Where the Rubber Meets the Road: Ecological Economics and Intensive Vegetable Cultivation

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This is a guest post by Jason Bradford who has written here previously on "Relocalization: A Strategic Response to Peak Oil and Climate Change" and "Does Less Energy Mean More Farmers?". Jason has a Phd in Biology, is the founder of Willits Economic Localization (WELL) and runs a CSA in Willits, CA.

"Can we rely on it that a 'turning around' will be accomplished by enough people quickly enough to save the modern world? This question is often asked, but whatever answer is given to it will mislead. The answer "yes" would lead to complacency; the answer "no" to despair. It is desirable to leave these perplexities behind us and get down to work." E.F. Schumacher, Small is Beautiful

I would rather have titled this essay "Where the Hoe Meets the Soil" but that phrase is not part of our cultural lexicon, which is itself a symptom of the problem I am working to address. Setting aside any prolonged discussion of whether or what about the modern world should be saved, this essay is primarily about what it means to "get down to work" as Schumacher puts it. But very quickly, to me saving the modern world means setting a goal for the human economy to be properly scaled relative to the global ecology, and maintaining a sufficiency of social stability necessary to manage a transition.

Before getting to work, I want to make sure the work I do is useful. This is where a clear understanding of the big picture helps.

Ecological Economics

The question of proper economic scale is examined by the field of ecological economics. In the ecological economics model, the human economy is a subset of the Earth system, and therefore the *scale* of the human economy is ultimately limited. The human economy depends upon the *throughput* or flow of materials from and back into the Earth system. Limits to the size of the human economy are imposed by the interactions among three related natural processes:

(1) The capacity of the Earth system to supply inputs to the human economy (Sources),

(2) The capacity of the Earth system to tolerate and process wastes from the human economy (Sinks), and

(3) The negative impacts on the human economy and the resources it relies on from various *feedbacks* caused by too much pollution.

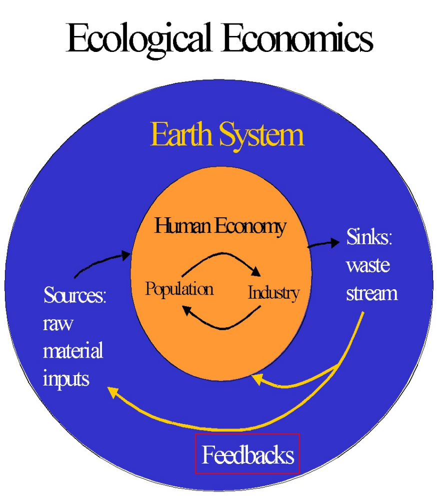

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Fig. 1. The ecological economics model of the relationship between the human economy and the Earth system highlighting the importance of sources, sinks, feedbacks and scale.[i]

For an expanded look at the relationship between our economy and the planet see the engaging on-line film "The Story of Stuff."[ii]

One measure of whether the human economy is too large is the ecological footprint (EF), which calculates on a nation-by-nation basis the consumption of resources and the build-up of wastes relative to resource regeneration rates and the waste-absorbing capacity of the environment. According to two independent EF analyses (which I will call EF 1 and EF 2) the human economy (population plus consumption and waste generation) is in a state of overshoot, meaning it is too large relative to the long-term capacity of the planet to cope.[iii] The Earth can provide for us beyond its means for a long time before the consequences become severe, just like a millionaire can, for a time, live high on the principal in a savings account instead of the interest. The degree to which we are drawing down principal as opposed to living on interest is called our "ecological debt."

