UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

Conducting a Sustainability Assessment

Of UBC Food Services' Meat and Meat Alternative Food Products

Kim Black

June Lee

Monica Petrusa

Chris Thoreau

Roger Tseung

University of British Columbia

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Kim Black, June Lee, Monica Petrusa, Chris Thoreau & Roger Tseung

Contents

Abstract

Concerns over environmental degradation are resulting in changes to the way we view our food system. Agriculture makes a significant contribution to greenhouse gas emissions, with livestock being a major component. The diet of an individual has been estimated to account for 25% of their overall emission factor, and a disproportionate amount of these food-related greenhouse gas (GHG) emissions can be attributed to animal agriculture. UBC Food Service is looking for ways to reduce their environmental impact through their food purchasing policies. The integration of vegetarian protein sources into UBC at Place Vanier (UBC residence) is one way to reduce food system generated CO2 emissions.

We researched food service establishments that were already making a difference through their policies and found that many in Vancouver, including several at UBC, were already changing the way they purchase food. A Life Cycle Assessment (LCA) of tofu was carried out in order to quantify the CO_2 emissions and assess the environmental impact of tofu production. The results of our LCA and literature review indicate that organic tofu production is likely more environmentally sustainable than conventional tofu, which produces 6700 g CO_{2e}/kg tofu. We also discovered that organic tofu is available for UBC foodservices to purchase at a lesser cost than non-GMO tofu. We recommend that UBCFS purchase organic tofu, and that their use of tofu and other vegetarian protein choices be increased. Our LCA of tofu is complemented by LCAs of beef, pork and chicken conducted by other current LFS 450 teams.

Introduction

The global environmental impact of the food system is currently a hot topic that needs to be dealt with. New policies and initiatives are currently under development, which aim to create a more environmentally sustainable food system (Baker-French, 2009). It has been well documented that many aspects of the food system have excessive negative impacts on the environment. Agricultural and livestock production, transportation, food storage, processing, packaging and waste lead to greenhouse gas (GHG) emissions, at levels which are substantially contributing to global warming (Adams et al, 2008). It has been estimated that 20-30% of global GHG emissions can be attributed to the food system (Pimentel & Pimentel, 1996; Garnett, 2008), with the agricultural sector alone being responsible for 8% to 13.5% of total GHG emissions (Environment Canada, 2007; FAO, 2009; van Aardenne et al., 2000).

The diet of an individual has been estimated to account for 25% of their overall emission factor (Collins & Fairchild, 2007), and a disproportionate amount of food-related emissions can be attributed to animal protein. Animal agriculture results in GHG emissions from deforestation, feed production, processing and transport of livestock feed and meat, and gas production from animal manure and enteric fermentation (Steinfield et al., 2006). To quantify the impacts, the production of one gram of animal protein takes ten times more fossil fuel than the production of one gram of plant-based protein, such as beans and grains (Pimental et al., 2004). The production of 1.5 metric tonnes of CO_2 per year occurs as the result of a single person consuming a 30% animal-based diet as opposed to a 100% plant-based diet (Eshel & Martin, 2006).

Energy is used much more efficiently when food is chosen from sources which are lower on the food chain; foods higher up on the food chain require large inputs of energy and resources for their production. Approximately 90% of organism energy is used for purposes such as breathing and digesting, and is therefore not available to be transferred from one food chain level to the next (Arcytech, 2000). On average, one gram of plant-based protein, such as soy, is used to generate one gram of animal protein (Reijenders & Soret, 2006), and Koneswaran and Nierenberg (2008) have estimated that 80% of the world's soybean crop is used for livestock feed. As these numbers illustrate, replacing a small amount of human's protein needs with plant-based protein sources, such as soy, would result in a substantial decrease in agricultural related GHG emissions.

Media coverage of the human health benefits of a vegetarian diet has been considerable, and the environmental benefits of a vegetarian diet are being publicized more and more, leading to increased consumer demand for vegetarian products. Plant-based meat alternatives such as tofu, quinoa and chickpea are convenient and affordable, and provide high quality protein. Tofu is particularly appealing because it is highly versatile and socially and culturally acceptable. Tofu can be stir-fried, added into a hot pot, dumplings, and soups, as well as incorporated into many other foods. The versatility of tofu is also increased due to it being available in a variety of forms, from soft to extra-firm to smoked to dessert. Consumption of soy beans has been correlated with many health benefits. Research has shown that the risk of heart disease can be reduced if 25 g of soy protein is consumed daily, and soy consumption is linked to the prevention of some types of cancer, reducing the effects of osteoporosis, and providing menopausal relief (Schyver & Smith, 2005).

UBC Food Services (UBCFS) has taken the initiative to strive towards a more sustainable food system at UBC. This initiative has been largely driven by the recognition of the impacts of the food system on the environment and acceptance of the responsibility as an educational institution to foster positive change in the global food system. UBCFS is currently committed to myriad sustainability initiatives, which address aspects of economic, environmental and social sustainability. Of note, UBCFS has committed to the composting of pre- and post consumer organic waste, waste reduction, recycling of cardboard, metal, glass, paper and plastic, the development of more sustainable procurement standards, and purchasing produce from UBC farm. UBCFS believes that being a leader in social, economic, and environmental change "is crucial to the sustainability and longevity of the campus community and, ultimately, the greater global community" (UBCFS, 2009).

The UBC residences, Place Vanier and Totem Park, are operated by UBCFS, and the cafeterias of these residences meet the bulk of the food needs of the 1900 students living in these residences, in addition to servicing other UBC students, faculty, and staff. Meals are provided three times a day, seven days a week, and are available for eating in or for take-out. In order to cater to the diverse population of customers there is a wide variety of foods available. At breakfast there is a selection of baked goods, hot & cold cereals, traditional breakfast fare and beverages. At lunch and dinner there is a selection of hot entrees, vegetarian options, daily specials, a full salad bar, homemade soups, a pasta bar, made to order salads and sandwiches, traditional grill items, Chinese food and oven baked pizza. Place Vanier and Totem Park cater to a young, progressive population, leaving ample room to creatively increase demand for vegetarian products, which has the potential to substantially decrease the carbon emissions of these residences. The executive chef at Place Vanier, Steve Golob, has a strong interest in working to reduce Place Vanier's carbon emissions, and due to the large volume of food produced everyday at this residence, believes that small changes can have a big impact (personal communication, March 2010).

