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Analysis of greenhouse gas emissions from ornamental plant production: A nursery level approach

G. Lazzerini*, S. Lucchetti[1], F.P. Nicese[1]

Department of Agrifood Production and Environmental Sciences (DISPAA), University of Florence, Italy

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ABSTRACT

The focus of the work is to define a methodology to evaluate greenhouse gas (GHG) emissions for the nursery industry, comparing two different plant production systems (field- and container-grown plants) and assessing different scenarios for the reduction of the emissions. The Life Cycle Assessment (LCA) methodology, with the "from cradle to gate" approach, was used. The analysis revealed that the total emission of CO_2eq is higher in container cultivations than in field cultivations, with emissions ranging between 26.1 and 34.7 Mg ha^{-1} year^{-1} for the former, and between 2.3 and 6.6 Mg ha^{-1} year^{-1} for the latter; greenhouse horticultural crops emit 2.2–10.3 Mg ha^{-1} year^{-1} of CO_2eq and arable crop emissions were measured as 6.2 Mg ha^{-1} year^{-1} of CO_2eq.

Different scenarios for the reduction of GHG emission were tested and a 15.5% reduction of GHG emission was achieved. Two of the scenarios applied – 50% recycled water usage (scenario 1) and 10% of green waste recovery for substrates (scenario 3) – are already in use in nursery farms.

Introduction

It is well known that agricultural practices contribute to emissions of greenhouse gases (GHG) (Flessa et al., 2002; Roy et al., 2009; Ruviaro et al., 2011; Warner et al., 2010). The three GHGs associated with agriculture are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Other important GHGs include water vapor and many halocarbon compounds, but their emissions are considered to not be influenced by agriculture (Snyder et al., 2009).

Agriculture contributes directly from 5.1 to 6.1 Pg CO_2eq to greenhouse gases, that is about 10% of global emissions (Weiske and Petersen, 2005). These emissions are mainly in the form of methane (3.3 Pg CO_2eq year^{-1}) and nitrous oxide (2.8 Pg CO_2eq year^{-1}), whereas the net flux of carbon dioxide is very small (0.04 Pg CO_2eq year^{-1}) (Bellary et al., 2008).

Emissions of N_2O and CH_4 are 10% of European GHG emissions, of which 63 and 49%, respectively, have been attributed from agriculture (Johnson et al., 2007). Nitrous oxide emissions are mainly associated with nitrogen fertilizers and manure applied to the soils. Fertilizers are often applied in excess and not entirely used by the crop plants (Zhu et al., 2005), meaning that some of the surplus is lost as N_2O to the atmosphere. Other emissions include the burning of biomass (10.1%), rice production (9.3%), manure management (6.2%), use of farm machinery (2.4%), and pesticide production (1.1%) (Bellary et al., 2008).

Greenhouse cultivation and nursery crop production are differentiated from other traditional agricultural activities because of an ever increasing use of technology that causes growing environmental impact on the ecosystems in which it is practiced. As an example, in order to have a clear idea of the situation regarding wastes produced by greenhouse cultivation, a collection of data was observed by Stanghellini et al. (2003): plastic residues coming from greenhouse film covering were estimated at 1100 kg ha^{-1} year^{-1} total weight; plastic from irrigation pipes, containers, etc. estimated at 500 kg ha^{-1} year^{-1}; 120 kg ha^{-1} year^{-1} for mulching or soil solarization; an additional 50 kg ha^{-1} year^{-1} for insect traps. In hydroponic greenhouse cultivation, the substrate generates about 2000 kg ha^{-1} year^{-1} of rockwool or perlite-based mineral residues and the non-edible biomass produced is estimated at 250 Mg ha^{-1} year^{-1} (Stanghellini et al., 2003). These simple examples underline the importance of better control regarding the use of resources and raw materials in the plant nursery industry, and at the same time the "environmental cost" of such practices.

Life Cycle Assessment (LCA), a technique used to assess the environmental impact of a system or product, is defined by an international standard (International Standards Authority, 1997, 1998), and can be an interesting tool to define and quantify GHG emissions (Casey and Holden, 2005). LCA can be applied using two

* Corresponding author at: Piazzale delle Cascine 18, 50144 Firenze, Italy. Tel.: +39 055 3288345; fax: +39 055 332472.
E-mail address: giulio.lazzerini@unifi.it (G. Lazzerini).
[1] Present address: Piazzale delle Cascine 18, 50144 Firenze, Italy.

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approaches, from "cradle to gate" or "cradle to grave" (Casey and Holden, 2005), and has been used for assessing a number of agricultural systems. Audsley et al. (1997) and Ceuterick (1996, 1998) compiled examples of complete LCAs for single crops and production processes. Kramer et al. (1999) used part of the methodology to assess GHG emissions related to the Dutch crop production system. Flessa et al. (2002) similarly evaluated GHG emissions from two farming systems in southern Germany and demonstrated the important contribution of individual gases to climate change. GHG emissions from the Irish milk production system were evaluated by Casey and Holden (2005), while Williams et al. (2006) focused their attention on greenhouse horticulture production and Warner et al. (2010) on short-day strawberry production in England. Furthermore, De Boer (2003), Cederberg and Mattsson (2000) and Haas et al. (2001) illustrated the possibilities of using LCA to compare agricultural production systems.

Very little research has been carried out on plant nursery production. An initial study on LCA application for nursery production systems (Pistoia District) was carried out by ARPAT (2001) with the LIFE CLOSED project, in which the environmental compatibility of recycling of farm green wastes were verified (ARPAT, 2001). Another study evaluating both the emissions and the carbon sink in the nursery was proposed by Nicese and Lazzerini (2012).

