How Big is the Fruit Growing Footprint?

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The popular media and scientific journals alike have been full of articles on global climate change, raising the profile of sustainability as a key question for our times. Fruit production, like most forms of agriculture, has its environmental impacts which vary considerably with the geographic location as well as the management used. Some groups advocate rating food products by their food miles, the number of miles traveled from farm production to end user (which can be greater than the simple distance with multi-ingredient and processed products). Others are promoting examination of the ecological or carbon footprint of our activities to help monitor sustainability. And certification programs such as organic and Food Alliance evaluate a farm against a set of sustainability criteria.

What is sustainability?

Sustainability was defined by the UN Brundtland Commission report (1987) as "meeting the needs of today without compromising the needs of future generations to meet their needs." In agriculture, sustainability is considered a three-part goal: economically viable, environmentally sound, and socially acceptable. Sustainability is best seen as a long-term goal rather than a set of farming practices. The goal is to maximize all three without serious trade-offs to any of the others. It is generally much easier to say what is not sustainable than what is, since hindsight is more accurate than prediction. Sustainability is relative to a changing world and to the assumptions we make. For example, current irrigation water use in Washington is generally sustainable, providing for farm, wildlife, recreation, and urban use. In 30 years, if climate change proceeds as predicted, summer stream flows will be much lower than today (Bauman et al., 2006). So even if we continue our irrigation use at the same rate, it may no longer be sustainable due to the changed conditions.

Key environmental sustainability issues for agriculture include pesticides, soil erosion, water quality and quantity, energy, emissions (greenhouse gas, methyl bromide, odor), biodiversity and loss of habitat, and farmland preservation. A number of these directly apply to tree fruit production in Washington State, and various efforts past and present have been made to address them, such as the areawide mating disruption program (Brunner et al., 2002).

What is a footprint?

An environmental footprint can be thought of as a measure of the impact of a system, practice, or product on one or more environmental factors. For agriculture, this could be the amount of petroleum fuel used in production, the amount of soil erosion, or the amount of pesticide residues reaching surface or ground water. Attempts are made to quantify key components and then sum them to describe a footprint. Ecological footprints were first proposed by Rees (1992) and often refer to the amount of resource area needed to support a given lifestyle. For example, calculations made for 2003 estimated a global biological capacity of 1.8 hectares (ha) per person available to provide food, fiber, and other land-based needs. The US footprint for that year was

9.6 ha, over five times the estimated carrying capacity. Values for other countries included Switzerland (5.1 ha), and China (1.6 ha) (Living Planet Report, 2006; Chambers et al., 2004). Such calculations provide a reference point (the Earth's capacity) and change over time can be monitored, but their calculation is not transparent and not always science-based.

Life Cycle Assessment (LCA) (ACLCA, 2007; IERE, 2007) is a tool used in many industrial sectors to evaluate environmental impact. This science-based, quantitative process tries to encompass all aspects "from cradle to grave," and has been successful in identifying waste and inefficiency that, once corrected, reduce impact and often improve profitability. A simplified version might be the "carbon footprint," where only CO_2 emissions, or all greenhouse gas emissions, are calculated. Life Cycle Assessment is being expanded to include some social dimensions such as worker health and safety, equity, and freedom of association (Makishi et al., 2006).

Programs have been developed to estimate the impact of pesticides in agriculture. The Environmental Impact Quotient (Kovach et al., 1992) looks at 14 parameters under the three categories of farmworker, consumer, and ecological impact and produces a single numerical result. It was used to compare three 'Red Delicious' apple production systems in New York State, resulting in scores of 938 (conventional), 167 (IPM), and 1799 (organic; high largely due to sulfur use). In contrast, a study in Washington State (Reganold et al., 2001) used a similar approach adapted to Washington that led to scores of 2,893 (conventional), 2,211 (integrated production) and 466 (organic), a very different result from New York. Thus, one must use these approaches carefully, and understand the assumptions that are made, what parameters are and are not included, the quality of data used, and how data gaps are handled. Perhaps these are most useful in monitoring change in a system over time rather than comparing location.

Finally, the simplest of footprint might be the "food miles" concept. However, this typically ignores production energy on the farm (which can vary considerably by geographic location), and different transport forms (e.g. truck vs. rail). A better measure is energy consumption in the food system. Again, results must be qualified and questions asked. Does renewable energy have a smaller impact than fossil fuel energy? In agriculture, do you only look at energy for production, or include the energy used to make tractors, irrigation pipe, and other fixed parts of the system? Do you compare systems on the basis of land area or output (energy per acre vs. energy per pound food)? Sometimes, ratios of energy in to energy out are calculated. This approach falls down when comparing a high caloric crop (e.g. wheat) to a low caloric crop (e.g. lettuce), not a valid comparison.

As currently used, all the footprint approaches only measure negatives. Including positives to be able to compare benefits and costs would be helpful in interpreting the results from many studies. If two systems have a similar footprint, but one produces much more benefit, we need to know that to make good decisions.