Due to the desire and great potential for UBCFS to act as a leader in sustainable food system change, and the utility of tofu to help UBCFS on this path, the objectives of our UBC Food Security Project (FSP) are as follows:

- To research what other food outlets are doing in their efforts towards sustainability in order to gain strategies that may be applied to UBCFS
- To develop a LCA for tofu to quantify the CO_2 emissions and assess the environmental impact of tofu production
- Based on our background research and the results of our LCA, to develop practical recommendations for UBCFS in regards to their use of protein sources

A Life Cycle Assessment (LCA) is a systems-based approach used to assess the environmental impact of a product, process, or service (Gloria, n.d.). Such an assessment is useful for comparing the environmental impacts of different products as well as where the most significant impacts occur within a product. Our LCA involves calculating the $CO_{2equivalent}$ emissions which are produced during each step of tofu production, from farming the soy beans to processing, packaging, and transportation.

Throughout this report, our working definition of sustainability is in accordance with UBC's Vision for a Sustainable Food System (see below). However, it is important to keep in mind the valid argument that for something to be sustainable, it must be also able to continue indefinitely, and all accompanying processes must be sustainable (Jensen & McBay, 2009).

Vision Statement for a Sustainable UBC Food System: *Plain Language* Version

The overarching goal of a sustainable food system is to protect and enhance the diversity and quality of the ecosystem and to improve social equity, whereby:

1. Food is locally grown, produced and processed.
2. Waste must be recycled or composted locally
3. Food is ethnically diverse, affordable, safe and nutritious
4. Providers and educators promote awareness among consumers about cultivation, processing, ingredients and nutrition
5. Food brings people together and enhances community
6. Is produced by socially, ecologically conscious producers
7. Providers and growers pay and receive fair prices

Group Reflections on Vision Statement for a Sustainable UBC Food System

Upon discussing the Vision Statement for a Sustainable UBC Food System, the overall opinion of our group is that the seven guiding principles are thorough and sound, and adequately describe a food system that UBC should strive towards. We unanimously agree with the testament of the vision statement that "the overarching goal of a sustainable food system is to protect and enhance the diversity and quality of the ecosystem and to improve social equity," although we felt that "quality" was an awkward word to describe the ecosystem, and would replace “quality” with “integrity”. In their paper describing the UBC Food System Project, Rojas, Richer and Wagner (2007), include a vision statement for a sustainable UBC food system with 8 guiding principles, and we feel this version is more descriptive and leaves less room for interpretation. We also feel the plain language version provided for us to critique lacks lustre and is not as inspiring.

Our group discussed the seven guiding principles from the perspective that they should inspire action towards a truly sustainable food system, a food system that can continue indefinitely. Our collective view was strongly influenced by the value each of us places on the wellbeing of the natural world. Viewing food system change from the perspective that all actions must not harm the land leads to a much different set of principles than would occur if human interests alone were considered. Some of the members of our group hold an ecocentric point of view, and therefore highly value nature beyond its role as a human life support system, while others hold a weak anthropocentric view. Weak anthropocentrism accepts the intrinsic value of nature, but maintains that human needs should come first. These different points of view were apparent in our discussion, as our group is divided regarding principle one, that in a sustainable food system "food is locally grown, produced and processed." Some of us feel a sustainable food system should exclusively include locally grown, produced and processed food, while others feel there is a place for imported foods in a sustainable food system. The argument for an exclusively local food system included that local foods support local producers and the regional economy and consumers can have a direct impact on the production of local foods. A place for imported foods was argued on the basis of diet diversity and more efficient growing methods in alternate climates. We all agree with principle four, which states that as part of a sustainable food system "providers and educators promote awareness among consumers about cultivation, processing, ingredients and nutrition," but feel it should be re-expanded to include personal responsibility (Rojas et al., 2007). Awareness alone does not necessarily lead to the action required to achieve a truly sustainable food system.

In addition to the current seven guiding principles, we suggest the addition of a principle that describes the importance of student awareness and action. Students can act as crucial agents of change on campus and in the broader, global food system, and this role extends far beyond their role as a consumer. We feel the importance of a relationship between grower and producer should be explicitly emphasized, including the necessity of stronger linkages between UBC farm and the UBC community as a whole.

Methods

Our literature review consisted of examining the findings and research of previous UBC FSP reports, with special attention being given to reports which considered the impact of the food system on the environment. Background info was collected from a variety of relevant websites, including the Food and Climate Research Network, Sustain UBC, Environment Canada, the US EPA, and the Worldwatch Institute. Information regarding sustainability initiatives in Vancouver and on UBC campus was gathered from both primary and secondary sources including in person and email communications. Green table members, including O'Doul's Restaurant and Bar, Raincity Grill and Pair Bistro, were contacted via email to inquire about their use of tofu. Dayspring Soyacraft and Sunrise Soyafoods were contacted regarding tofu production.

System boundaries for soybean production involved three major inputs: fertilizers, fuel, and pest control chemicals. Tofu production component boundaries include water (as an ingredient), energy, and soybeans. The working unit for the LCA is one kilogram of tofu.

Both primary and secondary sources of information were utilized for LCA data collection. Secondary data was utilized to gather soybean production information including energy and fertilizer use. Data from a previous Soybean LCA was utilized for its farm energy use figures.

Values for fertilizer and fuel use were calculated using Canadian average Soybean harvests from 1981 - 2004 (See Appendix 1) and from US average soybean fertilizer use data from 1988-2005 (See Appendix 2). Fertilizer Emissions were calculated from this data as summarized in Appendix 3, while Fuel Emission calculations are summarized in Appendix 4.

