Fall 2008

Sustainable soils: Reducing, mitigating and adapting to climate change with organic agriculture

Meredith T. Niles
Center for Food Safety, mtniles@uvm.edu

Recommended Citation
Niles, Meredith. "Sustainable Soils: Reducing, Mitigating, and Adapting to Climate Change with Organic Agriculture." Sustainable Development Law & Policy 9.1 (2008): 19.

Sustainable Development Law & Policy

Volume 9
Issue 1 *Fall 2008: Global Food & Agriculture*

Article 8

Sustainable Soils: Reducing, Mitigating, and Adapting to Climate Change with Organic Agriculture

Meredith Niles

Recommended Citation

Niles, Meredith. " Sustainable Soils: Reducing, Mitigating, and Adapting to Climate Change with Organic Agriculture." Sustainable Development Law & Policy, Fall 2008, 19-23, 68-69

Sustainable Soils: Reducing, Mitigating, and Adapting to Climate Change with Organic Agriculture

*by Meredith Niles**

Introduction

On April 2, 2007, the U.S. Supreme Court handed down its decision in *Massachusetts v. EPA*, its first case dealing with the issue of global warming.[1] Yet, even before the ruling, the effects of climate change were already being felt and documented throughout the world. In late 2007, the Intergovernmental Panel on Climate Change ("IPCC") released its Fourth Assessment Report, which famously noted that warming of the global climate system is now "unequivocal."[2] As policymakers throughout the world continue to feel the impacts of climate change and are compelled to action, oversight measures aimed at reducing greenhouse gas ("GHG") emissions and their impacts can no longer ignore the effect of industrial agriculture on climate change. Similarly, policymakers should recognize the role organic agriculture can play in stabilizing and lessening the impacts of climate change, and provide adequate funding for transition programs and initiatives utilizing organic production methods.

The IPCC's Fourth Assessment Report, and several subsequent reports, including a recent synthesis and assessment report by the U.S. Climate Change Science Program ("CCSP"), all conclude that climate change is already occurring and will likely accelerate in the future.[3] New research suggests that our food system will be singularly affected by climate change. Agricultural yields in the United States are set to notably decrease for crops ranging from corn to rice to sorghum.[4] Longer growing seasons will increase crop water requirements,[5] while rainfall events will become more sporadic and the intensity of rainfall events is expected to increase, resulting in more significant flood conditions.[6] Weed growth is projected to blossom as weeds respond positively to higher carbon dioxide ("CO_2") levels, and glyphosate, the most frequently used herbicide in the United States, will lose its efficacy.[7] Warmer temperatures will also likely increase the insect and pest populations throughout the United States, and a recent study has demonstrated that soybeans grown at elevated CO_2 levels had more than fifty percent more insect damage than soybeans grown in normal conditions.[8]

Such significant damage to our food system would have widespread implications throughout the world. As the evidence of climate change continues to mount, oversight paradigms like regional cap-and-trade programs have focused mostly on the industrial and transportation sectors as targets of GHG emissions mitigation. To date, the agricultural sector has been largely overlooked as both a source of GHG emissions and a potential tool for mitigation. Estimates of agricultural GHG emissions, as a percentage of total emissions, range from 13.5% to nearly 33% of all global emissions.[9] Furthermore, the U.N. Food and Agriculture Organization ("FAO") estimates that animal production alone accounts for eighteen percent of global GHG emissions.[10] In comparison, transportation emissions account for a little over thirteen percent of total global GHG emissions.[11] Clearly, there is a need for a shift in climate change policy to address the agricultural sector.

The agricultural sector has been largely overlooked as both a source of GHG emissions and a potential tool for mitigation.

As policymakers and individuals grapple with ways to reduce carbon footprints, it is essential that agriculture be recognized as a sector that needs to decrease its GHG emissions. Such reductions are essential, as they are in other sectors; however, agriculture has a unique role to play in climate change discussions because of its potential to mitigate GHG emissions through carbon sequestration, as well as lessen and prevent climate change impacts on agricultural, land, and water systems. This article will discuss recent and mounting evidence which suggests that organic agriculture, more than any other production system, has the greatest potential for combating climate change by reducing overall GHG emissions, sequestering more

** Meredith Niles is the Coordinator of the Cool Foods Campaign, a national initiative of the CornerStone Campaign and the Center for Food Safety. The Cool Foods Campaign educates the public about the environmental impact of food choice on global warming and empowers individuals with the resources to decrease their "FoodPrint." Meredith writes extensively about agriculture, food, and climate change as a guest columnist for Grist Environmental News and has contributed to National Public Radio, Environmental News Network, Wired Magazine, and Political Affairs, among other outlets. Previously she worked for the U.S. State Department in International HIV/AIDS assistance and holds a B.A. from the Catholic University of America in politics with honors in environmental studies.*

carbon, and promoting land management that lessens or eliminates the potential climate change impacts on land and agricultural systems.

Reducing GHG emissions in agriculture and adapting to climate change will depend on organic production systems for three reasons:

1) The overall emission reductions possible using organic production methods;
2) The increased ability of organic production systems to sequester carbon; and
3) The demonstrated ability of organic production to better adapt to potential climate change related events, including drought, floods, pest increase, and loss of biodiversity.

