Alternative Crop Production System
DATA COLLECTION TOOL

Objective

The purpose of this data collection tool is to assist operators of unique agricultural production systems in gathering the information necessary to evaluate the environmental performance of the production system. Expanding interest in local, fresh, sustainable food production has driven innovation and change around the globe. Various options for producing near year-round local produce in temperate regions have emerged. Evaluating the environmental implications of these options in order to inform choices on the most sustainable option as well as to drive further improvement and innovation requires empirical data on their operation. This tool aims to identify the data required and lower the barriers to effectively gathering that data. It is recommended that design and implementation of an environmental performance evaluation be done in collaboration with a LCA practitioner, and engaging that expertise early in the process will aid in refining data needs. Still, this tool will help get you started.

Background

Life cycle assessment (LCA) is a systematic accounting method that is used to quantify the effects on the environment from the systems and stuff that meet our human needs. LCA's organizing principal is consideration of environmental impacts throughout the life cycle of a product or service: from raw material and resource extraction, through manufacturing, distribution, use, and finally disposal. LCA excels at making comparisons between systems or products that offer the same service or function, but involve dramatically different processes. This is often the case with alternative crop production systems: how do we make meaningful comparisons between, for example, salad greens grown in a field and those grown in a meticulously controlled "green machine" shipping container? They seem so – different!

The environmental impacts commonly considered in LCA include things like fossil energy use, greenhouse gas emissions, land use and water use, eutrophication and acidification. They may also include human-toxicity and eco-toxicity, or biodiversity loss. Remember, these impact can occur far away geographically and far upstream from the actual "production" or use of the product in question! LCA calculates these impacts relative to a carefully defined, quantifiable measure of the "function" of the product or system, called a functional unit. In the salad greens example above, impacts could be expressed per kilogram of lettuce, or per '10 kg lettuce produced every week of the year'. The latter would capture the ability of the system to supply year-round greens, and may lead to notably different results from the LCA study.

Collecting data

While data for upstream processes like electricity generation and fertilizer production will ultimately be needed to complete an LCA, much of this is available through existing databases. The most important stage in understanding crop production systems will be collecting accurate information on the production stage itself. Perhaps the easiest way to think about this data collection is to consider the production system as a "black box" (i.e., without concern of the specific operations within the box). Focus is then placed on the material and energy inputs to and outputs from the box (see Figure 1). Often these inputs and outputs are called “flows”.

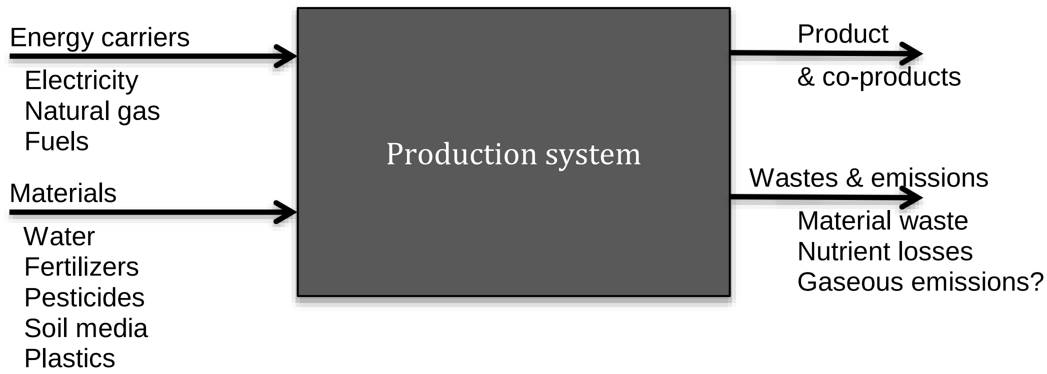

Figure 1. Representing a production system as a “black box” when considering inputs and outputs.

An excellent first step is to sketch out a diagram similar to Figure 1 and list in as much detail as possible the known flows of energy and materials in your production system. Identifying these flows is one thing: quantifying them can be quite challenging! Below are a few suggestions and tips to get you started. Note that the inputs and outputs required ultimately depend on the environmental indicators to be studied: for example, if water use impacts are not to be included, there is no need to collect water use data! Similarly, nutrient losses are likely only relevant if eutrophication impacts will be assessed.

1. LCA is a relative accounting method: we’re not reporting totals over a period of time, but flows relative to the functional unit for the study. Therefore, all flows need to be ultimately expressed relative to a reference flow that can then be related to the functional unit. Typically, this reference flow will be the desired product from the system. So, while we may measure, for example, electricity use over a set period of time, it will also be important to know the reference flow (product) output over the same time period. Ultimately, the appropriate time period will be determined by practicality and the chosen functional unit: if a comparison is to be made considering a full year of production, then ideally data would be collected to represent that year and any potential seasonal variability.
2. Material inputs like fertilizers (including organic fertilizers/soil amendments) will ideally be available from purchase or operational records. Include as much information as possible about the specifics of the material: fertilizer nutrient content, product brand and product names/numbers, etc. Noting packaging materials and (if possible) weighing individual packaging materials (e.g., PVC plastic, cardboard, etc) per unit of material input will improve the assessment.

