National Sustainable Agriculture Coalition

Agriculture & Climate Change: Impacts and Opportunities at the Farm Level

A Policy Position Paper

FOREWORD ON THE SCOPE OF THIS POLICY PAPER

This paper focuses on greenhouse gas (GHG) emissions related to agricultural production to the point of the farm gate. It is, however, also important to note that there are significant GHG emissions from the U.S. food system beyond the farm gate, including food and fiber processing, transportation, storage, and distribution activities, which are much higher than those from the agricultural production sector alone. A growing body of research indicates that sustainable, regional and local food processing and distribution systems can significantly decrease the GHG emissions from these food system activities beyond the level of production activities, while empowering communities to choose food production systems that promote local economies and adapt to changing environments.

The National Sustainable Agriculture Coalition supports the development of regional and local food systems which can also play an important role in reducing GHG emissions in our nation's farming and food system, while also conserving energy, improving the nation's health, and increasing the overall resilience of the U.S. farming and food system.

OVERVIEW

For over twenty years, the National Sustainable Agriculture Coalition (NSAC) has advocated for federal agricultural policies that foster the long-term economic, social, and environmental sustainability of agriculture, rural communities and natural resources.[i] Our long-term goal is the establishment of agricultural and food systems across the United States that can endure and meet the needs of present and future generations. NSAC works for policies that promote small and mid-sized family farms, new farming and ranching opportunities, and agricultural systems which build soil health on cropland and grassland, minimize energy input, and incorporate practices for crop residue management, conservation tillage, nutrient management, water management, and restoration of degraded soils.

In the last decade, an overwhelming consensus has emerged among scientists that the world has entered an era of rapid global climate change, much of which is attributable to green house gas (GHG) emissions from human activity. Rapid global climate change is expected to impact agriculture by causing shifts in temperature, precipitation, soil quality, pest regimes, and seasonal growth patterns. The exact nature and degree of these changes for any given region will be difficult to predict.

To cope with climate change that is likely to be both rapid and unpredictable, agricultural systems must be resilient and able to adapt to change. Resilient agriculture systems are those that are more likely to maintain economic, ecological and social benefits in the face of dramatic exogenous changes such as climate change and price swings. In the face of uncertainty, food production systems should be established which are diverse and relatively flexible, with integration and coordination of livestock and crop production.

At the same time that the agricultural sector is impacted by climate change, research indicates that current agricultural activities are a significant source of greenhouse gases that aggravate climate disruption. The amount of GHGs emitted from an agricultural operation depends on its system and management. Sustainable and organic agricultural systems can help reduce agricultural GHG emissions through energy conservation, lower levels of carbon-based inputs, lower use of synthetic fertilizer and other features that minimize GHG emissions and sequester carbon in the soil.

NSAC played a key role in defining "sustainable agriculture" in the 1990 Farm Bill:

The term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs;
- enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- make the most efficient use of nonrenewable resources and on-farm resources and integrates, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations; and
- enhance the quality of life for farmers and society as a whole.

(Public Law 101-624, Title XVI, Subtitle A, Section 1603 (7 U.S.C. § 3103(18)).

NSAC has also adopted principles and policy positions for agricultural energy conservation and renewable energy from agricultural land and resources. See SAC, *Renewable Energy from Farms* (2002), available at www.sustainableagriculture.net.

Agricultural land can serve as a sink for GHG emissions, especially through soil carbon sequestration, which could help moderate climate change. But agricultural land can serve as an effective GHG sink over

[i] The National Sustainable Agriculture Coalition was launched in January 2009 and adopted existing policy papers of its predecessor organizations - the Sustainable Agriculture Coalition and the National Campaign for Sustainable Agriculture.

the long-term only if agricultural systems are adopted which improve overall soil quality and provide for relatively stable GHG reduction or sequestration that can be verified and measured with reasonable accuracy. Agricultural crop and forage production systems intended to sequester carbon should also be assessed for the effects that changing soil carbon levels and other system features have on the potent GHGs nitrous oxide and methane. These system features include, among others, fertilizer use and efficiency, nitrogen sequestration and overall GHG emissions of associated livestock production systems.

Moreover, agricultural carbon sequestration should not be viewed as the only solution for dealing with GHG emissions from industry, vehicles and other human activities. U.S. climate change policy should require all sectors to adopt new technology and long-term permanent solutions to reduce GHG emissions.

THIS NSAC POSITION PAPER PROVIDES RECOMMENDATIONS ON POLICIES AND PROGRAMS IN THE 2008 FARM BILL THAT CAN MITIGATE THE IMPACTS OF RAPID CLIMATE CHANGE ON AGRICULTURE AND REDUCE OVERALL GHG EMISSIONS FROM AGRICULTURAL PRODUCTION ACTIVITY.

The National Sustainable Agriculture Coalition's position is that sustainable and organic agricultural systems offer the most resilience for agricultural production in the face of the extreme precipitation, prolonged droughts and increasingly uncertain regional climate regimes expected with rapid global warming. Moreover, adoption of these systems can significantly decrease net GHG emissions from agricultural production activities. The potential of these sustainable and organic agriculture systems to help mitigate climate change can be added to their benefits in improving the overall environmental performance of agriculture and protecting the health of rural communities. These systems provide the best that agriculture can offer to a wide array of potential frameworks for climate change policy. ***[See the Appendix for descriptions of the sustainable and organic agriculture systems and practices discussed in this paper.]***

The National Sustainable Agriculture Coalition calls upon federal policy-makers to prioritize support for federal farm bill policies and programs that enable farmers and ranchers to adopt sustainable and organic agricultural production systems to address the challenges posed by a rapidly changing global climate. We recommend specific actions in this paper that USDA, other federal agencies, and the Land Grant University system can take to assist farmers, ranchers and rural communities in coping with and mitigating the potentially devastating environmental consequences of rapid climate change. Federal policies must involve cooperation and support from all levels of government, community partnerships, the private sector, universities, and civil society to foster a coherent, effective and results-oriented approach to address climate change. Federal action should also promote sustainable resource use, energy conservation and GHG reduction, in addition to meeting food security and rural community development needs.

It is imperative and urgent that the Federal government assist communities and regions around the country to develop agricultural systems that:

- reduce greenhouse gases,
- use resources sustainably, and
- maximize energy conservation.

Federal policy should provide incentives for adoption of sustainable and organic agriculture systems and practices that both mitigate climate change impacts and help farmers, ranchers, and rural communities cope with rapid climate change.

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I. IMPACTS OF CLIMATE CHANGE ON U.S. AGRICULTURE

Significant effort to assess the potential impacts of climate change on agriculture began in 1978 when the National Defense University assembled an international group of climate experts to predict the probabilities of various climate change events and the resulting impacts on agriculture.[1] Since then, more structured scientific studies have resulted in a growing consensus on the interactions between climate change and agriculture, culminating in the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).[2]

In the 1980s, studies focused on the direct effects of climate change on crop production.[3,4] By the 1990s, new lines of research addressed the potential impacts on livestock.[5,6] In the late 1980s and early 1990s, regional economic studies began to account for farmers' responses to changing climate conditions.[7,8] And by 2000, research included a global perspective on the agricultural impacts of climate change and adaptive responses at both the local and international levels.[9,10] More recent research has led to detailed investigations of climate change impacts on agriculture around the world. In 2007, the European Union produced a comprehensive report assessing regional climate impacts on European agriculture and adaptation strategies for farmers, such as crop rotation, livestock and crop diversification, and conservation tillage practices.[11]

In May 2008, the U.S. Climate Change Science Program (CCSP) issued a report led by the U.S. Department of Agriculture (USDA) with the most comprehensive assessment of research on potential climate change impacts on agriculture in the U.S. to date.[12] The report was issued under the federal government's 2003 Strategic Plan for the United States Climate Change Science Program, which identified a need for the synthesis and assessment of 21 principal responses to the top-priority research, observation, and decision support needs of society. The 2008 report is entitled *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* (designated as CCSP Synthesis and Assessment Product 4.3 (SAP 4.3)).

The 2008 CCSP Report provides detailed consideration of potential impacts of climate change on major crops, pastureland, rangeland, and livestock operations. Among the general conclusions of the report, are the following:

Temperature and Precipitation Changes

- The U.S. warmed and became wetter overall during the 20th century, with changes varying by region. Parts of the South have cooled, while northern regions have warmed.
- Much of the eastern and southern United States now receives more precipitation than 100 years ago, while other areas, especially in the Southwest, receive less. The frequency and duration of heat waves has increased and there is some evidence of increased frequency of heavy rainfalls. Observational and modeling results indicate that these trends are likely to continue.
- Temperatures in the United States are very likely to increase by another 1^{o}C to more than 4^{o}C. The West and Southwest are likely to become drier, while the eastern United States is likely to experience increased rainfall. Heat waves are very likely to be hotter, longer, and more frequent, and heavy rainfall is likely to become more frequent.

Crop Impacts

- Horticultural crops are likely to be more sensitive to climate change than grains and oilseeds.
- Climate change is likely to lead to the northern migration of weeds. Weeds respond positively to CO2 and the commonly used herbicide glyphosate loses its ability in to kill weeds in a higher CO2 environment. This is particularly troublesome because the use of continuous no-till, which necessitates high applications of glyphosate, is seen as a means to offset GHG emissions.
- With increased CO2 and temperature rises there may be an initial expansion of grain and oilseed production. With continued rising temperatures this initial expansion may be short lived, particularly if precipitation patterns become more variable.

Livestock Impacts

- With the expected earlier springs and warmer winters, disease pressure from livestock pests, parasites and pathogens on cropland, pastureland and rangeland may increase and livestock producers may need to deal with increased parasites and pathogens as climate change results in increased survivability and expansion of the pests' range.
- Expected higher temperatures may increase livestock deaths in some regions unless some kind of shelter is made available.
- Forage production may be expanded as growing seasons lengthen, but this benefit will depend on water availability.
- Shifts in plant species in rangelands, particularly an increase in perennial herbaceous species, will create greater spring water demands.