Reducing Emissions through Organic Production Methods

Agriculture in the United States has changed significantly in the past several decades. Farming has shifted largely toward the adoption of industrial practices that rely heavily on synthetic chemical pesticides and fertilizers, equipment and machinery reliant on fossil fuels, and monoculture. Most large farms now grow only one crop, typically corn or soybeans. The industrialization of our food system has had a heavy impact on the environment and played a major role in increasing global GHG emissions—especially with the rapid adoption of synthetic fertilizers and pesticides.[12]

Each year, the U.S. food system uses nearly 40 billion pounds of synthetic fertilizers[13] and more than one billion pounds of synthetic pesticides.[14] The GHG emissions associated with the production, packaging, transport, and application of these chemicals contribute to climate change and air pollution. The production of synthetic fertilizers and pesticides contributes more than 480 million tons of GHG emissions to the atmosphere each year.[15] The U.S. Environmental Protection Agency ("EPA") estimates that, once on our soils, synthetic fertilizers generate over 304 million pounds of GHG emissions.[16] Frequent over-application of synthetic fertilizers results in "run-off" when fertilizers are carried off of fields during weather events and irrigation.[17] Build-up of synthetic fertilizers has caused hypoxia, or "dead zones" lacking sufficient oxygen, in water bodies throughout the world where animals, plants, and plankton are dying in vast quantities.[18]

Shifting to organic production systems will cause an immediate drop in GHG emissions as organic production systems produce fewer GHG emissions than conventional industrial farming systems. FAO concluded that, "[w]ith lower energy inputs, organic systems contribute less to GHG emissions and have a greater potential to sequester carbon in biomass than conventional systems."[19] Because organic production systems are prohibited from using synthetic fertilizers and pesticides, they often rely on less intensive methods for fertilization including animal manure, cover crops, and integrated pest management strategies.[20] Research performed at the Rodale Institute, in conjunction with Cornell University, demonstrated that a conventional corn production system required significantly more energy per hectare than organic systems.[21] The reduced reliance on fossil fuel energy in the organic system reduced energy inputs about thirty percent, mostly because the organic systems relied on animal and legume nitrogen nutrients rather than synthetic fertilizers and pesticides.[22] In addition, nitrate leaching from fertilizers is significantly higher for intensive conventional systems as compared to organic systems,[23] and organic compost has the ability to reduce nitrogen and phosphorus leaching five fold when compared to synthetic fertilizers.[24] Switching to organic production will thus reduce not only initial GHG emissions from the production of fertilizers, but will also prevent fertilizers from leaching into waterways and exacerbating emissions in hypoxic systems.

Many of the synthetic fertilizers and pesticides used in the United States are for feed crops for animal production. It is estimated that about half of the grain and oilseeds grown in the United States are fed to livestock,[25] and conventional grain-fed beef requires twice as many energy inputs as grass-fed beef.[26] Animals that are "grass-fed," or produced using organic methods, produce significantly fewer GHG emissions than conventionally raised animals. Organic systems typically require fewer synthetic inputs and less energy to operate than conventional industrial facilities.[27] In addition, because pastured systems require fewer feed crops than confined systems, significant reductions in nitrous oxide would result from a shift to grass-fed animal production.[28] Overall, the global warming potential of organic animal production is about one third as much as intensive animal farming.[29] USDA-certified, grass-fed animals "cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season."[30] While some animals (like chickens or pigs) do not eat grass and may rely on feed crops, if raised organically the animals are fed 100% organic feed grown without synthetic pesticides and fertilizers.[31] Thus, organic meat and dairy products result in significantly fewer GHG emissions than conventional meat and dairy.[32]

Animal production contributes nearly one fifth of all global GHG emissions,[33] and in addition to the impact of synthetic fertilizers and pesticides used on feed crops, manure management, and enteric fermentation are also significant sources of GHG emissions.[34] In 2007, EPA reported that livestock manure management is responsible for over 55 million metric tons of GHG emissions,[35] mostly in the form of methane and nitrous oxide, which are approximately 21 times and 310 times more potent as GHGs than CO_2, respectively.[36] Improper manure storage in large-scale, conventional animal production increase GHG emissions because waste is often pooled in large lagoons and holding ponds, rather than being directly incorporated into soils.[37] During manure storage and decomposition, gaseous by-products including hydrogen sulfide, CO_2, ammonia, and methane are produced and released into the atmosphere.[38] Research has documented that manure stores on conventional farms emitted about twenty-five percent more methane gas than organic farms, demonstrating the significant impact that organic animal production can have in reducing GHG emissions.[39]

Carbon Sequestration in Organic Agriculture

Addressing climate change issues involves not only reducing GHG emissions, but also incorporating mitigation techniques that can sequester excessive GHG emissions. More than any other sector, agriculture is uniquely positioned to sequester vast amounts of carbon and thus reduce the impacts of climate change. Microbes and other soil organisms play a vital role in maintaining the health of agricultural soils as they decompose organic matter, cycle nutrients, and convert atmospheric nitrogen into organic forms.[40] EPA estimates that composting one ton of organic materials results in a net storage of nearly 600 pounds of CO_2.[41] While all types of agriculture have the ability to sequester carbon, organic agriculture can sequester significantly more carbon than conventional systems, and even conventional no-till systems,[42] because organic agriculture prohibits synthetic fertilizer and pesticide use, incorporates leguminous cover crops, and prioritizes increasing soil organic matter.[43] Moreover, several studies have shown that organic soils can sequester more carbon than conventional soils and that synthetic fertilizer can have a negative impact on carbon sequestration.[44]

Organic agriculture, more than any other production system, has the greatest potential for combating climate change.

