Chapter 11: Agriculture's Role in Mitigating and Adapting to Climate Change[1]

If the United States begins its inevitable transition to a sustainable energy economy – a step that is essential to energy and climate security – there will be a rural renaissance in America. We will not drill our way out of our dependence on foreign oil; we will grow our way out. Agriculture is the nation's newest energy industry, harvesting not only energy crops, but also the clean power from wind and the sun. The benefits will include new jobs, industries and tax revenues for rural communities.

An alliance of agricultural and environmental leaders has set the goal of obtaining 25 percent of the nation's energy from renewable resources by 2025. America will depend on farms to supply much of that energy, including the feedstocks for ethanol and biodiesel fuels for the transportation system, for electric generation from biomass, and for many consumer products now made from petrochemicals, ranging from plastics to cosmetics. Rural biorefineries will create these fuels and products. Open farm and ranch lands will host wind turbines and solar collectors. Farms will use biofuels in their equipment and operations. Feedlots will produce electricity from methane, reducing the impact of a potent greenhouse gas. And farmers will earn extra income by adopting tillage practices that allow the land to store carbon and by selling credits in the emerging carbon market.

In addition, as we begin to recognize and reward the owners of farmlands and private forestlands for the environmental benefits well-managed land can provide, these lands may be able to bring in additional revenue by multi-tasking: providing wildlife habitat, cleaner water and air, commercial lumber, biomass for energy and carbon sequestration, along with food, fiber and building materials. Soon the principal challenge will be to balance the many competing demands on farmland and forests and to meet those demands in ways that sustain rather than deplete the land and water.

As the renaissance unfolds, America's best farmers will mentor us all on knowledge that we, but not they, have forgotten: the ability to make a living in active and constructive collaboration with the ecosystem.

At the same time, farmers and farming will have to adapt to the local effects of global climate change. Those effects, many of them already underway, include excessive rainfall in some areas and drought in others, new pests proliferating in new temperatures and changes in growing seasons. Competition between farms and cities for water supplies may intensify where rainfall declines. These unstable conditions will increase the risks for farmers and the uncertainties for all of us who depend on the food and fiber they produce.

Food may increasingly compete with fuel for the nation's limited arable land. We will face choices of priority among crops that can feed not only people and animals, but also cars and power plants. Already, food prices are rising as markets pull corn into fuel production and away from human food and livestock feed. Sugar and palm oils production are likely to follow this pattern.[2] "Worldwide basic food commodities now cost 21 percent more than in 2005, and important commodities such as grain and oil have gone up in price more than 30 percent"[3] – evidence of rising pressures from fuel versus food.

This tension is somewhat distorted, however, because much of our grain production is dedicated to livestock feeds.[4] In a recent study, Iowa State University researchers estimated that 30 percent higher corn prices increase all average food prices by 1.1 percent.[5]

However, the *types* of food we raise and the way we raise them influence competition for crops as well as who bears the brunt of rising food prices. Developing countries do have a legitimate concern about food supplies if the rich, developed countries in the North are allowed to "dump our demand" for renewable energy on them. In that scenario, biofuels for export could indeed cause increased hunger by displacing local food production in developing countries. There is strong opposition, for example, among peasant and land reform movements in Brazil to expanding unsustainable and exploitive sugar production there to export more to developed countries like the United States.[6]

Finally, agriculture will not be exempt from the need to reduce economy-wide greenhouse gas (GHG) emissions. Agriculture accounts for 6 percent of the nation's GHG emissions. To reduce these emissions, farmers may need to switch to nonpetroleum fertilizers and fuels, adopt more fuel-efficient methods of tilling and harvesting, and capture methane from animal wastes. Nationwide, we must find ways to reduce the energy consumption and carbon emissions that result from transporting food enormous distances.

Meeting all these demands will require us to revisit the way we farm, the way food comes to our tables, and the way farmland is used in the new energy economy.

Key Issues

1. The Climate Squeeze on Agriculture

Many studies, including the 2007 Intergovernmental Panel on Climate Change (IPCC) report, predict that while there will be stresses on agricultural lands, overall worldwide food production capacity appears to be relatively secure for the 21st century – at least during the initial phase of the warming trend.[7] This is an aggregate picture, however, and a closer look reveals winners and losers. Like other effects of global warming, agricultural stresses and opportunities will vary significantly by region and latitude, and regional changes are likely to be much more critical.[8]

Producers in nations with diverse agricultural infrastructure in the mid and higher latitudes, such as the United States, are likely to see increased yields, attributed to longer growing seasons, increased precipitation, and the potential "carbon fertilization" effect, in which higher concentrations of CO2 in the atmosphere are expected to stimulate plant growth.[9] Closer to the equator, where cereal crops such as rice are already growing close to the threshold of tolerable temperature ranges, yields are projected to drop.[10] This impact is likely to be greatest in Africa, Latin America and India, where food supplies already are failing to meet human needs.[11]

A new study by the Peterson Institute for International Economics concludes, " . . . at least modest global agricultural damage can be expected from business-as-usual climate change by late in this century, with losses about 15 percent greater if the carbon fertilization effect fails to materialize; and . . . the damages will be disproportionately concentrated in developing countries."[12]

Different crops will respond differently to varying climate conditions

As is the case for many natural systems, agricultural impacts and responses to climate will depend on a host of variables. These include variable climate and precipitation patterns, long-term temperature changes, elevated CO_2 in the atmosphere, and the varying responses of plants to water, temperature and changes in pests.

In the United States, under moderate climate change scenarios (defined as a doubling of current CO2 levels),[13] most of the northern agricultural zones will see decreased frost and extended growing seasons. Vineyards in California, for example, are expected to experience a dramatic increase in the yield of wine grapes. Already, larger yields and higher quality grapes have been recorded in the Napa and Sonoma valleys as a result of a dramatically longer growing season and reduced frost days.[14] The famed wine region in California is likely to become a permanent frost-free climate, with potentially exponential economic benefits (assuming these new conditions don't bring unexpected pests and other diseases to the vineyards).

The same scenario will have a very different effect, however, on low-latitude crops in the southern part of the nation where higher temperatures will overwhelm even hearty southern crops.

In the Midwest, changing climate is expected to cause significant reductions in yields of some crops, which translates into increased hardship for many farmers. "Soybeans are particularly vulnerable to climate variability," according to Michelle Wander, University of Illinois associate professor of soil fertility. "Perennial crops such as fruit trees and vineyards are also vulnerable because adjustments cannot be made as flexibly, putting long-term investments at risk," she observed, "and the combination of flooding and high heat is especially lethal to both corn and soybeans."[15]

More extreme temperature changes that extend beyond the "moderate" scenario will result in falling crop yields across the country. Because models and projections offer various scenarios, effective planning is challenging and must incorporate flexible strategies for adaptation.

Impacts on livestock

Like people, many animals are stressed by heat. Dairy cows, for example, produce more milk in cooler weather. "Heat stress in dairy cows can lead to poor feeding, weight loss, and reduced milk production, which begins to decline at temperatures as low as 77 degrees and can drop substantially as temperatures climb above 90 degrees. By mid-century, milk production is expected to drop two to four percent as a result of global warming."[16] Extreme conditions like drought and heat waves can also increase livestock stress and mortality, reduce livestock yields, and reduce reproductive capacity.[17]

Rangeland livestock will find that grasses they depend on are steadily being displaced in historic grasslands by woody shrubs such as fringed sage, which thrive on increased CO2 concentrations.[18] Changes in forage grasses will mean slimmer pickings for grazing range livestock, and may also be a factor in reducing feedstocks for cellulosic biofuels.