Beyond these already profound impacts, unforeseen climate change feedback events will likely further affect agriculture.[13] As temperature rises, precipitation amounts change and severe weather events happen more frequently. These changes could cause both negative and positive feedback outcomes in agricultural systems in ways that are difficult to predict. Although some regions of the U.S. may experience extended growing seasons due to rising temperatures, the possible positive outcomes of climate change in the U.S. do not erase the potentially devastating agricultural outcomes described above. Record high daytime and nighttime temperatures could become the norm even in temperate zones, with adverse effects on leaf and grain development and other harmful effects on crops as well as increased heat stress on livestock.[14]

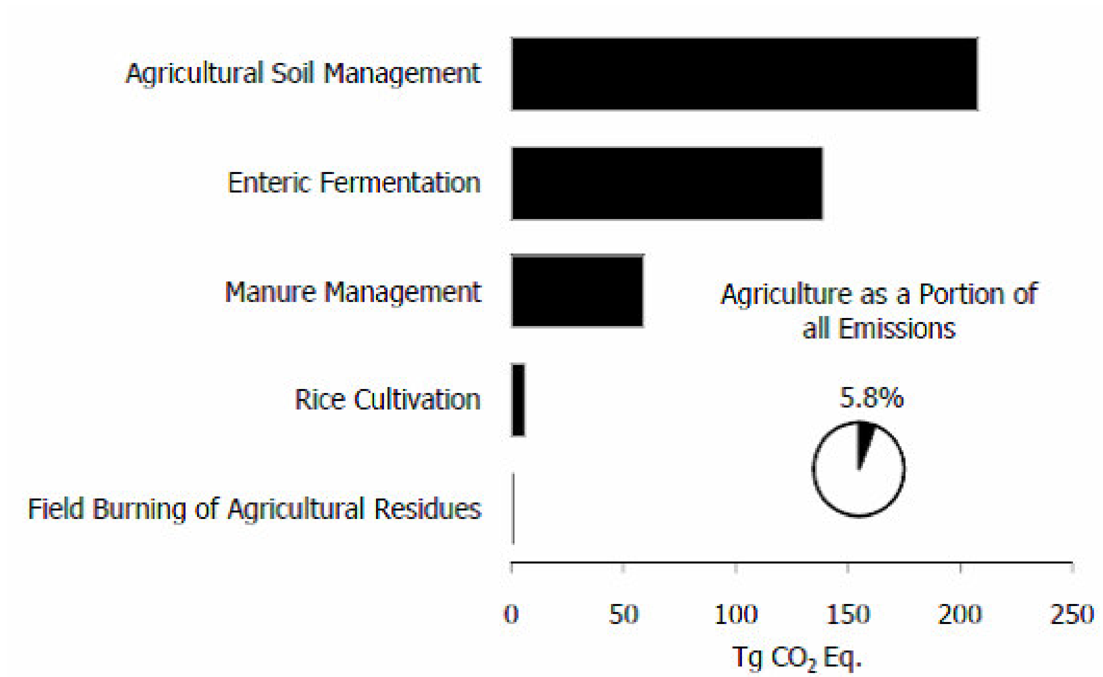
These climate change effects coincide with two additional disruptions that will require significant changes to the current reliance of U.S. agriculture sector on industrialized systems. These are the depletion of the world's oil reserves with the end of cheap concentrated fossil fuel energy and the depletion of significant fresh water reserves because of increasing demand by the agricultural sector and other users. The industrialized agriculture system was designed to work with cheap energy, abundant freshwater reserves and a period of relative stability in the climate, all of which are now in question.[15] The next generation of farmers and ranchers will need to switch to smarter agricultural systems that rely less on high-energy inputs and conserve water and other natural resources while also decreasing the carbon footprint of U.S. agricultural production.

II. IMPACTS OF U.S. AGRICULTURE ON CLIMATE CHANGE

Agriculture is not just affected by climate change - agricultural production systems also have the potential to mitigate or exacerbate climate change trends. This section looks at agriculture both as a significant emitter of GHGs and as a potential sink for GHGs.

A. U.S. agriculture as a contributor to climate change

The Intergovernmental Panel on Climate Change (IPCC) concluded that worldwide, agriculture exacerbates climate change trends by contributing about 13.5 percent of global GHG emissions.[16] The major GHGs emitted by agricultural production sources include carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). U.S. agricultural production is a relatively minor producer of CO2 from on-farm energy use, but it is a major source of CH4 and N2O emissions. As a GHG, CH4 has a greater global warming potential than CO2 but a shorter atmospheric life. Over a 100-year period, CH4 is 23 times as potent as CO2. N2O has a relatively low warming effect but a very long atmospheric life and over 100 years has a global warming potential that is about 310 times that of CO2. Both CH4 and N2O, while released in smaller over-all volumes than CO2, have significantly higher global warming potential than CO2. The term CO2eq (carbon dioxide equivalents) provides a measure that combines the global warming potential of these different GHGs from a source into one measurement.



Major agricultural sources of U.S. GHG emissions in 2007 and their contribution to total U.S. GHG emissions. From U.S. EPA, Inventory of U.S Greenhouse Gas Emissions and Sinks: 1990-2007 (Figure 6.1)(April 15, 2009). One Tg CO2 = 1 million metric tons CO2.

As seen in the Figure above, major agricultural activities in the U.S. in 2007 contributed a total of 413.1 Tg CO2eq, an estimated 5.8 percent to total U.S. GHG emissions. The categories of agricultural activity include the following:

● *Agricultural Soil Management* covers a broad array of practices including fertilization with synthetic fertilizer and animal manures; manure deposition by grazing animals, soil cultivation; production on N-fixing crops and forages; irrigation and other practices. The category covers GHG emissions from both cropland and grasslands.

● *Enteric Fermentation* is primarily methane produced by the digestive processes of agricultural animals which are emitted from the animals as gas.

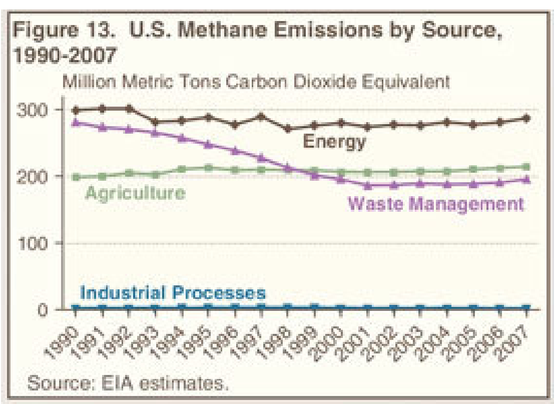
● *Manure Management* emissions are methane and nitrous oxide released from manure during storage and handling.

● *Rice cultivation*, which in the U.S. done under anaerobic conditions in flooded fields, results in methane emissions.

● *Field burning of agricultural residues* results mostly in CO2 emissions, which are not counted because it is assumed that CO2 will be reabsorbed by plants in the next growing season. Field burning, however, also results in release of methane, nitrous oxide and other minor GHGs.

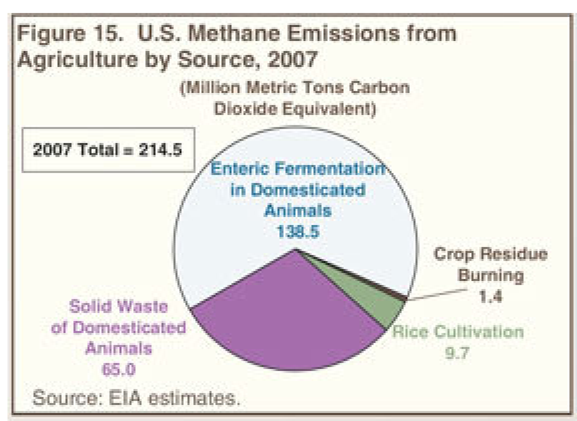
Not included in the chart in Figure 1 are CO2 emissions from cropland treated with lime or urea fertilization and GHGs from fuel combustion for on-farm vehicles and equipment. Agricultural production activity is a relatively minor contributor to total U.S. CO2 emissions.

1. U.S. Agriculture Productions Activities: Methane – CH4 (figures and other information from U.S. Dept. of Energy, Energy Information Administration, Emissions of Greenhouse Gases in the United States in 2007).



Agricultural production is a major emitter of CH4.

Methane emissions from enteric fermentation represented about 24 percent of total CH4 emissions and manure management represented about 8 percent of total CH4 emissions. Rice cultivation and field burning of agricultural residues made relatively minor CH4 contributions.



Methane Emissions from Agricultural Sources, 1990, 2006, and 2007

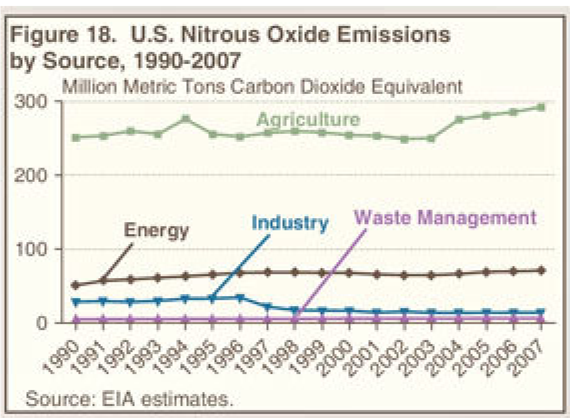
	1990	2006	2007
Estimated Emissions (Million Metric Tons CO_2e)	199.0	212.7	214.5
Change from 1990 (Million Metric Tons CO_2e)		13.6	15.5
(Percent)		*6.8%*	*7.8%*
Average Annual Change from 1990 *(Percent)*		*0.4%*	*0.4%*
Change from 2006 (Million Metric Tons CO_2e)			1.8
(Percent)			*0.9%*

Estimated CH4 emissions from agricultural production activities have been steadily increasing since 1990.

The increase in emissions from enteric fermentation is attributed primarily to an increase in the U.S. cattle population, both beef and dairy cattle, and to increase in the swine population.

In addition, since 1990 there has been a shift from livestock raised on pasture to large confined facilities with liquid management systems that increase the amount of methane generated from livestock waste.

