Renewable Agriculture and Food Systems: 24(1); 1–7 doi:10.1017/S1742170508002433

Foodshed analysis and its relevance to sustainability

Christian J. Peters[1,*], Nelson L. Bills[2], Jennifer L. Wilkins[3], and Gary W. Fick[1]

[1]Department of Crop and Soil Sciences, [2]Department of Applied Economics and Management and [3]Division of Nutritional Sciences, Cornell University, Ithaca, NY 14853, USA.
*Corresponding author: cjp20@cornell.edu

Accepted 18 September 2008; First published online 8 December 2008 **Commentary**

Abstract

Providing a wholesome and adequate food supply is the most basic tenet of agricultural sustainability. However, sharp increases in global food prices have occurred in the past 2 years, bringing the real price of food to the highest level seen in 30 years (FAO, 2008). This dramatic shift is a fundamental concern. The role of 'local food' in contributing to the solution of underlying problems is currently being debated, and the debate raises a critical question: To what degree can society continue to rely on large-scale, long-distance transportation of food? Growing concerns about climate change, the longevity of fossil fuel supplies and attempts to produce energy from agriculture suggest that energy efficiency will be critical to adapting to resource constraints and mitigating climate impacts. Moreover, these problems are urgent because energy prices, biofuel production and weather-related crop failures are partially responsible for the current world food price situation. Tools are needed to determine how the environmental impact and vulnerability of the food system are related to where food is produced in relation to where it is consumed. To this end, analyses of foodsheds, the geographic areas that feed population centers, can provide useful and unique insights.

Key words: local food, climate change, energy, biofuel, world food situation

Introduction

Agriculture and the food system may be entering a new era. At the end of the 20th century, it was clear that population growth and rising incomes, particularly in developing countries, were increasing global consumption of meat, eggs and other animal products and would have profound impacts on food production and human nutrition in the future[1]. However, just 8 years into the 21st century, climate change, rising energy prices and biofuel production have also entered the world food equation. Each of these forces has been implicated in the recent rise in food prices[2], and they are likely to continue to influence food production over the long term. This adds urgency to the goal of making food systems more ecologically sustainable.

Global concerns about food prices have arisen just as a vigorous discussion has emerged in several modern nations, exemplified by the United States and the United Kingdom, about the merits of organic and local foods. Relative to the larger matter of global food security, debate over the importance of organic and local foods may seem trivial. However, the local foods movement begs a larger question that is quite relevant to both developed and developing nations. Namely, to what degree can long-distance transportation of food continue unabated by concerns about energy and climate change? Indeed, tools are needed to inform policy decisions that, to the extent practicable, simultaneously ensure food security, improve nutrition and reduce greenhouse gas emissions all while adapting to rising energy costs and a changing climate. To this end, analysis of foodsheds, the geographic areas that feed population centers, may provide useful insights. In this paper, we will describe the origin of the foodshed concept and the relationship between local food and sustainability, primarily as they have been addressed in the US. In addition, we will discuss the bearing foodshed analysis might have on global issues such as climate change, energy security and the world food situation.

Concept of a Foodshed and Foodshed Analysis

Analogous to a watershed, the concept of a foodshed has been presented both as a tool for understanding the flow of food in the food system and as a framework for envisioning alternative food systems. In what may be the original use of the term, Walter Hedden described a 'foodshed' in 1929 as the 'dikes and dams' guiding the flow of food from producer to consumer[3]. Contemporary authors have used the term to refer to this geographic idea of a foodshed[4,5]. However, the term has also been used to describe the components of an alternative food system that connects local producers and consumers[4,6–8]. Since the term lacks consistent definition, we provide some history of its prior use and clarify its meaning in the context of foodshed analysis.

