Future Friendly Farming

Seven Agricultural Practices to Sustain People and the Environment

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Executive Summary

America's farmers provide food, fuel, and fiber for a growing nation. They also provide other valuable services like water management, water filtration, soil protection, recreation, and wildlife habitat. Today, people are placing increasing demands upon our lands for more goods and services. As a result, America's farmers and foresters must obtain the most from our lands while protecting these precious resources to meet the needs of future generations. In order to sustain ourselves and future Americans, farmers and foresters must take a fresh look at how they manage the land.

Increased variability in commodity prices, input costs, and weather patterns is leading to increased uncertainty for farmers. In an ever-changing world and industry, those best able to consistently produce while reducing costs will hold a competitive advantage. The innovative future friendly farming practices outlined in this report can help growers gain an economic advantage by reducing their costs while increasing their crop yields, productivity, and revenue.

In addition to providing tools to address increasing uncertainty and production challenges for farmers, future friendly farming practices offer solutions to pressing environmental issues. The techniques discussed here—cover crops, conservation tillage, organic management, rangeland and grassland management, forest management, anaerobic digesters, and increasing native ecosystems—benefit nature in the following ways:

- Cover crops increase water management capacity, reduce erosion and nutrient loss, and improve wildlife habitat.
- Conservation tillage reduces erosion while increasing nesting cover for birds and wildlife.
- Organic farming eliminates chemical use, increases soil fertility and increases wildlife habitat.
- Grassland management boosts soil fertility, biodiversity, and grassland ecosystem health.
- Forest management increases soil fertility and biodiversity.
- Anaerobic digesters reduce threats to water quality and provide local renewable electric and thermal energy.

- Retaining and returning land to native ecosystems increases biodiversity, wildlife habitat, and improves water quality.

The seven techniques highlighted in this report offer valuable ecosystem services that will save taxpayers, farmers, and consumers money. Implementing these practices will reduce costs associated with water filtration, flood prevention, wildlife habitat preservation, and other critical land management issues.

Climate change poses a threat to current and future generations, with serious implications for our food supply, water, and wildlife resources. Consequently, it is important to recognize key tools for reducing greenhouse gas (GHG) emissions and adapting to the realities of a changing climate with more extreme weather events. Future friendly farming and forestry practices offer shovel-ready and highly cost-effective emissions reductions and sequestration methods to begin decreasing atmospheric greenhouse gas concentrations. The practices discussed here will prove useful to farmers seeking to reduce the uncertainty tied to climate change. These cost-effective strategies will be vital in helping agriculture address and adapt to climate change, all the while improving profit margins for farmers and sustaining opportunities for the next generation to farm.

Duck habitat at wetland edge.

Photo courtesy of USDA NRCS

Introduction

Future Friendly Farming—*Agricultural and forestry management techniques that optimize the provision of all products (food, fiber, fuel) and services (carbon emissions management, air and water filtration, management of water levels) derived from the landscape. Benefits include cleaner air and water, stronger and more resilient ecosystems, greenhouse gas emissions reductions, increased long-term field and forest product production as well as more stable and improved farm and forest owner profitability.*

Ever-increasing demands are being placed on farmers and foresters to meet the food, fuel, and fiber needs of the country. The lands that feed, clothe, and power us also help maintaining soil fertility for future generations, protecting clean water, sequestering carbon in the soil, and providing habitat for wildlife. Fortunately, there are agriculture and forestry strategies that can maximize and optimize the production of multiple goods and services we demand from the land. This report focuses on seven techniques to maximize the benefits our land provides to society today and to our children in the future. These techniques include: cover cropping, conservation tillage, organic management, grazing land management, sustainable forest management, anaerobic digesters, and returning and retaining land to native ecosystems. Finding multiple benefits from the land is particularly important considering that, although U.S. land resources are finite, people's needs and desires for products and services provided by the land continue to grow. It makes sense to move toward land management that delivers as many benefits on as many acres of land as possible.[1]