In dairy country, the composition of pasture grasses that help define the unique flavor of regional artisan cheeses is also changing with the climate. Cheesemakers also know that warmer conditions mean that cows drink more water, which dilutes the concentrations of fats and proteins in milk, meaning it takes more milk (and thus increases production costs) to make cheese when cows are hot and thirsty.[19]

2. Commercial Agriculture is Part of the Climate Problem

Current, large commercial-scale, farming practices and policies are part of the climate problem and can also figure significantly in the solution. Large-scale monoculture (single-crop) farming is heavily dependent on petrochemicals for fuel, as well as fertilizers and pesticides. Agricultural chemicals and frequent tilling also take a toll on soils and other natural sites for carbon storage. Sound policies will elicit systemic changes that reduce petrochemical dependence, promote healthy soils and cover crops that can capture carbon, reduce other greenhouse gases such as methane and nitrous oxide, and sustain productivity on a warmer planet.

Subsidized surplus requires heavy fossil fuel inputs

Corn is the biggest legal cash crop in the United States, and one of the most heavily subsidized. U.S. farm policy currently stimulates the overproduction of corn.[20] Agricultural market deregulation – epitomized by the 1996 Farm Bill and the North American Free Trade Agreement – allows overproduction, which drives crop prices below the cost of production. Political pressure then reacts, and Congress pays farmers subsidies to make up the difference.[21] The press to overproduce increases fossil fuel use.

The 2007 U.S. corn crop is forecast at 13.054 billion bushels, 2.52 billion larger than the 2006 crop.[22] One bushel of corn requires the fossil energy equivalent of one-third gallon of oil, which translates into 66 gallons of oil per acre.[23] Put another way, conventional agriculture requires 10 calories of fossil energy to deliver one calorie to an American plate.[24] This inefficiency hurts farmers, as fuel costs have historically been 15 percent of total operating expenses. According to the USDA:

> Since 1992, direct fuel and electricity expenses for U.S. farms have averaged around 7 percent of total operating costs. Diesel fuel and gasoline are widely used for tillage, planting, transportation, and harvesting. Electricity, LP, gas, and natural gas are primarily

> used in drying; irrigation; operation of livestock, poultry, and dairy facilities; and on-farm processing and storage of perishable commodities. Expenses from indirect energy use increase total energy expenditures to 15 percent of operating costs. Fertilizers embody the most energy among production inputs because natural gas is the primary input (70–90 percent of the cost of producing nitrogen fertilizer).[25]

Rising fuel prices increase operating expenses. Between 2003 and 2006, direct farm energy expenses rose 47 percent.[26]

Nitrogenous fertilizer became viable commercially in 1947 as the result of the Haber-Bosch process, in which nitrogen and hydrogen gases are combined under heat and pressure in the presence of a catalyst. The heat and pressure come from electricity, and the hydrogen usually comes from natural gas. Thus, as the price of natural gas rises, so does the cost of fertilizer. Fertilizer expenses rose 52 percent between 2003 and 2006 as a result of higher natural gas prices.[27]

Nitrogen fertilizers are costly in other ways as well. Humans have doubled the amount of fixed nitrogen in the biosphere. More than half of this synthetic nitrogen is applied to corn, and the fertilizer contributes to global warming, annual fish kills[28] and also the dead zone in the Gulf of Mexico.

Farming and greenhouse gases

Agriculture is a significant source for two potent greenhouse gases: methane ($CH_{4)}$ and nitrous oxide (N_2O). In 2004, agriculture contributed a total of 120 million metric tons of carbon equivalent (MMTCE),[29] amounting to 6 percent of total U.S. GHG emissions.[30] Agriculture contributed 72 percent of total U.S. N_2O emissions and 29 percent of CH_4 emissions.

Nitrous oxide emissions come primarily from synthetic, nitrogen-based fertilizers, animal wastes, and burning crop residues. Fully 29 percent of anthropogenic methane emissions come from the digestive gasses (21 percent) and manure (8 percent) of cattle, sheep and other ruminant livestock.[31] Diet and nutrition influence the amount of methane an animal produces. “Typically, higher-quality feeds such as supplements, high-nutrient pasture, and high-energy diets, result in increased production and reduced methane emissions . . . over lower-quality feed such as rangeland. This is because higher quality feed is digested more efficiently and thus more energy is available to meet the animals' production needs for milk, pregnancy, or weight gain."[32]

Cattle have evolved to eat grass, but many producers feed them corn or other grains for a period prior to slaughter. Studies indicate that these types of high-grain diets can increase methane emissions.[33]

Although CO_2 emissions are not the primary GHG of concern for agriculture, policies that target their reduction have multiple benefits. Clearing land for cultivation, intensive production methods, and transportation contribute to 13.7 MMTCE of CO_2 emitted annually from the agricultural sector.[34] The average American calorie travels 1,494 miles, while food produced locally travels an average of 56 miles.[35] Thus, farmers markets and other programs to make locally grown products available are bona fide carbon-reduction measures.

3. *Learning from Ecology: High Productivity and Low Carbon from Natural Systems Agriculture*

While very high levels of biological productivity can be wrested from the earth through intensive resource inputs (e.g., fertilizers, pesticides, equipment use) and management, the long-term sustainability of biological production will ultimately be regulated by those ecological processes that govern an ecosystem's capacity to produce.[36] For this reason, we need to continue to apply the lessons we learn from natural systems to our current agricultural production systems.

For example, Natural Systems Agriculture (NSA) is based on this mental model: Nature is a showcase for the species that have survived a 3.8-billion-year evolutionary competition for energy and matter. The failures have become fossils; the winners are intricately connected in ecosystems that run on current sunlight. NSA practitioners are guided by Wendell Berry's questions, "What will the nature of the place permit us to do here without exhausting either the place itself or the birthright of those who will come later? What, even, might nature help us to do here?"[37] Ecologically astute farmers know that they can never do just one thing. They understand that systems consist of their individual components *plus* the interactions between those parts.

Prairies are a natural venue for natural systems agriculture. They are a rich and diverse ecosystem design that resists pests, disease, draught, fire and flood. The root structure of never-ploughed prairie is the source of this resilience. Prairie roots – a complex architecture that can run 25 feet deep – excrete organic pesticides and antibiotics, trap water for gradual release, thrive on fires, absorb and filter rainfall to reduce flooding and pollution, and store carbon (see Section 4 below).[38] Prairie roots are an excellent soil builder and decrease soil erosion. Prairie ecosystems offer an opportunity for a low-emissions farming method known as pasture farming.