Hedden's book, *How Great Cities Are Fed*, describes the economic forces that influence where foods are produced and how they are transported to the cities in which they are consumed. His work focused on New York City and was prompted by the threat of a halt in nationwide railroad transportation in October 1921 when 'it immediately became apparent that there was a dire lack of dependable information regarding the city's food needs, the sources from which they were supplied, and the manner in which these supplies were transported and handled'[3]. The fact that 8 million people were fed without anyone understanding the whole system highlights both the power of the marketplace to meet human demands and the peril of taking its function for granted until it is in danger. Hedden does not identify the specific threat, but he likely refers to a scheduled 30 October 1921 strike of the nation's five largest railroad worker unions (railroad conductors, locomotive engineers, switchmen, railway trainmen and locomotive firemen) that would have affected 42 states had it not been called off 3 days before the strike deadline[9,10]. Just as this transportation crisis passed, the term 'foodshed' dropped into obscurity.

Sixty years later, Arthur Getz reintroduced the concept of a foodshed to provide an image that helps people to understand how food systems work and that suggests food comes from a source that must be protected[11]. Getz found this image useful for envisioning how agriculture could thrive in low-density suburban and ex-urban areas by targeting consumers in metropolitan areas. Building on this local theme, Kloppenburg et al. used the term 'foodshed' to represent a more locally reliant, alternative food system that reduces the negative social and environmental impacts of agriculture[4]. Thus, the term often connotes a connection to local food systems even though its original use refers to the food system in general.

Though the literature lacks a precise definition, we adopt the term 'foodshed' here because its parent concept, the watershed, is so widely understood. However, we wish to clarify our use of the term. For the purposes of this paper, a 'foodshed' is the geographic area from which a population derives its food supply. As such, 'foodshed analysis' refers to study of the actual or potential sources of food for a population, particularly those factors influencing the movement of food from its origin as agricultural commodities on a farm to its destination as food wherever it is consumed. Such an analysis would be immediately relevant to the on-going debate about local food but could ultimately be applied to larger questions of food system sustainability.

Local Food and Sustainability

A growing body of literature connects local food to the larger goal of sustainable development. Advocates claim local food systems offer an array of economic, environmental and social benefits, but the evidence underlying these assertions is being challenged. Vigorous debate of these issues has entered the public discourse on food, as evidenced by recent articles in major popular press publications in the US[12] and the UK[13] and the selection of 'locavore' as the Oxford word of the year for 2007[14]. To understand the significance of local food to sustainability, the subject and the surrounding debate must be examined more closely.

The term 'local food' evades easy definition. In part, it is a geographical concept referring to the distance between food producers and consumers. For example, in a recent survey of US consumers, most respondents defined 'local' as produced within 100 miles or within their home state[15]. While several authors claim that no consistent definition of 'local' exists[16,17], terms like 'local food', 'local food system' and '(re)localization' are used almost interchangeably to refer to the concept of increasing reliance on foods produced near their point of consumption relative to the modern food system. In addition to this geographical meaning, 'local food' is also a political concept. This second construction refers to an alternative system of food production that addresses the perceived ills of the modern food system. It has been described as 'a banner under which people attempt to counteract trends of economic concentration, social disempowerment, and environmental degradation in the food and agricultural landscape'[18]. This connection between local and the creation of a more sustainable and just food system has been traced to seminal writings of Wendell Berry, Joan Gussow, Jim Hightower, and Frances Morre Lappé from the 1970s[19].

Given the breadth of the second definition, it is not surprising that a wide range of benefits have been attributed to 'local food'. These purported benefits encompass all three dimensions of sustainability: ecological, economic and social. Some of the advantages of local food arise from the physical proximity of producers and consumers, such as reducing the amount of energy used in the transport of foods[4,7,20,21] and the associated greenhouse gas emissions[22]. Similarly, local foods are purported to be better tasting and perhaps more nutritious than foods bred and picked for their ability to endure long-distance shipping[4,23]. Others benefits are attributed to a combination of shorter supply chains and the relationships forged between producers and consumers, such as improving the economic viability of local farms and their communities[7,21,24], increasing public awareness of issues related to the food system[21], improved environmental stewardship by producers[24] and greater public control over the food system[7,24].

Finally, it has been posited that a more local food system would decrease food safety risks by decentralizing food production[7,21]. Taken together, these claims suggest that 'localization' is a vital component of a transition to a more sustainable and more just food system.

