HO-90

Life Cycle Assessment

Implications for the Green Industry

Dewayne L. Ingram, Horticulture Department, University of Kentucky, and
Tom Fernandez, Horticulture Department, Michigan State University

Consumers and producers alike are becoming increasingly concerned about the environmental impact of the production and use of their products and services. "Sustainability" is often the term used to articulate that concern. There is an increasingly high expectation for products and services to be sustainable in terms of economics, natural resources and other environmental considerations and the health/safety of producers and consumers.

The purpose of this circular is to give green industry leaders and business managers a better understanding of the terms and processes used to judge the impact of various production system components and practices. Terms will be defined, standards will be identified and the relevance of Life Cycle Assessment (LCA) will be discussed in relationship to the nursery and greenhouse industry. Informed managers can communicate more effectively with the consuming public as well as make better decisions about their production systems. At some point in the near future, LCA tools specific to the green industry may be available that managers can use to assess the impact, as well as the cost, of specific production operations.

Use of the term "green" to describe a product or service that is more sustainable than those commonly available has resulted in an overuse and often a misuse of the term. Claims of "green" products must be judged against some standard. The production, use and maintenance of landscape plants, floral crops and turf describe the original "green" industry. The industry increases the function and aesthetics of the built environment and improves the quality of life of the individuals in those environments. However, the choice of inputs in the production and utilization of plants and related services will determine the degree of sustainability of the green industry.

Products and practices can be defined in terms of their **carbon footprint** and their **water footprint.** However, without widely accepted standards, misuses and confusion of even these terms are the result. One tool being used to apply standards to the discussion about sustainability is **Life Cycle Assessment** (LCA).

Environmental regulations by the U.S. Environmental Protection Agency (US-EPA) and various European governmental agencies were the initial driving force for the development of tools used to determine the impact of various processes and for a basis of policy and standards. The intent was to provide rigorous and reproducible scientific assessments for such things as registering pesticides for use on certain crops and in defined environments. Impact data were critical to the development of fair and comprehensive registration and regulations. Potential impact is expressed in terms of producer and consumer safety as well as operational impact categories such as global warming/climate change, acidification and resource depletion. The development of international standards for assessing various environmental and economic impacts became even more important as international trade exploded in recent decades. The International Organization for Standardization published a revised standard in 2006 entitled *Life Cycle Assessment, Requirements and Guidelines* (ISO14044:2006).

Definitions and the LCA process

Life Cycle Assessment is a systematic process of accounting for the diverse environmental impact of interrelated input components and processes of a product or practice during its complete life cycle, cradle to grave. The international standards for LCA require certain procedures be followed in the collection of data, the analysis of the data and the interpretation and validation of the results. The most common use of LCA is to analyze the components and their interactions in systems for the life cycle of products and services in terms of a **carbon footprint** (the total amount of greenhouse gas emissions caused by an organization, event, product or service). However, the objectives or question addressed by a specific LCA might be a product's **water footprint** (the water used, both directly and indirectly, by an organization, event, product or service), **toxicity potential** (releases that are toxic to humans and/or the environment, both acute and chronic) or some other environmental impact measures. The objective of the LCA will dictate how the output is expressed. For example, the carbon footprint of a product or activity is expressed in kg CO_2 equivalent emitted. Not only should the objective(s) of a LCA be determined up front and in response to a well-defined question or set of questions, but the functional unit of the product or activity and the scope (boundaries) of the analysis must be predetermined as well.

Proper LCA procedures define the functional unit for a product or activity up front. Functional units for a green industry product may be an individual tree in a 15-gallon container, a

2-inch caliper field-grown tree, a 32-count flat of flowering annuals or a 6-inch flowering potted plant. Upon the determination of a functional unit, the units of all inputs will be converted to that unit—i.e. the amount of substrate (growing medium) will be based on the volume required for that functional unit.