Primary data, including monthly natural gas, electricity, and soybean use, from Dayspring Tofu on Vancouver Island was used to calculate energy use per tofu unit (kilogram). This is summarized in Appendix 5.

Selected databases, academic papers, and other online sources were used to find emission factor information for fuels and fertilizers, as well as to obtain background info on the current consensus regarding the environmental effects of different soybean farming techniques. Data for the energy values of fuels was taken from the Bioenergy Feedstock Information Network (http://bioenergy.ornl.gov).

Transportation emissions were calculated using the Railway Association of Canada's Rail Freight Greenhouse Gas Calculator: www.railcan.ca/site_ghg_calculator/default.aspx?language=en.

No data was found for agricultural chemical emission factors.

A summary of Emission Factor values used were from various sources and can be found, with references, in Appendix 6.

The following flowcharts (figures 1 and 2) demonstrate the process use to calculate emissions for both soybean and tofu production.

Figure 1: Summary of Tofu Emissions Calculation Process

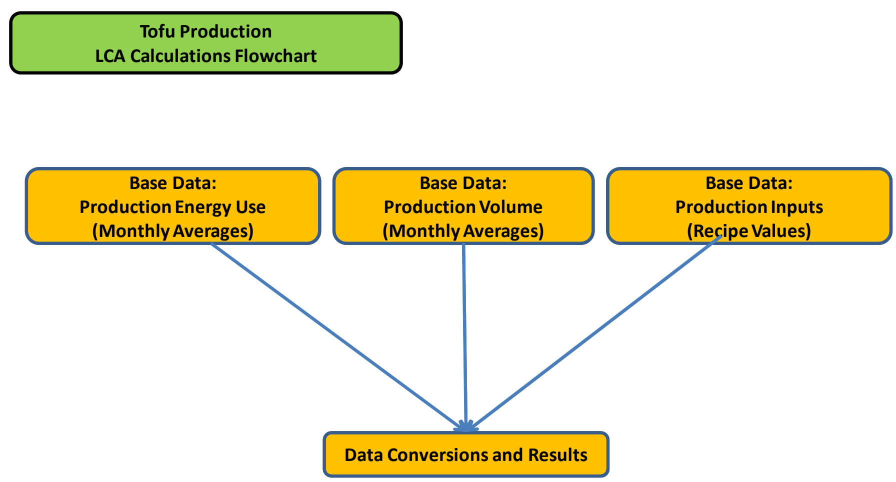
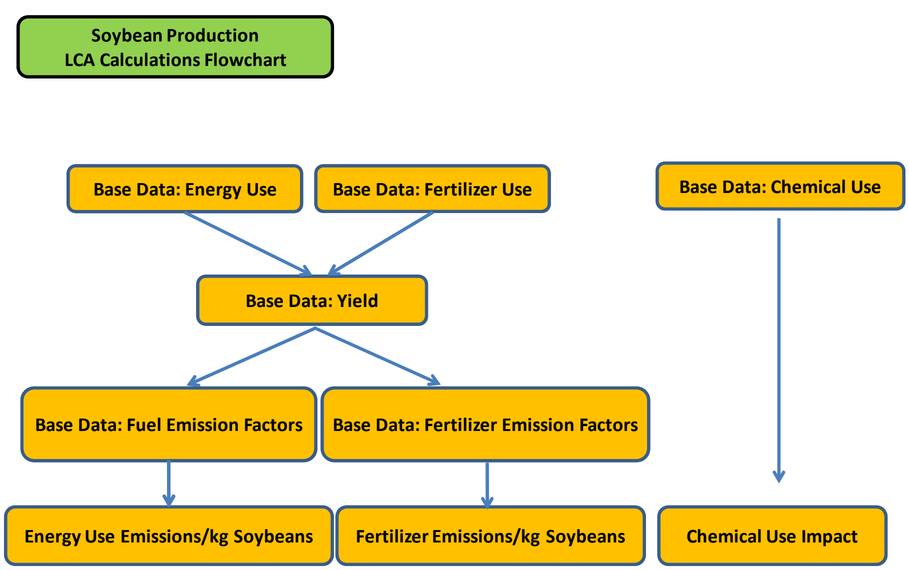


Figure 2: Summary of Soybean Production Emissions Calculation Process



Results and Discussion

Due to the short time line of this project and a lack of resources this research project has a number of limitations. Secondary data for soybean production was drawn from both American and Canadian sources and all the data were from conventional soybean production systems. No sufficient quantitative data were found for organic soybean production systems. No data were found for agricultural pesticides emission factors, though the environmental and human impacts of some chemicals are cited.

System boundaries for soybean production did not include land impact, water impact, and other consequences of conventional soybean farming. Further, the focus here is ecological and does not include economic or social impacts.

The State of Sustainable Food in Vancouver

Many food establishments throughout Vancouver are finding ways to reduce their environmental impact. Over 45 Vancouver restaurants are members of Green Table, is a non-profit environmental consulting team that is encouraging a paradigm shift in the food service industry so that "eating out doesn’t have to cost the earth” (Green Table Network, 2007). Green Table uses local and international standards to conduct audits on member restaurants in areas of solid waste, water conservation, energy conservation, pollution prevention, and purchasing (GTN, 2007). Many restaurants are also involved with EatBC, a partnership between the BC Restaurant & Foodservices Association and the BC Agriculture Council, which was established to promote BC foods and beverages and their sale in local farmer's markets.

The Green Table initiative demonstrates business support and effort in reducing greenhouse gas emissions and other wastes due to food production and consumption. Judging from the minimum requirements of being a Green Table member, restaurants must incur a number of costs to reduce their carbon footprint. This includes upgrading to energy efficient lighting; installing low flow spray nozzles; purchasing post-consumer recycled paper products; and eliminating Styrofoam and non-recyclable plastics (GTN, 2007). With financial success in the restaurant industry being difficult, these participating restaurants have shown commitment and leadership in their initiatives. Of the green table members we contacted, a response was received from O'Doul's Restaurant and Bar. It was discovered that they use Sunrise non-GMO extra firm tofu, which is the same product currently utilized at Place Vanier.