Of course, the validity of these claims has become a matter of debate. Within the scholarly literature, authors caution that there are potential risks (along with benefits) to localizing food systems[16] and that local food systems are not inherently more environmentally sustainable or socially just than the global food system[18,25]. Nonetheless, the weight of the evidence suggests to us that the local food movement is generally viewed in a positive light. Articles in the popular press raise broader issues such as the efficacy of consumer's attempts to promote change through their supermarket purchases[13] and the merits of organic relative to local food[12]. In response to growing public interest, Edwards-Jones et al. examined evidence to see if local food is best, principally in terms of its greenhouse gas emissions[17]. They concluded that because of the dearth of studies which examine greenhouse gas emissions across the entire food system, it is not possible to answer the question conclusively.

Given the contradictory nature of the available evidence, the prevalent claims from local food system proponents should not simply be dismissed. Rather, closer scrutiny is probably in order. More importantly, debate over whether or not 'localization' is desirable or if it is a first principle of sustainability misses a broader point. An interesting question is how might pressing issues of sustainability force the food system to become more local? To this end, several issues stand out because of their urgency and their potential to influence society's continued dependence on long-distance transport of food: namely, the challenges of climate change, petroleum depletion, and bio-energy production beg that this question be answered.

The Climate–energy Puzzle

There is growing consensus within the scientific community that climate change is a threat to sustainability that requires action in the near term. The warming of the planet's climate has been deemed 'unequivocal' by the most recent synthesis report of the Intergovernmental Panel on Climate Change (IPCC), and the available evidence strongly supports the assertion that this change in climate has anthropogenic origins[26]. In addition, while there is no clear agreement on how much warming could be tolerated by the Earth's ecosystems or human society, immediate action seems warranted. The IPCC clearly states that mitigation of emissions can help reduce, delay or avoid many of the negative impacts of climate change and that the risks of severe negative consequences increase the longer society waits to take action[26]. Meanwhile, the Scientific Expert Group on Climate Change and Sustainable Development (SEG) boldly asserts that collective action to address climate change is needed now[27], echoing a sense of urgency which appears to be shared by many scientists[28].

Expert bodies have concluded that since some warming is inevitable, both adaptation to and mitigation of climate change are necessary[27,29]. In addition, since no one sector alone can achieve the level of mitigation required[30], all emissions sectors (agriculture, buildings, energy, forestry and land use change, industry, transport and waste) must contribute to the effort. Since the food system crosses multiple emissions sectors, it is not easy to estimate its total impact. Agricultural production alone contributes 14% of anthropogenic greenhouse gas emissions[26]. However, according to a broader, multi-sector analysis of livestock production, the entire livestock production cycle (from emissions associated with clearing land for crop production or pasture to emissions from processing and transporting livestock products) accounts for 18% of total emissions[31]. Thus, the food system is an important source of emissions, and it is reasonable to evaluate how its impact will be mitigated.

Intimately related to climate change, a second global challenge to sustainability is the depletion of fossil fuel resources amidst rising energy demand. Global hydrocarbon (oil and natural gas) production has been forecast to peak and decline in the 21st century[32,33]. Since oil currently supplies about 35% of the world's energy[34], its depletion poses particular concern. According to a recent report by the US Government Accountability Office, most studies estimate that the peak in petroleum production has already occurred or that it will occur by 2040[35]. This is significant because the peak marks the transition from oil being a plentiful, relatively cheap resource to being an increasingly scarce and expensive resource[36]. Indeed, petroleum production capacity has just been able to keep pace with demand in recent years[35], and rising crude oil prices have surpassed records in both nominal[35] and real (inflation adjusted) terms[37]. Whether or not these price increases indicate that society is near the peak remains to be seen, but they have forced energy back into the public consciousness.

How important is this transition? Several authors believe the consequences are serious enough to warrant close attention, concluding that failure to adequately prepare for the peak will lead to serious economic disruption[33,35,38] or that reductions in population may be necessary to support people at an acceptable standard of living[39]. Others argue that the world can extend the use of petroleum by tapping unconventional sources such as tar sands and oil shale[40,41]. However, such resources are more energy intensive to extract and could significantly increase greenhouse gas emissions[41]. In either case, the energy constraints or potential climate impacts present a clear challenge to sustainability. Moreover, uncertainty about the quantity of reserves remaining and political instability in major oil-producing countries mean production is vulnerable to sudden disruptions[35]. Since the transportation sector is almost completely reliant on oil[35], it is reasonable to question how movement of foodstuffs will be affected by long-term depletion or sudden disruptions in oil production.