Future friendly farming practices have the potential to yield numerous additional benefits worth many times any initial up-front investment. These seven practices will yield multiple benefits for years to come, including reduced erosion and nutrient loss from farmland, improved water quality in our waterways and drinking water supply, improved flood mitigation in areas that have experienced considerable loss due to floods, improved air quality, increased biodiversity and wildlife habitat, reduced pest management costs as farmers struggle to stay ahead of changing pest dynamics, and increased farm productivity with reduced costs.[2] Additionally, as the realities of climate change lead to increases in extreme weather events, farmers face increasing uncertainty, costs, and risk to production. The techniques outlined here offer them improved risk management and mitigation, and in many cases, increased yields. By incorporating these practices now, farmers can establish a competitive advantage in volatile markets while preparing their farms for sustained long-term productivity, setting up future generations for long-term success, and producing additional environmental benefits.

Multiple benefits of agriculture and land management practices

Future Friendly Practice	Definition	Effect on Greenhouse Gases	Environmental Benefits	Wildlife Benefits	Landowner/ Farmer Benefits	Potential Trade-Offs or Problems
1 Cover Crops	Crops planted for the purpose of protecting and improving soil and nutrients rather than for harvest as a commodity, particularly during a period in which the land would have otherwise been barren	Sequesters carbon in plants and soil. In some regions, adding a cover crop to a conservation tillage system can nearly double the rate of carbon sequestration	Decreased soil erosion, improved nutrient retention, increased soil organic matter, improved water quality	Increased nesting areas for species such as ducks, high quality food sources for many grassland bird and game bird species	Increased profit through reduced fertilizer needs, improved soil fertility, and easier control of weeds	Requires extra time and knowledge to manage; and some new techniques for growing commodity crops
2 Conservation Tillage	A system in which 30% or more of the crop residue remains on soil after planting. No-till avoids tilling altogether	By disturbing the soil less, soil carbon storage is increased through enhanced soil sequestration, reduced CO_2 emissions from farm equipment	Reduced erosion, reduced water pollution	Increased bird nest density and nest success; increased bird use and aquatic biodiversity	Increased profits through reduced fuel, equipment, and labor costs	Potential increase in herbicide use; increased pest threats in repetitive single commodity production
3 Organic Agriculture	Uses crop rotation, compost, and biological pest control to maintain soil productivity and control pests without synthetic pesticides and fertilizers	Organic agriculture averages 60% less direct energy use compared to conven-tional production practices; organic soils have been found to sequester more carbon than conventional	Improved nutrient retention in soil, reduced soil erosion, reduced nutrient runoff	Increased biodiversity; eliminating the use of pesticides helps promote beneficial insects, birds, nearby aquatic organisms	Increased profit through premium prices and stronger long-term soil fertility through natural systems	Requires considerable knowledge, transition period can be difficult
4 Grazing Land Management	Modification to grazing practices that lead to net greenhouse gas reductions (e. g., rotational grazing)	Increases carbon storage through enhanced soil sequestration and may affect emissions of CH_4 and N_2O	Decreased soil erosion and reduced pollution	Improved habitat for grassland birds (both game and songbirds)	Increased profit through more diverse/ native grasses and managed grazing rotations	As with any good grazing strategy, requires careful management in some areas with sensitive species
5 Sustainable Forest Management	Managing plants to optimize wildlife habitat, biodiversity, wood production, and carbon sequestration	Increases plant growth which increases carbon sequestration	Improves water quality and ecosystem resilience	Enhanced fish and wildlife habitat and increased biodiversity	Sustained long-term income generation, may qualify for reduced property taxes, depending on location	Requires planning and up-front consultation
6 On-Farm Anaerobic Digesters	Digesters extract methane from animal waste; the methane can then easily be destroyed or used to create electricity	Significantly decreases emissions of methane, which is a potent greenhouse gas. Can also lead to indirect reductions in fossil fuel consumption	Improved air quality, reduced odor	Biological oxygen demand and pathogens greatly reduced, reducing the threat of oxygen depletion in water	Increased revenue streams through electricity and carbon credits, reduced fertilizer costs	High up-front costs; may incentivize large-scale confined animal operations
7 Retaining or Returning Native Ecosystems	Returning lands to original ecosystem conditions or preventing them from being destroyed	Sequesters carbon due to accumulation and incorporation of litter into surface soils as well as increased plant root development	Reduced erosion, improved water quality	Maintains or creates high value habitat	More profitable to place marginal or sensitive lands in CRP than to cultivate	Takes years to return to native ecosystem, foregone agricultural production