Natural Systems In Practice

Pasture farming is a profitable example of natural systems agriculture. Joel Salatin calls himself a grass farmer, even though he produces meat and eggs. His 100 acres of Shenandoah Valley pasture produce 40,000 pounds of beef, 30,000 pounds of pork, 10,000 broilers, 1,200 turkeys, 1,000 rabbits and 35,000 dozen eggs each year.[39] *David Klein runs a profitable prairie dairy farm in Ohio. His 40-head dairy farm makes a net profit of about $2,000 per cow, which is ten times higher than the national average.*[40] *Pasture rotation also has the advantage of dispersing animal wastes, eliminating the need for energy to haul, store, and otherwise manage concentrated manure, while slowly fertilizing pasturelands.*

Well-managed pasture farming has the potential to eliminate millions of tons of carbon emissions annually.[41] But, it will be difficult for these natural systems to compete with cattle feedlots, hog-confinement operations and large-scale dairy and poultry operations that rely on inexpensive feed grains if we don't maintain the cost of feed crops like corn and soybeans at the cost of production. Overproduction stimulated by current farm policy provides an indirect subsidy of below-cost feedgrains. A recent study shows this represented a $20-billion indirect subsidy to industrial hog and poultry production between 1997 and 2005.[42] This substantial indirect subsidy favors large, confined animal feeding operations by creating a substantial market advantage over independent diversified livestock operators who pay the full cost of production for their feed, because when they grow their own feed – pasture or other feed crops – they pay the real cost of production.

4. Opportunities for Sequestering Carbon

Carbon is climatically benign when stored in virgin soils, untilled fields, and thriving plant communities. Tillage can release carbon from the soil in the form of carbon dioxide or methane gas (from natural decomposition). Soils have lost, on average, one-third of the carbon they contained before widespread cultivation began in the 1800s.[43] Improved carbon sequestration may increase methane and nitrous oxide emissions in some soils due to chemical coupling,[44] but net offsets can still be significant. Different management strategies could increase carbon storage by between 104 and 318 million metric tons (mmt) per year. Converting cropland to forests could sequester another 91 to 203 mmt per year.[45]

The potential of different agricultural conservation practices to sequester carbon includes conservation tillage and residue management (contributing 49 percent capture) improved cropping systems (25 percent); land restoration (13 percent); land use change (7 percent); and irrigation and water management (6 percent).[46] As a side benefit, many of these same practices also improve air and water quality, soil fertility and productivity, reduce soil erosion, enhance water retention and improve wildlife habitat. Few if any other means of reducing atmospheric carbon emissions have so many co-benefits. Because of these associated co-benefits of soil carbon, they are sometimes called “charismatic carbon” reductions. There are no known negative impacts or environmental consequences associated with soil carbon sequestration, as with some other proposed mitigation options.[47]

If moderate incentives were available to farmers (up to $50 per metric ton of carbon; $12.50 per metric ton CO_2), farmland could sequester up to 70 million metric tons of carbon.[48] Programs that integrate climate mitigation with adaptation may help address the costs and uncertainties of sequestration projects.[49] For example, current (2007) Farm Bill proposals would provide payments to farmers to grow perennial grasses to create biomass energy crop reserves as future feedstocks for cellulosic ethanol plants.

Tillage matters

The best way to sequester carbon in soils is to reduce soil disturbance with conservation tillage. Research from the Pew Center on Climate Change indicates that three kinds of conservation tillage increase carbon sequestration: (1) no-till, where farmers do not disturb the soil; (2) ridge-tilling, where farmers cultivate rows, but leave much of the soil untouched; and (3) mulch-tilling, where farmers leave 30 percent of the crop residue on the surface, following tilling. While mulch-tilling is the most widely used practice, covering more than 50 million acres throughout the 1990s, no-till practices currently show the most dramatic growth.[50]

Conservation tillage is more cost effective than widespread land-use changes and increases carbon sequestration in two ways. First, farmers who leave crop residues on the ground increase soil carbon inputs. Second, and simultaneously, farmers protect those soil-based carbon stocks by simply not plowing and releasing them. Conservation tillage improves soil fertility and water quality and reduces fuel use. Conservation-tilled fields experience slower water movement, which increases percolation, reduces runoff and soil erosion, and reduces phosphorus loss. Farmers who reduce soil erosion maintain soil fertility and reduce water pollution. Because tilling requires energy-intensive equipment, less tillage means less fuel use and lower fuel emissions. Some no-till farmers, however, increase their use of fossil-fuel-based herbicides to control competing species in fields, which can offset some of the gains from fuel conservation.

Land use and crop/cover conversion

Policies that shift agricultural land to prairie, forests or wetlands can increase agriculture’s ability to sequester GHGs. Since 1985, land use has changed on nearly 50 million acres. Americans converted twenty million acres of cropland to forest, while reforesting 7 million acres of land from other uses. Urban developers, on the other hand, have played the primary role in removing forest from twenty-two million acres, converting the land into a variety of developments.[51] Note that the aggregate result is nearly even – as much land was deforested as was reforested. Likewise, privately owned land in the United States has remained relatively stable at approximately 61 percent. Privately owned land includes 99 percent of the nation's cropland, 61 percent of the grassland pasture and range, 56 percent of the forest-use land and 30 percent of the special-use, urban and miscellaneous land.[52] Still, as land is shifted from one primary use to another, its ability to sequester carbon changes.

Prairies, for example, sequester more carbon in their original, undisturbed state, and the capability of restored sites to sequester carbon vary with soil type and history of disturbance. Even so, restored prairies appear to store more carbon than nearby agricultural soils.[53] Prairie ecosystems require no tillage, no fertilizer, no watering, no pesticide, and very low maintenance. Their products and services include: habitat for native pollinators, habitat for predators that eat pests, rich soil with fixed nitrogen and phosphorous, complex root systems that prevent soil erosion, improved water quality, and farm income under the Conservation Reserve Program.[54] Farmers that convert strategic cropland to prairie reap multiple benefits.

Elevated CO_2 in the atmosphere is likely to increase new tree growth by up to 25 percent.[55] Increased production will offer increased revenue from forested lands, but must also be viewed with some caution, as dense stands of trees are prone to fire, which releases carbon. Some ambitious schemes have proposed genetically engineering trees to maximize carbon sequestration, which could have the effect of turning forests into industrial monocultures.

The Pew Center on Climate Change estimates that 115 million acres of agricultural land are considered marginal and should be evaluated for potential conversion to forest. Restoring forests, prairies and wetlands could increase carbon sequestration up to 270 mmt per year over the next century.[56]

Type of Conversion	Potential Carbon Sequestration Changes[57]
Cropland to grassland	0.3–1.0 Metric Tons of Carbon / hectare / year
Cropland to forestland	2–10 Metric Tons of Carbon/ hectare / year

Carbon trading on the farm

In emerging carbon-trading systems, industries and municipalities are able to purchase carbon credits from farmers (and others engaged in sequestration practices) in lieu of more costly mitigation measures. As a result of the current voluntary system of carbon trading in the United States, about 2,000 agricultural producers in 15 states have sold carbon credits on more than 1 million acres through the Chicago Climate Exchange. Buyers currently pay about $3.50 per ton per year for carbon storage.

The USDA is committed to a market-based approach to carbon mitigation in the agricultural sector and is working to build institutional capacity. The department has outlined three sets of actions: (1) develop better tools for estimating credits generated by agriculture, like the newly created Conservation Effects Assessment Program, (2) educate farmers about the benefits of participating in carbon trading, and (3) partner with other agencies to remove programmatic barriers.[58] Several bills in the 110th Congress contain pieces of these departmental objectives.