A number of UBC establishments are also making changes and acting as leaders in food system change. Sprouts and Agora Cafe, both operated by volunteer staff, source almost entirely local food (including from UBC farm) and work to educate their patrons on the environmental impacts of their consumption choices. At all non-franchise campus outlets, shade grown, fair trade coffee is offered, composting units are present, and compostable cups, cutlery and plates are provided to patrons (Sustain UBC, n.d.).

Place Vanier has made its own efforts to increase its sustainability by making changes to their food procurement and food preparation standards, implementing new waste, energy, and resource reduction strategies, as well as new wellness initiatives. To name a few of the strategies adopted, local is chosen when it meets affordability and quality standards, bulk orders are made in order to minimize the number of deliveries, and utilization of produce from

UBC farm has been steadily increasing in the past few years (S. Golob, LFS 450 class notes, 2010). Furthermore, Place Vanier features an EATBC menu, where at least 50% of the ingredients are sourced from British Columbia. With regards to protein choices, the Vancouver Aquarium's *Ocean Wise* recommendations have been implemented, and other UBC FSP are currently exploring recommendations for beef, pork and chicken.

Current Tofu Use at Place Vanier

Place Vanier has incorporated tofu as an important ingredient throughout its menu. They currently sell approximately 60-120 kg of extra firm tofu and 17-21 kg of smoked tofu each week (S. Golob, personal communication, March 10, 2010).

The extra firm tofu comes from Vancouver-based Sunrise Soya Foods. The tofu is made from non-GMO soybeans. It is packaged in recyclable hard plastic containers and shipped in recyclable cardboard boxes (K. Lee, personal communication, March 18, 2010). The extra firm tofu is purchased in 4.2 kg cases, and the cost is $22.10 per case.

The smoked tofu comes from Dayspring Soyacraft, located in Victoria on Vancouver Island. Their tofu is made from certified organic soybeans. It is packaged in recyclable soft plastic vacuum bags and shipped in reusable plastic crates. The smoked tofu is purchased in 4.2 kg cases and the cost is $52.20 per case. Extra firm tofu is not currently purchased by Place Vanier from Dayspring, but the cost we were quoted per 4.2 kg case of *organic* extra firm tofu is $18.69 per case (R. Ashton, personal communication, March 19, 2010).

Tofu production

Most of the soybeans processed in British Columbia are grown in Ontario, and are transported by cargo train in 25kg burlap bags (K. Lee, personal communication, March 18, 2010). To begin tofu production the soybeans are washed and then soaked in water for several hours to soften (Chang, 2006). The ratio between water to soy beans ranges from 3:1 to 2:1. The waste water produced during soybean processing is discharged into the municipal water treatment system. When the soybeans reach 2.2-2.3 times their original size, they are ready for further processing. The soaked soybeans are ground with water into a slurry. The residue, which is called okara, is separated from the soy slurry and is used for feeding dairy cows. Coagulant is then added to solidify the soybean slurry. Calcium sulphate is the most widely used coagulant; upon coagulation the resulting curd is pressed. The soy whey is expelled upon processing, and the final tofu product is cut and packaged (K. Lee, personal communication, March 18, 2010).

Packaging

Sunrise Soya Foods use a container made from high density polyethylene thermoplastic (HDPE), which is a petroleum-based plastic. About 1.75 kg of petroleum is required to make 1 kg of HDPE plastic. HDPE has strong tensile strength due to little branching and strong intermolecular forces. The container is opaque and can withstand high temperature. It is stiffer, harder and more gas impermeable than low density polyethylene (Billmeyer, 1984). The HDPE tofu containers used by Sunrise Tofu Company have the resin code 2, which is recyclable.

Dayspring uses soft plastic vacuum bags to seal the tofu into air tight packages which prevents microbial growth. Currently, Place Vanier does not recycle the plastic vacuum bags (S. Golob, personal communication, March 10, 2010); however, according to Rob Ashton from Dayspring Soycraft (personal communication, March 22, 2010) the vacuum bags are recyclable.

Soybean Production

Soybeans are produced on a massive scale in the United States with limited production in Canada's southeast. In 2008, over 75 million acres were planted in the US (USDA ERS, 2009) while in Canada just over 2.5 million acres were planted (Statistics Canada, 2009). In 2008 the United States recorded that 92% of soybeans were genetically modified (GM) (Organic and Non-GMO Report, 2009); in 2007 Canada reported that 67.5% of soybeans were GM (GMO Compass, 2010). In 2005, organic soybeans were planted on 122,000 acres in the US and 20,000 acres in Canada, representing a small portion of total soybean production (Hansen, 2010).

Fuel use is an important contributor to emissions in both conventional and organic production. Pimentel (2006) claims that fuel use amongst the two production systems are equivalent, though other sources suggest that fuel use is lower amongst organic producers (McBride and Greene, 2008).

Synthetic fertilizers are used to provide nutrients to conventional soybeans with the main fertilizers being nitrogen, phosphorus, and potassium (NPK). Synthetic fertilizers are prohibited in organic production and instead, animal manures, vegetable meals, or mined minerals are utilized. Further, since soybeans are legumes, they are able to fix their own nitrogen by forming symbiotic relationships with soil bacteria. This is an important growing strategy for organic growers, since when soy is combined with other legumes in crop rotation, the need for nitrogen fertilizer is virtually eliminated (Kuepper, 2003).