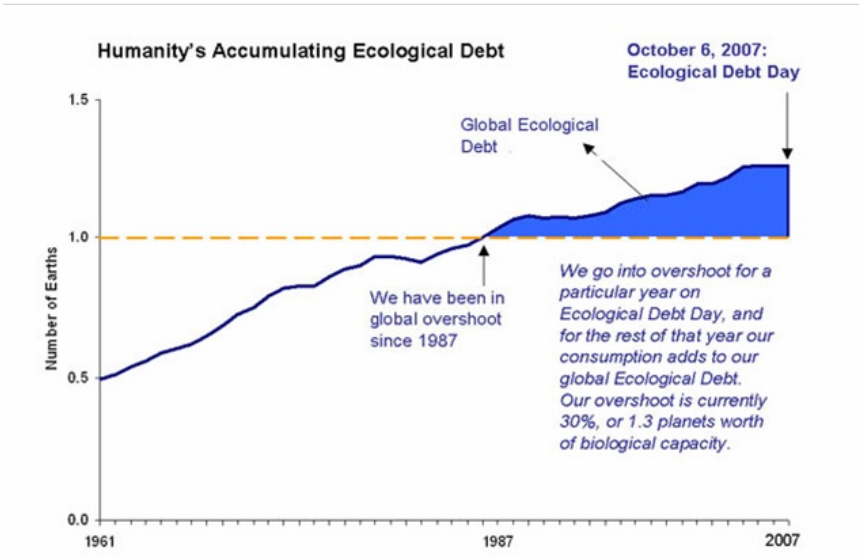

Figure 2. Change in ecological footprint over time according to EF 1 with our cumulative ecological debt in blue.[iv]

Getting More Specific: Fossil-fuel Depletion and Climate Change

Indicators like the ecological footprint are important for understanding we have a problem and giving us a sense of the scale, but they aren't very specific. In order to do something about reducing our footprint, it would help to know what is causing the ecological footprint to be so large. A significant portion of the ecological footprint represents consumption of fossil fuels and the resulting waste, mainly greenhouse gases. The "carbon" footprint component is about 52% for EF 1 and the similar "energy land" is 88% for EF 2.[v] According to EF 2, "energy land" is 93% of the North American footprint. A priority on reducing fossil fuel consumption appears justified. The human ecological footprint can be lowered below "1 Earth" only by eliminating the pollution from fossil fuel combustion.

EF analysis uses the capacity of the environment to absorb greenhouse gas emissions, which, as seen in the model shown in Fig. 1, means EF measures "sink" capacity. The real picture is more complex and more disturbing for a couple of reasons. Firstly, fossil fuel extraction is reaching limits sooner than expected. Since we have not been weaning our economy off fossil fuels steadily for the past few decades, rapid energy price inflation will likely make it difficult to maintain the kind of economic vitality and stability needed for a smooth transition to renewable energy alternatives. Secondly, recent evidence suggests that climate change is happening faster than expected. Ice sheet destabilization is one major indicator that the Earth system is more sensitive to greenhouse emissions than most scientists and policy-makers have presumed. Recent articles by Kurt Cobb[vi] and Richard Heinberg[vii] review all these points, and the "Climate Code Red" report[viii] goes into truly excruciating detail so I won't elaborate further here.

The bottom line is that every measure must be taken to rapidly eliminate fossil fuel consumption and dependency in every component of our lives. The key word is "rapidly." Don't passively assume inexpensive alternative energy substitutes will arrive to replace fossil fuels-we may have waited too long to respond to have a smooth transition. Therefore, focus most attention on reducing energy demand rather than substituting a new energy supply. And finally, in the context of ecological economics, fossil fuel depletion and climate change, ask whether what you do in your life, vocation, hobbies, and habits, contributes to the long-term function (or dysfunction) of society.

The U.S. Food System and Fossil Fuels

It would be hard to argue against a claim that a secure and healthy food supply is indispensable to society. A widely known and troubling fact is that the current food system in the U.S. (and most highly industrialized nations) is very dependent upon fossil fuels.

As far as I am aware, the most comprehensive study on the topic of energy use in the U.S. food system is by Heller and Keoleian of the University of Michigan's Center for Sustainable Systems.[ix] The report is from 2000 and makes use of data from the mid-1990s. Although the data are about 10 years old, I don't believe the basic structure and function of the U.S. food system has changed dramatically over the past 10 years. In fact, current trends of increased industrial meat consumption[x] and biofuels[xi], which both rely on grains, make the following case even stronger.