An effective LCA will include information about all three phases of a product or process, within the predefined system boundaries. The three primary phases include production/manufacturing, use phase and post-life phase. The **production phase** involves the assimilation of inputs and the processes required to produce the product. The **use phase** includes the impact of the product during its useful life. The **post-life phase** assessment focuses on the impact of the product as it is reused/recycled or disposed of. For example, the impacts of plastic production containers occur primarily during the production phase (use of energy, petroleum, etc.) and in the post-life phase with little direct impact during the use phase. The negative impact of shade tree production occurs primarily during production and transport; significant positive impact occurs during the use phase. Most experts would not consider negative impact of the post-life phase of shade trees because their life is 40 to 50 years, and they are organic matter at the end of life.

The base component of an LCA is the **inventory analysis.** This is an inventory of all inputs and processes and the contribution of each to measurable environmental impact within the defined system boundaries. Boundaries may include use, reuse and maintenance. Some refer to appropriate boundaries as cradle-to-grave or even cradle-to-gate, but defining what is the cradle and what is the grave or gate of a product or practice is an important issue. **Cradle-to-grave** refers to the impacts of a product during manufacturing, transport and use but ends with the impact of that product at the end of its useful life. The grave could be considered recycling or disposal. **Cradle-to-cradle** boundaries refer to the usefulness of products after their primary use life. The expectation of such a boundary definition is that products would have a "value" at the end of their primary useful life. Aluminum can recycling is one of the best examples. Recycling aluminum cans saves 95 percent of the energy used to make aluminum cans from virgin ore and diverts 1.7 billion pounds annually from landfills. Aluminum cans represent less than 20 percent of curbside recycling collections but 70 percent of the value, thus paying for collection of other materials.

Boundaries established for the inventory analysis may start with the definition of finished products used as inputs or the analysis boundaries may include the raw materials and processes used in the production of those inputs. In some cases, the differences in boundaries for analysis depend upon the availability of reliable impact data for the products used as inputs. For example, the boundary may be set for shade tree production at the life expectancy for a tree, at landscape installation, or at the end of production at the nursery. Another boundary could be the finished tree liner or it could begin with a seed. The boundary may be set at the plug stage of floral crop production with certain known impact factors such as the carbon footprint or may include the inputs for plug production as well.

The **system inventory** not only includes characteristics of inputs but also includes energy consumption (mixing, transporting, etc.), resource use (oil, nutritional ions, etc.), and wastes in production procedures. Certain inventory components may be available through recycling from other interrelated procedures in the system. Therefore, defined interaction of elements in the product cycle must also be part of the inventory. A by-product of one operation in the system may be an input for another step in production. For example burning of wastes from one operation may partially fuel a greenhouse furnace.

Determining the footprint of input inventories is a difficult step in developing a LCA for horticultural products because the information is simply not available for a highly diverse yet highly specific set of inputs. Although information is available for some physical systems in published databases, use of general information in a specific horticultural system can lead to errors in interpretation. The diversity of impact of similar products can be illustrated by the fact that for many forms of nitrogen fertilizer the embedded energy (or carbon footprint) is approximately 1 pound of CO_2 per pound of nitrogen. However, ammonium nitrate has a footprint of 2.6 pounds of carbon dioxide (CO_2) per pound of nitrogen.

Environmental impact measures in a LCA are defined through international standards. The primary measure is **Greenhouse Gas Emissions** (GHG). Unfortunately for the greenhouse industry, the term "greenhouse gases" in the context of global environmental impact refers to emissions that add to the atmospheric carbon dioxide concentrations and climate change. The primary greenhouse gas is carbon dioxide (CO_2) and the **Global Warming Potential** (GWP) of any greenhouse gas is compared to the GWP of CO_2, which is set at 1.0. CO_2 evolution through such processes as burning fossil fuel has negative impact and CO_2 uptake or sequestration has a long-term positive impact on the atmosphere. A **carbon footprint** is expressed as the net pounds or kilograms of CO_2 (or equivalence of other greenhouse gases such as CH_4 and N_2O) released per functional unit of the product or practice.