The federal government needs to provide rigorous monitoring and verification to ensure that carbon sequestration programs are reliable and effective. Several agencies are working to quantify and predict carbon sequestration by farmland including the U.S. Department of Agriculture (USDA), Department of Energy (DOE), and U.S. Geological Survey. Guidelines for the Voluntary Greenhouse Gas Reporting Program, established in the 1992 Energy Policy Act, enable farmers and landowners to estimate, report and register greenhouse gas reductions and carbon sequestration.[59] DOE maintains the program's public database and encourages widespread reporting to foster improved policy formulation and transparency.

However, so far farmer participation in these programs has been limited because of uncertainty about the emerging science and economics of sequestration. In a recent listening session, a group of Iowa farmers said that their participation in a carbon market would depend on their trust in the buyer (and the technical assistance provided); the program's simplicity; whether conservation tillage, pastures, newly planted trees, etc., worked at their location; consistency in the reward structure; and whether it made financial sense (or increased relative net returns).[60]

Carbon sequestration has multiple benefits

Many of the practices intended to improve carbon sequestration have positive spillover effects. For example, permanently protected farmland on the edge of cities can also help contain sprawl and reduce vehicle miles traveled, thereby reducing emissions.

Well-managed soils sequester more carbon, maintain soil fertility and retain moisture. Because these soils are less prone to erosion, they also improve regional water quality and help retain floodwater.[61] Reestablished prairie and wetlands on marginal lands moderate flooding, reduce turbidity and nutrients in waterways, and increase wildlife habitat and biodiversity. Reforestation protects and stabilizes soils, regulates stream flows, and provides habitat for wildlife, while also increasing timber supplies and biomass fuels.

Cover crops, trees, and good soil conservation practices can also reduce polluted runoff from farming operations which can produce deadly conditions that compound negative impacts from climate change. Fertilizer application and other cropping practices are the largest sources of N_2O emissions in agriculture, accounting for 80 percent. Manure management and field burning are also small sources of N_2O emissions.[62] Nitrogen in fertilizers can be washed into surface waters during heavy rains, leach from the soil into groundwater and streams, or volatize into the air. Nitrogen is a nutrient pollutant that is especially harmful to biodiversity in freshwater and marine ecosystems and water quality.[63] The dead zone in the Gulf of Mexico – an oxygen-depleted area covering more than 8,000 square miles – is primarily caused by nutrients from agricultural runoff in the vast Mississippi River watershed.

Policies and practices that sequester carbon and reduce GHG emissions, such as grass buffer strips or improved tillage practices, will also address these related water pollution problems. EPA is encouraging water-quality-trading pilot projects that allow farmers who implement practices to reduce nutrient runoff on their farms to sell nutrient credits to polluting industries. It may be possible to put a priority on practices that simultaneously sequester carbon. As an additional incentive to farmers, they may then be able to sell carbon credits as well.

All of these conservation strategies will help protect soil productivity and control soil erosion, which in itself is a major source of carbon emissions. Rattan Lal of Ohio State University estimates that land degradation and desertification may account for as much as about 30 percent of the world's greenhouse gas releases. Every year, 100,000 square kilometers of land loses its vegetation and becomes degraded or turns into desert. Climate change makes this worse, as rapid evaporation and changes in precipitation intensify soil degradation, reinforcing the cycle."[64]

Equally important, many of these practices enhance adaptation because they make farmers less vulnerable to the impacts of a warmer, stormier and drier world. Policies that sequester carbon and foster systemic resilience are good for today's farmers and especially good for future farmers. It is important to note, however, that most researchers view carbon sequestration by agriculture as a bridging strategy to longer term solutions since soils have a finite capacity to store carbon. In testimony before the U.S. Senate, Dr. Lal concluded "Actions that improve soil and water quality, enhance agronomic productivity and reduce net emissions of greenhouse gases are truly a win-win situation. It is true that soil C [carbon] sequestration is a short-term solution to the problem of gaseous emissions. In the long term, reducing emissions from the burning of fossil fuels by developing alternative energy sources is the only solution. For the next 50 years, however, soil C sequestration is a very cost-effective option, a "bridge to the future" that buys us time in which to develop those alternative energy options." [65]

Sustainable Forest Management

Sustainable forest management is an approach to managing forests for forest health, diversity and productivity, financial returns and job generation. It focuses on growing large logs of a variety of species, providing continuous forest cover and regular harvests, and relying largely on natural regeneration. According to the Oregon-based Ecotrust, it has great potential for carbon sequestration, especially in the long-lived forests of the Pacific Northwest where managing forests for longer rotations (70–80 years or more vs. the current 40 years) could generate higher carbon storage, more timber production, higher quality logs, greater biodiversity, better recreational options, a more resilient forest, and more scenic vistas. **[66]**

If landowners are compensated only for timber production, the net present value of sustainable forest management would be less than that of conventional forestry, because timber harvests, though greater, would be longer in coming. However, through participation in carbon markets that compensate landowners for carbon storage, sustainable forest management can generate equivalent or higher private returns, while providing a significantly higher level of public benefits.[67] Nationwide in the United States, afforestation (planting trees on land not previously forested) and forest management have the potential to mitigate a total of 384 million metric tons of CO2 per year,[68] or 6.5 percent of total U.S. emissions.[69]

One type of forest offset currently being tried by Ecotrust is establishing carbon reserves on steep and unstable slopes, where logging is more expensive, dangerous and more likely to cause erosion and sedimentation of salmon streams below. By setting aside these areas in permanent carbon reserves – and selling the incremental carbon – the landowner can be compensated efficiently (the opportunity cost of forgoing logging is lower on steep slopes), carbon accumulates, and steep slopes over salmon-bearing streams are stabilized.[70]

In 2005 Ecotrust Forests LLC launched a forestland investment fund; it has acquired 12,000 acres in Oregon and Washington and is managing them to provide competitive returns to investors, produce ecosystem services and jobs, and improve forest structure, diversity, and long-term productivity. It is using the California Climate Action Registry forest project protocol for assessing carbon storage, adding projects in Oregon and Washington to a number in the process of being certified in California.[71]

5. Renewable Energy from Agriculture: Promise and Challenge

Recent estimates suggest that 9–24 percent of current greenhouse gas emissions could eventually be offset through the use of biofuels, assuming that competitive cost structures emerge to make the new technology affordable.[72] A new, low-carbon energy economy will depend heavily on ethanol and biodiesel fuels, as well as the capacity of farms to produce electricity from methane generators, wind and solar energy. However, growing concerns raised in some studies about other greenhouse gas emissions from biofuel production and use – especially high levels of nitrous oxide – mean that benefits and impacts will need to weighed in biofuel development and use.[73]

Ethanol

Ethanol fuels alone are expected to contribute up to a 13-percent reduction overall in GHG.[74] The Energy Policy Act of 2005 included a Renewable Fuel Standard (RFS) mandating the use of 7.5 billion gallons of renewable fuels annually by 2012. Early estimates suggest that actual production of ethanol in the United States will easily exceed this amount, largely in response to higher gasoline prices and market forces.

President Bush first spoke about the potential for ethanol fuel in his 2006 State of the Union address. A year later, he called for 35 billion gallons of biofuels production annually to be required in a mandatory fuels standard by 2017.[75] In May 2007, Congress adopted a resolution supporting the 25 x 25 Initiative (achieving 25 percent renewable energy consumed nationally by the year 2025).[76]

However, “To be cost effective, even with higher oil prices, investment in ethanol relies on already existing support measures, namely a 51-cent per gallon tax credit along with a 54-cent-per-gallon tariff on imported ethanol for fuel use. The production of ethanol has soared because of these measures, aided by the fact that it integrates easily into the U.S.’s gasoline-based economy.”[77] Many argue that maintaining the ethanol tariff will be crucial if we are to make the leap to cellulosic ethanol. They make the case that the tariff will discourage importing too much sugar ethanol from Brazil, which could undermine the price of domestic ethanol and corn and suppress the developing capacity for ethanol production in the United States.