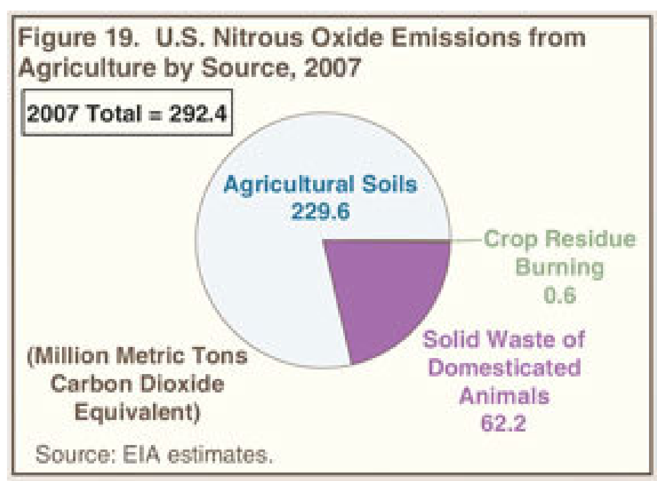
2. U.S. Agriculture Productions Activities: Nitrous Oxide – N2O (figures and other information from U.S. Dept. of Energy, Energy Information Administration, Emissions of Greenhouse Gases in the United States in 2007).



Agriculture is the largest anthropogenic source of U.S. N2O emissions.

About 75 percent of agricultural emissions of N2O are from nitrogen fertilization of soils, including direct emissions from synthetic fertilizers, biological fixation in crops, and crop residues. There are also indirect emissions attributed to soil leaching of N2O and atmospheric deposition of nitrogenous compounds from agricultural activities.

A large amount of nitrous oxide is also emitted from microbial denitrification of solid waste from livestock, primarily cattle. The amount released depends on the size of the animal, the amount of nitrogen in the waste, and the method of managing the waste.



U.S. Anthropogenic Nitrous Oxide Emissions from Agriculture, 1990, 2006, and 2007

	1990	2006	2007
Estimated Emissions (Million Metric Tons CO_2e)	251.2	285.5	292.4
Change from 1990 (Million Metric Tons CO_2e)		34.3	41.2
(Percent)		*13.6%*	*16.4%*
Average Annual Change from 1990 *(Percent)*		*0.8%*	*0.9%*
Change from 2006 (Million Metric Tons CO_2e)			7.0
(Percent)			*2.4%*

N2O emissions from agricultural activities have not increased steadily. From 1994 to 2003 emissions fell to a level of 250.1 Tg CO2e. They then rose sharply from 2003 to 2007, largely because of an increase in the use of synthetic fertilizers. In part, the increased level of synthetic fertilizers has occurred because of a shift from corn-soybean rotations to more corn acres and a drop in soybean production. Soybeans fix their own nitrogen and can also contribute soil nitrogen to corn in rotation.

Note that this GHG emission data for agricultural activities does not include indirect GHG emissions from the production and distribution of off-farm inputs, especially manufactured fertilizers and pesticides. GHG emissions from these inputs add to the overall carbon footprint of agriculture. For example industrial fertilizer production is estimated to emit 6.7 kg CO2 eq per kg N manufactured.[17]

B. U.S. Agriculture and mitigation of climate change: The potential for significant carbon sequestration in agricultural soils. (figures and other information from U.S. Dept. of Energy, Energy Information Administration, Emissions of Greenhouse Gases in the United States in 2007).

Soils are one of five principal global carbon pools, which also include the oceans, fossil fuel deposits, biotic (plant-based carbon), and the atmosphere. Carbon cycles among these pools, with atmospheric carbon primarily in the form of the GHG CO2. The burning of fossil fuels is the major anthropogenic source of increased atmospheric CO2. The oceans are taking up atmospheric CO2 but this uptake results in chemical reactions which make the oceans more acidic. Oceanic acidification may disrupt important marine ecosystems by interfering with the ability of marine organisms to develop carbonate and by dissolving carbonate sediments.[18]

U.S. soil organic carbon has been depleted as land has been converted from forests, native prairie and other grasslands, and wetlands to more intensive agricultural uses. Long-term extractive farming practices, such as deep tillage without rebuilding of soil carbon, have further depleted levels of carbon in agricultural soils. U.S. agricultural soils have lost an estimated 30-50 percent of the carbon contained prior to cultivation. The result is that agricultural soils have the capacity to take up carbon through roots, litter, harvest residues, and animal manures used in agricultural production. In 2003, Rattan Lal and colleagues estimated the total potential of carbon sequestration in soils in agriculture, grazing, and forestry ecosystems at 144 to 432 Tg C per year, with an average of 288 Tg C per year for up to 30 years, the point at which most soils would reach their capacity to hold carbon. Significant long-term soil carbon sequestration could be achieved by a mix of recommended agricultural systems and management practices and the conversion of degraded soils and drastically disturbed lands to restorative uses. An increase in overall soil carbon also has positive effects on soil quality and could result in increased productivity for many carbon-depleted soils.[19]

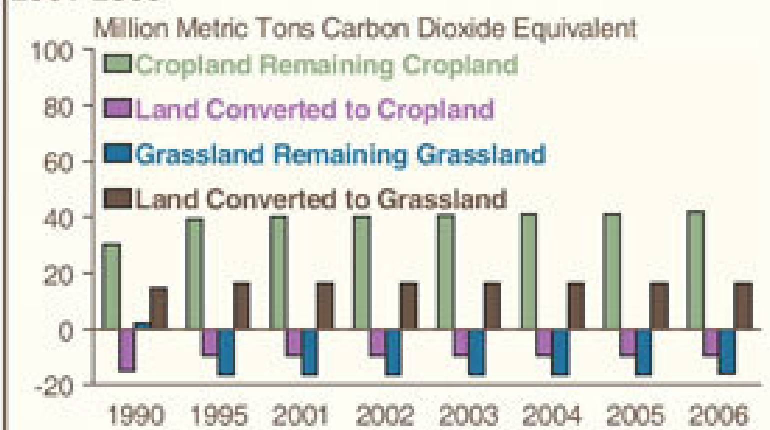
Carbon Sequestration in U.S. Croplands and Grasslands, 1990, 2005, and 2006

	1990	2005	2006
Estimated Sequestration (Million Metric Tons CO_2e)	31.9	31.6	32.5
Change from 1990 (Million Metric Tons CO_2e)		-0.3	0.6
(Percent)		*-0.9%*	*1.9%*
Average Annual Change from 1990 *(Percent)*		*-0.1%*	*0.1%*
Change from 2005 (Million Metric Tons CO_2e)			0.9
(Percent)			*2.8%*

The overall estimate for current carbon sequestration in U.S. croplands and grasslands is summarized in the table to the left. Changes from year to year have been relatively minor. The total sequestration is derived by combining the carbon sequestrated or emitted from the categories of Cropland Remaining Cropland, Land Converted to Cropland, Grassland Remaining Grassland, and Land Converted to Grassland. In 2006, the net aggregate flux of CO2 in the four agricultural categories resulted in overall sequestration of 32.5 Tg CO2eq. in 2006

The figure to the right shows the net changes in carbon sequestration for each category of cropland and grassland. Overall, carbon sequestration in Cropland Remaining Cropland increased between 1990 and 1995 and has remained relatively steady. Land Converted to Cropland lost soil carbon each year and was a significant and persistent source of carbon emissions.

Figure 29. Carbon Sequestration in U.S. Croplands and Grasslands, 1990, 1995, and 2001-2006



Source: U.S. EPA estimates.

Grassland Remaining Grassland has seen a net loss of carbon since 1995. This loss may be related to drought conditions which can reduce the amount of biomass retained in grassland systems. This effect demonstrates a potential feedback effect of climate change that exacerbates temperature increase. Rising temperatures could result in increased CO2 emissions from grassland ecosystems, which in turn would add to the levels of atmospheric CO2. Land Converted to Grassland from cultivated land, forest land and other sources has resulted in a net overall increase of carbon sequestration in each year.

C. Overall conclusions from GHG Emission Data for Agriculture

Overall, the EPA GHG emissions inventory leads to the following conclusions:

- Agricultural soil management is the single greatest contributor to GHG emissions from the agricultural production sector.
- Soil management, enteric fermentation from livestock digestive processes particularly of cattle and other ruminants, and manure management are the top three sources of agricultural GHG emissions, representing about 81 percent of total emissions from the U.S. agricultural production sector.
- The conversion of land to cropland from grassland and forest land results in net GHG emissions.

- The U.S agricultural production sector is a moderate source of total U.S. GHG emissions, with an estimated total from major agricultural production activities of 5.8 percent in 2007, ranging up to 8 percent per year when minor sources are also included.

- Most GHG emissions increases from U.S. agricultural production activities currently come from CH4 and N2O. A large amount of CO2 was lost from soils in the past because of conversion of vast acreages of native grasslands and forests to agricultural uses and losses on a smaller scale continue each year.

- **The U.S. agricultural production sector is a net emitter of GHG emissions. That is, agricultural production annually creates more GHG emissions than it captures. There is, however, the potential for the agricultural production sector to sequester significantly higher levels of soil carbon through management and land use changes.**

- **Despite some improvement since 1990 in certain areas, overall the U.S. agricultural production sector has increased its GHG emissions, increasing its impact on climate change.**

The impact of current U.S. agriculture production on climate change is significant, but the impact can be alleviated. Sustainable soil, land, and livestock management systems hold great potential to lower GHG emissions from the agricultural production activities and improve the capacity of soils to sequester carbon. These sustainable and organic agricultural production systems can also improve soil quality, productivity and the overall conservation performance of the nation's agricultural land.

III. THE ROLE OF SUSTAINABLE AND ORGANIC SYSTEMS IN MITIGATING THE IMPACTS OF CLIMATE CHANGE

A large part of agricultural GHG emissions result from management choices which give farmers and ranchers a significant role to play in decreasing emissions from agricultural production. Sustainable agriculture systems, not just individual practices, can best help provide producers with ecologically sound management decisions. Management decisions are based on multiple factors that can be difficult to alter, such as habit, custom, profit maximization, ecological context and longstanding public policies. Federal research funding and federal program development must take all of these factors into account.

Overall, the sustainable and organic agricultural systems - described in more detail in the Appendix of this policy paper - integrate soil, crop, livestock and water management techniques that can increase production while enhancing soil carbon sequestration and reducing GHG emissions. Examining relationships in complex, integrated farming systems does not lend itself easily to isolating cause and effect of the system on various factors. But research on these systems has made clear that mitigation of the adverse effects of rapid climate change cannot be achieved simply by picking out individual agricultural practices in isolation. Rather, a holistic system of agricultural practices must be adopted in order to attain the full measure of a productive and resilient agriculture.[20] Sustainable and organic agriculture systems offer this holistic or "whole farm approach."