We learn from the study that over 10% of the energy consumption in the U.S. can be attributed to the food system, and that about 20% of this occurs in the agricultural production sector. Home energy consumption (e.g., refrigeration and cooking) consume the largest share at about 30%. Between the farm and the home are everything else (transportation, processing, packaging and retail). Much of this middle portion is a function of the geographic disconnection between production and consumption. Eating food out of season either requires long-distance transportation or energy demanding processing. Both transportation and processing require investments in storage.

Sorting out the proper scale of operations for farms, processing and transportation systems is very difficult, however, because optimization for one factor (e.g., transportation), may be sub-optimal for another (e.g., heat intensive food processing). Within a category, such as transportation, the technologies analyzed may be limited too. A study comparing rail cars, large semi-trucks and small produce trucks may conclude that bigger is better, but what about hyper-local transportation systems using bikes, small electric vehicles and bipedal locomotion? Another complicating issue is that studies may assume the U.S. food system should be more or less similar in its mix of products while lowering energy consumption. For example, tomatoes can be processed using canning or drying. Canning lends itself to centralized operations and so does drying if fossil fuels are used as heat sources. But a naturally decentralized and fossil-fuel free technique such as passive solar dehydration may not even be considered. Large energy savings can be found everywhere in the food system, but especially so if assumptions about scale and consumer-level demand are allowed to change.

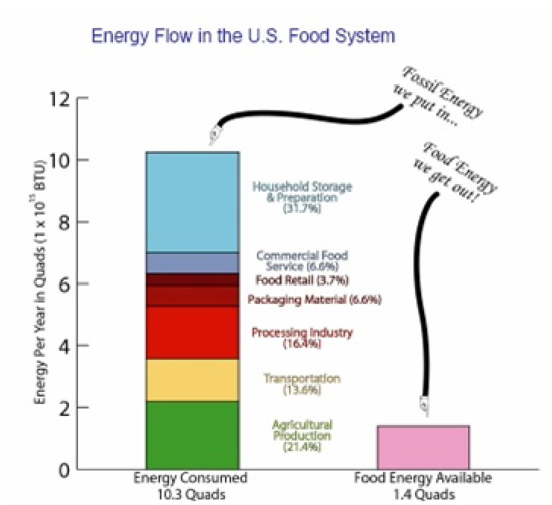

Fig. 3. The energy inputs to the U.S. food system are several times larger than the energy content of the food. A life-cycle analysis identifies how energy consumption is partitioned among economic sectors.[xii]

Another graphic from the Heller and Keoleian report clearly identifies a huge savings potential. Over 50% of U.S. grains are fed to domestic animals, and most export grains go to animal feed as well. Overall, only 26% of U.S. grain production in 1995 went to domestic human consumption.

Although poultry need grains, red meat and milk products dominate the feed market and grains are not a natural part of their diets. If red meat and dairy production were reduced to only what harvested hay and pasture could provide, perhaps half of annual U.S. grain production could be eliminated. The acreage out of food production could be used for green manure crops to build soil and fix nitrogen. A 2004 Congressional Research Service report showed that fertilizers are the largest part of farm energy use, and that natural gas to produce nitrogen comprised 75-90% of the fertilizer input (Fig. 5).[xiii] Fixing nitrogen naturally, therefore, saves significant energy. Some of the vast cropland area no longer producing grains could then be used for appropriately scaled biofuels to power farm equipment instead of fossil fuels.