Corn ethanol only as a transitional fuel

Grain ethanol from corn and biodiesel fuel from soybeans currently meet less than 4 percent of the nation's consumption of fuels for transportation. Most experts agree that grain-based ethanol, produced by the fermentation of plant sugars and starches into "grain alcohol," probably will never supply more than 10 percent of our current or future fuel demands.[78] Moreover, corn ethanol production still requires considerable fossil fuel energy, as does large-scale corn production. However, corn *could* be grown much more sustainably. We could, for example, provide farmers Conservation Security Program (CSP) payments if they would agree to grow corn according to Tier III (the highest tier of conservation practices) CSP standards.

Not all ethanol is created equal. Different feedstocks require different types of cultivation, fertilization and pest management, as well as harvest methods, and transportation. In addition, various crops have different levels of natural sugars or starches. All these factors help define the ultimate net energy output, or energy balance (the ratio of energy derived from a crop balanced with the energy required to produce and refine it).

Figures vary on the specific energy balances from particular crops, and ratios depend in part on variables in a given study. However, some crops are clearly higher net energy producers than others. For example, some studies show that sugar cane has a positive energy balance of as much as 8-to-1 or higher.[79] In comparison, various sources rate the energy balance of corn ethanol in the range of only 1.2-to-1 to 1.67-to-1, making it an energy source with low net benefits in the long run.[80] Another concern with corn ethanol is its heavy dependence on natural gas for processing and refining. Robert Rapier, an oil-industry engineer who hosts the R-Squared Energy Blog described corn ethanol as "essentially a way of recycling natural gas."[81]

A simple switch to high-energy, sugar-based ethanol isn't, however, as straightforward as it seems. Major expansion of Brazilian ethanol production, for example, poses significant social and environmental risks, because it could push more small farmers off their land and increase pressure to clear cut more rainforest lands.

Concerns that large-scale corn production for ethanol will result in water shortages and soil erosion have been verified by recent research.[82] Minnesota, the only state with complete records on water use by ethanol plants, estimates that those plants consume 3.5–6.0 gallons of water for every gallon of ethanol produced. Expanding that estimate nationwide means that corn ethanol production is expected to consume almost 30 billion gallons of water in 2008,[83] in addition to the water used to grow the corn.

As large-scale corn production increases, so will greenhouse gas emissions from farm fuels. In addition, assuming that farmers are likely to use higher impact tillage methods to support this production, carbon sequestration in soils will decrease.

The downsides of today's ethanol are offset, in part, by the nation's need for nonpetroleum transportation fuels to reduce oil imports. In addition, grain ethanol production means higher farm income resulting from higher prices for key commodity crops. Corn growers, in particular, will benefit. Prices have already risen from less than $2.00/bushel at the end of 2005 to more than $3.50 per bushel in April 2007.[84] As farmers find a steady revenue stream from corn ethanol, their need for federally subsidized farm supports will decrease. In 2006, higher prices for corn resulted in approximately $6 billion in savings from federal support programs.[85]

Still, the environmental costs and marginal energy output ratio of grain ethanol undermine its promise as a long-term biofuel solution. In a renewable and sustainable energy strategy, corn ethanol can at best, be considered a "bridge" to transition to cellulosic ethanol – a fuel that, while still under development, promises less intensive agriculture and higher net-energy and net-carbon benefits. Given the many incentives and subsidies to increase grain ethanol production, national policy should require the institutions and infrastructure developed to support corn to also be capable of supporting cellulosic ethanol production and distribution.

Cellulosic ethanol

Biofuel derived from cellulose could replace about 20 percent of vehicle fuels and 30 percent of total U.S. petroleum consumption by 2030, according to DOE.[86] Collectively, plant materials, crop residues, brush, forestry byproducts, and organic wastes are considered "biomass." Plant materials high in cellulose, such as cornstalks, switchgrass and other prairie grasses, and even woodchips can release glucose (sugars) that can produce ethanol as well. Benefits of cellulosic sources include the ability to produce energy from perennial grasses and agricultural or forestry "waste" products (as opposed to primary or secondary food sources), which means less need for cultivation (and thus less erosion and pollution and sedimentation in waterways), less need for farm fuels, and less need for chemical fertilizers or pesticides to produce high yields. However, we face some major challenges in transitioning to cellulosic biofuels.

First, cellulose-based sources require a different enzyme to metabolize their complex sugar polymers than the yeasts that break down corn sugars. Much of the research and development for cellulosic ethanol is focused on finding an effective enzyme that will make large-scale production practical.

Second, the dispersed, diverse and low-density nature of crop biomass poses another challenge. To be cost-effective, farmers will need improved or alternative methods to collect, handle, and store biomass such as corn stover (leaves and stalks that are left in the field after harvest). These systems will have to harvest stover at any level of moisture, even while the grain is being harvested; collect all of the cobs; keep the stover from touching the ground; and leave a controlled amount of residue on the soil to meet any conservation requirements.[87]

Third, we will need to determine the most efficient ways to produce biofuels from biomass. For example, one intriguing avenue of research involves biochar, a form of activated charcoal that forms during the low-temperature pyrolysis of biomass. During the conversion of biomass to biochar, about half of the original carbon is retained in the biochar. This, in turn, could be returned to farm fields as soil amendment to increase soil fertility and crop yields.[88]

Researchers estimate a 10-to-15-year timeline to develop strategies for the production, harvest, storage and delivery of cellulosic feedstock to biorefineries in an economically and environmentally sustainable way.[89] The transportation costs of wood chips remain a barrier to the use of this resource, resulting in some experimentation in the use of mobile biodigesters that can be set up closer to woodlands and moved when thinning is done.

Federal grant programs in the Healthy Forests Restoration Act (2003) and the Energy Policy Act (2005) offer start-up support for the fledgling biomass industry, but many of the authorized programs have not yet had funds appropriated. Programs that are funded include efforts toward improved interagency cooperation, and USDA and DOE are collaborating on a number of programs designed to foster growth in biofuels. For example, the Biobased Products and Bioenergy research program is studying ways to store carbon and to use bioenergy to offset carbon emissions. The Biomass Research and Development Initiative,[90] first authorized in the 2000 Biomass Research and Development Act, is conducting a series of "vision" and "roadmap" workshops around the country, and will ultimately coordinate and accelerate all federal bio-based products and bioenergy research and development.

One caveat with all liquid biofuels is their potential to contribute to greenhouse gas emissions from N2O emissions.