The 2008 Farm Bill[21] includes programs and funding which can be used to provide farmers and ranchers with information, technical resources and funding to make ecologically sound choices that also address climate change. In addition, EPA, the Department of Energy, the U.S. Geological Survey and other federal agencies also have a role in moving U.S. agriculture towards the sustainable production systems discussed in this section.

A. The Starting Point: Reducing Agricultural GHGs Emissions through Energy Conservation and Increased Energy Efficiency

As provided in NSAC's position paper on *Renewable Energy from Farms,* the immediate priority of any energy policy is to increase conservation and energy efficiency. Reducing unnecessary use of energy is common sense, saves money, and helps the environment. Likewise, numerous studies have shown that improving the efficiency with which energy is used is the cheapest and quickest energy "source."

Agricultural policy for reducing GHG emissions from agricultural production activities and helping farmers and ranchers to cope with climate changes should emphasize energy conservation measures and increased energy efficiency for on-farm activities. In addition, policymakers should look for opportunities for farmers and ranchers to reduce costs and overall GHG emissions by reducing inputs that rely on high levels of fossil fuel for their production. A prime example is to encourage farmers to incorporate nitrogen fixing plants into crop rotations and pastures to provide nitrogen and reduce synthetic fertilizer use. This can eliminate the fossil fuel used to produce the synthetic fertilizer, reduce N2O emissions from synthetic fertilizer applications, and help farmers cope with the increasing spikes and volatility in the costs of synthetic fertilizer.[22]

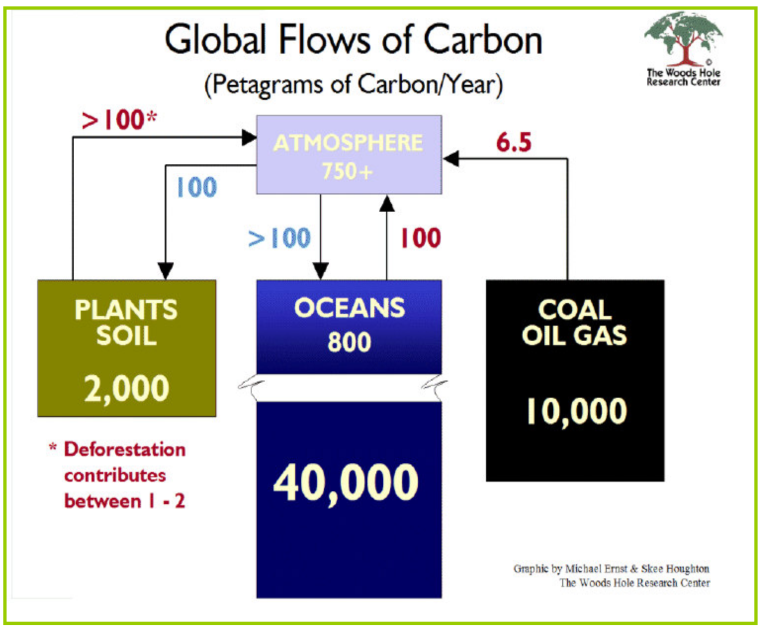
B. Land Conversion: Keeping the Land in Grass

Protecting native grasslands to retain their huge reserve of soil organic carbon is the best way to use grasslands as a carbon sink. A recent USDA study concludes that conversion of native prairie to cropping systems releases significant carbon. Restoration of permanent cover on the land through programs such as the farm bill's Conservation Reserve Program and the Wetlands Reserve Program fails to bring the land back to its original potential for storing soil organic carbon.[23]

Converting cropland, especially marginal cropland, to pasture-based systems can also provide significant carbon sequestration benefits. The EPA estimates that converting cropland to grassland can increase the soil's carbon sequestration rate by 0.9 to 1.9 Tg CO2eq per acre per year. And improving the management of existing grasslands can provide for additional sequestration of 0.07 to 1.9 Tg CO2eq per acre year.[24]

Although the impacts of deforestation, agriculture, and other human activities on climate change have been well-documented, current efforts to combat climate change do not substantially address other contributions of land use to climate change. Land use changes can result in emission of CO2 to the atmosphere that impact the Earth's radiation balance. Changes in land surface can also change the radiation balance by altering the Earth's surface albedo, the extent to which the surface reflects light from the sun. In addition, changes in land surface can alter the fluxes of heat to the atmosphere and thus the distribution of energy within the climate system and, in so doing, can alter climate at the local, regional, and even global scale.[25] Variations in land use and surface cover have a significant effect on climate change, in addition to effects of variation in GHG emissions from land use changes.[26]

C. Carbon, Soil Quality and Cropping Systems



As displayed in Figure 2, globally, almost three times as much carbon is stored in soils as is currently in the atmosphere, making soil one of the planet's largest carbon sinks. Agricultural production effects on soil quality have significant impacts on net carbon balance. Prior to conversion to cropland, soil in uncultivated grasslands and forests typically holds from 6 to 10 percent soil carbon. Converting native prairie to cropland can release 45 to 55 tons of carbon per acre.

Comparative studies have found soil organic that some cropping systems can help mitigate soil carbon losses, as well as decrease soil erosion, reduce energy use and lower the cost of production. These systems include the use of cover crops and resource conserving crops rotations and the integration of livestock production into the cropping system.[27]

Figure 2. Global Flows of Carbon

Using no-till cropping systems has been shown in some studies to increase soil organic carbon when compared to levels in conventional tillage systems. It appears, however, that carbon sequestration depends on microclimates, soil types and crop choices. Studies of the impact of tillage and fertilization on carbon storage have yielded contrasting results in different regions. For example, research on carbon sequestration in clay loam soils in the cool and humid region of Eastern Canada found very little difference in soil organic carbon levels across the entire soil profile between a no-till cropping system and a system using moldboard plowing. No-till accumulated more soil organic carbon near the surface while the moldboard plow resulted in higher carbon levels near the bottom of the plow layer.[28]

A recent review examined a number of studies that have compared no-till, in which soil is undisturbed from harvest to planting, with more intensive tillage systems. In almost all the studies reviewed soil carbon levels were sampled down to 30 cm. The authors of the review were concerned that these comparative studies relied on shallow soil sampling based on the assumption that the distribution of roots with depth was the same in no-till and more intensively tilled systems. But that may not be the case. A number of factors control root growth, such as differences in soil temperature, which could result in shallower roots in no-till systems. In contrast, the authors found that studies comparing no-till to more extensive tillage systems which sampled to depths greater than 30 cm showed little difference in overall soil organic carbon but did show that in the no-till system more carbon was concentrated near the surface than lower in the soil profile. The authors emphasized that no-till systems have many benefits and should be promoted. But they cautioned that simple changes in tillage practices should not be assumed to increase soil organic carbon without incorporation of other practices into the system, for example the addition of cover crops, fertilization with animal manures, or other practices to build soil quality.[29]

Other research comparing both tillage and fertilization systems has shown that in some no-till systems synthetic fertilizer use is associated with higher levels of nitrous oxide emission than more intensive tillage using the same amount of synthetic fertilizer. In these no-till systems the reduction of GHG emissions from increased carbon sequestration may be significantly reduced or even zero out by increased emissions of nitrous oxide.[30] Clearly the best long-term strategies should combine appropriate reduced tillage practices which increase soil carbon sequestration with improved fertilizer management. Reduction in tillage also results in reduced CO2 emissions from fuel used in tillage and ground preparation, with cost savings to the farmer as well.

Conservation tillage systems, which combine reduced tillage practices suitable for the region and soils along with additional practices to add carbon to the soils, directly benefit farmers. The amount of organic matter, mostly carbon, in soil is a key driver of soil quality, including higher fertility, better ability to hold water and more resistance to wind erosion. By increasing the organic carbon content of soils through organic and sustainable practices, farmers can make their operations more resilient in the face of climate change and in many cropping systems will also have a net reduction in GHG emissions. Establishing farming systems with strong incentives for increasing soil carbon should be at the center of any framework for climate stabilization.[31]

D. Livestock Management

Livestock access to healthy, living soil with forages that in turn support healthy livestock. Photo: Alice Beetz, NCAT.

Conventional livestock production generates large amounts of GHGs. Livestock production uses 70 percent of the world's agricultural land, accounts for more than 8 percent of human water use, and produces 9 percent of global CO2 emissions, including 37 percent of global CH4 emissions and 65 percent of global N20 emissions.[32] The primary GHGs associated with livestock production, CH4 and N2O, are generated by natural biological processes when microbes break down feed in the stomachs of ruminants and when manure decomposes.

On average, about 4 percent to 12 percent of gross energy intake for livestock is converted to CH4.[33] Nearly two-2/3's of the GHGs generated directly by livestock production, not counting GHGs from feed production, is from ruminant fermentation. The remainder is emitted from livestock waste.

The total amount of GHGs from livestock is determined by the number of livestock produced and the methods used to produce livestock and manage manure. The world's ever-growing meat consumption exacerbates livestock's climate impact. According to the United Nations Food and Agriculture Organization (FAO), total world meat production doubled from 1977 to 2002.[34] During that time, meat consumption per person grew by 35 percent. Today, meat consumption is growing fastest in developing countries, notably China and India, even if per capita meat consumption is still higher in developed countries. The FAO projects that world meat consumption will grow another 40 percent by 2030. Some researchers have suggested that decreasing the GHG emissions from livestock will require moving toward a more balanced global average of daily protein intake.[35]

With regard to livestock production methods, different production systems produce significantly different levels of GHGs. In grass-based systems, access to high-quality pasture, in comparison to mature grass, reduced CH4 emissions from steers by 50 percent in Manitoba. In addition, livestock on legume-grass pastures had about 25 percent lower CH4 emissions than those on grass-only pastures.[36] Intensively managed rotational grazing, originally developed to increase the quality of livestock forages and reduce pasture run-off, also has significant benefits in GHG reduction.