Cover Crops

Cover Crops—*non-commodity crops planted in between rows of commodity crops or during fallow periods to prevent leaching or soil erosion or to provide nutrients to feed commodity crops. Benefits include reduced erosion, reduced fertilizer use, and increased wildlife habitat and carbon sequestration.*

Photo courtesy of USDA NRCS

Cotton planted into rye cover.

On many farms, row crop fields lay bare after corn, soy, wheat, or another commodity crop has been harvested. Fields can stay bare for up to seven months until spring planting begins. For example, corn farmers in Iowa usually harvest by the end of November. The soil is then left fallow until the first week of May, when they plant their next crop. Some farmers will plow or disk the soil in the fall after harvest, minimizing the work to be completed in spring. Barren or partially-tilled fields will lose nutrients and topsoil to wind and water erosion, requiring additional amendments in the spring to ensure enough nutrients for the next crop. Soil loses carbon to the atmosphere when exposed to air for an extended length of time while in a barren or tilled condition. As soil loses carbon it loses the ability to hold and deliver nutrients and water to crops.

After a commodity crop is harvested, cover crops are planted to protect and improve soil quality. These plants grow through early spring and may be plowed under or rolled over with a crimper to add nutrients to the soil. Farmers can also use cover crops during the growing season as ground cover between rows of commodity crops.

Cover crops add nutrients to the soil and greatly reduce erosion from wind and water, saving farmers time and money. For example, many legume cover crops, such as hairy vetch or sweet clover, maintain soil nutrients and add up to 200 pounds of nitrogen per acre.[3] This natural fertilization process directly reduces fertilizer costs. When the cover crops are followed by commodity crops, especially nitrogen-hungry corn, the reduction of fertilizer costs can single-handedly more than offset the costs of establishing a cover crop.[4] Additionally, by reducing erosion from wind and water, cover crops reducing the amount of nutrients farmers must replace.[5]

By providing vital soil protection, cover crops prevent nutrients from eroding with soil particles left unprotected to wind and water, leaching down into the ground out of the root zone, or volatizing into the atmosphere and adding to greenhouse gas concentrations in the atmosphere. Cover crop uptake of soil nutrients allows

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Minnesota Corn and Soybean Farmer Grows Profits, as well as Water Quality and Climate Benefits

Source: Minnesota Department of Agriculture, Energy and Sustainable Agriculture Program, Mark Zumwinkle.

Doug Keene, Fillmore County Resource Conservation Technician, examines a nicely growing winter rye cover crop before soybean harvest on Tom Boelter's farm.

Tom Boelter grows corn, soybeans, hay and beef on his farm in southeastern Minnesota, in the Root River watershed. Tom has increased his profits by using cover crops, while reducing sediment and nutrient loss, as well as removing carbon dioxide from the atmosphere. Tom's cover crops soak up nitrates that would otherwise escape into the Root and Mississippi Rivers and down to the Gulf of Mexico. He recently added winter rye, a commonly used cover crop, to his farm. He seeded the winter rye directly into his soybeans before harvest, and then grazed the rye after soybean harvest. Tom allowed the rye to grow over the winter and then grazed the rye again in the spring. He then planted the corn directly into the cover crop stubble. The carbon and nitrate stored by the cover crops will provide a lasting benefit to Tom's farm. Soil carbon helps hold water and nutrients, and nitrate is a vital plant nutrient—so future cash crops will have access to more water and nutrients, improving plant growth while reducing fertilizer needs.