Heating with biomass

One of the major hurdles on the path to developing cellulosic fuels is solving the chicken-and-egg dilemma. Which comes first, ensuring a stable supply of feedstock crops such as switchgrass (through strong markets or incentives) or developing production facilities and accompanying infrastructure (like specialized planting and harvesting equipment, on-farm storage facilities and transport) for production, refining and distribution that will drive markets, but which need adequate and reliable feedstocks to come up to scale? Encouraging farmers to grow perennial biofuel crops is challenging in the context of high corn prices, which attract farmers to corn production. But more than just corn prices are influencing a farmer's decisions on what crops to grow. Farmers in the Corn Belt also have decades of experience in growing corn and soybeans; they know how to manage risks and have made substantial investments in the infrastructure (equipment, transport and storage facilities) necessary to produce these crops. (In

2001, the average Illinois farmer had about $218,000 invested in equipment.)[91] Equally important, corn and soybeans thrive on the prime farmland soils in the Corn Belt. For this reason, many think corn stover and cereal straws will be the near-term feedstocks for biorefineries.[92]

A promising step in creating a market for biomass crops during the development phase for cellulosic fuel is to use biomass for direct heating in buildings on and off the farm. Burning biomass for heat (with an efficiency of 80–90 percent) versus burning it for electricity (at 30-percent efficiency) makes good economic and energy sense. Incentives for producing biomass should be coupled with incentives to support the most efficient use, including both thermal and combined heat and power. Current technologies emphasize either using wood chips or compressing biomass into dense pellets that can be burned in specially designed stoves, furnaces or even industrial boilers. Recent advances in the field have improved the efficiencies and reduced potential pollutants such as ash. Biomass has the potential to heat greenhouses, cheese plants, laundries, hospitals, dairies, etc., as well as homes, reducing the need for fossil heating fuels such as natural gas, heating oil and propane.[93] A Canadian assessment showed that one acre of switchgrass can heat one average (2000-square-foot) house.[94]

Expanding the applications of biomass for heat in the near term might help create the infrastructure and feedstocks that will make cellulosic ethanol production viable sooner, while reducing greenhouse gases from buildings at the same time.

Biodiesel

Biodiesel comes from vegetable oils (primarily soybean oils in the United States and, increasingly, tropical palm oils), used restaurant oils and greases and animal fats. Biodiesel is made through a chemical process called transesterification whereby the glycerin is separated from the fat or vegetable oil. The process leaves behind two products – methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold to be used in soaps and other products).[95] Unlike petroleum diesel fuel, biodiesel is biodegradable, nontoxic, and essentially free of sulfur and aromatics.[96]

Concerns about ramping up agricultural production for biodiesel echo those about corn, although the scale of soybean production in the United States is not comparable to corn. In fact, the market for corn is shifting some fields out of corn-soybean rotation, with implications for soil fertility and soybean yields.[97] Elsewhere in the world, concerns are rising about the conversion of tropical rainforests to palm oil plantations to cash in on biofuel production, or sugar cane for ethanol.

“In the case of the developing countries where sugar cane and palm oil are efficient sources of biodiesel, that means we're going to see enormous growth in the tropics and subtropics in both ethanol and biodiesel,” Earth Policy Institute President Lester Brown told the Inter Press Service. “What this is going to lead to is very rapid deforestation if no one intervenes. It is leading to a lot of land clearing in the Amazon, Indonesia and Malaysia.”[98]

Wind and Solar

Farm and ranch lands in certain areas of the United States have the potential to host solar and wind power generation. From North Dakota to Texas, where wind resources are the best in the nation, wind is becoming a new “crop” for agriculture. Farmers and ranchers can earn as much as $2,000-$4,000 annually in lease payments for each wind turbine they allow a power producer to locate on their land, without significant disruption to grazing or conventional cropping. New wind turbines produce energy at a cost that is competitive with conventional electric generation. Xcel Energy, (an energy company that serves 8 Western and Midwestern states), and other utilities are actively engaged in efforts to increase electric transmission infrastructure to reach more areas with high wind resources.

Methane capture for rural electricity

At concentrated animal feeding operations, cattle, sheep, goats, poultry, and swine, generate 920,000 tons of manure every day[99] – approximately 336 million tons every year –and manure management at this scale is a major public health and safety issue. Methane digesters can turn this animal waste into electricity, heat, and money. One unit of methane has the global warming potential of 21 units of carbon dioxide, but combustion converts methane into carbon dioxide, dramatically reducing its heat-trapping potency. Nonetheless, as *Science* reports, including methane in a GHG emission-reduction strategy reduces our national costs to abate greenhouse gas emissions by 25 percent, compared to strategies that involve carbon dioxide alone.[100]

Manure digesters are best suited for large cattle operations that produce concentrated loads of manure in a confined area and where the manure is scraped instead of flushed with water.[101] Instead of storing manure in lagoons where it releases methane and noxious odor into the atmosphere, digesters consolidate the manure into large holding tanks, capture the methane, and burn it. The heat powers a generator, which produces electricity that can be used on site or sold back to the local utility. The "waste" heat can also be used to heat nearby buildings, water heaters, and the manure tank itself. Other advantages are that manure stored in tanks is less likely to seep into surrounding aquifers and pollute groundwater,[102] and the remaining solid waste is a valuable fertilizer, rich in nitrogen, phosphorous, urea, and organic matter[103] and less prone to run off fertilized fields.[104] (As noted above, however, smaller, diversified farms that practice pasture rotation can avoid the waste concentrations that necessitate mass manure management at confined animal facilities.)

Across the country, animal-feeding operations are exploring the potential for methane-to-energy plants,[105] which varies depending on the type of livestock, local regulations, manure-management methods, and financial incentives. California, Minnesota, Iowa and Oregon offer revolving loans, where farmers pay off the loan with money saved from lower utility bills.[106] Farmers who install methane digesters usually qualify for an incentive in the form of lower property taxes (Iowa offers a 100-percent exemption on applicable property taxes). In addition, the Chicago Climate Exchange has developed simple, standardized rules for issuing Carbon Financial Instrument® contracts for agricultural methane collection and combustion at livestock operations. Eligible systems include covered anaerobic digesters and complete-mix, plug flow digesters, as well as covered lagoons.[107] Investment in methane digesters, however, has been sluggish as farmers are leery of installation costs and future regulations. Currently, the United

States has about 50 manure methane-to-electricity facilities.[108] To help defray installation costs, some state agencies, utilities, colleges, and philanthropists have provided grants.

Landfill gas is another critical fuel for rural methane-to-electricity generation. Landfill gas, generated from the decomposition of organic matter in landfills, can also be burned to generate electricity. Waste stored in a landfill will produce landfill gas for about 30 years, and most states require the landfills to capture the methane and burn it on site. According to the EPA, 750 U.S. landfills, located mostly in rural areas, are economically viable for landfill gas-to-electricity facilities.[109] Landfill gas projects in Iowa alone could generate 31 megawatts, which is enough electricity to power 27,000 homes. The emissions reductions would be equivalent to removing 235,000 cars from the road.[110] By turning waste into fuel, rural economies can reduce their carbon footprint at a profit.

Biodiesel for farm equipment

Farm equipment runs almost exclusively on diesel fuel, and biodiesel can replace petroleum diesel without engine modification. In fact, Rudolph Diesel presented his engine at the 1900 World's Fair in Paris with peanut oil as its fuel source.[111] Petroleum diesel replaced biodiesel in the 1920s, when oil was cheap, abundant, and climate change was not on the public radar.[112] Now petroleum diesel dominates the market – in 2001 total U.S. diesel use was 39.5 billion gallons, farm equipment used 3.4 billion gallons, and biodiesel met 0.1 percent of this demand.[113]

Biodiesel critics highlight four problems with this fuel source: higher cost, higher nitrous oxide emissions, reduced fuel economy, and competition for food resources. Proponents counter that it is it is a renewable fuel source with lower emissions of key pollutants and safer handling, as well as having the ability to increase farm income, use diverse feedstocks, and produce a relatively efficient energy return on investment.