In response to growing concerns about climate change and energy security, biofuels are being sought as a partial solution to both problems. However, while biofuels are a renewable energy source they face several major constraints: the scale of potential production relative to current energy demand, competition with food production and the carbon emissions of land conversion. With regard to scale, it is illustrative to examine the production of ethanol in Brazil and the US, who together produce 70% of the world's ethanol[42]. For example, were the entire US corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) crops used to produce ethanol and biodiesel, just 12% of gasoline demand and 6% of diesel demand could be satisfied[43]. In contrast, the sugar cane (*Saccharum officinarum* L.)-based ethanol industry in Brazil supplied 39% of the country's gasoline demand (based on energy content) with ethanol in 2004[42] even though just 10% of its cropland is devoted to growing sugar cane[44]. However, this comparison is unbalanced because Brazil consumed just 8.4 billion gallons of gasoline in 2004 relative to the 142 billion gallons consumed in the US[42]. Moving beyond these two countries, Giampietro et al. estimated the land needed for 21 countries (including Brazil and the US) to supply both food and energy from agricultural land, assuming that energy needs in temperate regions were supplied from corn and sorghum (*Sorghum bicolor* (L.) Moench) ethanol and in tropical regions were supplied from sugar-cane ethanol[45]. None of the 21 countries included in the analysis had enough arable land to meet both food and energy needs, though Brazil had a more favorable ratio of land needed to land available than the US (3.0 versus 14.6) because of its lower per capita energy consumption and reliance on the more efficient sugar cane-based ethanol system[45]. On balance, 'first generation' biofuels (fuels produced from grains, oilseeds and sugar crops) appear to have limited potential to replace society's current use of fossil fuels.

Even 'second generation' biofuels, which would produce fuel from cellulose, beg the same question about scale. Studies of the potential energy contribution from global biomass production vary widely, but generally suggest that biomass could provide between 100 and 400 exajoules (EJ) of energy by 2050[46]. For comparison, global energy consumption in 2004 was 472 EJ[47]. On the surface, this seems promising. However, the total amount of biomass needed to achieve this level of energy output is comparable with the levels already harvested in the agricultural system[48,49]. Thus, both the ecological and socio-economic consequences of such large-scale production are causes for concern[49].

One such ecological concern is the emission of carbon dioxide from conversion of land to agricultural production. Recent studies have shown that although production of biofuel feedstock removes carbon dioxide from the atmosphere and thus displaces fossil fuel emissions, the net climate impact is greatly influenced by land use change[50,51]. The term 'carbon debt' has been coined to describe the period of time that would be required for a biofuel system to mitigate the emissions caused by converting land to active agricultural use[50]. The size of the carbon debt varies depending on the previous use of the land converted to crop production and the system of biofuel in question. For example, the 'payback' period ranges from 17 years for ethanol derived from sugar cane (*S. officinarum* L.) planted on former savannah to 420 years for biodiesel from oil palm (*Elaeis guineensis* Jacq.) planted on peatland rainforest[50]. Moreover, even if biofuel production itself occurs on active agricultural land, it may push food production onto new land or land that had been abandoned for agricultural use. As a result, even cellulosic ethanol production from perennial crops such as switchgrass (*Panicum virgatum* L.) can indirectly cause land conversion that result in net carbon emissions for decades[51]. Thus, it has been argued that from the standpoint of climate emissions, biofuel production should be derived from waste products[50,51] or from feedstocks produced on abandoned or marginal lands[49,50].

In light of these findings, it seems fair to conclude that society cannot simply 'grow' its way out of the climate change and energy security problems. Nonconventional sources of petroleum can be used as substitutes for conventional oil, but are likely to exacerbate climate emissions. Biofuels are more promising, but face limits in their potential scale and will have to be developed carefully to avoid unintentionally increasing emissions. Thus, more attention must be paid to possibilities for reducing emissions and demand for energy through more efficient transport and different patterns of consumption. To this end, evaluating the potential for strategies, such as increased reliance on local and regional food production, to reduce energy use and emissions is worthwhile.