Other environmental impact measures include the **Acidification Potential** (AP), the **Eutrophication Potential** (EP) or human and eco-system potential **toxicological impact**. AP refers to the ability of certain substances to build up and release hydrogen ions, thus acidifying that environment. For example, air pollutants such as sulfur dioxide and nitrogen oxide interact with water to form acids and result in such things as acid rain. The AP of a given gas is reported in sulfur dioxide equivalents. Eutrophication is the enrichment of nutrients in a certain place, be it water or soils. The EP of a production input is expressed in phosphate equivalents. It is important to note that EP differs regionally and is influenced by geology and climate, among other things. The Chesapeake Bay, the largest estuary in the U.S., is an example of eutrophication from nutrient runoff (from both agricultural and urban sources) that has caused an increase in phytoplankton, and a decrease in water clarity, the diversity and number of submerged vascular plants, and declines in crab, oyster and other sea life. A retention basin or pond in a container nursery system could similarly be enriched by runoff nutrients and impact algae growth and oxygen content of the water resulting in reduced irrigation water quality.

Assessment of potential toxicological impact was one of the earliest uses of a systems approach such as LCA to determine risk potential for human and ecological health for pesticides being registered (licensed) for use in strictly identified situations. Manufacturers of pesticides must complete extensive testing of the potential hazards (toxicities) of their products when used according to expected label restrictions.

The term **Resource Depletion** in LCA usually refers to the amount of non-renewable resources used. Authors are usually comparing the use of these resources in the targeted product or process to their utility in other processes and the expected long-term supply of those resources. LCAs considering resource depletion in the analysis have limited geographic range because many of the nonrenewable resources must be viewed from a local perspective. For example, an abiotic resource such as soil (or loss thereof from erosion) is highly localized while fossil fuels are more global in scope.

The importance of inclusion of certain environmental impact measures in a LCA will be dictated by the nature of the system being analyzed and its specific location. In general, the carbon footprint is currently perceived to be the most important environmental impact measure to include in green industry LCAs. Toxicological impact, water footprint, and/or eutrophication potentials might be considered in the assessment of an open system involving some degree of water runoff or infiltration from the property.

When the impact measures and potentials of all individual input components and the interrelated system procedures are known and are converted to the chosen functional unit, the calculations are relatively simple. The impacts are usually additive, and spreadsheet or database programs can be used to speed up the calculations and allow repeated queries of the model based on possible input changes.

Interpretation and validation of the results of a LCA have the potential for bias and can result in incorrect application of the findings. The interpretation should be within the predetermined scope of the LCA. The key factors to use in judging the findings of an LCA are the presentation or availability of key input data, inherent assumptions about the system and its components and the calculations used in the analysis. The procedures should follow the published international standards for a LCA (ISO, 14040:2006), and underlying data and calculations should be published for others to review and scrutinize. The international standards do not contain guidelines for every situation, particularly agricultural operations. Even published standards are more readily applied to abiotic systems than to biological systems; therefore, review and acceptance by interested parties with diverse perspectives is a strong validation for the results and their interpretation. The ultimate validation would be a third party certification, an unbiased individual or group knowledgeable of the standards who can check the details of the entire LCA.

Relevance of LCA to the green industry

The original green industry—the production and use of nursery, sod and floral crops—has a big stake in the discussion of sustainability, and LCA will be a primary tool used to define it. The industry should enter the national conversation, internally as well as with external interest groups and consumers, about sustainability but must be armed with defensible, accurate, science-based information. Such science-based information will also allow producers to determine which practices contribute most to the carbon footprint of their products and to judge the impact of changing practices or input components on that footprint and related production costs.

LCA can be used to analyze components of the production systems and the systems as a whole. The potential impact of biodegradable and/or plantable containers and biodegradable plastics being designed for use in the industry will be determined using LCA. The implications of reuse and recycling can be studied with LCA, as well as long-term "eco-services" of living plants. Such advances or alternatives will be assessed based on not only environmental impact but economic impact and consumer preferences.