Renewable consumer products from crops

Agricultural products have the potential to replace several synthetic products. The European Parliament proposes the following agricultural products[114]:

- **Oil crops.** The same crops that make biofuels can be used to make lubricants, surfactants, paints, solvents, polymers, and linoleum. These crops include barley, corn, grain sorghum, oats, rice, wheat, soybeans, sunflower seed, canola, crambe, rapeseed, safflower, flaxseed and mustard seed.
- **Fiber crops.** Hemp, Flax, and wood can be used in textiles, paper, composites, construction packaging, filters, insulation and building materials.
- **Carbohydrate crops.** Starch from these crops is used in paper, board, organic chemicals, detergents, polymers and several industrial applications.
- **Specialty crops.** High value crops can be grown on a small scale for pharmaceuticals, flavors and fragrances.
- **Biomass for heating.** (See discussion above.)

There are two important caveats on nonfuel and nonfood products from agricultural oils. First, rigorous and dependable monitoring is necessary to uphold product quality and maintain consumer confidence. Second, because crops absorb carbon dioxide during photosynthesis, most agriculturally derived products have lower GHG emissions than their synthetic counterparts. However, the carbon savings from agricultural products are highly dependent on the way the crop was cultivated, harvested and processed.

Locally owned biorefineries and wind farms

Farmer-owned energy projects provide the same services as absentee corporate-owned projects, but local ownership stimulates more growth in rural economies.[115] Ten 30-million-gallon ethanol plants produce as much as three 100-million-gallon plants. But while the big plants may lead to modest and short-term growth in the local economy (and largely benefit distant owners), the diversified smaller plants will have thousands of local owners, and represent a durable economic foundation.

Farmer owners of ethanol facilities take in 30–40 cents per bushel in dividend payments, whereas corporate-owned plants do not pay dividends to farmers.[116] Compared to refineries with absentee corporate owners, the local facility has a 5–30 percent greater impact on the local economy, because farmers tend to spend their income locally.[117] Wind farms show a similar trend: They stimulate more rural economic growth when locally owned. A corporate-owned turbine will contribute $100,000 to a local economy over 20 years.[118] In the same timeframe, a farmer-owned turbine will earn more than $1 million. The local and regional economic impact of that locally owned turbine is substantially greater than the economic impact of a corporate-owned project.[119]

Some propose that large corporate-owned projects are more efficient, and therefore justified in their reduced contribution to local economies. Recent price data from the USDA indicates that 100-million-gallon-ethanol facilities can save two cents per gallon on the production price of ethanol, when compared to a 30-million-gallon plant.[120] This reduced production cost lowers ethanol's wholesale price by less than one percent, while the benefits of local ownership are lost.

Wind farms show similar tendencies. One 200-megawatt farm can produce electricity at a 25-percent lower cost than a local 10-megawatt farm, but the large farm requires new transmission lines to send power across long distances. If the 200-megawatt farm sends its power 500 miles, transmission costs and losses nearly offset the lower production cost. By contrast, twenty 10-megawatt projects injecting their power into an existing transmission system could produce the same power at nearly the same cost, while providing substantial local economic benefits.

Federal policies that include blanket renewable mandates, without stipulating who will own the production facilities, lead to a preference for large wind farms and big ethanol plants. Policies that encourage local ownership will strengthen rural economies, while meeting the country's growing energy demand.

I

6. Strategic Opportunities for Systemic Policy Change

The USDA supports and influences farming through a complex web of subsidies, voluntary incentive programs and infrastructure development. Farm subsidies and incentives fall into three major categories: crop production incentives by way of farm commodity programs, crop insurance, and conservation programs, each of which will be shaped by global warming. As crop varieties and yields change with the climate, and as farming for energy continues to shape food supplies and markets, farm policies will need to be forward-thinking as well as responsive.

Rethinking commodity subsidies

The influence of energy production as a major new role for agriculture is shifting U.S. commodity practices and the global marketplace. The rising price of corn has already dramatically re-shaped assumptions about corn subsidies in only a few years. American farm policy has historically subsidized a corn surplus, which has shifted benefits in the farm economy to large-scale monoculture producers and confined animal feeding operations. Over time, economic forces have resulted in both expansion in the size of livestock operations and the geographic concentration of the animal industries. Regional clusters have formed around economic advantages, such as climate, processors, transportation access and costs, infrastructure, and proximity to inputs. In addition, industry marketing practices, such as contracting, have resulted in higher concentration of poultry and swine production in a few geographic areas. This has made it extremely difficult for farmers growing their own feed for their own livestock on diversified farms to compete.[121] The environmental consequences of these shifts have been increased agricultural energy-use, concentrated animal wastes, soil erosion, polluted runoff and reduced acreage for local food supplies and crop diversity.

America’s commodity subsidies and tariffs on agricultural imports also influence world markets and are increasingly points of tension in international trade. The International Food and Agriculture Trade Policy Council makes this projection:

> As farmers shift acres from other crops to corn, this will moderate the rise in corn prices, but cause the production of . . . other crops to fall and the price to rise for wheat, soybeans, and others. Analysts note that a substantial increase in ethanol

> refining capacity is coming on line in the next few years, and those commitments mean the price of corn will stay high, even if the price of oil declines and even if production of corn expands substantially.
>
> For most [commodity] program crops, current projections are for market prices well above loan rates such that little or no production-enhancing subsidies are expected for the next five years or more. If these projections are correct, the farm bill subsidies for these crops will be irrelevant to world markets. But, these projections also imply that the United States has the opportunity to eliminate the subsidy programs with no impact on farmer revenues. If such a major shift were undertaken, the long-term price effects of U.S. subsidies would be permanently removed.[122]

Conversely, others note that if policies such as the ethanol tariff were removed, then prices would fall again and many small-to-medium-sized farmers would be forced out of business because they would not survive without subsidies.

Although American agriculture is deeply invested in historic commodity support, we may be at a juncture where these programs can be reconsidered in the light in which federal farm programs were first conceived – as a way to provide stability for America's farmers, large and small. Some of that stability might well come from shifting significant resources from current commodity production incentives into programs that reward stewardship, conservation practices, and raising perennial biofuel crops, as noted below. This would create incentives and support structures for sustainability during a time when conservation will be sorely needed in the rush to increase production of bioenergy.

Crop insurance

Already, the USDA compensates farmers for damage due to extreme weather and crop failure. In 2005, the USDA allocated $1.2 billion as compensation for agricultural losses.[123] These funds were distributed by way of five new programs created specifically to address damage to agriculture following extreme weather.[124] The federal government also operates the Federal Crop Insurance Program (FCIP). Since 1980, the FCIP's exposure has increased 26-fold, to $44 billion.[125]

Crop losses due to drought, excessive precipitation or pests are among the predicted effects of climate change. A more proactive adaptation strategy for agriculture could save money, improve efficiency and reduce catastrophic losses for farmers.

