Title:

Life Cycle Analysis and Assessment of Crop Production Methods

Author(s):

Tracy Gartner

tgartner@carthage.edu

Abstract:

Students use their ecological knowledge of soil processes, energy, water systems, and human interactions to compare the environmental impact of food production. Each group of 3-4 students develop life cycle analyses (LCA) for a single crop grown under different scenarios. As individuals, students are responsible for developing two LCA for that crop, and then together in their groups, they compile those LCA to assess which combination of growing method and location is most "green" if you are purchasing this product at the location of our college. In their joint assessments, students justify their answer based on findings from their LCA. Through this activity, students recognize that there is not one simple answer (e.g., always buy organic) but rather, which methods are most ecologically sustainable are often dependent on the crop, the local conditions, and the impacts of both humans and the environment.

Learning objectives:

1. *Students will be able to describe the difference between organic and conventional farming methods*
2. *Students will be able to develop and interpret LCA of food products grown under different agricultural approaches and in different locations.*
3. *Students will be able to apply their ecological understanding of soil process, energy, water systems, and human interactions to compare the environmental impacts of different approaches to food production*
4. *Students will be able to evaluate the consequences of their own consumer choices*

Timeframe:

This activity can be completed in 1-2 three-hour laboratory sessions

List of materials:

Computers with access to the internet

Procedure and general instructions (for instructor). REQUIRED.

Life cycle analysis (LCA) is an important tool for assessing the total impact of products we consume. A LCA typically includes four primary sections: (1) an assessment of the source of the raw materials for the product, including extraction, pre-processing, and transportation (2) an assessment of the materials and processes used to construct the product, (3) an assessment of *the impact of using and maintaining the product once it is produced, and (4) an assessment of the process of recycling or discarding waste products once the products are used. Usually, LCA are used for manufactured consumer products such as clothing, electronics, or other factory items, and as such can be a useful tool for making decisions about our consumption patterns.*

One consumption decision all individuals face regularly is what to eat. In this activity, students use the LCA approach to compare the ecological and environmental impacts of growing various crops using organic or conventional agricultural techniques, on a local or distant farm, or on farms of different sizes. Based on their LCA, they evaluate what should be the most important factors to consider when purchasing various food items.

In a class discussion, students brainstorm about various crops that are grown locally (e.g., in Wisconsin) and are also grown elsewhere. Either the faculty can assign students to particular crops (in order to engineer groups based on expertise or other metric) or students can select crops of interest for further research. There should be 3-4 students assigned per crop.

Once students have their crop selected, they research how that crop is grown in order to describe the process and to create LCA of their crops grown under different agricultural regimes. Students are encouraged to directly contact local farmers (by calling those listed in the Farm Fresh Atlas or other directories, or visiting our local farmer's market). They can also use the internet to find information about farms that have an electronic presence.

It is helpful to have access to the EPA Life Cycle Assessment: Principles and Practice (see reference list) to introduce the LCA approach, and to discuss with the students the examples from the General Guidelines before they get started. While it is helpful for students to have some previous exposure to water, energy, and soil processes before they begin this project, students can typically pick up what they need along the way, with supplementation as necessary as they work independently on their projects. The activity can also be used as a springboard for more detailed discussion of these topics. We typically use the interrupted model, in which we introduce the LCA project in a single lab session, then talk about soil, water, energy, and nutrient cycles in lecture/discussion/activities while students work on their projects outside of class, followed by presentations and discussion of their findings in another lab session later in the term. The length of interruption between lab sessions depends on the knowledge foundation of the students in the class as well as the overall learning goals for the course.