3. Water inputs will likely require the addition of a water meter to measure total volume applied, especially if watering is automated. If watering is manual, measuring a flow rate through

the exact application method (hose, nozzle, etc.) via the "time required to fill a bucket" method, and then careful records of application times will likely be sufficient. Noting the source of water (municipal, well, surface) may also be important for the analysis.

4. The first place to turn in quantifying energy carriers is billing records. Bills/invoices from electricity or gas providers can provide a good record of usage – if the system of interest is the only activity on the meter. Quantifying energy carriers can be a bit trickier if metering and billing are not specific and isolated to the production system in question. Additional metering and measurement may be required. Check with your facility maintenance specialist or electrician for assistance. Clamp-on current meters like the one shown here can offer a straightforward way of collecting electrical current data, if data log features and/or min/max/average features are available. Average current (in Amps) multiplied by the voltage (in Volts) multiplied by a timeperiod (in hours) will give the electrical energy used (in Watt-hours, or when divided by 1000, kWh). It will be important to capture ALL equipment requiring electricity, either by measuring at the main disconnect for the production system or individually measuring each piece of equipment. The necessary timeperiod of measurement will depend on cycling or fluctuations of energy use, but generally longer is better. Ideally, the timeperiod will be easily relatable to the reference flow product output (e.g., a typical harvest cycle). Beyond electricity use for lighting, other important but less obvious electricity use may include water well pumps, air conditioning, fans/pumps associated with space heating.
5. Alternatively, it may be possible to make informed estimates of energy use based on knowledge of the equipment and basic engineering calculations. In cases where additional metering is cost-prohibitive, such as with natural gas supply, these estimates may be the best option. For example, equipment specifications for a gas furnace and decent records of time and frequency of operation should yield sufficient information on gas usage.
6. If solid waste in the form of packaging materials, disposable planting trays, agricultural fabric, etc. is a concern, measurement can be as simple as collection of waste materials going to landfill over an appropriate growing cycle, and then weighing the gathered material. Records of materials recycled may also be useful. These should be collected over an appropriate growing cycle, separated by material types (e.g., plastics by recycling numbers, cardboard, paper, metal, glass) and weighed.
7. Nutrient and gaseous emissions are likely not of major concern from most well-designed vegetable production systems. Measurement of these emissions will require special equipment and experimental design. One potential area of concern, however, may be nitrous oxide emissions from hydroponic operations. Nitrous oxide (N_2O) is a potent greenhouse gas, 265 times more so than CO_2, and excessive nitrogen fertilization is a major factor in the increase of N_2O emissions. A complex array of factors determine N_2O emissions from agricultural soils, including the abundance and composition of microorganisms and temperature, pH, moisture, oxygen level, organic content, and nitrogen availability. As a result, N_2O emissions are extremely variable and difficult to predict. A cursory review of the literature

suggests that N_2O emissions from soilless growing media and hydroponic growing systems remain poorly researched and understood.

Equipment infrastructure

Infrastructure such as buildings, tractors, and other capital equipment, due to their long lifetimes and depreciations, have been demonstrated to have negligible influence on the results of food production LCAs, and are therefore often excluded. However, in the case of making comprehensive comparisons between alternative production systems that may be dependent on unique infrastructure such as greenhouses or other climate control structures, inclusion of such infrastructure may prove important. The challenge for the data gatherer, then is to: 1) inventory relevant infrastructure and equipment, 2) determine an expected lifetime over which the impact of making the infrastructure can be depreciated, and 3) relate this to the functional unit, likely through a product yield over an extended period of time, perhaps one year.

1. Inventory relevant infrastructure – The concern here is with the production of the actual materials used in infrastructure: steel, aluminum, plastics, etc. Notable energy resources and associated emissions are associated with producing these materials. But, since such infrastructure typically has a long lifetime (multiple decades), it is only large quantities of materials that are relevant: “don’t sweat the small stuff.” It is likely impossible to directly weigh, for example, the steel that forms the structure of a hoophouse or the body of a shipping container; estimates based on size, wall thickness and material density will suffice. Alternatively, shipping records may have a reasonable estimate. When inventorying plastics, identify the specific material type (e.g., polypropylene, PVC, etc).
2. Expected lifetime – The expected lifetime of the infrastructure will typically be a gross estimate based on the experience of manufacturers or merely an educated guess: typically 20-40 years for steel structures. Other materials, such as hoophouse plastic or planting boxes, will have a much shorter and well known lifetime. Again, the purpose of estimating this lifetime is to allocate the impacts of making the infrastructure materials to the product output (e.g., lettuce) itself.
3. Relating to functional unit – The impacts of producing infrastructure will ultimately need to be related back to the functional unit of the LCA; typically this will be through a yield or production quantity per year (or other appropriate time duration). For example:

$$\frac{\text{1800 kg steel}}{\text{40 year lifetime}} \times \frac{\text{0.67 year}}{\text{4000 kg lettuce}} = 0.075\ \frac{kg\ steel}{kg\ lettuce}$$