In comparisons of field trials of organic and conventional farming plots, researchers found that while soil carbon levels were initially the same, after more than two decades the organic systems had significantly higher soil carbon levels. The organic systems—one using legume cover crops and the other using manure—retained more carbon in the soil, "resulting in an annual soil carbon increase of 981 and 574 kg per hectare . . . , compared with only 293 kg per hectare in the conventional system."[45] Similar long-term research at the United States Department of Agriculture ("USDA") demonstrated that organic agriculture increased overall soil health more than conventional no-till methods and resulted in increased yields over conventional production.[46] In addition, carbon sequestration is not exclusive to crop systems and can also provide substantial opportunities for farmers in animal production.[47]

Utilizing Organic Agriculture to Adapt to Climate Change Impacts

Climate change will impact many aspects of our lives, but the effects on agriculture may be the most noteworthy. CCSP noted:

> Ecosystems and their service (land and water resources, agriculture, biodiversity) experience a wide range of stresses, including pests and pathogens, invasive species, air pollution, extreme events and natural disturbances such as wildfires and flood. Climate change can cause or exacerbate direct stress through high temperatures, reduced water availability, and altered frequency of extreme events and severe storms.[48]

One of the greatest challenges of climate change will be finding ways to adapt to its myriad potential impacts. Securing and maintaining a food system that can continue to produce, despite unexpected weather and climate events, is crucial for the future. Organic agriculture, which is more resilient to climate change impacts, will be a necessary component to this challenge.

Among the greatest threats of climate change will be the impact on biodiversity and the potential global loss of life. Biodiversity contributes to ecosystem functioning and maintenance; as biodiversity decreases it will be extremely difficult to retrieve and recover.[49] Endangered and extinct species are already documented throughout the world, but climate change is causing more subtle losses in species and diversity.[50] Many of the species more prevalent in organic farming were known to have declining diversity and numbers as a result of previous agriculture intensification.[51] The biodiversity benefits associated with organic farms likely derive from the management practices absent from or rarely utilized in most conventional systems.[52] Specifically, organic farms have considerably more spiders,[53] birds,[54] butterflies,[55] and other species,[56] in both number and species count. Maintaining biodiversity on farms will be crucial to sustaining food production and ecosystem functions and organic production can certainly perform this task.

Climate change also has the potential to threaten agriculture through changing water and weather patterns increasing both drought and run-off.[57] Soil organic matter and soil carbon content are important for water absorption and retention and can be greatly affected by changes in these elements.[58] Increasing organic matter in soils leads to a direct increase in the ability of soils to retain water[59] and will be an important tool for combating drought and potential flood conditions from increasing snow melt and runoff.[60] Organic soils have higher levels of soil carbon and research has shown that in drought conditions, organic systems produced corn yields twenty-eight to thirty-four percent higher than conventional systems.[61] As weather patterns and precipitation continue to change, organic agriculture will be better able to adapt and continue to produce in uncertain conditions.

Providing the Framework for Transitioning to Climate Resilient Agriculture

Climate change is real, and its current and foreseeable future impacts can no longer be overlooked. As policymakers in the United States examine ways to reduce GHG emissions, mitigate climate change, and adapt for its effects, it is apparent that our food and agriculture system cannot be ignored. Conventional agriculture cannot continue on the same path because it causes a significant portion of our global and domestic GHG emissions. Without a paradigm shift in farming, excessive and unnecessary GHG emissions will continue and our food system will become ever more susceptible to collapse as a result of climate change.

The policy and legal approaches to addressing climate change through agriculture must involve a transition to a more organic way of farming. In 2007, the U.S. government allocated more than $3.7 billion in direct subsidies for corn, soy, and wheat.[62] Less than one percent of corn, soy, and wheat are grown organically in the United States, meaning almost all of these subsidies were given for industrial or conventional production.[63] Moreover, as described by Environmental Working Group:

> Direct payment subsidies are provided without regard to the economic need of the recipients or the financial condition of the farm economy. Established in 1996, direct payments were originally meant to wean farmers off traditional subsidies that are triggered during periods of low prices for corn, wheat, soybeans, cotton, rice and other crops.[64]

Yet, prices for these commodities are currently at record highs, with the cost of corn per bushel rising nearly sixty percent between 2006 and 2007.[65]

Such subsidies contribute to significant increases in annual GHG emissions and promote increased production and over-application of synthetic fertilizers, loss of biodiversity, and simplification of the soil that leads to reduced soil health, which in turn reduces carbon sequestration capacity. Meaningful reductions in GHG emissions from agriculture will require broad-based and large-scale legislative initiatives that stop rewarding an agriculture system that is worsening the global climate change crisis. Billions of dollars of subsidies for conventional production could be reallocated to organic transition programs and water and land conservation initiatives that will ensure that agriculture in the United States will continue to produce and function.