PROFITABILITY:

At a cost of just $38 per acre, the winter rye Tom planted provided $85 per acre worth of spring feed for his cattle, providing Tom a profit of $47 per acre from his cover crops. Tom and his neighbors hired a pilot to apply rye seed to their fields.[i] They planted 75 pounds of rye seed per acre, at a cost of $18 per acre. The helicopter and pilot's time cost $20 per acre, so total costs of seeding were about $38 per acre. The rye cover crop produced forage for 16 days of grazing for 25 pairs of cow/calves in the fall from October 25 through November 10. In the spring he grazed 80 cows for 21 days from April 30 to May 20. Tom saved about $5,600 in spring feed costs through grazing 66 acres of cover cropped fields, and yields of the following crops were maintained.

> *Tom has increased his profits by using cover crops, while reducing sediment and nutrient loss, as well as removing carbon dioxide from the atmosphere.*

Farm Bill conservation programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) can provide incentives and cost-share assistance to farmers for implementing cover cropping and other conservation practices. Minnesota farmers can get $32 per acre through EQIP cost-sharing for planting cover crops.[ii] In the future, farmers may be able to sell the carbon sequestration or water quality benefits of their cover cropping on a market. For example, a water quality market is developing in the Chesapeake Bay watershed, and a compliance market in greenhouse gas emissions is developing in the state of California and in the Northeast.

ENVIRONMENTAL BENEFITS:

The Root River watershed, the Mississippi River, and the Gulf of Mexico are all cleaner thanks to Tom's use of cover crops. Soil tests conducted by the Minnesota Department of Agriculture on neighboring farms compared to data from Tom's farm found that cover crops absorbed two-thirds of the soil nitrate present after a crop. Nitrate levels in the soil following cover crops were only 7 parts per million, compared to 23 parts per million on non-cover cropped fields. Without cover crops, the excess nutrients would escape to ground and surface water. Elevated levels of nitrates in drinking water can cause the deadly 'blue baby syndrome,' as nitrates make infant's blood incapable of carrying sufficient oxygen. In the Gulf of Mexico, nitrates feed algae, which multiply rapidly and use up all the oxygen in the water. Without oxygen, fish and other aquatic life die.

In Minnesota, each acre of cover crops sequesters on average .6 metric tons of carbon dioxide.[iii] There are about 182 million acres of land in the United States that could be cover cropped. If each acre sequestered .6 metric tons of carbon dioxide, based on the example provided here, about 2% of the United States' annual greenhouse gas emissions would be taken out of the atmosphere.

MORE RESOURCES:

Practical Farmers of Iowa:
http://www.practicalfarmers.org/assets/files/field_crops/cropping-systems/Cover_Crops_on_Crop_Yield_2009.pdf

Managing Cover Crops Profitably (USDA SARE):
http://www.sare.org/publications/covercrops/covercrops.pdf

Midwest Cover Crop Council:
http://www.mccc.msu.edu/

Burleigh County Soil Conservation District:
http://www.bcscd.com
(Farmer interviews, Powerpoints, Papers)

ENDNOTES

[i] A helicopter needs at least 50 acres to be cost effective for the pilot to seed a field. A helicopter can seed 50 acres in thirty minutes. In the future, Tom is exploring using a high boy tractor to apply rye, instead of relying on a helicopter pilot.

[ii] 2009 Minnesota EQIP Conservation Practice Payment Schedule, NRCS **http://efotg.sc.egov.usda.gov//references/public/MN/2009MNEQIPwRingDike71109.pdf** accessed Dec. 27, 2010.