In grain-based systems, changes in grain to forage ratio, grinding and pelleting of feed, reducing protein content, addition of fats, and the use of enzymes have all been shown to have a significant impact on methane emissions. Proper feed storage and handling practices can also reduce system emissions by reducing spoilage and loss. In its "Green Cow Project," Stonyfield Farms found that feeding dairy cows a diet high in natural omega-3 sources, such as alfalfa, flax, hemp, and grasses, rebalanced the cow's rumen and reduced enteric emissions of CH4 from the cows by as much as 18 percent, with an average of 12 percent reduction. In addition the feeding regime increased by 29 percent the omega-3s in the milk.[37]

Waste management also significantly impacts livestock GHG emissions. Anaerobic decomposition of manure, for example in anaerobic liquid waste lagoons, liquid/slurry storage systems, or large stockpile systems, converts much of the carbon in the manure to CH4. Under aerobic conditions, such as in dry-bed or compost systems, N2O is produced. Research in Canada indicates that CH4 and N2O emissions are smaller for compost than for manure slurry or manure stockpiles. For dairy manure, slurry emitted 1.9 times more GHGs than compost; stockpiled manure emits 1.5 times more. For beef manure, emissions of CH4 and N2O are much lower than in dairy. Slurry emitted 4-6 times more GHGs than compost, while stockpiling was 1.3 times higher than compost.[38] In addition, composts have been shown to turn over slowly in soil with significantly more nitrogen available to plants in the years after application.[39]

GHG emissions arising from the production of livestock may vary significantly depending on the system for raising livestock. Comparative assessments of GHG emissions from confinement facilities versus pasture-based facilities should be based on a comprehensive life cycle analysis.[40] This analysis should include an assessment of GHG emissions from the conversion and more intensive cultivation of land used to produce feed grains for confinement systems, as well as GHG emissions from the production of synthetic fertilizers and pesticides used in growing the grain. In addition, confinement facilities use large amounts of energy for heating and cooling and for ventilation needed to protect livestock from exposure to lethal levels of ammonia, hydrogen sulfide and other substances from waste storage and handling that can build up in the confinement facility.

Another factor to be considered in a life-cycle assessment is over-application on land of waste from confined animal operations. In many regions of the U.S, the amount of waste produced exceeds the capacity of the surrounding land base to utilize nitrogen in the waste for plant production.[41] Some of the excess nitrogen is converted on the land to N2O. Nitrogen in the waste is also volatized into the air as ammonia or leaches and runs off the land into water. When re-deposited on land, it can ultimately be converted in to N2O.[42] Additional CH4 may also be generated from manure that has been over-applied and covered with water. This can occurs commonly in the absence of restrictions on applying animal waste to land covered with snow or ice. Research studies comparing confinement systems to pasture-based systems often assume that in the real world confinement waste is being applied in keeping with a nutrient management plan for nitrogen and phosphorus intended to balance crop needs with waste applied. But the reality is that in most states there is little or no monitoring of land application, either by the confinement operation or by farmers who contract to receive the confinement waste.

Climate change could make livestock production more challenging in some regions due to increased heat stress, lower quality feed, water shortages and migration of disease and insects to new areas. Sustainable production systems that reduce the overall stress on the livestock, such as grass-based rotational grazing systems that maintain high quality forage, could help livestock deal with stresses brought on through climate change, while reducing the contribution of livestock to GHG emissions. In addition, well-managed pasture systems with practices that can reduce GHG emissions can also minimize environmental damage to soil, air and water, as well as build soil fertility. Animals that can engage in natural behaviors outside as opposed to being crowded together indoors tend to be healthier and need fewer antibiotics, which reduces the rate of antibiotic resistance in food-borne bacteria.[43] All of these benefits working together will increase the resilience of livestock production systems in the face of rapid global climate change.

E. Organic Farming Systems

Strictly regulated under the Organic Foods Production Act of 1990, organic production is a system that is managed according to the Act's regulations to ". . . respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity."[44] Organic systems avoid the use of synthetic fertilizers, relying instead on practices such as green manures, the addition of nitrogen fixing crops to rotations and the use of composted animal manures. In addition, organic systems avoid the use of synthetic pesticides and rely on practices such as crop rotations which break up pest cycles and beneficial insects. These restrictions on fossil-fuel based fertilizer and pesticide inputs can significantly reduce the overall GHG footprint of organic systems in comparison to conventional production systems. In the last few years, the U.S. agricultural system has used between 40-46 billion pounds of synthetic fertilizers, with increases over that amount since the inception of the corn ethanol boom in 2003.[45] The U.S EPA estimates that once on soils, synthetic fertilizers generate over 304 million tons of GHG emissions each year. Current estimates are that over one billion pounds of synthetic pesticides are used by agriculture each year.[46]

Research on established organic crop farming systems shows superior soil carbon sequestration over both conventional and no-till systems.[47] One of the longest running and most notable studies comparing the carbon sequestration ability of organic and conventional systems is the Rodale Institute's Farming Systems Trial®. In this study, organic systems showed an increase of almost 30 percent in soil carbon over 27 years while the conventional system showed no significant increase in soil carbon over the same time period. The organic farming systems included cover crops, composting and crop rotation to reduce atmospheric CO2 by pulling it from the air and storing it in the soil as carbon. The Rodale Institute found a 33 percent reduction in fossil fuel use for organic corn/soybean farming systems that use cover crops or compost instead of chemical fertilizer.[48]

Another long-term study has been conducted by John Teasdale and colleagues at the USDA Agricultural Research Service's Sustainable Agricultural Systems Laboratory. The 9-years of data comparing various no-till systems to organic systems indicate that despite the need for tillage to control weeds in the organic system, the carbon and available nitrogen concentrations were higher at all soil depths in the organic system. Work at other research centers, including the University of California at Davis, University of Illinois, and Iowa State University corroborate the results of the Rodale study.[49] This body of research demonstrates a vast, untapped potential of organic farming systems to mitigate climate change by increasing soil carbon storage. The Rodale Institute estimates that organic agriculture, if practiced on the planet's 3.5 billion tillable acres, could sequester nearly 40 percent of current CO2 emissions. Current estimates are that 70 to 220 Tg CO2eq could be added to U.S agricultural soils over two to three decades.[50] This represents the reduction of between 3.7 percent and 12 percent of all U.S. GHG emissions in 2006.

Research also indicates that organic production systems are more resilient than conventional systems under both flood and drought conditions.[51] This resilience is critical in the face of a changing climate where more weather extremes are predicted. The combination of practices, including crop rotation and crop diversification, create a system that can literally "weather" the extremes. For example, organic agricultural systems with organically managed soils are better adapted to weather extremes. These soils can better retain moisture, which can alleviate the impact of periodic droughts. These systems also retain more water during high rainfall events and release the water more slowly. At the landscape level, this increased water retention capacity helps decrease the severity of flooding from high rainfall events.

Many organic systems also incorporate a wider array of multi-season crops. The greater biodiversity of most organic systems increases their ability to adapt to climate change, while continuing to provide both economic and ecosystem benefits.[52] Without sacrificing the yields of conventional agriculture,[53] organic farming systems provide benefits to water quality, biodiversity, rural communities and human health. Organic systems provide a promising solution to mitigating the progression of climate change and adapting to its effects.[54]

G. Water Management

Sustainable and organic farming systems can incorporate agricultural water management practices that influence the level of GHG emissions from a farming operation. For example, the amount of water in the soil influences the decay of soil organic matter decay and the amount of carbon sequestered in the soil. Water retained in the soil affects soil organisms' activity and consequently, the timing, nature, and magnitude of this decaying process. GHG emissions can also be reduced through better management of nutrient and residue management, especially management of nitrogen. Practices such as manure effluent spraying can lead to saturation of the land, which in turn can increase CH4 production from the waste in the effluent and lead to leaching of nitrates from the effluent which may ultimately be converted into N2O. Farmers who irrigate can decrease GHG emissions from energy use by increasing irrigation efficiency of pumping, conveyance, and application infrastructure or relying on solar or wind power for energy sources.

Weather extremes including local drought and flooding, are predicted to become more common with rapid climate change. Environmentally responsible water management will therefore be a critical part of a sustainable agriculture future. By both conserving water and sequestering carbon through sound water management, farmers and ranchers can better manage their own water supply while reducing agriculture's impact on climate change. Watershed managers can rely on the benefits of sustainable and organic farming systems to devise long-term strategies that capture storm water, recharge groundwater, improve water quality, store carbon, and protect local habitat.[55]

Conserving water is the least environmentally damaging way to achieve efficiency in water use. Reusing highly treated wastewater is another way to meet water needs without depleting current water sources.

Importantly, groundwater and surface water need to be managed with a "whole system" approach that protects instream flows and terrestrial habitat, and prevents groundwater overdraft. Sustainable agriculture strategies for conserving water include converting cropland to managed grassland in riparian areas, constructing and restoring wetlands, measuring and conserving irrigation water, creating conservation easements, choosing water-efficient crops and resource-conserving crop rotations, and limiting the impact of nitrogen and pesticide runoff from farms into local water supplies. Sustainable and organic farming systems with high soil organic carbon levels can retain more water during periods of drought and can also capture and store more water to mitigate flooding impacts.[56]

IV. AGRICULTURE, ENERGY AND CLIMATE CHANGE

Agriculture has a major role in producing and using energy in ways that mitigate climate change. Powering America's farms with low carbon renewable energy rather than fossil fuels can increase the control of farmers and ranchers over their energy sources, reduce costs, and combat climate change. The production and use of agriculture-based fuels, such as biomass and biofuels, must be accompanied by careful consideration of environmental and social responsibility and rigorous and comprehensive assessment of the GHG emissions from production of the biobased energy.

A. Low Carbon Energy: Solar and Wind

Low-carbon alternatives to fossil fuels include wind (to generate electricity or power pumps) and solar (to generate electricity and heat water or buildings). On-farm energy production eliminates the need to run electric lines or pipelines to remote locations. It also allows farmers to decrease their reliance on increasingly expensive fossil fuels, produce energy from low carbon sources with fewer GHG emissions, develop new value-added revenue sources, reduce on-farm costs, and complement organic and sustainable farming practices. The National Sustainable Agriculture Information Service (ATTRA) provides extensive resources on renewable energy options for farms and ranches.[57]

Cows on a wind farm. NCAT

Solar energy, or the use of photovoltaic cells to convert sunlight into electricity, can be used on farms and ranches to meet or supplement numerous energy needs.[58] Solar air and space heaters can reduce energy costs for livestock and dairy operations that require careful temperature control. Solar water heating can provide water for pen cleaning. Farmers can also use solar energy to heat, as well as light, greenhouses. Solar electric or photovoltaic systems can power general electricity needs including fencing, lighting, water pumping, and crop drying.