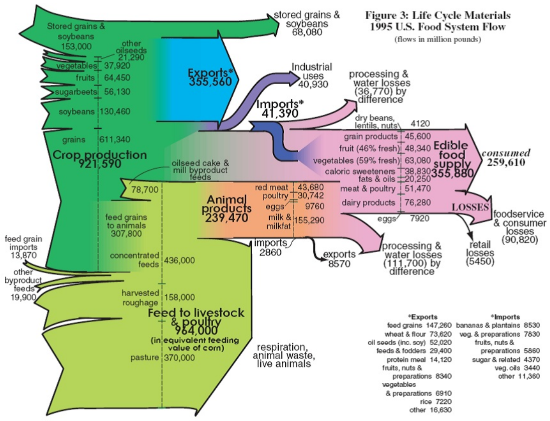

Fig. 4. A reprint of Fig. 3 from the Heller and Keoleian report. (click to enlarge)

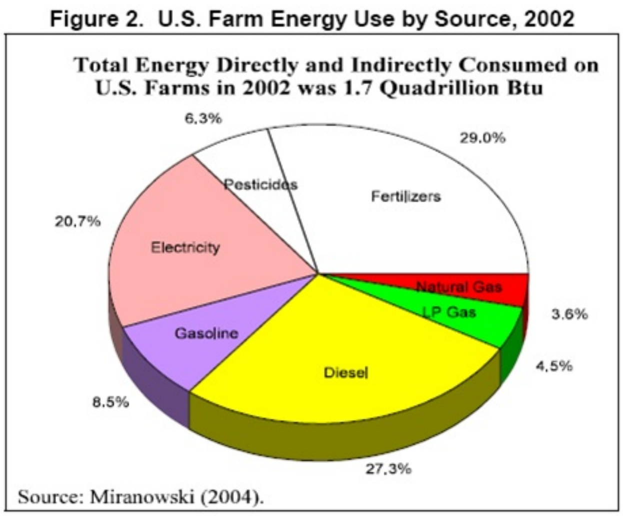

Fig. 5. A reprint of Fig. 2 from a 2004 Congressional Research Service report.

An older and less comprehensive on-line review paper[xiv] titled "Energy Use in the U.S. Food System: a summary of existing research and analysis" by John Hendrickson of the Center for Integrated Agricultural Systems, UW-Madison concluded that:

"It appears that some of the greatest saving can be realized by:

- reduced use of petroleum-based fertilizers and fuel on farms,
- a decline in the consumption of highly processed foods, meat, and sugar,
- a reduction in excessive and energy intensive packaging,
- more efficient practices by consumers in shopping and cooking at home,
- and a shift toward the production of some foods (such as fruits and vegetables) closer to their point of consumption."

Table 5. Energy use comparison of food preservation techniques with homegrown and purchased fresh produce

Food	Energy Consumption (BTU/lb.) Home grown	Fresh	Canned	Frozen	Dehydrated
Corn	-	5,250	10,300	12,750	37,100
Carrots	1,300	4,750	9,200	12,750	37,100
Apples	917	5,950	400	9,200	23,200
Potatoes	2,850	6,250	9,000	14,950	26,700

From Buffington and Zar 1977 p. 704. They reference: Federal Energy Administration (1975) *Monthly Energy Review*, August. Accession no. PB-242769-08. National Technical Information Center, Washington, D.C. and Fritsch *et.al.* 1975.

Hendrickson's paper is helpful in republishing and comparing tables from many previous studies, including "Table 5" reprinted here on the energy consumption of home grown versus market-purchased fruit and vegetables.

Taking Responsibility: Brookside Farm Examples

With this extensive background I introduce the project I have been working on for about two years now, Brookside Farm. This is a 1-acre mini-farm in Willits, CA. It operates as a program of the non-profit corporation North Coast Opportunities, functions as a working farm with a community supported agricultural program serving 15 "shares" per year, exists at an elementary school and is therefore open to classes and tours, and conducts research and demonstrates aspects of a local food system with the collaboration and support of Post Carbon Institute.[xv]

Brookside Farm thinks about food from a "farm to fork" and back again perspective. Farmers create artificial ecosystems, and we therefore look to ecology to guide our practices. Highly productive and stable ecological systems are noted for a diversity of species both in kinds and functional forms. When these diverse species interact effectively, they maximize the rates of productivity and nutrient retention in the system using ambient energy sources. We view ourselves as human members of the farm ecosystem with our labor and wastes as parts of the whole.