Conventional soybeans also utilize a number of pesticides in their production (USDA, 2006). Though no emission factor data was available for any of the commonly used pesticides, the Pesticide Action Network lists several pesticides, including Metribuzin, and S-Metolachlor, as PAN Bad Actor chemicals. PAN Bad Actor chemicals (Pesticide Action Network, 2002): are known to be at least one of the following:

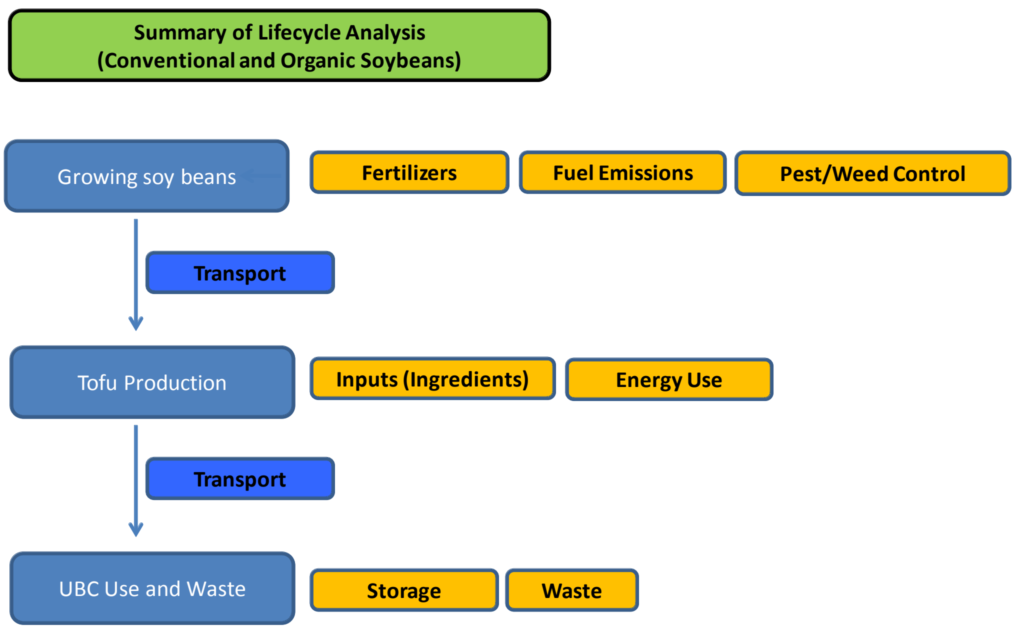
- Probable carcinogen
- Reproductive or developmental toxicant
- Neurotoxic cholinesterase inhibitor
- Ground water contaminant
- High levels of immediate toxicity (within seven days)

Several other chemicals were also stated as having moderate concerns in many of these categories. Synthetic pesticides such as these are prohibited in organic production.

Tofu Production Lifecycle Assessment

The Tofu production Lifecycle Assessment is summarized in figure 3, showing four main components: soybean production, tofu production, UBC storage and waste, and transport.

Figure 3: Summary of Lifecycle Assessment



Conventional soybean production was calculated to contribute 6416 g CO_{2e} per .36 kilograms of soybeans produced (the amount of soybeans required to produce 1 kg of tofu). This high value is due mostly to nitrogen (N) use and the N_20 emissions associated with both N production and application. 2170 g CO_{2e} of emissions are created in N production while a further 4220 g are created due to soil N emissions. Phosphorus and potassium were calculated to emit only 6.5 g CO_{2e} per .36 kilograms of soybeans produced, while fuel accounted for 20.6 g CO_{2e}, though these figures should be expected to be lower than actual values due to limited information availability.

Insufficient data was available to perform an equivalent LCA for organic soybean production, but inputs are summarized below (Figure 4). Pimentel (2006) has asserted that organic soybean production uses the equivalent fuel as conventional production.

Figure 4: Conventional Soybean Production Inputs and Emissions

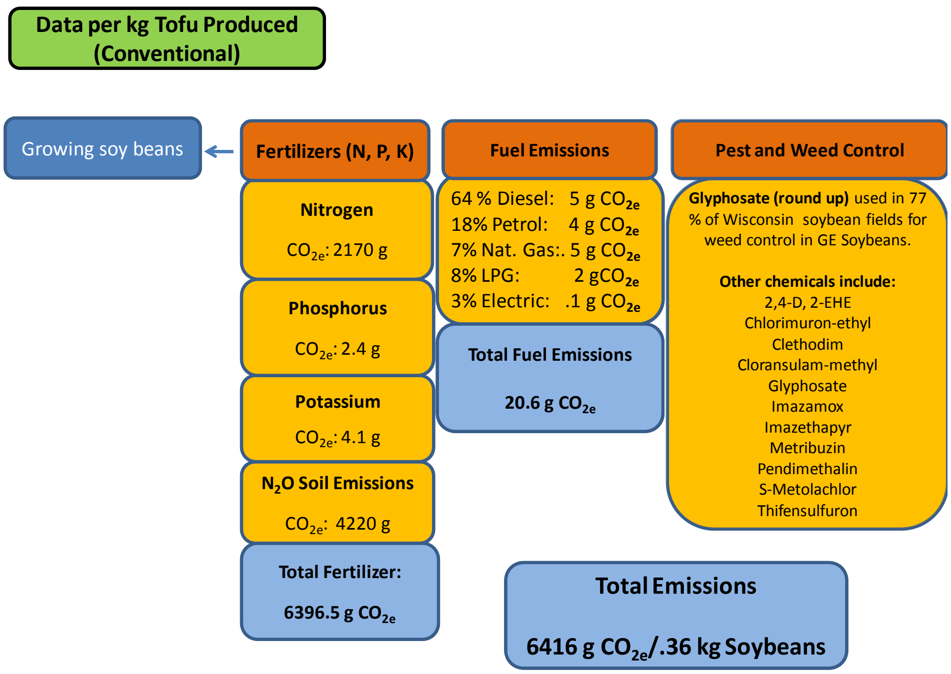
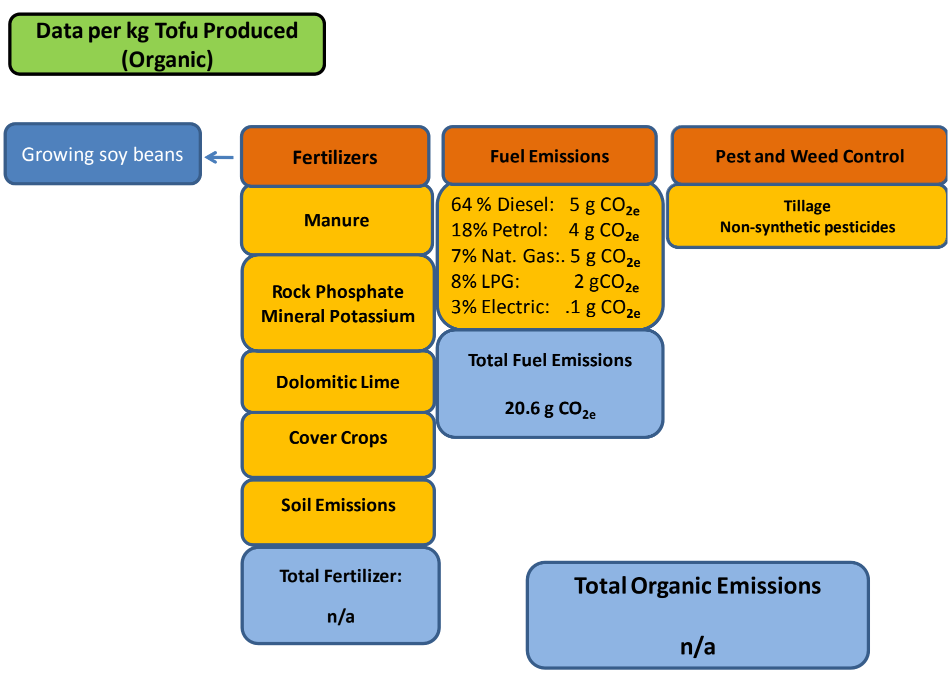