Farmers and ranchers who own one acre of land or more and live in an area with good wind resources may consider harnessing wind energy to meet their energy needs in a cost-effective and environmentally responsible way. Wind turbines convert the kinetic energy in wind to mechanical energy, which can then be used to generate electricity. Farmers and ranchers who live in a state with net metering programs may be able to sell excess energy back to their utility providers.

B. Energy from Agricultural Biomass

Agricultural biomass is being targeted as a "second generation" agricultural source for bioenergy, following on the heels of corn starch based ethanol. Much of the biomass being targeted is crop residues. The eminent soil scientist Rattan Lal, however, has raised concerns about this use of crop residues when he observed:

This is a dangerous trend because crop residue is not a waste. It is a precious commodity and essential to preserving soil quality. In addition to controlling erosion and conserving soil water in the root zone, retaining crop residues on the soil is also necessary for recycling nutrients, *improving activity and species diversity of soil micro- and macro-fauna, maintaining soil structure and tilth, reducing nonpoint source pollution and decreasing the risks of hypoxia in the coastal regions, increasing use efficiency of fertilizers and other inputs, sustaining biomass/agronomic yield, and improving/maintaining soil organic matter content . . . . In view of its numerous environmental and agronomic benefits, there is a strong justification for adopting the slogan "grains for people, residues for the soil." This equity is essential to maintaining soil quality at a level at which it can provide all ecosystem services and functions essential to sustainable use of soils for generations to come. Use of biofuels could substantially reduce gaseous emissions, provided that appropriate sources of feedstock are identified, especially those which do not degrade soil and environment quality.*[59]

Recent research by a team of USDA Agricultural Research Service scientists led by Wally Wilhelm, a scientist with the Agroecosystems Management Research Unit in Nebraska, indicates that the corn stover needed to replenish soil organic matter was greater than that required to control either water or wind erosion in the ten counties investigated (including nine counties the top eleven corn producing states in the U.S.). Another recent study examined the impacts of corn stover removal over a 4-year period from sites with different soils in Ohio. The study showed that removal above 25 percent of the stover resulted in adverse impacts on soil quality. In addition, this and other studies indicate that removal of the corn stover has the most adverse impacts on sloping or erosion prone soils.[60]

This research calls into question the estimates of biomass available in the U.S. for biomass-based energy production provided in the 2005 *Billion Ton Annual-Supply Study*.[61] Before major decisions are made about the percent of corn biomass or other crop residue that can be designated for energy production, efforts will be needed to explore less conventional crops that could supply a more sustainable supply of cellulosic feedstock without reducing soil organic matter and undermining the productive capacity of the soil.[62]

C. Agricultural Bioenergy Crops

1. GHG Emission Life Cycle Analysis

A primary objective of U.S. public policy that supports the production of bioenergy, especially biofuels using agricultural resources, is to reduce global GHG emissions. The reasoning is that biofuels are derived from plant-based carbon, which is drawn from atmospheric CO2 during photosynthesis. When biofuel is combusted, CO2 is released back into the atmosphere, with no net increase in atmospheric CO2.

There is significant controversy, however, regarding the overall “carbon neutrality” of bioenergy – particularly when derived from oilseeds (biodiesel), feed corn starch (ethanol) or even from some cellulosic sources. The controversy focuses on which factors should be included in the life cycle analysis for bioenergy, with much attention on the issue of indirect land conversion. If large amounts of agricultural land are used for bioenergy production, in the face of growing world population and increased food prices, the pressure increases to convert other land in grasslands or forests to agricultural food production. When land is broken for cultivation, a large amount of soil carbon is released. The released CO2 could exceed the amount of net GHG emission reductions, relative to fossil fuel production and use, from the system for production of the bioenergy feedstock.

GHG increases from land conversion cannot jbe limited just to a local assessment because rapid climate change is a global phenomenon.[63] The determination of bioenergy GHG emissions requires careful life-cycle analysis of the biofuel under consideration, including analysis of global land use change implications of establishing the specific biofuel feedstock.[64] Life-cycle GHG emission analysis should also include GHG emissions from synthetic fertilizer and pesticides and other inputs used to produce the bioenergy feedstocks.

Agricultural bioenergy production could have some advantages. The establishment of a perennial crop such as switchgrass may require less synthetic fertilizer and pesticides than corn. An annual biofuel crop could improve the conservation performance of an annual crop production system. A prime example is camelina, an oil crop with yields about 2x the oil of soy. Camelina has been grown for years in Montana and a number of land-grant colleges around the country have conducted research and field trials on camelina. It can be incorporated into northern Plains wheat-fallow rotations and can help break up pest cycles and increase wheat productivity, with an overall reduction in pesticide use in the crop rotation system. Camelina also contains sufficient concentration of omega-3 fatty acids to make camelina meal, a good candidate for livestock feed which is a by-product of crushing camelina for oil.

Research by David Tilman and colleagues have shown that the best overall systems for bioenergy production are mixtures of native perennial grasses and flowering plants. These systems provide more usable energy per acre than corn grain ethanol or soybean biodiesel and are far better for the environment. The GHG performance of these systems can be improved even more if they are established on degraded or abandoned agricultural land which can result in a significant increase in soil carbon sequestration.[65]

2. Other Environmental Considerations

Even if a biofuel feedstock results in net reduction of GHG emissions relative to the use of fossil fuels, there are other important questions about the effects of its establishment on the environment. In recent biofuel life-cycle analyses by EPA, both corn ethanol and soybean biodiesel production were found to result in net GHG emissions increases. Most of these production systems did have lower net GHG emissions than the gasoline and diesel they replaced.[66] There are, however, important environmental questions about further expansion of corn monocultures or simple corn-soybean rotations. Over the long term, corn, soybeans and other row crops must also be considered in relation to other systems for bioenergy production from agricultural systems, especially the mixtures of native perennial grasses and other flowering plants which could provide more usable energy per acre and are far better environmentally.

Analysis of ecological impacts of bioenergy projects should not be limited to the field level but should also include changes to landscape diversity and potential impact to primary and secondary habitat.[67] An example of such analysis is research on the expansion of corn acreage in the upper Midwest fueled by the recent corn ethanol boom. Douglas Landis and colleagues studying the impacts in upper Midwest corn states found that the lower landscape diversity lowered the supply of natural enemies of the soybean aphid. Farmers who relied on integrated pest management strategies to control the aphid lost an estimated $239 million per year in ecosystem services across a 4-state region[68] Pesticide use increased, with increases in GHG emissions from pesticide production, distribution and application. These landscape level changes can have profound effects on overall GHG emissions, the surrounding ecosystems and farmers' income.

Another issue is the potential for bioenergy crops to become invasive. Several crops targeted for development as bioenergy sources are novel grasses and trees with invasive characteristics including rapid growth, ability to propagate vegetatively, prolific seed production, few pests and diseases, and ability to tolerate water stress and low fertililization levels. Moreover, genetic engineering of many of these bioenergy candidate species is underway to increase these invasive traits. Genetically modified crops are subject to some environmental assessment before their introduction but there are currently no requirements to asses the environmental risks of wide-scale introduction of bioenergy plants that have not been genetically modified, unless the plant is already listed as a noxious weed.[69]

3. Social Considerations

The mix of crops and livestock produced on agricultural land can also have profound effects on the structure of the social landscape, including the scale of farm operations and opportunities for entry into farming and the diversity and quality of employment in rural areas. These are critical issues which should not be ignored in any policy choices about which crops and systems receive public subsidies or other public incentives, including incentives for biofuel production.

A comprehensive study in Minnesota evaluated possible effects on various factors in two Minnesota watersheds which could arise from changes in farming systems, from the increased adoption of minimum tillage to the reestablishment of perennial plants and wetlands.[70] Projected outcomes included both environmental outcomes, including GHG emissions and carbon sequestration, as well as net farm income, opportunities for beginning farmers and increases in social capital and interconnections within the communities in the watersheds. Overall the study indicates that more diverse farming systems with increased use of perennials and a broader base of crops and sustainable livestock systems could result in increased social benefits to rural communities, including more farming opportunities, a more diverse income base and an increase in social networks within the communities. These social considerations should be accounted for in policies to reduce GHG emissions, including policies that are intended to stimulate bioenergy production.

National Sustainable Agriculture Coalition Policy Recommendations

The organic and sustainable farming systems described in this position paper can and must play an important role in addressing climate change. These systems have been proven to help farmers and ranchers reduce GHG emissions and increase storage of carbon in agricultural soils. These systems can also increase the resilience of their farming and ranching operations to deal with the climatic changes that appear likely under global warming scenarios. They are also the best systems for minimizing other conservation and environmental impacts from agricultural production.

Major points from the research considered in this paper are:

● Protecting grassland and pasture-based agricultural systems and converting row crop systems to grass-based systems can provide for significant levels of retained and newly sequestered soil carbon.

● No-till likely does not sequester new carbon in the soil. The establishment of sustainable and organic systems that include use of cover crops and green manures and conversion from annuals to perennials for pastures and grassland systems will increase carbon sequestration.

● High levels of synthetic fertilizer can reduce soil carbon as well as increase NO2 emissions. Sustainable and organic systems reduce or eliminate synthetic fertilizer use through use of nitrogen-fixing plants in rotations, use of green manures, and use of animal manures integrated into cropping systems or as part of intensively managed rotational grazing systems. These systems can also retain more nitrogen in soils, reducing nitrogen runoff and leaching which also contributes to NO2 emissions.

● Sustainable and organic livestock production systems that include pastures, perennial forages, and the effective management, composting and incorporation of manure can significantly lower methane emissions from livestock production.

● Sustainable and organic agricultural systems provide for better management of water, control soil erosion and provide conservation benefits in addition to the reduction of GHG emissions that can increase the environmental and economic resilience of farming systems and better enable farmers to cope with rapid climate change.

● Farmers and ranchers have significant opportunities to lower energy use on-farm and to generated on-farm energy, especially solar and wind power. On-farm biofuel production can be based on incorporation of perennial feedstocks or new crops in resource-conserving crop rotations that can result in overall reduction of net GHG emissions from the farm or ranch.

● The sustainable and organic systems that result in lowered GHG emissions and increased carbon sequestration also provide significant conservation and environmental benefits and increase the overall health of soils which can increase agricultural production as well.