The World Food Situation

The urgency of these converging problems becomes most apparent when one examines their effect on what has traditionally been the principal goal of agriculture, food production. In the late 1990s, rising incomes and associated dietary shifts were projected to boost consumption of livestock products in the developing world by 2020 and necessitate a significant increase in the intensity of agricultural production[1]. Nonetheless, it was expected that supply would be able to keep pace with demand over this interval[52–54]. While the environmental implications of increased livestock production were a concern, this transformation held promise for improving the incomes of small farmers and adding diversity to the diets of people in the developing world[1].

Recently, assessments of the world food situation have become less sanguine. Global food prices, in real terms, have increased by an average of 15% annually between 2006 and 2008, relative to a modest rate of 1.3% between 2000 and 2005[55]. Poor grain harvests due to droughts, rising oil prices and increasing demand for biofuels, in addition to the more familiar drivers of rising incomes and population growth, have all been implicated in the rising commodity prices that have caused these increases in world food prices[2,56]. Prior to the recent spike in food prices, food security was already a long-standing concern. Approximately 840 million people suffer from chronic hunger and more than 2 billion suffer from micronutrient deficiencies or 'hidden hunger'[57]. Increases in food prices threaten to reduce the purchasing power of household incomes, pushing more people into deprivation. If this is an indication of how responsive our food system is to climate perturbations and competition between food and energy, then society has cause for alarm.

In this context, a major challenge facing agriculture and the food system in this century will be trying to improve food security and human nutrition while using less fossil energy and reducing its greenhouse gas emissions. Given the tension between agriculture as a source of food and fuel, changing consumption patterns may be essential to achieving these goals. Though lifestyle changes may be difficult to initiate, it is possible to reduce demand for food and feed commodities without sacrificing dietary quality[58]. The most obvious example is reducing excess consumption of calories, which could address both environmental and resource issues as well as health problems associated with obesity. Another example would be substituting plant protein sources for livestock sources, which can reduce the land requirements for growing feed crops while still supplying adequate nutrition. Thus, it is worth investigating how efforts to modify diets might contribute to solving the food–climate–energy puzzle by reducing the demand for the foods that occupy the most extensive areas of land, require the greatest energy inputs or cause the largest emissions of greenhouse gases.

To this end, would shifts to diets based on more local foods reduce energy use or climate forcing emissions? A recent review of the assertion that local food systems emit less greenhouse gas emissions concluded that too few life cycle assessments of food system emissions exist at present to answer the question[17]. Thus, it would appear further analysis is warranted. Moreover, the concept of carbon debt shows that *where* something is grown is as important as *how* it is grown. Thus, facing these problems will require us to reconsider not only *how* food is produced but *where* it is produced.

Foodshed analysis may provide valuable insights into such questions. While attempts have been made to quantify the energy use or greenhouse gas emissions associated with each stage of the food system, the framework of foodshed analysis is unique because it considers geography in two distinct ways. First, a foodshed analysis would entail tracing the flow of food from its origin as an agricultural commodity on a farm to its ultimate point of consumption. Secondly, it would also measure different 'costs' of producing and transporting the products through the system, such as energy consumed, greenhouse gases emitted, or prices paid, not only at each stage in the food system, but for different locations. Such a framework would be valuable for evaluating how the geography of the food system influences its impact on the environment and the vulnerability of populations to disruptions in their food supplies. Moreover, foodshed analysis would help to plan how the geography of food systems should change to enhance sustainability. Many variations on this theme are possible. One example, which is explored in an upcoming paper, is estimating the capacity for population centers to supply more of their food from local sources[59].

Conclusions

Climate change and fossil energy depletion must be addressed in the 21st century. In this process, agriculture will undoubtedly be affected both as a source and sink of climate forcing emissions and a user and producer of energy. Local food systems proponents have long argued that such systems can both reduce greenhouse gas emissions and save energy, but the actual benefits are still a matter of debate. Nonetheless, the urgency of these issues has been highlighted by rising food prices, and analysis is needed to understand how the food system should change to become more sustainable.