Russo et al. (2008) evaluated GHG emissions from cut flower (Rose production) and pot plant (Cyclamen production) greenhouse cultivation in the southern Italian region of Apulia. The study clearly showed that the use of pots made of recyclable or degradable materials could reduce the emission of plastic materials. Moreover, the adoption of energy saving techniques could reduce the consumption of fuel.

Recently Blonk et al. (2010) defined a methodology for assessing carbon footprints for the ornamental and horticultural sector; Kendall and McPherson (2012) evaluated GHG emissions for the tree production system in the USA; while Ingram (2012, 2013) applied LCA methodology in field-grown systems at nursery and landscape level.

Most of the research used "kg of product" as functional unit. However it must be carefully determined if production efficiency is an appropriate goal of a specific agricultural LCA (Audsley et al., 1997; Wegener Sleeswijk et al., 1996). Haas et al. (2000) referenced different optional functional units (farm: t, area: $t\,ha^{-1}$, livestock: t livestock-unit^{-1}, milk product: $t\,t^{-1}$) for the evaluation of GHG emissions. Depending on the environmental impact and aim of the investigation, different functional units can be chosen (Haas et al., 2000).

For the present work it was decided to use a LCA approach to analyze the impact of GHG emissions connected with the production of plants. According with other authors (Cellura et al., 2012), in this study LCA was used as a support tool to address local policies for sustainable production. Specifically, the aim of the study was: (i) to define the methods to measure GHG emissions for nursery crop production; (ii) to define a system boundary; (iii) to estimate GHG emissions for this system boundary; and (iv) to apply different scenarios to assess reduction of GHG emission within the Pistoia Nursery District.

Materials and methods

Goal, scope and functional unit

The purpose of the present paper was to estimate the local environmental impact in terms of GHG emissions through the application of LCA methodology in nurseries characterized by different production systems in the Pistoia district (Italy).

To better understand the critical points of the farm management, the analysis was undertaken using the hectare (1 ha) as functional unit, while the temporal unit was one year's cultivation, differently from other works based on product unit (single plant) (Kendall and McPherson, 2012; Ingram, 2012, 2013). This was due to the fact that the different nurseries considered in this paper produced very different plants (in terms of size, age, type of production), making them essentially incomparable. Table 1 outlines the characteristics of the different nurseries under study.

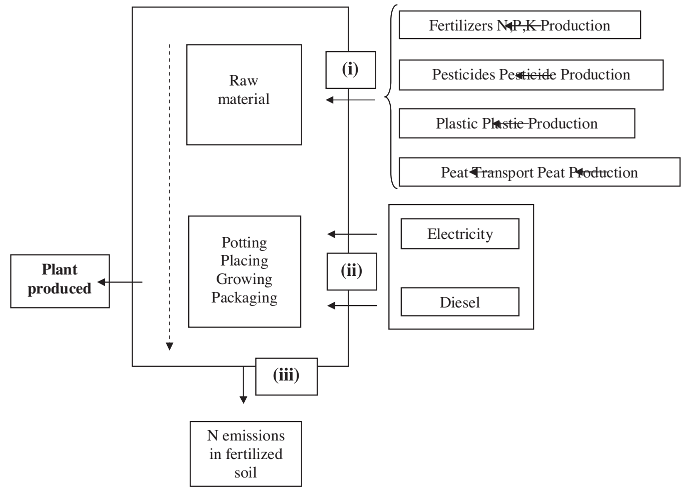

Fig. 1. Flowchart of the "cradle to farm-gate" nursery production system representing the processes included to describe nursery units considered in the present research. (i) Emissions associated with the raw materials purchased (e.g. fertilizers, pesticides, plastic pots, peat); (ii) electricity and diesel fuel associated with agricultural operations (e.g. potting and placing plants, irrigation, package); (iii) emissions associated with application of N.

The normative reference for the implementation of international LCA studies is represented by the International Organization for Standardization's Life Cycle Assessment, Requirements and Guidelines 14044:2006 (ISO 2006) and the British Standards Institute's specifications in PAS 2050:2011 (PAS 2050:2011). This investigation was conducted in accordance with the above cited regulations. The analysis was effectuated without a specific software but rather using a conventional spreadsheet to collect the primary data from the studied nurseries.

The system boundary

The system boundary was defined by the GHG emissions associated with nursery crop production using the "from cradle to gate" approach. This approach supposes that every product/service assumes a "story", before and after its use. As a consequence, the data must be collected starting from the extraction and manufacture of the raw materials, following them through all the steps of production till the completion of the final product.

The system (Fig. 1) includes the physical limits of the nursery crop production units and its activities, considering the emissions associated with: (i) the raw materials used (e.g. fertilizers, pesticides, plastic pots, peat); (ii) electricity and diesel fuel for agricultural operations (e.g. potting machines, tractors, irrigation plants, package machines); and (iii) denitrification of fertilized soil (IPPC, 1996).

The emissions from farm equipments and structures (e.g. nursery facilities, greenhouses, warehouses, plastic covers for container cultivations, irrigation and fertigation systems) were not taken into account because these aspects were considered minimally relevant for the aim of our study (Ekvall and Weidema, 2004; PAS, 2050 2011). As a matter of fact, outdoor ornamental plant production is generally characterized by a less considerable set of structures and equipment compared to other types of nursery production,