Fortunately, apples and most crops have little inherent footprint. To grow an apple, one can simply plant a seed, provide water if needed, minimize competition for a few years, pick the fruit when ready, and throw away the core. All this can be done with human labor and minimal environmental impact. However, as we add management, we add footprint. We use tractors to plant trees (energy in the steel and fuel; soil compaction; air emissions). We use irrigation piping and pumps for watering (energy, petroleum for plastics, mining for aluminum and copper). We pick, transport, and store fruit in bins (energy to harvest trees and manufacture plywood, impacts on water from tree harvest). We store fruit in controlled atmosphere facilities (CO_2 impact of concrete and steel; energy to produce and transport industrial gases; energy to drive refrigeration). We use trucks for transport to market and to haul away waste (energy, minerals, emissions, …). Lower impact possibilities for producing and marketing apples exist; our challenge is to balance these with the economic goal and realities of the current market system. In contrast, think about a car. Every aspect of it has a footprint: metal, glass, plastic, paint, fuel, paved road. Thus, there is far more potential to reduce the footprint of apples than that of cars.

Food Miles and Energy Use

While the notion of food miles is appealing and simple, it generally does not reflect the actual energy or carbon footprint of the product. As an example, let's consider consumers in the New York City suburbs buying apples. If they drive their GMC Suburban 4 miles round-trip to the store, they would use about 0.031 gal/ton-mile (the fuel needed to move one ton one mile; car weighs 4000 lb, gets 16 mpg town). If they buy 5 lb of apples as part of 50 lb of groceries, they would use 0.005 gal/lb apple. A semi-truck carrying 48,000 lb of fruit will average 6 mpg on the highway, which equates to 0.0038 gal/ton-mile, one-tenth the fuel per pound of apple used by the shopper.

We need to then look at the distance the truck travels (Table 1) to make some comparisons. Clearly, all other things equal, the further the haul by truck, the more gal/lb of fruit, or greater food miles impact. Yet hauling fruit from Michigan uses about the same fuel per pound of fruit as the shopper does going to and from the store. Washington fruit uses the most energy for truck transport. But if our fruit is shipped by rail, it too equals the shopper's fuel use. And if growers in Michigan or Washington can produce the fruit with less energy, then the net use may be less, even with transport. There are many other reasons to support more local foods with less food miles, but local does not guarantee a smaller energy footprint.

Table 1. Fuel use for transporting fruit to New York City.

To NYC market from:	Fuel (gal)	Gal/lb fruit
NY 200 mile by truck	34 gal	0.0010
MI 1000 mile by truck	167 gal	0.0035
WA 3000 mile by truck	500 gal	0.0100
WA 3000 mile by rail	169 gal	0.0035
Shopper (4 mi RT)	0.25	0.0050

The same can be said for scale. In several studies by Dr. Elmar Schlich (Schlich and Fleissner, 2003; Schlich et al., 2006), he compared the life cycle energy use for a number of agricultural products. He looked at a range in size of producers in Germany, other EU countries, and key global exporting countries and found that the energy used per unit of food product dropped dramatically as scale increased, and then flattened out. He attributed this to greater internal efficiency and better logistics with larger producers, suggesting there is an "ecology of scale." Small producers apparently do not necessarily have a smaller energy footprint than larger producers.

As indicated above, the form of transport will influence the energy or carbon footprint. The figures in Table 2 show how rail uses one-tenth the energy of highway trucks, while air freight uses seven times more. These ratios do not translate directly into CO_2 emissions. While water transport is similar to rail in energy use, it is much higher in emissions, perhaps due to the quality of fuel used on ships. And if biofuels become widely used, the energy and emissions from these sources will need to be separated from the fossil fuel sources to do a fair accounting.

Table 2. Energy and CO_2 emissions for various transport modes.

	Energy[1]		Emissions[2]	
	(Btu/ton-mile)	Relative to truck	(g CO_2e/ MT-km)	Relative to truck
Highway truck	3,163		270	
Rail	325	0.1x	21	0.08x
Water	511	0.16x	130	0.5x
Air	21,967	7.0x	1,101	4.0x
[1] *DOE EERE, 2004*; [2] *Environment Canada, 2002; ave. 1990-2000*				

Life Cycle Assessment

Food miles and carbon footprints only tell part of the environmental impact story. Life Cycle Assessment (LCA) is increasingly being used to evaluate the impact of many products, and food is now getting some attention. LCA is a quantitative approach that requires hard numbers. It covers a wide range of potential impact categories (Table 3), touching on human health, ecosystem quality, climate change, and resource use. It is very useful for identifying high impact parts of a production system that can be prioritized for change. There are several scoring systems used to integrate LCA results from the various parameters. All scoring systems that combine different impacts are values-based (R. Schenck, pers. comm.). LCA standards require that you do the science before the scoring, and then disclose both.

Table 3. LCA categories for measurement.