To get by on ambient energy as much as possible, we have sought alternatives to fossil fuels in every aspect of the food system we participate in. Table 1 considers each type of work done on the farm, to the fork, and back again and contrasts how fossil fuels are commonly used with the technologies we have applied.

Type of Work	**Common Fossil-Fuel Inputs**	**Alternatives Implemented**
Soil cultivation	Gasoline or diesel powered rototiller or small tractor	Glazer hoe, broadfork, adze, rake and human labor
Soil fertility	In-organic or imported organic fertilizer	Growing of highly productive, nitrogen and biomass crop (banner fava beans), making aerobic compost piles sufficient to build soil carbon and nitrogen fertility, re-introducing micro-nutrients by importing locally generated food waste and processing in a worm bin, and application of compost teas for microbiology enhancement.
Pest and weed management	Herbicide and pesticide applications, flame weeder, tractor cultivation	Companion planting, crop rotation, crop diversity and spatial heterogeneity, beneficial predator attraction through landscape plantings, emphasis on soil and plant health, and manual removal with efficient human-scaled tools
Seed sourcing	Bulk ordering of a few varieties through centralized seed development and distribution outlets	Sourcing seeds from local supplier, developing a seed saving and local production and distribution plan using open pollinated varieties

Food distribution	Produce trucks, refrigeration, long-distance transport, eating out of season	Produce only sold locally, direct from farm or hauled to local restaurants or grocers using bicycles or electric vehicles, produce grown with year-round consumption in mind with farm delivering large quantities of food in winter months
Storage and processing at production end	Preparation of food for long distance transport, storage and retailing requiring energy intensive cooling, drying, food grade wax and packaging	Passive evaporative cooling, solar dehydrating, root cellaring and re-usable storage baskets and bags
Home and institutional storage and cooking	Natural gas, propane or electric fired stoves and ovens, electric freezers and refrigerators	Solar ovens, promotion of eating fresh and seasonal foods, home-scale evaporative cooling for summer preservation and "root cellaring" techniques for winter storage

Table 1. Feeding people requires many kinds of work and all work entails energy. In most farm operations the main energy sources are fossil fuels. By contrast, Brookside Farm uses and develops renewable energy based alternatives.

Our use of food scraps to replace exported fertility also reduces energy by diverting mass from the municipal waste stream. Solid Waste of Willits has a transfer station in town but no local disposal site. Our garbage is trucked to Sonoma County about 100 miles to the south. From there it may be sent to a rail yard and taken several hundred miles away to an out of state land fill. We are also planning to irrigate using an on-site well and a photovoltaic system instead of treated municipal water or diesel-driven pumps.

How much energy does Brookside Farm save?

The complexity of the food system makes it difficult to calculate how much energy Brookside Farm is saving. A research program at UC Davis now devoted to just this sort of question is recently underway, but with few results to share thus far.[xvi]

From previous studies we can find clues about the high energy inputs to fruit and vegetable cultivation. From Fig. 4. above, we can see that fruits and vegetables account for (102,370/921,590) 11% of crop production by weight. Table 3 (given below) of the Congressional Research Service report shows that energy invested in fruit and vegetable production is proportionally higher, accounting for (3759/18364) 20% of the energy for crops at the farm level.

Table 3. Farm Energy Costs (Value and Share) by Activity, 2002

Activities[a]	Total Costs of Production (COP)	Total Energy Costs	Energy Share of COP	Share of Total U.S. Farm Energy Costs by Activity
	—— $ million ——		%	%
Crop Activities	**80,343**	**18,364**	**22.9**	**76.4**
Major Field Crops	50,091	13,627	27.2	56.7
Vegetable & Fruits	19,737	3,759	19.0	15.6
Greenhouse & nursery[b]	10,514	979	9.3	4.1
Livestock Activities	**95,857**	**5,701**	**5.9**	**23.7**
Beef cattle ranching	20,038	2,323	11.6	9.7
Aquaculture & other	5,617	445	7.9	1.9
Dairy cattle & milk prod.	18,451	1,241	6.7	5.2
Hog & pig farming	11,312	526	4.6	2.2
Poultry & egg prod.	17,649	534	3.0	2.2
Cattle feedlots	22,143	577	2.6	2.4
United States	**173,199**	**24,036**	**13.7**	**100.0**

Source: USDA, NASS, *2002 Census of Agriculture*.

