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Environmental life cycle assessment of Ethiopian rose cultivation

Abiy Sahle [a], José Potting [a,b,*]

[a] Environmental Systems Analysis (ESA), Wageningen University (WU), The Netherlands
[b] Environmental Strategies Research (fms), KTH Royal Institute of Technology, Sweden

HIGHLIGHTS

- ► Environmental life cycle assessment of Ethiopian rose cultivation from cradle of inputs to the Ethiopian airport.
- ► Primary data of inputs and outputs for 21 Ethiopian rose farmers (e.g., over 212 pesticides, 30 fertilizers, packaging).
- ► Toxicity impact of most active ingredients in pesticides assessed with both CML 2 and Recipe characterization methodology.
- ► Producing exceeds using inputs in most impact categories (except in toxicity, eutrophication and acidification).
- ► Nutrient and pesticide management are obvious starting-points to improve the environmental performance of rose cultivation.

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ABSTRACT

A life cycle assessment (LCA) was conducted for Ethiopian rose cultivation. The LCA covered the cradle-to-gate production of all inputs to Ethiopian rose cultivation up to, and including transport to the Ethiopian airport. Primary data were collected about materials and resources used as inputs to, and about the product outputs from 21 farms in 4 geographical regions (i.e. Holleta, Sebeta, Debre Ziet, and Ziway). The primary data were imported in, and analyzed with the SimaPro7.3 software. Data for the production of used inputs were taken from the EcoInvent®2.0 database. Emissions from input use on the farms were quantified based on estimates and emission factors from various studies and guidelines. The resulting life cycle inventory (LCI) table was next evaluated with the CML 2 baseline 2000 V2/world, 1990/characterization method to quantify the contribution of the rose cultivation chain to 10 environmental impact categories.

The set of collected primary data was comprehensive and of high quality. The data point to an intensive use of fertilizers, pesticides, and greenhouse plastic. Production and use of these inputs also represent the major contributors in all environmental impact categories. The largest contribution comes from the production of the used fertilizers, specifically nitrogen-based fertilizers. The use of calcium nitrate dominates Abiotic Depletion (AD), Global Warming (GW), Human Toxicity (HT) and Marine Aquatic Ecotoxicity (MAET). It also makes a large contribution to Ozone Depletion (OD), Acidification (AD) and Fresh water Aquatic Ecotoxicity (FAET). Acidification (AC) and Eutrophication (EU) are dominated by the emission of fertilizers. The emissions from the use of pesticides, especially insecticides dominate Terrestrial Ecotoxicity (TE) and make a considerable contribution to Freshwater Aquatic Ecotoxicity (FAET) and Photochemical Oxidation (PhO). There is no visible contribution from the use of pesticides to the other toxicity categories. Production and use of greenhouse plastic are another important contributors, and just a bit less than the contribution of calcium nitrate to Abiotic Depletion (AD). The results of this study clearly indicate nutrient management and emissions from pesticide use, especially insecticides, as a focus point for environmental optimization of the rose cultivation sector in Ethiopia.

Abbreviations: AC, Acidification; AD, Abiotic Depletion; CLCA, Consequential Life cycle assessment; EEPCo, Ethiopian Electric Power Corporation; EHPEA, Ethiopian Horticulture Producer Exporters Association; EHPEACoP, Ethiopian Horticulture Producer Exporters Association Cop code of practice; ERA, Environmental risk assessment; EU, Eutrophication; FWET, Freshwater Aquatic Ecotoxicity; GDS, Global Development Solutions; GW, Global Warming; HT, Human Toxicity; IPCC, Intergovernmental panel for climate change; LCA, Life cycle assessment; LCI, Life cycle inventory; LCIA, Life cycle impact assessment; MAET, Marine Aquatic Ecotoxicity; M.a.s.l, Meters above sea level; MPS, Milieu Programma Sierteelt; NMVOCs, Non-methane volatile organic compounds; OD, Ozone Depletion; PhO, Photochemical Oxidation; SDPRP, Sustainable Development and Poverty Reduction Program; TE, Terrestrial Ecotoxicity.

* Corresponding author at: P.O. Box 47, 6700 AA, Wageningen, The Netherlands. Tel.: +31 317 482983; fax: +31 317 419000.
E-mail address: Jose.Potting@wur.nl (J. Potting).

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1. Introduction

Floriculture, specifically rose cultivation, is a young sector in Ethiopian economy. It is the result of an Ethiopian trade policy reform in 1993 that brought various incentives, such as easy access to land, tax holidays, and tax exemption of inputs for agricultural and other sectors. These benefits have attracted an enormous amount of investment in the country (Chala et al., 2010; McKee, 2007). The floriculture sector has got the lion's share of benefits. The country's suitable edaphic, climatic conditions and available workforce also helped a fast growth of the sector. The total area of land covered with flowers has as a result increased from less than 100 ha in the late 1990s to more than 1200 ha in 2008 (over 990 ha or 82% for rose cultivation). The earnings from the floriculture sector amounted to more than 131 million USD in the year 2009 (GDS, 2011). The country is now the second largest exporter of cut flowers in Africa (Gebreeyesus and Iizuka, 2012). This makes floriculture one of the most important branches of Ethiopian agriculture and indeed of Ethiopian economy as a whole.