Figure 5: Organic Soybean Production Inputs and Emissions



Although no detailed yield and fertilizer application rates data were available for organic soybean production inputs we are still able to make some comparisons between organic and conventional soybean production. Most important is the use of synthetic nitrogen in conventional soybean production which is responsible for much of the emissions assessed in the LCA. Synthetic N releases emissions in its production and accelerates soil N loss when used as a fertilizer (Huo et al, 2009)

Organic soybean production uses no synthetic nitrogen so N-production emissions are eliminated and soil N emissions are significantly reduced. Further, the use of synthetic N and other fertilizers have been shown to reduce soil microbial populations which are crucial for nutrient cycling in organic systems (Bulluck, Brosius, Evanylo, & Ristaino, 2002), as well as other important soil processes.

Organic food production has been postulated to contribute less GHG emissions due to reduced energy input from the elimination of chemical pesticides and fertilizers (Baker-French, 2009) That being said, organic farms still use resource-based fertilizers, including greensand and rock phosphate, which create emissions in their mining. More research needs to be conducted to quantify the environmental impact of organic versus conventional soybean agriculture.

Tofu production was calculated to produce 284 g CO_{2e} per kilogram of tofu produced, with most of these emissions coming from natural gas use. One kilogram of tofu was also shown to utilize .36 kg of soybeans and .64 kg of water as ingredients. Water for other uses in production was not accounted for. Data from Sunrise Soyacraft was used for the LCA, with energy use summarized as: 219.13 kg tofu/Gj natural gas and 2.51 kg tofu/kWh electricity. These numbers are comparable, though lower, than those of Dayspring which produces 259.9 kg of tofu/GJ natural gas and 4.5 kg of tofu/kWh electricity. The energy use is more efficient at Dayspring due to significantly larger production volume.

Plastic packaging for one kilogram of tofu was estimated to contribute approximately .11 grams CO_{2e} from its production, but according to a US EPA paper by Freed et al. (1999), *land filled* plastic carbon is not 'counted' by the International Panel on Climate Change (IPCC) since it is, in fact, being returned to the Earth. Further, emissions created from incinerated plastic were also not counted by the IPCC if energy was produced which would offset the use of fossil fuels (Freed et al., 1999).

Transport was shown to contribute .19 g CO_{2e} to transport one kilogram of soybeans 4700 km from Ontario to Vancouver by train using the Railway Association of Canada's GHG emission calculator. Emissions from transporting one kilogram of tofu from the factory to UBC were estimated at a tiny .014 g CO_{2e} while emissions for removing plastic waste from UBC to the landfill were negligible at .007 g CO_{2e}.

Storage of one kg of Tofu at UBC contributes an estimated .16 g CO_{2e} per week of storage assuming a walk-in cooler with an annual Energy use of 16,200 kWh (Natural Resources Canada, 2009) and holding 2000 kg of produce.

The overall estimated emissions for one kg of tofu were thus estimated at approximately 6700 g of CO_{2e}. This can be compared to emissions for beef emissions which Avery and Avery (2008) estimate at approximately 22 kg CO_{2e}/kg beef.

Recommendations

For Place Vanier

- Due to the reduced impact of vegetarian protein alternatives on the environment, we recommend continuing and expanding use of extra firm tofu and other varieties of tofu products, such as tofu puffs, dried tofu, and dried bean curd in order to increase the creativity of their menu

- We further recommend that Vanier purchase more organic tofu. We believe organic tofu has an overall lower environmental impact than conventional tofu. Current supplier, Dayspring Soyacraft, can provide organic extra firm tofu at a lower price than the conventional tofu and ship it in reusable crates. (In fact, when presenting this paper, we learned that the crates were now being used for Dayspring's current deliveries of smoked tofu).

- Place Vanier should explore options for recycling plastic tofu packaging.

For Future UBC Food System Projects

- We recommend that future years' groups conduct a more thorough LCA of organic tofu production, so that a quantifiable comparison can be made between the environmental impacts of organic versus conventional tofu. A LCA of organic tofu production would require finding data for organic fertilizer emission factors, including manure and rock phosphate.