To this end, Hedden's impetus for studying foodsheds is illustrative: when the transportation system is threatened, it is imperative to know where food *is* coming from and where it *might* come from. The goals of a foodshed analysis should be to answer either or both of these questions in the context of vulnerability of the food system to perturbations in food production or distribution, but also in the context of assessing the potential for food systems to mitigate greenhouse gas emissions and reduce dependence on fossil energy. Such an analysis should provide valuable insights into the crafting of policy that enhances food security and reduces the food system's ecological impact.

Acknowledgement. This research was supported in part by the National Research Initiative of the USDA Cooperative State Research, Education, and Extension Service, grant number 2005-55618-15640.

References

1 Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., and Courbois, C. 1999. Livestock to 2020: The Next Food Revolution. 2020 Vision for Food, Agriculture, and Environment. Discussion Paper 28. International Food Policy Research Institute, Washington, DC.

2 von Braun, J. 2007. The World Food Situation: New Driving Forces and Required Actions. Food Policy Report No. 18. International Food Policy Research Institute, Washington, DC. Available at Web site http://www.ifpri.org/pubs/fpr/pr18.asp (verified 14 March 2008).

3 Hedden, W.P. 1929. How Great Cities Are Fed. D.C. Heath and Company, New York.

4 Kloppenburg, J. Jr, Hendrickson, J., and Stevenson, G.W. 1996. Coming in to the foodshed. Agriculture and Human Values 13(3):33–42.
5 Stagl, S. 2002. Local organic food markets: potentials and limitations for contributing to sustainable development. Empirica 29:145–162.
6 Pretty, J. 2000. Towards sustainable food and farming systems in industrialized countries. International Journal of Agricultural Resources, Governance and Ecology 1(1):77–94.
7 Halweil, B. 2002. Home Grown: The Case for Local Food in a Global Market. Worldwatch Institute, Washington, DC.
8 Feagan, R. 2007. The place of food: mapping out the 'local' in local food systems. Progress in Human Geography 31(1): 23–42.
9 Anonymous. 1921. Strike to affect forty-two states. The Washington Post, 16 October 1921, 1, 22.
10 Anonymous. 1921. Peace vote unconditional: 'Big Four' unions and the Switchmen act after critical day. New York Times, 28 October 1921, 1.
11 Getz, A. 1991. Urban foodsheds. The Permaculture Activist 24:26–27.
12 Cloud, J. 2007. My search for the perfect apple. Time 169(11):42–50.
13 Anonymous. 2006. Voting with your trolley. The Economist, 9 December 2006, 73–75.
14 Oxford University Press. 2007. Oxford Word of the Year: Locavore. Available at Web site: http://blog.oup.com/2007/11/locavore/ (verified 22 May 2008).
15 Hartman Group. 2008. Consumer Understanding of Buying Local. Available at Web site: http://www.hartman-group.com/hartbeat/2008-02-27 (verified 22 May 2008).
16 Bellows, A.C. and Hamm, M.W. 2001. Local autonomy and sustainable development: testing import substitution in localizing food systems. Agriculture and Human Values 18:271–284.
17 Edwards-Jones, G., Milá i Canals, L., Hounsome, N., Truniger, M., Koerber, G., Hounsome, B., Cross, P., York, E.H., Hospido, A., Plassman, K., Harris, I.M., Edwards, R.T., Day, G.A.S., Tomos, A.D., Cowell, S.J., and Jones, D.L. 2008. Testing the assertion that 'local food' is best: the challenges of an evidence-based approach. Trends in Food Science and Technology 19:265–274.
18 Hinrichs, C.C. 2003. The practice and politics of food system localization. Journal of Rural Studies 19:33–45.