Students then work individually (either as part of the class with the instructor roaming, or as homework) to create two LCAs, along with written narratives that describes them, for their crop as assigned. One person in the group will compare LCA on this product as it is conventionally grown in local (e.g. Wisconsin) and distant (e.g. Florida, California, Central America) sites. A *second person will compare LCA on this product as it is grown locally, but will compare organic and conventional growing methods. The third person of the group will compare LCA on this product as it is grown at distant sites, but will compare organic and conventional growing methods. If there is a fourth member of your group, that person will evaluate that product grown organically, but on small and large farms. In this way, each group should have the full complement of LCAs available to make the comparisons of local vs. distant and organic vs. conventional such that as a group they should be able to evaluate which choices are more important (from an ecological standpoint) for that particular crop.*

The following class session (or outside of class time), groups bring together their 6-8 LCAs. Comparing these, they must build consensus about whether they believe it is more important (from an environmental/ecological perspective) to purchase their assigned crop locally or to purchase this crop when it is grown using organic methods.

Students then can present these findings either as part of a paper narrative, a presentation, or both. Ensuing discussion can center around comparisons of different crops, what it means to be organic and conventional (and everything in between), or specific impacts on soil, water, or other ecological processes. We also typically include a discussion of the human dimension, including issues associated with accessibility of information, what drives our decisions about food, and how we can impact the food system as non-farmers. The activity could also be a springboard to other environmental or ecological topics, such as materials cycles, energy flow, environmental toxins, and biodiversity.

Procedure and general instructions (for students).

<u>Life Cycle Analyses (LCA) of Food Items</u>

Life cycle analysis (LCA) is an important tool for assessing the total impact of products we consume. An LCA typically includes four primary sections: (1) an assessment of the source of the raw materials for the product, including extraction, pre-processing, and transportation (2) an assessment of the materials and processes used to construct the product, (3) an assessment of the impact of using and maintaining the product once it is produced, and (4) an assessment of the process of recycling or discarding waste products once the products are used. Usually, LCA are used for manufactured consumer products such as clothing, electronics, or other factory items, and as such can be a useful tool for making decisions about our consumption patterns.

One consumption decision all individuals face regularly is what to eat. In this activity, you will use the LCA approach to compare the ecological and environmental impacts of growing various *crops using organic or conventional agricultural techniques, on a local or distant farm, or on farms of different sizes. Based on your LCA, you will evaluate what should be the most important factors to consider when purchasing various food items.*

In groups of three or four, you will be assigned a food item that is grown both locally and non-locally, and is also commonly grown organically and conventionally.

- *One person in your group will compare LCA on this product as it is conventionally grown in local (e.g. Wisconsin) and distant (e.g. Florida, California, Central America) sites.*
- *A second person will compare life cycle analyses on this product as it is grown locally, but will compare organic and conventional growing methods.*
- *The third person of the group will compare LCA on this product as it is grown at distant sites, but will compare organic and conventional growing methods.*
- *If there is a fourth member of your group, that person will evaluate that product grown organically, but on small and large farms.*

Together, you will assess which combination of growing method and location is most "green" if you are purchasing this product in Wisconsin. In your assessment, you should justify your answer based on findings from your LCA.

Part 1. LCA <u>Report</u>
The final LCA and narratives should be single-spaced, 11 or 12-pt font, 1 inch margins, and should include citation of your references. Refer back to notes from our discussions and the "Life Cycle Assessment: Principles and Practice" handout for a reminder of the LCA protocol.

- *Each person will turn in **two** LCA diagrams, **one** individual narrative, and a group rubric*
- *Each group will turn in **one** joint assessment report*

Part 2. LCA <u>Presentation</u>
Your group will present your LCA to the class in a 15 minute powerpoint presentation. You will receive points for both your individual contribution and your group performance during the presentation.