[iii] Anderson, J Beduhn, R et al "The Potential for Terrestrial Carbon Sequestration in Minnesota" A Report to the Department of Natural Resources from the Minnesota Terrestrial Carbon Sequestration Initiative February 2008 University of Minnesota, St. Paul, MN

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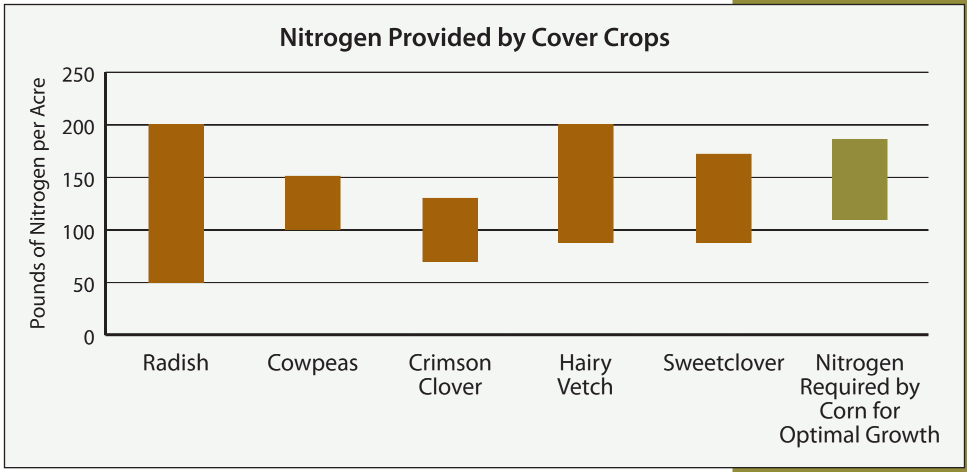
for the slow release of those nutrients as the crop decays, making more of the nutrients available for longer periods to commodity crops throughout their growth cycle.[6] Cover crops also add additional nutrients, especially nitrogen, to the soil.[7]



Cover crops have the potential to meet the high nitrogen needs of corn production, presenting corn farmers with the opportunity to drastically reduce or even eliminate expensive fertilizer applications.[8]

The process of building nutrients in the soil is assisted by small soil organisms called arbuscular mycorrihizal fungi, which feed on nutrients exuded by plant roots. Through a symbiotic relationship, these fungi help plants absorb water and nutrients from the soil. Plants with these fungi near their roots have higher water use efficiency, higher rates of photosynthesis, and are more effective at moving carbon compounds to the roots.[9] When crops are harvested and the land lays barren or is tilled, mycorrihizal fungi cannot survive. When the next commodity crop is planted the following year, the fungi slowly rebuild in population. With cover crops planted between commodity crop growing seasons, the fungi can shift their relationship to cover crop roots, allowing the fungi population to be maintained or continue to grow. When commodity crops are planted during the next growing season, these fungi can migrate to the commodity crops. And since more fungi survived between growing seasons, thanks to cover crops, these fungi can have a bigger impact in helping commodity crops take up nutrients for plant growth.

Fundamentally, cover crops play an important role in managing soil structure and making commodity crop growth

Nitrogen Inhibitors

Nitrogen fertilizer is a common input to row crop production. Each year, over 63 million tons of nitrogen fertilizer is applied to corn, wheat, cotton and soybeans in major crop producing states, with the vast majority going to corn acres.[10] Unfortunately, less than half of that applied nitrogen will be used by crops.[11] Much of that nitrogen leaches into the ground, moves into waterways via storm water runoff, or volatizes when exposed to oxygen and escapes into the atmosphere. The application of nitrogen fertilizer in large single doses, too much for plants to immediately take up, causes this inefficiency. Nitrogen-dependent plants require this nutrient throughout the growth cycle.

Nitrogen inhibitors, chemicals that influence the reaction of ammonium to nitrate, offer the potential to slow nitrogen release over a few weeks. This allows row crops more time to absorb the nutrient rather than losing the chemical element to leaching, runoff, or volatilization that will contribute to climate change. If coupled with precision agriculture, which uses global positioning systems and yield monitors on harvesting equipment to determine site specific nutrient needs, nitrogen inhibitors can play a role in reducing the total amount of fertilizer applied to row crops. This would reduce volatilization of nitrogen as well as the green-house gas emissions associated with the production of fossil fuel-based fertilizers. However, nitrogen inhibitors do not provide the additional benefits typical of cover crops. Additionally, research has found that nitrogen inhibitors do not provide substantial benefits in terms of increased yields on dryland or irrigated corn on fine-textured soils in Minnesota, the Dakotas and other states west of the Missouri River.[12]