Midpoint categories	Endpoint categories
Human toxicity Respiratory effects Ionizing radiation Ozone layer depletion Photochemical oxidation	Human Health
Ozone layer depletion Photochemical oxidation Aquatic ecotoxicity Terrestrial ecotoxicity Acidification Eutrophication Land occupation	Ecosystem Quality
Global warming	Climate change
Non-renewable energy Mineral extraction	Resources

(Yrigoyen and Castells, 2006)

The LCA approach can be used on a more narrow set of parameters. Since it is "cradle to grave," it is a more rigorous approach than just looking at the energy in transport or the fuel used on a farm. Researchers at Lincoln University in New Zealand took this approach in response to criticism about food imports in the UK, particularly those from New Zealand (Saunders et al., 2006). They calculated the energy used and the CO_2 emissions generated by several products, including apples, based on being produced and consumed in the UK, or produced in New Zealand and consumed in the UK. Their calculations showed that New Zealand apples exported to the UK (fresh crop New Zealand) resulted in lower energy use and CO_2 emissions than apples grown in the UK and stored for 5 months (Table 4). Their results also indicate that the footprint of New Zealand apples would be the same as the UK apples without storage.

Table 4. Energy and CO_2 footprint of apples – New Zealand and UK.

	Energy (MJ/MT apple)		Emissions (kg CO_2/MT fruit)	
	NZ	UK	NZ	UK
Farm	950	2,961	60.1	186.0
Direct energy	573	2,337	29.8	152.1
Indirect (N,P,pesticides,…)	300	624	24.7	33.8
N fertilizer	104	362	4.8	18.1
Equipment, buildings	78	?	5.6	?
Post-harvest	2,030	2,069	124.9	85.8
Cold storage UK 6 mo	-	2,069	-	85.8
Ocean ship (17.8K km)	2,030	-	124.9	-
Total	2,980	5,030	185.0	271.8
(Saunders et al., 2006)				

A similar study for apples was conducted by Blanke and Burdick (2005) comparing New Zealand to Germany. In this study, results were opposite the Saunders study, with imported fruit requiring 27% more energy than German fruit stored for 6 months. They estimated the farm energy in New Zealand to be twice that of Saunders, and the energy for storage to be less than half that in the UK. In addition, they used 23,000 km as the transport distance compared to 17,840 km by Saunders. Farm energy use was nearly identical in Germany and the UK. These contradictory results illustrate the need to clearly understand the data sets used, the assumptions made, and the system boundaries. Without this, one cannot come to any conclusion other than the country of origin of the study is well correlated with a favorable outcome for that country.

A more inclusive study of the food system in the UK was done by Pretty et al. (2005) in which they examined all the external costs of the food system (soil erosion, water contamination, energy use, etc.) and put an economic valuation on them. This totaled $160 per person per year, about 8% of the average food basket expenditure. From their calculations, one can determine the relative contribution of different parts of the food system to overall impact (Table 5). Most impact came from domestic transport, agricultural production, and shopping travel, while sea/air transport and waste disposal were trivial. Their finding suggests that reducing food imports might do very little to reduce the footprint of the food system in the UK, while a large impact would come from reducing truck transport within the country,

Table 5. Contribution of food system segments to external costs.

	% of externalities
Ag production	19
Domestic transport	29
Sea, air transport	<0.01
Shopping	16
Waste disposal	<0.01

(Pretty et al., 2005)

Making Sense of It

Like so many things, the devil is in the details for calculating the footprint of fruit production. Most of us cannot technically evaluate the quality of data used in a particular study. We can look at a number of studies, if they exist and if they are comparable, and see if they tend to point to a similar conclusion. There are international standards for doing an LCA under the ISO 14040 family (Ecobilan, 2006). However no international standard exists on the system boundaries for food LCAs. Every method used has its assumptions, which must be transparent to the reader. All methods need a reference point for useful interpretation. These methods are probably more useful in relative comparisons – how a system changes over time, how two different systems compare. However, the footprint approach or the LCA approach can be very useful to an operation for understanding the areas of greatest environmental impact and where investment in change would likely lead to the most reduction in impact per dollar spent.

The studies cited above suggest that comparisons among fruit production areas hinge on a tradeoff between energy use in storage/processing and energy use in transport. For systems where the energy use is "clean" i.e. reliant on carbon-free sources such as hydropower, one can expect that the carbon footprint of storage will be relatively low. In this respect, the carbon footprint of apples grown and stored in Washington is likely to be smaller than that for storage in regions where a significant portion of the energy is derived from coal. As more members of the food system request (or require) this type of information, the Washington tree fruit sector would be wise to invest in a high-quality LCA and therefore be positioned with defensible information on the topic.

Looking ahead, the big challenges with regards to environmental footprint, and fruit production in general, are likely to include energy, water, and pesticides. In addition, labor is a large sustainability issue, and various methods to assess this are being developed so the social component can be included. Still, all methods need a way to incorporate the positive attributes of fruit production and balance them against the footprint. We humans will continue to have a footprint on the planet – we need to make it smaller so the planet can tolerate it.

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