[a]Activities are organized by North American Industry Classification Ssytem (NAICS), see "Appendix A" of *2002 Census of Agriculture* for details; available at [http://www.nass.usda.gov/census/census02/volume1/us/index1.htm].
[b]Includes floriculture.

Much of the savings at Brookside Farm occurs off the farm by replacing what would normally be imported, through passive solar preservation and storage techniques, and by shifting consumer habits towards seasonally fresh cuisine proportionally high in vegetables.

Does Brookside Farm Scale? Lawns to Food

Before it was Brookside Farm, it was a field of mostly grass at an elementary school. The school district watered and mowed it (Fig. 6).

Fig. 6. Brookside Farm in early spring, 2007. The image shows the farm site adjacent to the forest and bordered by grassy fields, school buildings and a residential neighborhood. Arrows from a home contrast distance and direction of food coming from the local Safeway supermarket and Brookside Farm. The 1 acre Brookside Farm occupies about a quarter of the available play field at Brookside Elementary School.

Using satellite imagery, the area of lawn in the United States has recently been estimated:

> "Even conservatively," Milesi says, "I estimate there are three times more acres of lawns in the U.S. than irrigated corn." This means lawns-including residential and commercial lawns, golf courses, etc-could be considered the single largest irrigated crop in America in terms of surface area, covering about 128,000 square kilometers in all.[xvii]

The same study identifies where and how much water these lawns require:

> That means about 200 gallons of fresh, usually drinking-quality water per person per day would be required to keep up our nation's lawn surface area.

Let me put the area of lawn from this study into a food perspective. The 128,000 square kilometers of lawns is the same as 32 million acres. A generous portion of fruits and vegetables for a person per year is 700 lbs, or about half the total weight of food consumed in a year.[xviii] Modest yields in small farms and gardens would be in the range of about 20,000 lbs per acre.[xix] Even with half the area set aside to grow compost crops each year, simple math reveals that the entire U.S. population could be fed plenty of vegetables and fruits using two thirds of the area currently in lawns.

Number of people in U.S.	300,000,000
Pounds of fruits and vegetables per person per year	700
Yield per acre in pounds	20,000
People fed per acre in production	29
Fraction of area set aside for compost crops	0.5
Compost-adjusted people fed per acre	14
Number of acres to feed population	21,000,000

Acres in lawn	32,000,000
Percent of lawn area needed	66%

Labor Compared to Hours of T.V.

For its members Brookside Farm's role is to provide a substantial proportion of their yearly vegetable and fruit needs. Using our farming techniques, we estimate that one person working full time could grow enough produce for ten to twenty people. By contrast, an individual could grow their personal vegetable and fruit needs on a very part-time basis, probably half an hour per day, on average, working an area the size of a small home (700 sq ft in veggies and fruits plus 700 sq ft in cover crops). American's complain that they feel cramped for time and overworked. But is this really true or just a function of addiction to a fast-paced media culture? According to Nielsen Media Research:[xx]

> The total average time a household watched television during the 2005-2006 television year was 8 hours and 14 minutes per day, a 3-minute increase from the 2004-2005 season and a record high. The average amount of television watched by an individual viewer increased 3 minutes per day to 4 hours and 35 minutes, also a record. (See Table 1.)