- It would be beneficial for future years to explore the environmental impacts and utility of other non-meat protein alternatives that may be incorporated into the menu at Place Vanier. Products we feel have great potential for increased use include chickpea, lentils, and quinoa. Further, it has been suggested by Steve Golob as another tofu product which could be potentially incorporated into their menu in the future.

- Recommendations regarding how Place Vanier could increase student interest in non-meat protein alternatives would be very helpful. Recipes with inventive and tasty ways to use vegetarian protein sources may be helpful.

- Our recommendations may be expanded to Totem, as we are aware that Totem uses extra firm and smoked tofu on a smaller scale. That being said, we recommend that future years contact Totem directly and investigate their purchasing practices and tofu use, in order to make specific recommendations for Totem cafeteria.

Conclusion

Taking our findings into consideration it may be appropriate to suggest an increase in the use of tofu as an alternate protein source. This suggestion is based on the evidence that vegetarian sources in general have less of an impact on the environment when compared to animal sources. We do recognize that using tofu as an alternative to animal protein sources is not a perfect solution as its production still contributes to GHG emissions.

Due to time constraints, we were not able to fully compare the emissions of animal protein sources to the emissions of tofu which would have validated our recommendation.

This paper provides a framework upon which future research projects can be built, as there are gaps in our research that need to be filled. Once these gaps become filled there would be more conclusive evidence to suggest the use of vegetarian protein sources instead of animal protein sources to help reduce the environmental impact of the food system.

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Appendix 1

Historical Provincial Estimates by Crop , 1981-2004 (Soybeans)
From OMAFRA: http://www.omafra.gov.on.ca/english/stats/crops/estimate_imperial_historical.htm

	Soybeans Harvested Area (acres)	Soybeans Production ('000 bu)	Soybeans (bu/acre)	Soybeans Price per unit ($/bu)	Soybeans Total Value ($'000)
2004	2,300,000	91,000	39.6	7.69	700,200
2003	1,990,000	63,500	31.9	9.87	627,000
2002	2,065,000	70,000	33.9	8.5	595,000
2001	2,225,000	47,000	21.1	7.31	343,500
2000	2,235,000	85,000	38	7.07	601,100
1999	2,125,000	86,000	40.5	7.17	616,600
1998	2,100,000	86,000	41	7.58	651,900
1997	2,315,000	88,000	38	9.16	806,100
1996	1,890,000	70,000	37	10.07	704,900
1995	1,815,000	75,000	41.3	8.8	660,000
1994	1,875,000	76,000	40.5	7.43	564,700
1993	1,740,000	67,000	38.5	8.15	546,100
1992	1,450,000	50,000	34.5	6.84	342,000
1991	1,409,063	51,000	36.2	6.18	315,200
1990	1,150,000	44,500	38.7	6.26	278,600
1989	1,290,000	43,200	33.5	6.61	285,600
1988	1,280,000	41,300	32.3	8.46	349,400
1987	1,120,000	46,000	41.1	7.19	330,700
1986	939,738	34,900	37.1	6.3	219,900
1985	1,000,000	37,200	37.2	6.71	249,600
1984	1,000,000	33,700	33.7	7.55	254,400
1983	900,000	27,000	30	9.33	251,900
1982	900,000	31,200	34.7	6.8	212,200
1981	689,061	22,297	32.4	7.19	160,300
		Average:	**36**		
		Energy Use	**22084**	**Btu/bu**	
		=	**368.0666667**	**Btu/lb**	
		=	**167.3030303**	**Btu/kg Soybeans**	
			36	**Bu/acre**	
			2160	**lbs/acre**	
			981.8181818	**kg/acre**	
			0.001018519	**acre/kg**	

Appendix 2

From Huo et al. (2008)
US Fertilizer Use for Soybeans: 1988 - 2005

Year	**Percent Acreage Receiving Nitrogen Fertilizer**	**Nitrogen Application rate (lb/received acre**	**Percent Acreage Receiving Phosphorus**	**Fertilizer Phosphorus Application rate (lb/received acre)**	**Percent Acreage Receiving Potassium**	**Fertilizer Potassium Application rate (lb/received acre)**
1988	16	22	26	48	31	79
1989	17	18	28	46	32	74
1990	17	24	24	47	29	81
1991	16	25	22	47	23	76
1992	15	22	22	47	25	75
1993	14	21	21	46	25	79
1994	13	25	20	47	25	82
1995	17	29	22	54	25	85
1996	15	24	25	49	27	85
1997	20	25	28	50	33	88
1998	17	23	24	48	27	81
1999	18	21	26	46	28	78
2000	18	24	24	48	27	76
2001		24		49		84
2002	20	21	26	49	29	89
2003						
2004	21	28	26	69	23	121
2005						
Average	**16.9**	**23.5**	**24.3**	**49.4**	**27.3**	**83.3**
		10.68181818	kg/acre	22.44318182	kg/acre	
		12.56684492	kg NH_3/acre	40.07711039	P205/acre	
		36	Bu/acre yield			
		981.8181818	kg Soybeans/acre			
		0.012799564	kg NH_3/kg Soybeans			
		12.79956427	g NH_3/kg Soybeans			