Increasing Funding for Organic Certification, Conservation and Conversion

The 2008 Farm Bill allocated a total of $22 million for the national organic certification cost share program, which is designed to help decrease the amount of money farmers pay for organic certification.[66] While this allocation did increase the annual cost-share eligibility from $500 to $750 per operation,[67] it pales in comparison to the vast subsidies received by larger conventional industrial farms. The National Organic Program received $39 million through 2012[68] and was authorized up to $10 million dollars for organic research.[69] To foster the transition of farmers to organic production systems and reduce GHG emissions, future legislation must allocate significantly greater funds.

Unique opportunities also lie in providing carbon offsets to farmers who transition to organic agriculture. Given the increasing evidence that organic agriculture is better suited to sequester carbon, offset programs established within cap-and-trade programs and public-based carbon offset initiatives should consider adding offset components for agriculture. Currently, only a few agriculture-based offset programs are in place within cap-and-trade programs, including a methane digester offset program in the Northeast Regional Greenhouse Gas Initiative.[70] While converting methane from manure can reduce emissions, research estimates that methane digesters could potentially only provide about 0.0002% of the energy currently consumed in the United States.[71] Moreover, the compression of methane gas requires significant amounts of energy, which may offset any potential emissions reductions.[72] Transportation of methane gas may also present difficulties, as most large scale farms will be able to produce more gas than they can use on farm; yet, given the economic investment of digesters, only large farms are usually able to invest in this technology.[73] Creating opportunities for farmers transitioning to organic production to receive carbon credits will create incentives for organic production and also help decrease the costs of transition.

Reducing Feed Crops and Transitioning to Pasture-based Organic Animal Production

With roughly fifty percent of grains grown in the United States being fed to livestock, much of corn, soy, and wheat subsidies are diverted to animal production.[74] Livestock and animal production is an important source of income for billions of people throughout the world; yet, our current production methods are not sustainable. Transitioning livestock production to pasture-based organic systems will utilize grasses unsuitable for human consumption and, through proper management, increase carbon sequestration.[75] Reducing crop production for animal feed is one of the most efficient methods for mitigating GHG emissions from agriculture[76] and ensuring sustainable food sources in the face of increasing fossil fuel prices. "[N]o other form of agriculture is less dependent on external, finite resources, such as fossil fuels, and/or external, potentially environmentally disruptive resources, such as fertilizers or pesticides, than grazing of native grasslands."[77]

Advocating for Organic Conservation Measures

Transitioning to organic agriculture is not a process that can happen overnight and will certainly require significant investments of time and money. Yet, in the meantime, many organic practices can be incorporated into existing conventional farming methods that will help to reduce GHG emissions. For example, integrating perennial crops, riparian zones, cover crops, and grasslands, and increasing crop diversity on farms have a demonstrated ability to not only reduce the climate change impacts of agriculture, but also increase yields and decrease costs associated with land management and fertilizer.[78]

Traditionally, the USDA's Conservation Reserve Program ("CRP") has assisted farmers and ranchers to comply with federal, state, and tribal environmental laws, and encourages farmers, by providing annual rental payments under multi-year contracts, "to convert erodible cropland or other environmentally sensitive acreage to vegetative cover" including native grasses, trees, or riparian buffers.[79] The CRP has increased carbon sequestration and promoted the maintenance of important ecosystem functions that help reduce environmental pollution. Since 1985, the program "has protected 170,000 miles of streams and restored 2 million acres of wetlands and buffer zones."[80] Unfortunately, with recent steady increases in ethanol production, land-use has begun to change. Subsidies for ethanol production have caused land previously held in reserve under the CRP to be taken out of conservation for corn production.[81] In 2006, USDA Chief Economist Dr. Keith Collins testified before the Senate Committee on Environment & Public Works about ethanol production, noting that the CRP, "which has 36 million acres set aside from crop production for environmental reasons, may provide a source of additional crop acreage. . . . [A] preliminary assessment concluded that 4.3 to 7.2 million acres currently enrolled in the CRP could be used to grow corn or soybeans . . . ."[82]

Policies that advocate for the removal of CRP land for ethanol production will not decrease GHG emissions.[83] Instead, increased ethanol production is releasing carbon stores in grasslands and creating a "carbon debt."[84] If ethanol production increases to the congressionally suggested 15-36 billion gallons by 2022, nitrogen fluxes into the Gulf of Mexico could increase by as much as thirty-four percent.[85] Such measures would have devastating effects on water quality, aquatic ecosystems, and GHG emissions. Policies encouraging ethanol production, specifically with land-use changes, should be strongly reconsidered in this context and re-evaluated for their overall effectiveness at reducing GHG emissions. Instead, CRP funding should continue and be strengthened to encourage organic conservation methods to be incorporated into farms throughout the country.

Conclusions

Climate change is a critical environmental issue and has broad implications for sustainable development and the future of our economy, health, and food system. The ability to respond to the momentous task of regulating GHG emissions will have implications for the overall well-being of our entire country. Reducing and sequestering GHG emissions and adapting to climate change impacts demand comprehensive approaches that fully integrate agriculture, recognizing its contribution to climate change and unique ability to sequester GHG emissions and reduce climate change impacts. Organic agriculture offers much hope for the future of environmental sustainability and food production and should be recognized for the many contributions it can make. Providing and increasing funding for organic transition, certification, and conservation programs will allow the United States and other countries throughout the world to reduce and offset GHG emissions. At the same time, organic agriculture policy initiatives will ensure environmental protection in our waterways and promote biodiverse ecosystems in the face of looming global reductions in species. Ensuring the future of our environment and the vitality of our food systems in the shadow of climate change depends on organic production systems and our ability to transition to more sustainable agricultural policies.