more successful. Cover crop roots help break up the soil and increase porosity throughout the root zone, as well as add organic matter that helps soil absorb and retain water. Therefore, plants have a greater chance of surviving periods of excess water as well as dry spells. As a result, commodity crops planted after cover crop can survive with less frequent irrigation.[13] In addition to the soil and water benefits cover crops provide farmers, these plants are also useful for weed management. Cover crops reduce weed growth through competition for sunlight and by releasing phytotoxic chemicals that inhibit weed growth.[14] All of these positive agronomic characteristics add up to reduced costs for farmers and higher profitability. Extension agents and crop advisers can be useful resources for farmers implementing cover crops.

Additionally, cover crops provide wildlife habitat and food for multiple species. These plants supply homes for ground nesting species like ducks, especially in areas located near other vital habitat such as waterways, forests, or wetlands. Furthermore, cover crop residue provides habitat and nutrients for earthworms and insects, two vital food chain links for higher level species.[15] Generally, the key to successfully deriving wildlife benefits from cover crops is to plant vegetation that complements wildlife needs and minimizes disturbance during nesting periods. Legumes such as red clover, white clover, and annual lespedeza (Korean or Kobe) are often planted to produce summer cover. These cover crops not only address soil and plant nutrient issues for farmers, they also provide high quality plant material and attract insects that provide the high protein feed that young turkey and quail need to grow and develop. Small grain cover crops planted in the fall provide food and protection for wildlife from late fall until early spring, increasing winter survival rates.[16]

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Lana Vetch cover in a CA date orchard.

Photo courtesy of USDA NRCS

Cover Cropping North Dakota Grain and Cattle Farmers Grow Profits, as well as Climate and Soil Benefits

Patrick and Marlyn Richter are brothers who grew up together on their family's farm in Burleigh County, North Dakota. The farmers produce corn, sunflowers, wheat, peas, milk cows and beef cattle on 15 inches of rain per year. They decided to add cover crops to help address their concern about soil quality and to increase the organic matter on their land. Patrick says, "cover crops have worked to improve soil health and profitability on our farm." As the third generation on their family's land, the Richters want to preserve the health of their soil for future generations. In 2007, the brothers decided to implement cover crops as a strategy to reduce herbicide costs, increase crop yields and increase land carrying capacity for cattle. By planting a multispecies cover crop mix, they increased their profit. The cover crops also stored about 1.6 tons of carbon dioxide per acre per year, helping to slow climate change while improving their soil health, which will boost soil fertility and future yields. As an added benefit, the Richters' found cover crops provided habitat and food for the wildlife they enjoy.

PROFITABILITY:

The Richter's increased their profit by $135.70 per acre by implementing cover crops. This increase in profit came from decreased herbicide cost and increased yield and grazing capacity of the land. Pat and Marlyn incorporated cover crops onto one of their fields after harvesting field peas on July 4, 2007. They used herbicides to kill any weeds after the harvest to prepare for planting corn the following year. They seeded a mix of millet, cowpea, soybean, turnips, radish, sunflower and sweet clover into the field pea stubble on July 7, 2007. The mix cost $20 per acre, and seeding cost $13 per acre. The Richters found the cover crops suppressed weeds more effectively than herbicides by out-competing the weeds for sunlight. In September of 2007, only the non-cover cropped field required another herbicide application, which cost an additional $12 per acre. In May of 2008, nine months after planting cover crops, available water was roughly equal in the cover cropped and non-cover cropped fields. The brothers planted corn in May. The plant material residue from the cover crops suppressed weeds, so the cover cropped field did not need an herbicide application in June, saving $15.95 per acre. They save a total of S27.95 per acre from reduced herbicide costs.