No matter what role U.S. agriculture is called on to play in federal climate change legislation or international climate change frameworks, these sustainable and organic farming systems provide the best long-term approach to dealing with climate change, the best future for our nation’s farmers, ranchers and rural communities, and the best overall food and farming system for our people.

The 2008 Farm Bill provides authority to the U.S. Department of Agriculture (USDA) to implement policies that recognize the benefits of sustainable and organic agriculture systems for our nation's farmers, ranchers, rural communities and environment in dealing with climate change. Climate change legislation might increase this USDA authority and that of other federal agencies. As federal climate change authority develops, widespread adoption of these sustainable and organic systems must be recognized as fundamental to addressing agricultural concerns related to climate change.

THEREFORE, WE PROVIDE THE FOLLOWING RECOMMENDATIONS:

1. Establish a USDA National Priority for Sustainable and Organic Farming Systems

We welcome recent efforts by USDA to a **strategic plan for climate change.** We recommend that USDA establish a national priority for the reduction of GHG emissions from agricultural production, sequestering carbon in soils, and assisting farmers and ranchers to adapt to rapid climate change. That policy should have as its cornerstone the support and promotion of sustainable and organic agricultural systems throughout USDA's programs and initiatives. These systems offer the best course for meeting the challenges to U.S. agriculture from rapid climate change, including increased soil carbon storage and reduction of GHG emissions from U.S. agriculture.

USDA has made soil and water quality national priorities, and that is reflected throughout USDA conservation, farming research and rural development programs. By making GHG emissions reduction, carbon sequestration and adaptation to climate change national priorities, USDA should logically focus a significant portion of conservation, energy, research and rural development program spending on systems and practices that will address these important issues through funding allocation, ranking, support services, financial assistance and other policies throughout its suite of programs.

2. Strengthen USDA Conservation Programs

a. Increase the focus of USDA conservation programs on climate change and energy conservation.

USDA should continue and expand the use of both the Environmental Quality Incentives Program (EQIP) and the new Conservation Stewardship Program (CSP), both of which are authorized to promote energy conservation, to assist farmers and ranchers in obtaining energy audits of their operations, improving the energy efficiency of their operations, and establishing renewable energy systems. In addition, federal conservation programs need to reward farmers and ranchers for conservation practices that improve soil health and water and air quality while also reducing GHG emissions, storing carbon and increasing the resilience of agricultural production systems to cope with the impacts of rapid climate change.

More specifically, USDA should:

● Incorporate on-farm energy audits into NRCS comprehensive conservation planning and energy-specific conservation activity plans.

● Increase the capacity of NRCS to provide technical assistance on energy conservation and renewable energy on farms.

● Use grants and cooperative agreements to involve state, local and non-profit partners with expertise in energy audits, energy conservation and on-farm renewable energy systems.

● Increase the number of energy conservation practices and systems approved for technical and financial assistance through conservation programs, especially those which provide for relatively low cost, long-term or permanent farming system changes or use low carbon energy sources such as wind and solar power, and provide significant funding for applicants requesting assistance for energy conservation measures.

● Add, retool and strengthen conservation practices, conservation practice standards and resource management quality criteria to reflect the new emphasis on energy conservation and production, GHG emission reductions and carbon sequestration, making extensive use of decades of sustainable agriculture research results and the on-farm experience of farmers working with agricultural systems.

● Expand the use of EQIP and CSP to fund energy audits and the establishment of on-farm renewable energy, including on-farm biofuels and other bioenergy, especially low carbon energy including wind and solar power.

● Provide full life-cycle assessment, including factors such as indirect land use changes related to feed production or other inputs and overall energy consumption, in assessing the net GHG emission levels for systems receiving EQIP ro CSP funding intended to reduce GHG emissions. This analysis is particularly important for Concentrated Animal Feeding Operations (CAFOs). CAFOs generally rely on large-scale row crop grain production using synthetic fertilizers and pesticide and often store animal waste in lagoons and other systems that generate additional GHG emissions. Without a comprehensive life-cycle analysis of GHG emissions, public funding could be used to increase net GHG emissions.

● Retain and expand a CSP focus on conservation systems that improve soil quality, including increased soil organic matter, and target CSP enhancement activities on conservation and production systems and practices that minimize overall GHG emissions, including GHG emissions from the production of farm inputs. These practices and systems include but are not limited to conversion of marginal cropland to grass, resource-conserving crop rotations, continuous cover cropping, management intensive rotational grazing, organic conversion, conservation tillage, and advanced high-level integrated nutrient and pest management.

● USDA authority to oversee GHG emission offsets from agricultural production should be administered through existing programs, with a new permanent easement component for the Conservation Reserve Program and the Grassland Reserve Program and with GHG reduction measures incorporated into the Conservation Stewardship Program. This approach will save additional administrative costs and optimize conservation goals and GHG reduction benefits within a unified conservation planning approach.

b. Fully implement the Organic Priority and the special Organic Conversion provision for EQIP and the special focus and organic crosswalk for CSP established in the 2008 Farm Bill.

Promoting organic agriculture will make agriculture more resilient in the face of climate change while reducing GHG emissions from the agriculture production sector.

More specifically, USDA should:

● Modify conservation practice standards to more adequately reflect organic system plans, with special focus on the organic conversion process.

● Train staff in organic systems and assist in the development of a cadre of organic technical service providers.

● Ensure that financial and technical assistance for organic systems in general, and organic conversion in particular, are available through EQIP in every state and country in the nation.

● Incorporate specific CSP enhancements for organic cropping and livestock systems and include organic-specific options for more generally available enhancements such as conservation tillage, pest management, and invasive species control.

● As part of the organic crosswalk between CSP and the National Organic Program, produce decision support tools to assist farmers in making use of both programs in a coordinated manner.

***c. Expand the role of the Conservation Reserve Program by including carbon sequestration measures*.**

The Conservation Reserve Program (CRP) and other programs that take land out of row crop production and requires long term grass or tree cover. The CRP clearly provides one of the largest, if not the largest, soil carbon sinks created by a federal program. The CRP and other programs that keep land in permanent cover with predominantly perennial plant systems should be bolstered to ensure that current carbon storage services are not diminished. Changes in these programs may include added payments to enhance the carbon sequestration capacity of these lands while maintaining soil erosion measures and measures for wildlife and water quality protection. The use of these lands for biomass/biofuel feedstocks should occur only if instituted in a way that retains and protects them for multiple ecological functions.

Much could be done to enhance the carbon sequestration potential of CRP lands. Ensuring that more of the land is provided permanent protection from annual crop production would definitively enhance CRP as a means to sequester soil carbon. Permanent protection options could be targeted to the most highly erosive land or land with the highest ecological benefits for wildlife and water protection. Legislation should be considered for a permanent easement option on CRP ands to serve as soil carbon banks.

For CRP land that is coming out of CRP contracts, USDA should fully implement the CRP transition option in the 2008 Farm Bill. This option provides incentives and assistance to beginning and socially disadvantaged farmers and ranchers to establish organic production systems and managed grazing systems that keep the land in perennial vegetation, both of which can increase the levels of sequestered carbon and lower GHG emissions.

3. Strengthen Conservation Compliance Measures and Institute Sodsaver Measures

Conventional row crop operations subsidized through Farm Bill commodity programs have been identified as systems with relatively large levels of net GHG emissions. USDA should immediate steps to ensure effective enforcement of existing conservation compliance measures for controlling soil erosion. Legislative measures should be considered to require additional measures such as conservation tillage combined with cover cropping and other practices to increase soil carbon levels and measures such as nutrient management planning and integrated pest management measures to reduce the inputs of synthetic nitrogen and pesticides.

USDA should use existing authority to protect existing grasslands, particularly native prairie and other ecologically important grasslands by requiring that newly cultivated land not receive crop insurance benefits without actual production history. Many of these grasslands are in areas with high erosion levels when perennial cover is removed. USDA should conduct outreach and education to inform farmers about the difficulties of meeting conservation compliance requirements for soil erosion in these regions. Legislative measures should be considered to ensure that public funding is not used to promote the cultivation of grasslands for subsidized crop production with the resulting massive loss of carbon soil.

4. Emphasize Sustainable Agriculture Systems in USDA Research Programs

a. Focus climate change research efforts on whole-farm systems.

Given the range of uncertainty about the specific impacts of climate change on agriculture in any given location, adaptation strategies should not be viewed as a set of single practice prescriptions. Resilience in agricultural systems is a function of the health of the agricultural ecosystem. It is therefore essential that strategies for adaptive response to climate change focus on *whole-system* approaches, as opposed to piecemeal components. Small changes in an otherwise vulnerable system may provide some benefit but fail to be sufficiently adaptive. We strongly encourage USDA to emphasize "sustainable systems for agricultural production," and not just "sustainable practices" in its research, education and extension activities concerning climate change.

b. Increase the capacity of the SARE program to meet the challenges of rapid climate change with elements of the SARE program incorporated into USDA's Climate Change Strategic Plan for Research, Education and Extension.

Since 1988, the Sustainable Agriculture Research and Education (SARE) program has been at the forefront at USDA in developing and disseminating the knowledge and tools necessary for the adoption and advancement of sustainable agriculture. Over its 20 years of operation, the SARE program has been highly successful in building the knowledge and tools necessary to promote sustainable agriculture, and in getting that knowledge and tools into the hands of farmers and ranchers. In many cases, producers themselves have been involved in developing and conducting research and education, adding a practicality to the outcomes that is yet to be matched in other USDA programs. In addition, regional councils guiding the program have addressed region-specific questions, which in the face of climate change will be highly valuable, as different regions are expected to face different climate challenges.

We strongly encourage USDA to dramatically ramp up funding for SARE to incorporate climate change mitigation and adaptation into the SARE program. This funding should be targeted both to long-term systems research and more immediate on-farm research, demonstration and outreach based on SARE-developed systems that save energy, reduce GHG emissions and build healthy soils. We also recommend that USDA, in developing a strategic plan for addressing climate change in Research, Education and Extension, build upon the programmatic elements of SARE. These elements have made SARE a success at translating research into outreach, education and adoption of sustainable farming systems by farmers and ranchers.

c. Support climate change research on sustainable and organic production systems.