Some General Guidelines:

- *The goal is to produce a table that could be included in an article about your product.*
    - *An educated reader with no environmental background should be able to understand it.*
- *The table can be either one or two pages, no longer – there is only so much room in an article.*
    - *If it is two pages it should be split in a logical place and manner, so that the crease of a magazine could fall on the edge of the pages and not interfere with the table.*

- *The table (including title and caption) should be able to stand alone.*
    - *The narrative can (and should) be used to expand on the details, but the reader should be able to look at the table by itself and understand the essentials of what you are trying to tell them.*
- *Tables will be judged on both <u>content</u> and <u>clarity</u>.*

Content

- *The table should include five sections for each component, as follows:*
    - *The name of the component or category of components*
    - *A brief description of what the component is and/or how it is used, as specific as possible*
    - *A number or estimate that reflects the quantity of the component, where possible*
    - *Information on any inputs and where they come from*
    - *Information on any outputs and where they go*
- *Sections can be left blank if they are not applicable or if information is not available.*
- *Use subheadings/bullet points/parentheses to provide additional or related information where appropriate.*

Clarity

- *The table should be produced on a computer.*
- *The layout should make the sections and the connections between them clear and easy to follow*
- *It should be easily readable in black and white, as it would commonly be printed*
- *The fonts should be of a readable size when the table is printed.*

Title

- *A brief description of what the table is about.*

Caption

- *A few sentences describing what the table contains and what you want the reader to get out of it*
- *Should provide the content and explanation needed to understand the table*

Narrative

- *Should expand on the information included in the table.*
- *Should include comments on any information you think is important but weren't able to find, any estimates you made, any options/possibilities/ranges that didn't fit into your table, and any clarifications necessary to understand the nature and importance of the information.*
- *Should begin with a bullet point list describing a typical life cycle for your product.*

SAMPLE TITLES

Life Cycle of a Potato from a Large Scale Organic Farm

Life Cycle Stages of a Conventionally-Grown Potato

SAMPLE NARRATIVE BULLET POINT LIFE CYCLE

Local organic potatoes	*Local conventional potatoes*
** Fields are prepared from year before*	** Fields are prepared from year before*
** Seeds are planted early spring*	** Seeds are planted early spring*
** Manure or approved fertilizers applied*	** Synthetic fertilizers applied*
** Leaves/stalks emerge after a few weeks*	** Leaves/stalks emerge after a few weeks*
** Weeding begins and environmentally-generated plant-killing compounds applied as needed*	** Synthetic pesticides, herbicides, and fungicides applied as needed*
** Potato plant begins to bud and tubers begin to grow*	** Potato plant begins to bud and tubers begin to grow*
** Potatoes are harvested around July; potato plants are pulled from the ground and the tubers are collected*	** Potatoes are harvested around July; potato plants are pulled from the ground and the tubers are collected*
	** Potatoes are bathed in chloropropham, a chemical that prevents potatoes from sprouting*
** Potatoes packed and shipped*	** Potatoes packed and shipped*

SAMPLE TABLE CAPTIONS

Table 1 diagrams a complete life cycle analysis for a large scale organic potato operation. The diagram highlights, at a basic level, the inputs, processes such as raw material acquisition, manufacturing, use, reuse, maintenance, and recycle/waste management, and the outputs that are incorporated in the making of a given organically grown potato.

Table 1 diagrams a complete life cycle analysis for a a conventionally-grown potato. The four stages display the raw materials required to produce the potato, the manufacturing process, the use, reuse, and maintenance of the potato, and the recycling and waste management that takes place at the end of the potato's lifetime. The enclosed text provides information on what materials and processes are involved and in approximately what quantities. A description of the inputs and outputs required at each stage is also included.

