi Food & Feed (ThinkStep, 2016), AusLCI (Grant, 2015), World Food LCA Database (Nemecek et al., 2015), Agri-footprint (Blonk Agri-footprint, 2014), AGRIBALYSE (Koch and Salou, 2015) and ecoinvent (Weidema et al., 2013).

funded by European Commission

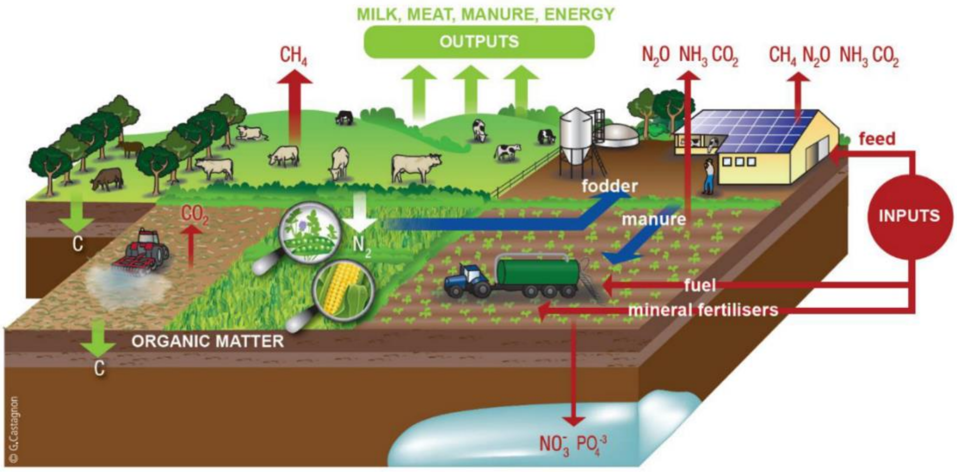

Figure 1: Illustration of material and energy flows in a dairy farming system

There are four phases in an LCA study: Goal and Scope Definition, Life Cycle Inventory Analysis (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation. The Goal and Scope Definition includes the reasons for carrying out the study, the intended application, and the intended audience (ISO, 2006). It is also the place where the system boundaries of the study are described and the functional unit is defined. The functional unit is a quantitative measure of the functions that the goods (or service) provide. The result from the LCI is a compilation of the inputs (resources) and the outputs (emissions) from the product over its life-cycle in relation to the functional unit. The LCIA is aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of the studied system related to the AsOP (ISO, 2006). The impact categories attributed to the three AsOP (natural environment, human health, and resources) and also recommended by EC (ILCD) (European Commission, 2008) are presented in the table 1. In the Interpretation, the results from the previous phases are evaluated in relation to the goal and scope in order to reach conclusions and recommendations (ISO, 2006).

Table 1: Environmental issues (pollutants and resource use) as related to LCA impact categories in the EC recommendation

Environmental pollution and resource use	LCA impact category
Nitrogen pollution (including ammonia, nitrogen oxides and nitrous oxide emissions to air, nitrate leaching to water)	(i) climate change, (iv) human toxicity – cancer effects, (v) human toxicity – non-cancer effects, (vi) particulate matter, (vii) photochemical ozone formation, (viii) acidification, (ix) terrestrial eutrophication, (x) freshwater eutrophication, (xi) marine eutrophication
Phosphorus pollution	(ix) terrestrial eutrophication, (x) freshwater eutrophication, (xi) marine eutrophication
GHG (nitrous oxide, methane, carbon dioxide) emissions	(i) climate change
Toxic compounds	(iii) freshwater ecotoxicity, (iv) human toxicity – cancer effects, (v) human toxicity – non-cancer effects
Energy and resource use	(xiii) water resource depletion and (xiv) mineral, fossil, & renewable resource depletion
Land use	(xii) land use

References

Blonk, H., Kool, A., Luske, B., Ponsioen, T., Scholten, J., 2010. Methodology for Assessing Carbon Footprints of Horticultural Products. Blonk Milieu Advies, CA Gouda, Netherlands.

Eory, V., Kabbe, C., Hajdú, Z., & Hidalgo, D. (2009). EIP-AGRI Focus Group - Nutrient recycling Assessing the environmental effects of nutrient recycling from organic materials used as fertilisers, 1–10.

European Commission, 2008. European Platform on Life Cycle Assessment. <http://lca.jrc.ec.europa.eu/>.

European Food SCP Roundtable, 2013. ENVIFOOD Protocol, Environmental Assess- ment of Food and Drink Protocol, European Food Sustainable Consumption and Production Round Table (SCP RT), Working Group 1, Brussels, Belgium. http:// www.food-scp.eu/files/ENVIFOOD_Protocol_Vers_1.0.pdf (Accessed March 2014).

Finnveden, G., Moberg, E, 2005. Environmental systems analysis tools – an overview. J. Cleaner Prod. 13, 1165–1173.

Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., … Suh, S. (2009). Recent developments in Life Cycle Assessment. Journal of Environmental Management, 91(1), 1–21. https://doi.org/10.1016/j.jenvman.2009.06.018

Grant, T., 2015. AusLCI Database Manual. Version 1.1. 4th March 2015. Australian Life Cycle Inventory Database Initiative. http://alcas.asn.au/AusLCI/Documents/ AUSLCI_Manual%20V1_1.pdf

ISO, 2006. ISO 14040 International Standard. In: Environmental Management –Life Cycle Assessment – Principles and Framework. International Organisationfor Standardization, Geneva, Switzerland

Nemecek, T., Bengoa, X., Lansche, J., Mouron, P., Riedener, E., Rossi, V., Humbert, S., 2015. Methodological Guidelines for the Life Cycle Inventory of Agricultural Products. Version 3.0, July 2015. World Food LCA Database (WFLDB). Quantis and and Agroscope, Lausanne and Zurich, Switzerland.

Ness, B., Urbel-Piirsalu, E., Anderberg, S., Olsson, L., 2007. Categorising tools for sustainability assessment. Ecol. Economics 60, 498–508.

Ponsioen, T. C., & Van Der Werf, H. M. G. (2017). Five propositions to harmonize environmental footprints of food and beverages. Journal of Cleaner Production, 153, 457–464. https://doi.org/10.1016/j.jclepro.2017.01.131

ThinkStep, 2016. New Extension Database for Food & Feed. http://www.gabi-http://www.gabi-software.com/databases/gabi-databases/food-feed/. Assessed in June 2018.

Weidema, B.P., Bauer, C., Hischier, R., Mutel, C., Nemecek, T., Reinhard, J., Vadenbo, C.O., Wernet, G., 2013. Overview and Methodology. Data Quality Guideline for the Ecoinvent Database Version 3. Ecoinvent Report 1 (V3). The ecoinvent Centre, St. Gallen

Wood, S., and Annette Cowie, A., 2004. A Review of Greenhouse Gas Emission Factors for Fertiliser Production. Research and Development Division, State Forests of New South Wales. Cooperative Research Centre for Greenhouse Accounting.For IEA Bioenergy Task 38.

funded by European Commission