Additional support for sustainable and organic research, education, and extension is critical to maximizing agriculture's role in mitigating climate change and ensuring that U.S. agriculture can remain resilient in the face of anticipated climate change scenarios (increasing frequency of extreme weather events, unpredictable weather patterns, increasing temperatures, etc.). Conventional agriculture as currently practiced is a net source of GHG emissions and is highly susceptible to changes in weather, but emerging research on sustainable and organic production systems is showing that these production systems can provide CO2 sinks deep into the soil profile. They are also more resilient in the face of variable and extreme weather events. Developing, improving, and fostering the widespread adoption of sustainable and organic production systems will require significant research, education and extension investments.

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Greater efforts should be made to promote sustainable and organic agriculture as a system of production that can build soil health, lower fossil fuel energy inputs and thereby lower GHG emissions from agriculture. More research will improve sustainable and organic systems so that tillage carbon losses and fossil fuel use can be lowered even further. Major funding increases or redirection should be made to pursue these lines of inquiry through the Agricultural Research Service and other competitive grant programs. Particular attention should be given to ensure the continuation of existing research and establishment of new research that includes long-term comparative studies of farming and cropping systems and of systems for livestock and poultry production.

d. Increase research resources for the development of publicly available seeds and animal breeds adapted to regional climate regimes.

The scientific consensus is that climate change will result in rapid and unpredictable changes in the growing regimes for crops and forages and conditions for animal agriculture that may vary on a regional basis. The development of publicly available seeds and breeds suited to a variety of local climate conditions will be critical to farmers and ranchers in coping with climate change. A major factor in the resilience of sustainable and organic agricultural systems will be plant varieties and animal breeds that are selected to perform under specific local climate conditions, forage availability, and pest regimes. As local climate conditions change, the availability of a diversity of plant and animal genetic resources will be needed to address the growing challenges of global climate change, increasing pest and pathogen pressure, food security, and safety and resiliency concerns.

Therefore, ensuring the access to the greatest diversity of germplasm resources, and the capacity to develop adapted seed and breed varieties is crucial to resiliency of farm and ranch systems. A major recommitment is required to bolster funding for classical plant and animal breeding through the Agricultural Research Service and the Agriculture and Food Research Initiative competitive grants program. Additional specific recommendations to USDA on incorporating a seeds and breeds initiative throughout its research programs is provided in the National Sustainable Agriculture Coalition's position paper on Seeds and Breeds, available at
http://www.sacdev.org/wp-content/uploads/2008/10/seedsbreeds2005.pdf.

5. Design USDA Energy Programs Based on Current, Rigorous Scientific Research that Meet the Needs of Farmers, Ranchers and Rural Communities

a. Rural Energy for America Program (REAP)

USDA should fully utilize the Rural Energy for American Program, which offers critical grants and loans to farmers and business who want to conserve energy. Non-profit organizations with experience in outreach and education to farmers and ranchers on energy issues should be included as entities under REAP eligible to provide farmers and ranchers with assistance on preparing energy audits and establishing renewable and energy efficient systems that can reduce net GHG emissions from agricultural production. Emphasis should be given to low carbon on-farm energy resources, especially small wind and solar technologies.

In addition, categories of projects eligible for REAP funding should be subjected to a comprehensive life-time assessment of GHG emissions. REAP funding should not be used to fund single components of farming systems which overall emit large amounts of GHGs through high fossil fuel energy use or reliance on inputs which generate high levels of GHGs..

b. Biomass Crop Assistance Program (BCAP)

BCAP provides incentives to farmers to provide bioenergy feedstocks in projects with bioenergy refineries to provide the next generation of bioenergy, including cellulosic biofuels. Farmers are provided with financial incentives to establish new bioenergy crops in keeping with a conservation plan to protect wildlife, water, air and other natural resources. USDA should implement this program to ensure that the highest priority is given to projects that involve the establishment of perennial feedstocks with a high potential to reduce GHG emissions. Projects with the highest potential to increase carbon sequestration involve the establishment of perennial crops or trees on land that is currently in row crop production. In addition, projects that incorporate that establish resource-conserving organic systems can have a potential to achieve relatively high levels of carbon sequestration. In addition sustainable biofuel feedstock systems that incorporate leguminous feedstocks or new crops that break up pest cycles can also help lower the level of GHGs emitted from synthetic fertilizer and pesticides.

The BCAP provides financial incentives for biomass collection, harvest, storage and transportation, including funding to remove crop residues. Recent research by USDA Agricultural Research Service scientists and others have raised concerns about the long-term or widespread use of crop residues for energy biomass. The research indicates that residue requirements necessary to increase carbon soil sequestration are likely to be significantly higher than levels required for erosion control. USDA should conduct and support the research needed to make prudent, scientifically valid choices about which agricultural feedstocks are appropriate for biomass energy in light of the overall GHG emissions from their production and their use for bioenergy feedstocks. This assessment should include increases that are related to diverting the feedstocks from other uses, including the retention of residues an agricultural production system to increase soil carbon sequestration.

USDA should expand development of existing crops, discover and develop unconventional crops, and create and deploy advanced cropping systems that exploit the potential of all crops so that biomass production can be expanded to provide a sustainable supply of cellulosic feedstock without reducing soil organic matter, a critical component of the productive capacity of the soil.

CONCLUSION

The National Sustainable Agriculture Coalition supports an immediate and environmentally beneficial transition to a resilient agri-food production system based on sustainable agricultural systems and practices. We call upon federal and state governments to prioritize sustainable agriculture systems and policies that enable farmers, ranchers and rural communities to address through a variety of mechanisms the challenges posed by a changing climate.

The Coalition and its members believe that it is possible and necessary to begin building this resilient agricultural system and employing sustainable practices immediately. We also believe that implementing sustainable practices will be affordable and cost-effective, and that higher energy costs affecting all parts of the farm system make these shifts to sustainable agriculture essential.

Climate change poses a serious threat to our environment, our rural communities, our farmers and ranchers, and the millions of Americans who rely on them for food and fiber. Shifting to a more resilient, sustainable agricultural system will mitigate climate change while building an agri-food system that is better for our planet and its people. Failing to do so will result in devastating consequences for agriculture and the environment.

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APPENDIX. SUSTAINABLE AGRICULTURE SYSTEMS THAT MITIGATE CLIMATE CHANGE

Biological nitrogen fixation
The conversion of molecular nitrogen (N_2) to ammonia (NH_3) through biological fixation by bacteria begins the process of making nitrogen available to plants. Once this "fixed" nitrogen is incorporated into the plant biomass, it can become part of the soil reservoir and taken up again by plant roots as nitrate (NO_2). Biological nitrogen fixation allows nutrients in soil to be actively cycled in the ecosystem, rather than relying on throughflow of nutrients to nourish plants.

Conservation tillage
Conservation tillage refers to strategies and techniques for establishing crops in the previous crop's residues, which are purposely left on the soil surface. The principal benefits of conservation tillage are improved water conservation and the reduction of soil erosion. Additional potential benefits include reduced fuel consumption, planting and harvesting flexibility, reduced labor requirements, and improved soil tilth (NCAT/ATTRA).

Crop residue management
Crop Residue Management refers to any tillage method that leaves crop residue on the surface to reduce erosion. Crop residue left on the surface shields the soil from rain and wind until emerging plants provide a protective canopy. Crop residue also improves soil tilth and adds organic matter to the soil. Less tillage reduces soil compaction and saves farmers time and fuel.

Integrated pest management
Integrated pest management (IPM) is an effective and environmentally sensitive approach to pest management that uses current, comprehensive information on the life cycles of pests and their interaction with the environment to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

Manure Composting
Composting is the aerobic decomposition of organic matter by certain microorganisms. These microbes consume oxygen and use nutrients including carbon, nitrogen, phosphorus, and potassium as they feed on the organic matter. The resulting composted manure is a humus-like organic material, fine-textured, low-moisture, and with a non-offensive earthy odor. If high enough temperatures have been reached during the composting process, pathogens and weed seeds have been killed.

Nutrient management
Nutrient management is the practice of using nutrients wisely for optimum economic benefit, while minimizing impact on the environment. Proper application of plant nutrients help achieve optimum crop yields; while improper application can lead to water quality problems.

Organic agriculture
Organic agriculture is a system of agriculture that uses crop rotation, green manure, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control for pests. Organic agriculture does not use synthetic fertilizers or pesticides, plant growth regulators, livestock feed additives or genetically modified organisms.

Polyculture and crop rotation
Polyculture is the practice of growing multiple crops in the same space, as crops would grow in a natural ecosystem. Polyculture includes techniques such as crop rotation (growing different crops in the same area in sequential seasons), multi-cropping (growing different crops simultanneously), and inter-cropping (growing different crops in between rows of a primary crop). Crops grown in this way are less susceptible to disease than monoculture crops, and also increase local biodiversity.

Resource conserving crop rotation
As defined in 2008 Farm Bill at Section 1238G, resource-conserving crop rotation includes at least one resource conserving crop, reduces erosion, improves soil fertility and tilth, interrupts pest cycles, and in applicable areas, reduces depletion of soil moisture, or otherwise reduces the need for irrigation.

Restoration of degraded soils
Soil restoration seeks to minimize the degradation of soil as a resource that takes hundreds of thousands of years to form, and to promote functional plant-soil systems. Returning soils to their original state as soon as possible after disturbance, stopping application of chemicals, using bacteria to break down pollutants, and applying cover crops are all ways to help restore degraded soil. Without soil restoration, soil erosion and loss of soil organic matter and nutrients damage agricultural outputs in addition to the larger ecosystem.

Rotational grazing
Rotational grazing is periodically moving livestock to fresh paddocks, to allow pastures to regrow. Feed costs decline and animal health improves when animals harvest their own feed in a well-managed rotational grazing system (NCAT/ATTRA).

Seeds and Breeds
The concept of “Seeds and Breeds” refers to the maintenance of genetic resources of plant varieties and animal breeds that are necessary for the survival of sustainable and organic agricultural systems for current and future generations.

Water management
Sustainable agriculture strategies for conserving water include converting cropland to managed grassland in riparian areas, constructing and restoring wetlands, measuring and conserving irrigation water, creating conservation easements, choosing water-efficient crops and resource-conserving crop rotations, and limiting the impact of nitrogen and pesticide runoff from farms into local water supplies. Water management strategies for maximizing carbon sequestration include monitoring soil organic carbon and soil inorganic carbon pools and sediments affected by erosion processes, irrigation, drainage, and sub-irrigation.

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