Conservation programs

Of the 938 million acres of farmland, cropland makes up 400 million acres (the rest is grasslands, permanent grazing lands and pasturelands). About 160 million acres of cropland are currently enrolled in USDA voluntary, incentive-based, conservation programs. Of these, 120 million acres are enrolled in programs that improve environmental management of working farms and ranches and 35 million acres are enrolled in land-retirement and land-restoration programs. Another 196 million acres are affected by conservation compliance measures to protect highly erodible soils – a requirement for farmers who receive commodity subsidies.[126]

The Conservation Security Program rewards farmers who practice good stewardship. "The CSP already has mechanisms and incentives to reward farmers willing to shift program crop acreage into sustainable bioenergy feedstocks. Conservation goals are achieved through 5-to-10-year contracts that provide farmers with technical assistance and financial incentives that encourage higher conservation performance. Incentives are offered for on-farm energy conservation, on-farm use of biofuels, as well as production of renewable electricity. Historically, the major obstacle to implementing CSP provisions has been the unwillingness of both the Bush administration and Congress to fully fund the program, which has limited its implementation."[127] There are opportunities to build on programs such as this to also reward carbon sequestration and emission reductions.

The Conservation Reserve Program (CRP) has been a highly effective program for farmers and environmental quality, keeping highly erodible lands out of cultivation and protecting or creating important habitat. Cover crops and woodlots planted under this program also have value as carbon storage. However, CRP payments may become less attractive as the price of corn and other crops rise, and farmers are already beginning to pull significant acreage out of conservation protection in order to plant more crops.[128]

A thorough review of state and federal financial flows as they relate to climate change offers a host of opportunities for tightening and re-focusing farm programs to promote successful farming, strengthen rural economies, safeguard the environment, improve food quality and crop diversity, provide new energy sources, and reduce international trade tensions associated with U.S. commodity surpluses.

7. Support Systems for Adaptation

Dialogue with farmers, farm communities and the agricultural industry is essential for integration of the agricultural sector into climate change efforts. Effective communications programs can help expedite new developments in technology, markets, farming practices and carbon trading mechanisms.

A traditional institution for technology transfer – the Cooperative Extension Service – could be employed for this purpose. USDA, land-grant universities and colleges, and county extension offices administer the Cooperative Extension Service. Its early mission to serve the agricultural sector and connect with rural communities, regarded by some as the most effective technology-transfer program in American history, has guided its work for decades.[129] Budget outlays from appropriations have steadily increased since 1999,[130] and Congress demonstrates consistent support for the program. Still, infrastructure is often outdated, and there is a pressing need to re-configure content to better respond to changes in community demographics, globalization and environmental conditions.[131]

Even the most rural farmers now have access to the internet, empowering them to seek out information. The challenge of exchanging information with the agricultural community about emerging issues and technologies may not be one of access but rather quality. Farmers will need tools to identify which information is the most accurate, credible and current, while policy makers will need to understand challenges and practical realities on the farm.

Guiding Principles

Three currents of climate-change action will influence American agriculture as our nation wrestles with strategies to reduce greenhouse gasses, mitigate the impacts, and adapt to a changing environment. Farms, food production and the rural environment will be altered by a changing climate, with benefits for some and costs and losses for others. Agriculture as a sector will be called upon to reduce its use of petrochemicals and emissions of GHGs. And, we will be turning to farms and fields for renewable energy sources at unprecedented scales and with urgent need.

The tensions between opportunity and need, between promising solutions and potential environmental damage, between food and fuel, require strategies to be opportunistic, but also well considered from many perspectives. In our rush to cultivate biofuel crops, we must factor in potential costs to water quality or soil productivity. We must also consider that global warming is imposing multiple stresses on the world’s poor – less food, more expensive food, shrinking water supplies and the potential for mass disease and dislocation. Our agricultural policies can either address and improve these conditions or make them worse.

Strategies for addressing agriculture and climate change must target both mitigation and adaptation. Many of the guiding principles offered in the chapter on natural resources in this volume apply equally well to agriculture, with one fundamental difference: Where most natural ecosystems are largely passive in the face of changing climate, the agricultural sector holds tremendous promise for adaptation. Guiding principles can therefore be categorized according to these two approaches.

Mitigation

As noted earlier, the agricultural sector is not a major emitter of carbon dioxide, but it does have a dual role in climate change mitigation: reducing emissions of methane and nitrous oxide, while providing carbon-sequestration services. Mitigation strategies should:

- Focus on reducing emissions of the two most prominent agricultural GHGs: methane and nitrous oxide. Reductions can be achieved through improved efficiency in fertilizer use, anaerobic digesters and improved manure management, and high-quality pasture rotation.
- Maintain and intensify carbon-sequestration opportunities in soils and living plant material, both through bolstering existing conservation programs and through management changes such as low-till and no-till cultivation. Agriculture should contribute 20 percent of U.S. total reductions in GHGs.[132]
- Provide incentives for commercial forestry to sequester carbon, in addition to more conventional agricultural systems. Plantation forestry must be considered separately from natural forested ecosystems.
- Prioritize market-based approaches, bolstered by policies and regulations. An “upstream” cap-and-auction system provides a promising market mechanism, as do USDA’s current efforts to encourage new private-sector markets to supplement existing conservation and forestry programs.
- Encourage collaboration. Since agricultural mitigation efforts can affect other sectors, state and federal agencies, as well as entities devoted to mitigating climate change across the international spectrum, should join forces wherever possible.
- Policies should be selected based on a careful assessment of the costs to society[133], the likelihood of achieving the desired outcomes, and the feasibility of implementation.

Adaptation

Agriculture is adaptable from the bottom –up, as farmers become more aware of and savvy about adjusting management practices to respond to changes in the local climate. Adaptation may also occur from the top –down, as farming strategies shift in response to new policies, subsidies and incentive programs from state and federal governments. Adaptation strategies should:

- Be proactive. The extent to which farmers adopt adaptation strategies will depend on adequate information flow, access to capital and flexibility of government programs.[134]
- Prioritize market-based approaches bolstered by policies and regulations. Farmers will respond to incentive structures and price shifts more readily than they will to new regulatory requirements.
- Consider indirect impact, including changes in pests and pathogens, soil erosion and soil degradation.
- Build upon existing policies and programs. The Farm Bill is the most obvious target, and new versions of the bill should dramatically increase the profile of climate change. Among other modifications, incentive structures should be shifted from traditional crop subsidies to renewable-fuel production and conservation farming.
- Encourage collaboration. State and federal agencies, as well as university extension offices and rural farming cooperatives, should work together cooperatively and with sufficient resources to build on their synergy.
- Support mechanisms that strengthen local ownership of biofuel refineries and local investments of biofuel capital.

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[1] Much of the data and many of the action items proposed in this chapter are based on research conducted for the Presidential Climate Action Project by Ann Sorenson of American Farmland Trust. We also want to recognize contributions by Andrew Barnett of the Presidential Climate Action Project staff, Dennis Olson (Institute for Agriculture and Trade Policy) and other reviewers who provided additional feedback and resources.

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12 Ibid.

[13] Estimates under this moderate scenario suggest a global temperature increase of 2.5–5.2 degrees Celsius by 2100. The IPCC has predicted global surface temperature increases of 1–3.5 degrees Celsius by 2100. For more information, see: http://www.pewclimate.org/global-warming-in-depth/all_reports/agriculture/

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[19] Ketzel Levine, "Cheesemakers Taste a Change in the Weather," National Public Radio, http://www.npr.org/templates/story/story.php?storyId=13981929. Retrieved September 4, 2007.

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