SAMPLE TABLE SECTIONS AND CONTENT

	1. RAW MATERIALS ACQUISITION			
Input/Source	**Constituent**	**Description**	**Quantity**	**Outputs**
Agriculture	Potato Eyes	From potatoes from previous season, usually stored onsite	1-2 eyes per potato	
Aquifers	Water	Fresh rain water or water from aquifers	150,000 gallons/yr/acre	
Nutrients	Approved synthetic fertilizers and insecticides	USDA approved list of synthetic fertilizers and pesticides	213 lb/acre (fertilizer) 2 lb/acre (pesticide)	Contaminated runoff
Cows	Manure	Excrement from cows		Methane and runoff
	2. HARVESTING/MANUFACTURING			
Input/Source	**Constituent**	**Description**	**Quantity**	**Outputs**
Mining	Crude oil	Mostly diesel used for harvest machinery and machinery used to remove dirt.	1.2 gallons/acre	CO_2
Forestry	Crop boxes	Boxes for shipping	Depends on size of harvest; one standard box = approximately 50 potatoes	

	3. USE/REUSE/MAINTENANCE			
Input/Source	**Constituent**	**Description**	**Quantity**	**Outputs**
Mining	Oil	Energy for irrigation and tilling application	1.5 gallons/acre	CO_2
Mining	Transportation oil	Energy for truck transport	8.3 gallons/acre	CO_2
	4. RECYCLE/WASTE MANAGEMENT			
Input/Source	**Constituent**	**Description**	**Quantity**	**Outputs**
	Plant material	Green stalk left over after harvest	One per plant	Can be used for compost or on-site green manure
	Sewage	Human waste once the potato is consumed		Waste water and chemical use in sewage treatment

Group Rubric: *Please turn in this assessment of your group's sharing of responsibilities with your completed assignment. Each person in the group must fill out this form separately. Your paper will not be graded if this form is not included from all members. Scoring will remain confidential. For each category, designate the percentage that each person contributed. The percentages from everyone in your group must add up to 100%. For example, if each of you contributed equally in one of the categories, each cell in that column would receive 33%. Justify all your numbers.*

Group Members (You are #1)	*Background Research*	*Assessment Paper Process/Writing*	*Presentation Planning/Writing*	*Grade you would assign*
1.				
2.				
3.				
4.				
	100%	*100%*		*Overall grade:*

Provide justification for these ratings:

OPTIONAL SECTIONS (other sections you can add if applicable)

Suggestions and materials for assessing student learning

Students receive individual and group scores for their presentation based on content (accuracy and clarity), organization, and delivery. They receive individual scores for their contributed LCA tables and narrative, and a group score for the final written summary of the "best" agricultural practice for their crop. Groups scores may be modified by assigning individual students a percentage of the overall group score based on instructor observations of group dynamics and student evaluations of how their group worked (see group rubric in student instructions). An example rubric for providing feedback on the narratives, summary assessment, and presentations is included as an excel file (Rubric for Crop LCA).

Student data

Reference list

Carnegie Mellon University Green Design Institute. (2008) Economic Input-Output Life Cycle Assessment (EIO-LCA), US 1997 Industry Benchmark model [Internet], Available from:<http://www.eiolca.net> Accessed 7 August 2018.

EPA National Risk Management Research Laboratory 2006. Life Cycle Assessment: Principles and Practice.

Farm Fresh Atlas or other list of local farmers

Horrigan, L., R.S. Lawrence, and P. Walker. 2002. How Sustainable Agriculture Can Address the Environmental and Human Health Harms of Industrial Agriculture. Environmental Health Perspectives 110 (5): 445-456

Rigby, D. and D. Caceres. 2001. Organic farming and the sustainability of agricultural systems. Agricultural systems 68: 21-40.

Robertson, G.P. and S.M. Swinton 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Ecology and the Environment 3(1): 38-46.

Tilman, D., K.G. Cassman, P.A. Matson, R. Naylor, and S. Polasky. 2002. Agricultural sustainability and intensive production practices. Nature 418: 671-677.

Tuomosto, H.L., I.D. Hodge, P. Riordan, D.W. MacDonald. 2012. Does organic farming reduce environmental impacts? e A meta-analysis of European research. Journal of Environmental Management 112: 309-320.

Weil, R.R. 1990. Defining and using the concept of sustainable agriculture. Journal of Agronomy Education 19(2): 126-130.

Student assignments related to the activity

Any other appendices appropriate for your particular activity