Endnotes: Sustainable Soils

1 *See generally* Massachusetts v. EPA, 549 U.S. 497 (2007). The decision was a landmark victory for environmentalists because it legitimized the urgency of the global warming crisis and the claim that the Bush Administration was illegally withholding regulation that could help address this crisis. The Court held, among other things, that the Environmental Protection Agency ("EPA") was legally bound to address greenhouse gas ("GHG") emissions under the Clean Air Act. *Id.* The momentous decision fundamentally altered the climate change debate in the United States and has led to a flurry of activity by the federal and state governments, as they attempt to piece together regulations and interim rules on how to best comply with the Court's decision and to generally address climate change. *Id. See also* Environmental Protection Agency, *Advanced Notice of Proposed Rulemaking: Regulating Greenhouse Gas EmissionsUnder the Clean Air Act*, 73 Fed Reg 44354-44520 (July 30, 2008); Department of the Interior, *Implementation of the National Environmental Policy Act (NEPA)*, 73 Fed. Reg. 126 (Jan. 2, 2008); Government Accountability Office (GAO), *Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources*, GAO-07-863 (Aug. 7, 2007); Letter from Henry Waxman, U.S. Congressman, to Stephen L. Johnson, EPA Administrator (Mar. 12, 2008); Ctr. for Biological Diversity v. Nat'l. Highway Traffic Safety Admin., 508 F.3d 508, 550 (9th Cir. 2007) (NHTSA failed to evaluate adequately global warming impacts of changes to fuel efficiency standards for vehicles); Ana Compoy, *States Sue EPA Over Refinery Emissions*, Wall Street Journal, Aug. 26, 2008, at A3; Beth Daley, *Mass. leads bid to limit greenhouse emissions; 18 states ask court to press EPA on car, truck gases,* Boston Globe, Apr. 2, 2008; Lieberman-Warner "America's Climate Security Act," S. 3036, 110th Cong. (2008); Bingaman-Specter "Low Carbon Economy Act" of 2007, S. 1766, 110th Cong. (2008); Midwest Greenhouse Gas Reduction Accord, http://www.midwesternaccord.org/; Regional Greenhouse Gas Initiative, http://www.rggi.org/home (Ten Northeast States signed on Sept. 25, 2008).

2 Intergovernmental Panel on Climate Change [IPCC], Climate Change 2007: Synthesis Report, Summary for Policy Makers 2 (2007), *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf (last visited Nov. 13, 2008).

3 For instance, forest fires are growing in frequency and intensity, and snowpack in the western United States has decreased and melts earlier. *See, e.g.*, U.S. Climate Change Science Program [CCSP], The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States 3 (2008), *available at* http://www.climatescience.gov/Library/sap/sap4-3/final-report/sap4-3-final-exec-summary.pdf (last visited Nov. 13, 2008); IPCC, *supra* note 2, at 7-9 (discussing projected climate change and its impacts).

4 CCSP, *supra* note 3, at 30.

5 *Id.* at 39.

6 *Id.* at 58.

7 *Id.* at 59.

8 Evan H. DeLucia et al., Brookhaven Nat'l Lab., Influence of Elevated Ozone and Carbon Dioxide on Insect Densities 13 (2005), *available at* http://www.pubs.bnl.gov/documents/30743.pdf (last visited Nov. 13, 2008).

Endnotes: Sustainable Soils
continued on page 68

[9] JESSICA BELLARBY ET AL., GREENPEACE INT'L, COOL FARMING: CLIMATE IMPACTS OF AGRICULTURE AND MITIGATION POTENTIAL 5 (2008), *available at* http://www.greenpeace.org/raw/content/international/press/reports/cool-farming-full-report.pdf (last visited Nov. 13, 2008); IPCC, *supra* note 2, at 5.

[10] HENNING STEINFELD ET AL., FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, LIVESTOCK'S LONG SHADOW: ENVIRONMENTAL ISSUES AND OPTIONS 112 (2006), *available at* ftp://ftp.fao.org/docrep/fao/010/A0701E/A0701E00.pdf (last visited Nov. 13, 2008).

[11] IPCC, *supra* note 2, at 5.

[12] David Pimentel et al., *Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems*, 55 BIOSCIENCE 7, 579 (2005), *available at* http://www.ce.cmu.edu/~gdrg/readings/2007/02/20/Pimental_EnvironmentalEnergeticAndEconomicComparisonsOfOrganicAndConventionalFarmingSystems.pdf (last visited Nov. 13, 2008) [hereinafter Pimental et al., *Farming Systems*].

[13] Food and Agriculture Organization, FertiStat: Fertilizer Use by Crop Statistics, http://www.fao.org/ag/agl/fertistat/fst_fubc1_en.asp?country=USA&commodity=%25&year=%25&search=Search+%21 (last visited Nov. 12, 2008).