19 Feenstra, G.W. 1997. Local food systems and sustainable communities. American Journal of Alternative Agriculture 12(1):28–36.
20 Gussow, J.D. and Clancy, K.L. 1986. Dietary guidelines for sustainability. Journal of Nutrition Education 18(1):1–5.
21 Gussow, J.D. 1999. Dietary guidelines for sustainability: twelve years later. Journal of Nutrition Education 31(4): 194–200.
22 Pirog, R., Van Pelt, T., Enshayan, K., and Cook, E. 2001. Food, Fuel, and Freeways: An Iowa Perspective on How Far Food Travels, Fuel Usage, and Greenhouse Gas Emissions. The Leopold Center, Iowa State University, Ames, IA.
23 Lapping, M.B. 2004. Toward the recovery of the local in the globalizing food system: the role of alternative agricultural and food models in the US. Ethics, Place, and Environment 7(3):141–150.
24 Lyson, T.A. and Green, J. 1999. The agricultural marketscape: a framework for sustaining agriculture and communities in the Northeast. Journal of Sustainable Agriculture 15(2/3):133–150.
25 Born, B. and Purcell, M. 2006. Avoiding the local trap: scale and food systems in planning research. Journal of Planning Education and Research 26:195–207.
26 IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Core Writing Team, R.K. Pachauri and A. Reisinger (eds)). IPCC, Geneva, Switzerland. Available at Web site http://www.ipcc.ch/ipccreports/ar4-syr.htm (verified 29 April 2008).
27 Scientific Expert Group on Climate Change. 2007. Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable. R.M. Bierbaum, J.P. Holdren, M.C. MacCracken, R.H. Moss, and P.H. Raven (eds). Report prepared for the United Nations Commission on Sustainable Development. Sigma Xi, Research Triangle Park, NC, and the United Nations Foundation, Washington, DC. Available at Web site http://www.unfoundation.org/files/pdf/2007/SEG_ExecSumm.pdf (verified 18 April 2007).
28 Kerr, R.A. 2007. How urgent is climate change? Science 318:1230–1231.
29 IPCC. 2007. Summary for policymakers. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK. p. 7–22. Available at Web site http://www.ipcc.ch/ipccreports/ar4-wg2.htm (verified 29 April 2008).
30 IPCC. 2007. Summary for policymakers. In B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, and L.A. Meyer (eds). Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovern-mentalPanel on Climate Change. Cambridge University Press, Cambridge, UK and New York. p. 1–23. Available at Web site http://www.ipcc.ch/ipccreports/ar4-wg3.htm (verified 29 April 2008).
31 Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., and de Haan, C. 2006. Livestock's Long Shadow: Environmental Issues and Options. FAO, Rome, Italy. Available at Web site http://www.virtualcentre.org/en/library/key_pub/longshad/a0701e00.htm (verified 29 April 2006).
32 Edwards, J.D. 1997. Crude oil and alternative energy production forecasts for the twenty-first century: the end of the hydrocarbon era. American Association of Petroleum Geologists Bulletin 81(8):1292–1305.
33 Bentley, R.W. 2002. Global oil and gas depletion: an overview. Energy Policy 30:189–205.
34 International Energy Agency. 2007. Key World Energy Statistics. International Energy Agency, Paris, France. Available at Web site http://www.iea.org/textbase/nppdf/free/2007/key_stats_2007.pdf (verified 22 May 2008).
35 Government Accountability Office. 2007. Crude Oil: Uncertainty About Future Oil Supply Makes it Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production. US Government Printing Office, Washington, DC. Available at Web site: http://www.gao.gov/new.items/d07283.pdf (verified 18 April 2007).