For some industries, data on the carbon and water footprint of inputs are well known. This is not generally true for horticultural products and services. We know that the use of plastics in nursery and greenhouse production is a significant contributor to the carbon footprint of landscape and floral plants. Plastic use in all U.S. agriculture was 519 million pounds in 1994, 850 million pounds in 1998 and 1,000 million pounds in 2001. Sixty-six percent of plastic use in U.S. agriculture in the early nineties was for containers in the nursery and greenhouse industry. Only 1 percent of plastic production containers were being recycled in 2008. Individual companies and university scientists are studying the impact potential of common inputs and practices.

Biodegradable containers can be manufactured from biomass such as corn, straw and coconut husks or perhaps can be manufactured from plastics that are biodegradable. The carbon footprint for production of a biodegradable container may or may not be smaller than for a standard plastic container but the carbon footprint of the waste would be expected to be smaller, or zero. LCA is a tool being used to query the impact of such changes in system components. Results of such system analyses must conform to international standards. For example, biodegradable plastic is defined by the American Society for Testing and Materials (ASTM) as "a degradable plastic in which degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae." Degradable plastic is designed to undergo a significant change in its chemical structure under specific environmental conditions, resulting in a loss of some properties that may be measured by standard test methods that determine its classification. Compostable plastic undergoes degradation by biological processes during composting to yield CO_2, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and leaves no visible, distinguishable or toxic residue. These definitions are derived from ASTM D6400 and are specific to plastics.

Life Cycle Assessment can be used to determine the potential impact of reusing inputs in nursery or greenhouse crop production. For example, production containers can be reused as production containers. Reuse usually involves investment of energy to handle, transport and clean the used containers. In relation to a LCA, reuse means the functional life has been extended at some cost (economic and environmental) and one or more additional plant product is generated from that life extension.

Recycling can also impact the carbon footprint of crop production. Recycling would result in the reuse of a material to make the same product or some unrelated product. Plastic containers could be recycled for another use. "Lower value" plastic materials could be recycled to make plastic containers for the industry. A LCA could account for CO_2 released and/or lack of CO_2 released by extending the boundaries of the assessment on either end of the production timeline. In other words, the analysis could include the use of recycled materials in production or recycling materials after production.

Landscape plants and plants in interior environments provide post-production "eco-services." Shade trees obviously have a greater impact on carbon capture (carbon sequestration and a positive carbon footprint), oxygen evolution, improved air quality and microclimate comfort compared to flowering annuals due primarily to their greater leaf surface, biomass (long-term carbon sequestration) and longevity. Documentation of eco-services of landscape plants in the urban and suburban environment can also add science-based information to the public discussion of sustainability.

A LCA approach can also be used to determine the water footprint of a product or process. As in calculating a carbon footprint, the initial establishment of boundaries and scope for a water footprint is essential. The amount of water applied to a nursery or greenhouse crop during production can be measured directly and expressed in gallons or liters per plant. The effectiveness of irrigation delivery techniques can be assessed in such a systems approach. However, if the boundaries are set wide enough, the water footprint would also include the amount of water required to produce inputs such as fertilizers, pesticides and plastics.

The consumer will ultimately determine the economic value of the relative impact of sustainable practices. Nursery and greenhouse crop producers should be able to determine the economic and environmental implications of production system modifications, but they must also know market implications. A properly designed LCA can help managers judge the environmental impact realities of practices. For example, is it better to grow bedding plant plugs in northern states or produce them in the tropics? What are the tradeoffs between the transportation impact and the impact of greenhouse heating and the differential production time in different climates? In conjunction with marketing and cost information, LCAs can also help answer such questions as: What will be consumer acceptance and demand for lower environmental footprint products? Will the market support a higher cost for a particular product in order to reduce environmental impact or support the local economy?

Summary and Implications

Life Cycle Assessment is an effective tool in understanding the inputs, outputs and impacts of systems producing a product or activity. Educators, researches and industry leaders must understand the terms related to this tool and the potential application of the tool itself. That understanding will help us identify and address improper use of the tool when it occurs and apply information generated from an unbiased and properly defined LCA. Information gained from a proper LCA of production systems can help managers better understand their production system and practices and help them better articulate an improved "value proposition" for their products in the market place.

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Issued 6-2011