[14] David Pimentel et al., *Reducing Energy Inputs in the US Food System*, 36 HUM. ECOLOGY 459 (2008). *See also* U.S. GEN. ACCOUNTING OFFICE, AGRICULTURAL PESTICIDES: MANAGEMENT IMPROVEMENTS NEEDED TO FURTHER PROMOTE INTEGRATED PEST MANAGEMENT (2001), *available at* http://www.gao.gov/new.items/d01815.pdf (last visited Nov. 13, 2008) (noting that chemical pesticides account for three-fourths of pesticides used in the United States) [hereinafter Pimentel et al., *Reducing Energy Inputs*].

[15] BELLARBY ET AL., *supra* note 9, at 6.

[16] U.S. ENVTL. PROT. AGENCY [EPA], INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990-2006 6-19 (2008), *available at* http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf (last visited Nov. 13, 2008).

[17] *See* Robert E. Criss & M. Lee Davisson, *Guest Editorial: Fertilizers, Water Quality, and Human Health*, 112 ENVTL. HEALTH PERSPECTIVES A536, A536 (2004), *available at* http://www.ehponline.org/docs/2004/112-10/EHP112-pa536PDF.pdf (last visited Nov. 13, 2008).

[18] *See, e.g.*, Criss & Davisson, *supra* note 17. In the Gulf of Mexico, a dead zone the size of New Jersey is largely the result of excessive nutrients from conventional agricultural practices in the Midwest and is likely growing because of the increase in production of corn for ethanol. It is estimated that the annual hypoxic bloom in the Gulf of Mexico will be the largest ever in 2008, mostly because of the increase of synthetic fertilizer use. Simon D. Donner & Christopher J. Kucharik, *Corn-Based Ethanol Production Compromises Goal of Reducing Nitrogen Export by the Mississippi River*, 105 PROCEEDINGS OF THE NAT'L ACAD. OF SCI. 4513 (2008), *available at* http://www.pnas.org/content/105/11/4513.full.pdf+html (last visited Nov. 13, 2008).

[19] JODI ZIESEMER, FOOD AND AGRIC. ORG. OF THE UN, ENERGY USE IN ORGANIC FOOD SYSTEMS 4 (2007), *available at* http://www.fao.org/docs/eims/upload/233069/energy-use-oa.pdf (last visited Nov. 13, 2008).

[20] Pimental et al., *Farming Systems*, *supra* note 12, at 573.

[21] *Id.* at 575.

[22] *Id.* at 573.

[23] Guido Haas et al., *Comparing Intensive, Extensified and Organic Grassland Farming in Southern Germany by Process Life Cycle Assessment*, 83 AGRIC. ECOSYSTEMS & ENV'T 43, 49 (2001), *available at* http://doi.eng.cmu.ac.th/Thailca/pdf/organic_farming.pdf (last visited Nov. 13, 2008).

[24] Gregory Evanylo et al., Soil and Water Environmental Effects of Fertilizer-, Manure-, and Compost-Based Fertility Practices in an Organic Vegetable Cropping System, 127 AGRIC., ECOSYSTEMS & ENV'T 50, 56 (2008).

[25] Press Release, Cornell University, U.S. Could Feed 800 Million People With Grain That Livestock Eat, Cornell Ecologist Advises Animal Scientists (Aug. 7, 1997), *available at* http://www.news.cornell.edu/releases/aug97/livestock.hrs.html (last visited Nov. 12, 2008). *See also* V. SMIL, ENRICHING THE EARTH: FRITZ HABER, CARL BOSCH, AND THE TRANSFORMATION OF WORLD FOOD PRODUCTION 156-64 (The MIT Press 2000).

[26] DAVID PIMENTEL & MARCIA PIMENTEL, FOOD, ENERGY, AND SOCIETY 69 (CRC Press 2008).

[27] *See* R.K. Heitschmidt et al., *Is Rangeland Agriculture Sustainable?*, 82 J. ANIMAL SCI. E138, E139 (2004), *available at* http://jas.fass.org/cgi/reprint/82/13_suppl/E138.pdf (last visited Nov. 13, 2008).

[28] George Boody et al., *Multifunctional Agriculture in the United States*, 55 BIOSCIENCE 27, 32 (2005), *available at* http://www.oardc.ohiostate.edu/amp/BOODY_GEORGEmultifunctionalAg.pdf (last visited Nov. 13, 2008).

[29] *See* Haas, *supra* note 23, at 47.

[30] *See, e.g.*, United States Standards for Livestock and Meat Marketing Claims, Grass (Forage) Fed Claim for Ruminant Livestock and the Meat Products Derived From Such Livestock, 72 Fed. Reg. 58,631 (Oct. 16, 2007).

[31] Consumer Reports Greener Choices Eco-Labels Center, USDA: Organic, http://www.greenerchoices.org/ecolabels/label.cfm?LabelID=151&searchType=ProductArea&searchValue=Meat&refpage=productArea&refqstr=ProductCategoryID%3D174%26ProductAreaID%3D164%26showAll%3D0%26pagenumber%3D5 (last visited Nov. 12, 2008).

[32] David Pimentel, *Livestock production and energy use*, *in* ENCYCLOPEDIA OF ENERGY 671 (R. Matsumura ed., 2004).

[33] STEINFELD ET AL., *supra* note 10, at 112.

[34] *Id.* at 112.

[35] EPA, *supra* note 16, at 6-8.

[36] *Id.* at ES-3.