Appendix 3 (2 pages) – Fertilizer Emissions Calculations Spreadsheet

Nitrogen		Phosphorus		Potassium	
0.024	**=lbs N/kg Soybeans**	**0.050**	**lbs P/kg Soybeans**	**0.085**	**lbs K/kg Soybeans**
0.011	**=kg N/kg Soybeans**	**0.023**	**=kg P/kg Soybeans**	**0.039**	**=kg K/kg Soybeans**
0.013	**=kg NH_3/kg soybeans**	**0.041**	**=kg P2O5/kg soybeans**		
12.800	**=g NH3/kg Soybeans**				
0.020	**=kg CO2/kg soy beans**				**=T CO2/kg soy beans**
19.967	**g CO_{2e}/kg Soybeans**	**6.739**	**g CO_{2e}/kg Soybeans**	**11.371**	**g CO_{2e}/kg Soybeans**
7.188	**for production of N (36%)**	**2.42**	**For production of P**	**4.09**	**For production of K**
7.188	**N2O emissions**			**Note: since no potassium Emission factor was available, K was given an equivalent CO_{2e} value to phosphorus**	
2163.659	**Co2e equivalent N2O**				
2170.847	**Total Co2e**				
N Energy		**P energy**		**K Energy**	
45.90	**Btu/g N**	**13.29**	**Btu/g P**	**8.42**	**Btu/g K**
499.38	**Btu/kg Soybeans**	**303.79**	**Btu P/kg Soybeans**	**324.76**	**Btu/kg Soybeans**
526516.18	**J/kg Soybeans**	**320304.67**	**J/kg Soybeans**	**342415.51**	**J/kg Soybeans**
526.52	**kJ/kg Soybeans**	**320.30**	**kJ/kg Soybeans**	**342.42**	**kJ/kg Soybeans**
38.94	**N_2O emissions from soil**	**115.3096795**		**123.269585**	
14.01705882	36%				
4219.134706	**C02e equivalent (301x)**				
Total Energy Use due to Fertilizer		**6396.502**			
	1127.93	**Btu/kg Soybeans**			
	1189236.36	**J/kg Soybeans**			
	1189.24	**kJ/kg Soybeans**			
	428.1250897				
Average Ontario		**35.95**	**Bu/acre**		

Soybean Yield			
Energy Use		**22084.00**	**Btu/bu**
		368.07	**Btu/lb**
		167.30	**Btu/kg Soybeans**
		36.00	**Bu/acre**
		2160.00	**lbs/acre**
		981.82	**kg/acre**
		0.00102	**acre/kg**
Average N/acre Soybeans (USDA data)		**23.50**	**N.acre**
16-year average data		**10.68**	**kg N/acre**
		12.57	**kg NH3/acre**
		36.00	**Bu/acre yield**
		981.82	**kg Soybeans/acre**
		0.01280	**kg NH3/kg Soybeans**
		12.80	**g NH3/kg Soybeans**
Energy Values for Fertilizer Production			
Nitrogen	**45.9 Btu/g**		
Phosphorus	**12.29 Btu/g**		
Potassium	**8.42 Btu g/K**		
Emission Factors			
NH_3	**1.56**	**t $C0_{2e}$/t NH_3**	
P_2O_5	**165.1**	**g CO_{2e}/kg P_2O_5**	
Potassium	**unknown**		

Appendix 4 – Fuel Emission Calculations

The total energy use in conventional soybean production is estimated to be 22,084 Btu/bu: 64% diesel, 18% gasoline, 8% LPG, 7% natural gas, and 3% electricity (Huo et al, 2009).

Data for Energy Use/kg of Soybeans Produced									
	BTU/Bu	BTU/lb	BTU/kg	kJ /kg	Volume/kg	Unit	lbs CO_{2e}/kg	kg CO_{2e}/kg	g CO_{2e}/kg
Diesel	14133.76	235.56	518.24	546.7699188	0.00397	Gallons	0.0888	0.0404	40.3796
Gasoline	3975.12	66.25	145.75	153.7790397	0.00127	Gallons	0.0248	0.0113	11.2571
LPG	1766.72	29.45	64.78	68.34623985	0.00076	Gallons	0.0090	0.0041	4.0855
Natural Gas	1545.88	25.76	56.68	59.80295987	0.05514	ft^3	0.0030	0.0014	1.3671
Electricity	662.52	11.04	24.29	25.62983995	0.00712	kWh	0.0004	0.0002	0.1997
Total	22084.00	368.07	809.75	854.3279982	0.06826	0.00	0.1260	0.0573	57.2890

Appendix 5 – Tofu Emissions Calculation Spreadsheet

Tofu Data

Monthly Natural gas		Monthly Total Tofu production	
50.60	GJ	11088.00	kg

Monthly Electrcity		Monthly Firm Tofu Production	
4418.00	kWh	6840.00	kg
		62%	firm prod.

Natural Gas Conversion			
47959544.10	Btu	25.00	kg soybeans
		69.3	kg Tofu
		44.30	L water

Values per kg of Tofu

0.360750361	kg soybeans/kg tofu	
0.64	L water/kg Tofu	

Natural Gas		Electrcity		Soybeans		Water	
4325.36	Btu	0.40	kWh	0.36	kg	0.64	L

Emissions per kg Tofu

Natural Gas		Electricity		Soybeans
		0.02	lbs CO_{2e}	-
0.2295034	kg CO_{2e}	0.05	kg CO_{2e}	-
229.503374	g CO_{2e}	54.09	g CO_{2e}	-

Natural Gas Emission Data		Electrcity Emission Data	
53.06 kg	kg Co2/Mill. Btu	0.0617	lb co2e/kwh

Tofu Energy Use/Kg

Natural Gas		Electricity		Soybeans
0.004563492	GJ			
4563.492063	kJ	1434.415584	kJ	-
		3600	kJ/kWh	

Appendix 6 - Emission Factors

All conversions are accounted for in each spreadsheet listed previously.

Diesel: **22.37 kg CO_{2e} / L** (US Energy Information Administration, 2009)

Petroleum: **19.54 kg CO_{2e} / L** (US EIA, 2009)

LPG (Liquefied Petroleum gas): **138.75 lb CO_{2e} / MMBtu** (US EPA, 2004)

Natural Gas: **53.06 Kg CO_{2e} / Million Btu** (US EPA, 2004)

Electricity (Hydro): **28 t CO_{2e} / GWh** (BC Hydro, 2010)

Nitrogen Fertilizer: **1.56 t CO_{2e} / t NH_3** (Environment Canada, 2009)

Phosphorous Fertilizer: **165.1 g CO_{2e} / kg P_2O_5** (Wood and Cowie, 2004).