The dramatic growth of the Ethiopian floriculture sector had its downside (Getu, 2009). In 2007, the Japanese Embassy in Ethiopia conducted a study that highlighted environmental issues as one of the "most worrying negative factors" in the Ethiopian floriculture sector. These negative factors mainly arise from the intensive use of inputs due to a lack of knowledge and information on the optimum use of inputs and waste management practices (The Embassy of Japan in Ethiopia, 2008). The input use includes among others fertilizers, pesticides, growth regulators, water, growing structures, packaging materials, and energy (Krug et al., 2008; Hall et al., 2009).

The Ethiopian Horticulture Producer Exporters Association (EHPEA) together with other important stakeholders in the sector recognized above concerns and developed a Code of Practice (EHPEACoP) in 2007. EHPEACoP is a scheme designed to help farmers in attaining higher standards in social and environmental aspects of production. EHPEACoP has three compliance levels: bronze, silver, and gold. The EHPEACoP silver and gold levels are still under development. The bronze level is meanwhile in force. It was initially implemented voluntarily by 18 farms, later expanded to other flower farms in the country, and is now obligatory for any flower farm in Ethiopia. In July 2010, already 50 farms were certified with the EHPEACoP (EHPEA, 2010).

The bronze level of EHPEACoP requires farmers to conduct an environmental risk assessment at farm level. Environmental risk assessment focuses on potential environmental risk from particular substances on a local scale and in the near future (Sanne and Widheden, 2005; Payet, 2008). These assessments carried out on the farm are therefore helpful to assess and respond to local and short-term impact from farming activities. They don't give information, however, about the time and space integrated direct impact of farming activities and neither about the indirect environmental impact of the cradle-to-gate production of inputs used in the farming activities. This requires an assessment beyond the limited spatial and time scales in environmental risk assessment.

Assessing the impact at wider spatial and time scales is what Life Cycle Assessment (LCA) does by considering production and transport of inputs and, resulting emissions in a certain product or service system (Sanne and Widheden, 2005). The main feature of LCA is to quantify the direct and indirect environmental impact of a product, i.e. throughout its production chain or life cycle (Baumann and Tillman, 2004).

The objective of this study is to assess the environmental impact of Ethiopian rose cultivation from the extraction of resources up to, and including transport of the final product to the airport. This will generate vital information helping the sector to benchmark its environmental performance on a wider spatial and time scale.

2. Methodology

The LCA here follows the procedure as laid down in ISO 14044 (2006), and described in more detail in Baumann and Tillman (2004). The LCA procedure comprises four phases: goal and scope definition, inventory analysis, impact assessment, and interpretation of results. The *Goal and scope definition* phase is about the why (goal) and how (scope) of an LCA study. *Goal definition* defines the purpose and beneficiary of the study (see introduction). *Scope definition* describes the functional unit of the studied product, the product system and its boundaries, data collection and processing procedures, and environmental impact categories considered. The *Inventory analysis* phase quantifies the natural resources and other inputs and the environmental emissions and other outputs for each process in the product system. The *Impact assessment* phase translates the natural resource inputs and environmental emissions into their contributions to a range of selected impact categories. The final phase, i.e. *Interpretation*, interprets the results from the preceding phases of the LCA. (Baumann and Tillman, 2004).

Simapro 7.3 LCA software was employed to supplement and analyze primary data collected about Ethiopian rose cultivation. The software has access to the licensed database EcoInvent®2.0 that provided the larger part of the data on input production.

2.1. Rose cultivation

Farmers are responsible for three stages in the rose cultivation chain. The first stage, plant growth management, starts with planting-up, and ends with harvesting rose stems from the plant. The second stage, post-harvest handling, is where the harvested rose stems are bunched, packed, and made ready for shipment. The third stage concerns transport of the product from the farm to the local airport. This LCA study focuses on these three on-farm stages in the rose cultivation chain, including the cradle-to-gate production of inputs used in the three on-farm stages.

Rose plants produced for the cut flower market have a life cycle of 5 to 10 years, depending on the variety and the area where they are grown (Woods and Anderson, 1997). Cultivation starts in a greenhouse with seedlings grafted on a wild rose variety that is resistant to many soil borne diseases. Fertilizers and water are constantly supplied during the cultivation cycle in order to meet the nutrient and water requirements of the plant. Growers also use pesticides to combat invading pathogens and insect pests either by direct application to the plant or systemically through an irrigation system. Roses can be cultivated in an open or in a closed cultivation system. In an open cultivation system, rose seedlings are planted on a raised bed. The water and fertilizer mix, if not consumed by the plant, drains into the soil. A closed cultivation system, by contrast, uses substrate soil such as red ash and rockwool to grow roses, and catch and recycle water and fertilizers (De Vries, 2010).

Rose cultivation yields 200–350 stems m^{-2} $year^{-1}$, depending on the variety, growing area, and weather conditions (Woods and Anderson, 1997). Growers at higher altitudes produce mainly medium to large bud size rose varieties, while lower altitude farms mainly grow small to medium size bud roses (Joosten, 2007). After harvesting, the cut-roses are transported either to a cold room for precooling or are directly sorted, graded and packed in an on-farm pack house. Farms usually bunch 20 rose stems together for shipment. Some farms also bunch 10 stems together according to their specific market requirements. Farms use various types of post-harvest solutions at this stage to maintain flower quality. The packed flowers are stored in the final cold room until final transport to the airport. Most farms own a cold truck to transport their packed product to the airport. Not all farms have a cold truck. These farms use the transport service from transport companies. In addition to transport fuel, farms also