[37] Dave Marvin, *Factory Farms Cause Pollution Increases*, JOHNS HOPKINS NEWS-LETTER, Feb. 4, 2005, *available at* http://media.www.jhunewsletter.com/media/storage/paper932/news/2005/02/04/Science/Factory.Farms.Cause.Pollution.Increases-2243919.shtml (last visited Nov. 13, 2008). *See also* ERIC

Schlosser & Charles Wilson, Chew On This: Everything You Don't Want to Know About Fast Food 166 (2006) (noting that such lagoons and ponds can be as large as twenty acres and fifteen feet deep, containing up to twenty-five million gallons of manure).

38 Dawna L. Cyr & Steven B. Johnson, Barn and Manure Storage Safety Bulletin 2 (2002), *available at* http://www.umext.maine.edu/onlinepubs/PDFpubs/2304.pdf (last visited Nov. 13, 2008).

39 R.W. Sneath et al., *Monitoring GHG from Manure Stores on Organic and Conventional Dairy Farms*, 112 Agric. Ecosystems & Env't 122, 125 (2006).

40 Miguel A. Altieri, *The Ecological Role of Biodiversity in Agroecosystems*, 74 Agric., Ecosystems & Env't 19, 26 (1999).

41 EPA, Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks 55 (2006), *available at* http://www.epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf (last visited Nov. 13, 2008) (noting that .08 MTCE are stored initially with one ton of composted materials. Converting .08 MTCE to pounds of CO_2 involves: *.08MTCE*3.367=.26936MTC02*2205=593.9388 lbs. of* CO_2).

42 Don Comis, *No Shortcuts in Checking Soil Health*, Agric. Research, July 2007, at 4, *available at* http://www.ars.usda.gov/is/AR/archive/jul07/soil0707.pdf (last visited Nov. 13, 2008).

43 Pimental et al., *Farming Systems*, *supra* note 12, at 577.

44 *See, e.g.*, S.A. Khan et al., *The Myth of Nitrogen Fertilization for Soil Carbon Sequestration*, 36 J. Envtl. Quality 1821, 1823 (2007); Emily E. Marriott & Michelle M. Wander, *Total and Labile Soil Organic Matter in Organic and Conventional Farming Systems*, 70 Soil Sci. Soc. Am. J. 950, 954 (2006), *available at* http://soil.scijournals.org/cgi/reprint/70/3/950 (last visited Nov. 13, 2008); Adreas Fliessbach & Paul Mader, *Microbial Biomass and Size-Density Fractions Differ Between Soils of Organic and Conventional Agricultural Systems*, 32 Soil Biology & Biochemistry 757, 764-66 (2000), *available at* http://www.fibl.org/archiv/pdf/fliessbach-maeder-2000-biomass.pdf (last visited Nov. 13, 2008); *and* G. Philip Robertson et al., *Greenhouse Gases in Intensive Agriculture: Contributions of Individual Gases to the Radiative Forcing of the Atmosphere*, 289 Science 1922, 1922-24 (2000), *available at* http://weedeco.msu.montana.edu/Issues/science289_1922_900.pdf (last visited Nov. 13, 2008).

45 Pimental et al., *Farming Systems*, *supra* note 12, at 577.

46 Comis, supra note 42, at 4.

47 The IPCC reported that marginal cropland re-seeded to grassland would sequester 1,103 pounds of carbon per hectare per year, and after fifty years, sequestration would increase to 1,764 pounds of carbon per hectare per year. Robert T. Watson et al., IPCC, Special Report on Land Use, Land-Use Change and Forestry tbl. 4 (2000) *available at* http://www.ipcc.ch/pdf/special-reports/spm/srl-en.pdf (last visited Nov. 13, 2008). Increased ground cover can stabilize soil and reduce emissions associated with erosion. It may also offer an opportunity to integrate grazing livestock with cropland. Pastured animals in rotational grazing could increase soil carbon to offset GHG emissions by 15 to 30 percent. H.W. Phetteplace et al., *Greenhouse Gas Emissions from Simulated Beef and Dairy Livestock Systems in the United States*, 60 Nutrient Cycling in Agroecosystems 99, 102 (2001).

48 CCSP, *supra* note 3, at 184.

49 *Id.*

50 *Id.* at 9-10, 151-81.

51 A majority of seventy-six studies on conventional and organic farming systems and biodiversity clearly showed that biodiversity is far more prevalent in organic agriculture. D.G. Hole et al., *Does Organic Farming Benefit Biodiversity?*, 122 Biological Conservation 113, 121 (2005), *available at* http://www.englishnature.org.uk/news/news_photo/Organic%20farming%20paper.pdf (last visited Nov. 13, 2008).

52 *Id.* at 121-23.

53 R.E. Feber et al., *The Effects of Organic Farming on Surface-Active Spider (Araneae) Assemblages in Wheat in Southern England, UK*, 26 J. of Arachnology 190, 197, 199 (1998), *available at* http://www.americanarachnology.org/JoA_free/JoA_v26_n2/JoA_v26_p190.pdf (last visited Nov. 13, 2008).

54 John T. Lokemoen & Julia A. Beiser, *Bird Use and Nesting in Conventional, Minimum-Tillage, and Organic Cropland*, 61 J. of Wildlife Mgmt. 644, 653 (1997), *available at* http://www.npwrc.usgs.gov/pdf/npwrc1013_birduse.pdf (last visited Nov. 13, 2008).