36 Duncan, R.C. and Youngquist, W. 1999. Encircling the peak of world oil production. Natural Resources Research 8(3): 219–232.
37 Mouawad, J. 2008. Oil prices pass record set in '80s, but then recede. New York Times, 3 March 2008. Available at Web site http://www.nytimes.com/2008/03/03/business/worldbusiness/03cnd-oil.html?hp (verified 29 April 2008).
38 Hallock, J.L. Jr, Tharakan, P.J., Hall, C.A.S., Jefferson, M., and Wu, W. 2004. Forecasting the limits to the availability and diversity of global conventional oil supply. Energy 29(11): 1673–1696.
39 Youngquist, W. 1999. The post-petroleum paradigm—and population. Population and Environment 20(4):297–315.
40 Greene, D.L., Hopson, J.L., and Li, J. 2004. Running out of and into oil: analyzing global oil depletion and transition through 2050. Transportation Research Record 1880 : 1–9.
41 Brandt, A.R. and Farrell, A.E. 2007. Scraping the bottom of the barrel: greenhouse gas emission consequences of a transition to low-quality and synthetic petroleum resources. Climatic Change 84:241–263.
42 Seelke, C.L. and Yacobucci, B.D. 2007. Ethanol and Other Biofuels: Potential for U.S.–Brazil Energy Cooperation. Congressional Research Service. Available at Web site http://assets.opencrs.com/rpts/RL34191_20070927.pdf (verified 6 September 2008).
43 Hill, J., Nelson, E., Tilman, D., Polasky, S., and Tiffany, D. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Sciences, USA 103:11206–11210.
44 Goldemberg, J. 2007. Ethanol for a sustainable energy future. Science 315:808–810.
45 Giampietro, M., Ulgiati, S., and Pimentel, D. 1997. Feasibility of large-scale biofuel production: does an enlargement of scale change the picture? BioScience 47(9):587–600.
46 Berndes, G., Hoogwijk, M., and van den Broek, R. 2003. The contribution of biomass in the future global energy supply: a review of 17 studies. Biomass and Bioenergy 25: 1–28.
47 Energy Information Administration. 2007. International Energy Outlook 2007. Energy Information Administration, Office of Integrated Analysis and Forecasting, US Department of Energy, Washington, DC. Available at Web site http://www.eia.doe.gov/oiaf/ieo/index.html (verified 29 April 2008).
48 Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., and Fischer-Kowalski, M. 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proceedings of the National Academy of Sciences, USA 104:12942–12947.
49 Field, C.B., Campbell, J.E., and Lobell, D.B. 2007. Biomass energy: the scale of the potential resource. Trends in Ecology and Evolution 23(2):65–72.
50 Fargione, J., Hill, J., Tilman, D., Polasky, S., and Hawthorne, P. 2008. Land clearing and the biofuel carbon debt. Science 319:1235–1237.
51 Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., and Yu, T. 2008. Use of U.S. croplands for biofuels increase greenhouse gases through emissions from land-use change. Science 319:1238–1240.
52 Rosegrant, M.W. and Ringler, C. 1997. World food markets into the 21st century: environmental and resource constraints and policies. The Australian Journal of Agricultural and Resource Economics 41(3):402–428.
53 Alexandratos, N. 1999. World food and agriculture: outlook for the medium and longer term. Proceedings of the National Academy of Sciences, USA 96:5908–5914.
54 Johnson, D.G. 1999. The growth of demand will limit output growth for food over the next quarter century. Proceedings of the National Academy of Sciences, USA 96:5915–5920.
55 Food and Agriculture Organization (FAO). 2008. Soaring Food Prices: Facts, Perspectives, Impacts and Actions Required. High-level Conference on World Food Security: The Challenge of Climate Change and Bioenergy, 3–5 June 2008, Rome, Italy. Available at Web site http://www.fao.org/fileadmin/user_upload/foodclimate/HLCdocs/HLC08-inf-1-E.pdf (verified 3 September 2008).
56 FAO. 2007. Food Outlook—November 2007. FAO, Rome, Italy. Available at Web site http://www.fao.org/docrep/010/ah876e/ah876e00.HTM (verified 29 April 2008).
57 Kennedy, G., Nantel, G., and Shetty, P. 2003. The scourge of 'hidden hunger': global dimensions of micronutrient deficiencies. Food, Nutrition, and Agriculture 32:8–16.
58 Bender, W.H. 1994. An end use analysis of global food requirements. Food Policy 19(4):381–395.
59 Peters, C.J., Bills, N.L., Lembo, A.J., Wilkins, J.L., and Fick, G.W. In press. Mapping potential Foodsheds in New York State: a spatial model for evaluating the capacity to localize food production. Renewable Agriculture and Food Systems.

https://doi.org/10.1017/S1742170508002433 Published online by Cambridge University Press