So if we imagine families having the discipline to cut out a single sitcom viewing per day, or one baseball or football game per weekend during the growing season, that would free-up sufficient time to become self-reliant in fruits and vegetables and likely improve overall health.[xxi] (A note of caution though, an article from The Onion warns "that viewing fewer than four hours of television a day severely inhibits a person's ability to ridicule popular culture.")[xxii]

Conclusions

For those wanting to contribute to a lower-energy food system, starting with fresh produce makes sense for several reasons:

(1) Significant production is possible in a small area, often what people already have,

(2) Tools and equipment are simple, inexpensive and readily available,

(3) Fruits and vegetables are heavy due to high water content, and therefore energy-intensive to transport and process either by canning or dehydrating,

(4) Growing vegetables and fruits is generally more energy intensive than other crops because of high fertilizer and irrigation inputs,

(5) Quality declines rapidly after harvest, so home or locally available food has higher nutritional value and usually tastes better,

(6) Labor, packaging and storage demands of fruits and vegetables are high in mechanized production systems, making the investment in home-grown produce financially competitive, and

(7) Gardening and small-scale fruit and vegetable farming lend themselves to physical and social activities across generation and income gaps that improve health and enhance a shared sense of purpose and fun.

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[i] This graphic was developed based on the principles discussed in Chapter 2 of Daly and Farley "Ecological Economics: Principles and Applications" (2004, Island Press)

[ii] http://www.storyofstuff.com/

[iii] http://www.footprintnetwork.org and http://www.rprogress.org/ecological_footprint/about_ecological_footprint.htm; the original ecological footprint analysis (EF1) is at the first reference, and the second type (EF2) at the second. The major difference between the two is that the second attempts to incorporate aquatic systems (e.g., oceans), total terrestrial productivity, and biodiversity reserves.

[iv] Graphic from: http://www.footprintstandards.org/

[v] For the 50% figure see: http://www.footprintnetwork.org/gfn_sub.php?content=global_footprint; for the greater than 90% and discussion of differences between methods see: http://www.rprogress.org/publications/2006/Footprint%20of%20Nations%202005.pdf

[vi] http://scitizen.com/screens/blogPage/viewBlog/sw_viewBlog.php?

idTheme=14&idContribution=1397

[vii] http://globalpublicmedia.com/richard_heinbergs_museletter_big_melt_meets_big_empty

[viii] http://www.climatecodered.net/

[ix] http://css.snre.umich.edu/main.php?control=detail_proj&pr_project_id=29

[x] See especially Table 2. in: http://www.fao.org/docrep/005/AC911E/ac911e05.htm

[xi] http://www.theoildrum.com/node/2431

[xii] Graphic from: http://css.snre.umich.edu/css_doc/CSS01-06.pdf

[xiii] http://www.ncseonline.org/NLE/CRSreports/04nov/RL32677.pdf

[xiv] Although no date appears on this paper, it is clearly related to a 1994 conference and workshop: http://www.cias.wisc.edu/pdf/energyuse.pdf; http://www.cias.wisc.edu/archives/1994/01/01/energy_use_in_the_us_food_system_a_summary_of_existing_research_and_analysis/index.php

[xv] http://www.energyfarms.net/

[xvi] http://asi.ucdavis.edu/conferences/farmtofork/; http://californiaagriculture.ucop.edu/0704OND/editover.html; http://asi.ucdavis.edu/Research/ASI_Program_Proposal_Brief_-_Energy_Life_Cycle_Assessment_in_Food_Systems_9-13.pdf

[xvii] http://earthobservatory.nasa.gov/Study/Lawn/

[xviii] http://www.ers.usda.gov/Data/FoodConsumption/FoodGuideIndex.htm

[xix] An acre is ca. 43,000 sq ft. Our experience at Brookside Farm suggests about 1 lb of produce per square foot of cultivated space is to be expected, with infrastructure and paths requiring significant area. Fruit orchards in Mendocino County yield about 20,000 lbs per acre: http://www.co.mendocino.ca.us/agriculture/pdf/2006%20Crop%20Report.pdf

[xx] http://www.nielsenmedia.com/nc/portal/site/Public/menuitem.55dc65b4a7d5adff3f65936147a062a0/?vgnextoid=4156527aacccd010VgnVCM100000ac0a260aRCRD

[xxi] http://www.csun.edu/science/health/docs/tv&health.html

[xxii] http://www.theonion.com/content/node/30863