55 R.E. Feber et al., *The Effects of Organic Farming on Pest and Non-Pest Butterfly Abundance*, 64 Agric., Ecosystems & Env't 133, 135 (1997).

56 Hole, *supra* note 51, at 121-23.

57 CCSP, *supra* note 3, at 3, 191-92.

58 Walter J. Rawls et al., *Effect of Soil Organic Carbon on Soil Water Retention*, 116 Geoderma 61, 62 (2003).

59 *Id.* at 71.

60 Pimental et al., *Farming Systems*, *supra* note 12, at 578.

61 *Id.* at 575.

62 Environmental Working Group, 2007 Direct Payments, http://farm.ewg.org/farm/dp_analysis.php (last visited Nov. 8, 2008).

63 U.S. Dep't of Agric., Economics Research Service, Organic Production, Certified Organic and Total U.S. Acreage, Selected Crops and Livestock, 1995-2005, http://www.ers.usda.gov/data/Organic/index.htm#tables (follow hyperlink to table 3) (last visited Nov. 13, 2008).

64 Ken Cook & Chris Campbell, Environmental Working Group, Amidst Record 2007 Crop Prices and Farm Income Washington Delivers $5 Billion in Subsidies, http://farm.ewg.org/farm/dp_text.php (last visited Nov. 8, 2008).

65 U.S. Dep't of Agric., Feed Grains Database: Yearbook Tables, Corn and Sorghum: Average Prices Received by Farmers, United States, http://www.ers.usda.gov/Data/Feedgrains/StandardReports/YBtable9.htm (last visited Nov. 12, 2008).

66 Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246, § 10301, 122 Stat. 1651, 2108 [hereinafter 2008 Farm Bill]. *See also* 7 U.S.C.S. § 6523 (LexisNexis 2008) (establishing the national organic certification cost-share program to assist producers and handlers of agricultural products in obtaining certification under the national organic production program); Farm Security and Rural Investment Act of 2002, Pub. L. No. 107-171, 116 Stat. 134, 514 (current version at 7 U.S.C.S. § 6523 (LexisNexis 2008)).

67 2008 Farm Bill § 10301.

68 2008 Farm Bill § 10303.

69 2008 Farm Bill § 10302.

70 *See, e.g.*, Fact Sheet, Central New York Resource Conservation & Development Project, Inc., Carbon Trading: Market Opportunities for Agriculture Workshop, One Farm's Experience (May 20, 2008), *available at* http://www.agcarbontrading.org/learn/factsheet/A6_JWCP_One_Farms_Experience_FINAL_to_WEB.pdf (last visited Nov. 13, 2008).

71 Rachel Saltzman, Sierra Club, An Analysis of the Benefits of Farm-Scale Anaerobic Digesters in the United States 5 (2006), *available at* http://www.sierraclub.org/factoryfarms/factsheets/manuredigesterpaper.pdf (last visited Nov. 13, 2008).

72 Janelle Hope Robbins, Waterkeeper Alliance, Understanding Alternative Technologies for Animal Waste Treatment: A Citizen's Guide to Manure Treatment Technologies 81 (2005).

73 Saltzman, *supra* note 71, at 4-5.

74 Smil, *supra* note 25.

75 Simon D. Donner, *Surf or Turf: A Shift from Feed to Food Cultivation Could Reduce Nutrient Flux to the Gulf of Mexico*, 17 Global Env't Change 105, 111 (2007), *available at* http://yosemite.epa.gov/sab/sabhap.nsf/2a890dc663b46bc685256d63006ac3aa/0172ca7b30bd023a8525729f004e3729/$FILE/Donner07.pdf (last visited Nov. 13, 2008).

76 H. Flessa et al., *Integrated Evaluation of Greenhouse Gas Emissions (CO_2, CH_4, N_2O) from Two Farming Systems in Southern Germany*, 91 Agric., Ecosystems & Env't 175, 188 (2002).

77 Heitschmidt et al., *supra* note 27, at E139.

78 Boody et al., *supra* note 28, at 31.

79 U.S. Department of Agriculture, Conservation Reserve Program, http://www.nrcs.usda.gov/programs/CRP (last visited Nov. 8, 2008).

80 Sue Kirchhoff & Jeff Martin, *America's Grasslands Vanishing Amid Agricultural Boom*, USA Today, Apr. 25, 2008, *available at* http://www.usatoday.com/money/industries/environment/2008-03-27-farming-plowing-grasslands_N.htm (last visited Nov. 13, 2008).

81 David Morris, The New Rules Project, Ethanol and Land Use Changes (2008), *available at* http://www.newrules.org/de/Ethanol-and-Land-Use.pdf (last visited Nov. 12, 2008).

82 *Oversight on Federal Renewable Fuels Programs Hearing Before the S. Comm. on Env't & Pub. Works*, 109th Cong. (2006) (statement of Dr. Keith Collins, Chief Economist, U.S. Dept. of Agric.), *available at* http://epw.senate.gov/hearing_statements.cfm?id=262516 (last visited Nov. 13, 2008).

83 J. Fargione, et al., *Land Clearing and the Biofuel Carbon Debt*, SCIENCE, Feb. 5, 2008, at 1236.

84 *Id.*

85 Donner & Kucharik, *supra* note 18, at 105.