In addition to decreased need for herbicide use, cover crops also provided valuable nutrients that increased commodity crop yields following the cover crop. After planting corn, the Richters discovered cover cropped fields had 82 bushels of corn per acre, and non-cover cropped fields had only 73.5 bushels per acre. At $3.50 per bushel of corn, the yield increase was worth $29.75 per acre. At current corn prices near $7 per bushel, this value would be almost $60 per acre. The cover crops increased commodity crop profits by $24.70 per acre.

Furthermore, the Richters were able to increase their profitability by using cover crops as forage for their beef herd. Pat and Marlyn worked with their Natural Resources Conservation Service agent, Jay Fuhrer, to develop a diverse mix of cover crops. The mixture of species provided a more complete diet for the cattle and extended the grazing season, increasing cattle weight gain. Richters grazed 141 pair of cattle on the cover crop from October 1st to October 17th. The cattle gained an average of 101.8 lbs per acre, which at $1.09 per pound is worth another $111 per acre. In total, the cover crops increased commodity crop and grazing profit by $135.70 per acre to the Richter farm. Farm Bill programs administered by the Natural Resources Conservation Service, such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP), may pay farmers to add cover crops to their crop rotation or provide cost-share to add cover crops.

The Richter brothers are setting themselves up for long term profitability through cover crops. Since 2001, by using

Patrick and Marlyn Richter's fields in Burleigh County, North Dakota. On left, a cover crop mix of millet, cowpea, soybean, turnip, radish, sunflower and sweet clover. On right, bare fields. The field at left would require less herbicide and produce more corn.

Source: Josh Dukart, Burleigh County Soil

no-till and cover crops, Pat and Marlyn have increased the average soil organic matter levels on their fields to 2.5% from an initial value of 1.5%. In 2010, their soil tests found soil organic matter levels above 3% in some fields for the first time. The increased soil organic matter increases the nutrient carrying and delivery capacity of their soil, making the soil more productive and profitable.

ENVIRONMENTAL BENEFITS:

Cover crops can play a significant role in reducing erosion and nutrient loss in two ways. First, cover crops provide excellent cover for the soil and provide roots that hold soil in place. With these plants, soil is less susceptible to erosion. Second, cover crops absorb nutrients from the soil and make them available for cash crops. By locking away nutrients in plant matter, the nutrients that normally get lost to erosion or leaching instead get held in place until subsequent cash crops can use them.

North Dakotans benefit from the Richters' cover crops through an increase in wildlife. From earthworms and birds to pheasants and deer, the brothers support an abundant wildlife on their farm. Cover crops feed a healthy diversity of soil biota, including fungi, bacteria and invertebrates. The Richters noticed earthworms in their soil for the first time since they began cover cropping two years ago. And those soil biota and earthworms provide the food sources for growing wildlife populations.

The Richters' no-till cover crop strategy sequesters 1.65 metric tons of carbon dioxide per acre per year. There are about 182 million acres of land in the United States in which farmers could implement no-till and cover crops. If each acre sequestered an average of 1.6 metric tons of carbon dioxide like what the Richters achieved, about 5% of the United States' annual greenhouse gas emissions would be stored. This carbon storage happens because in the absence of a cover crop, fields typically lay empty during the fall and spring and no photosynthesis occurs during this time. Cover crops grow during those seasons, and remove carbon from the atmosphere, storing it in soils.

MORE RESOURCES:

Managing Cover Crops Profitably (USDA SARE):
http://www.sare.org/publications/covercrops/covercrops.pdf

Midwest Cover Crop Council:
http://www.mccc.msu.edu/

Burleigh County Soil Conservation District:
http://www.bcscd.com

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In western Kansas, cover crops increased pheasant populations by 80 percent compared to areas with bare ground.[17] Researchers studying cover crops have shown that cover crops can provide habitat and forage for wildlife without significantly affecting the growth of the cover crop and the other benefits they provide.[18]

By transferring carbon from the air to the soil, cover crops improve soil health and commodity production and reduce the amount of carbon dioxide in the atmosphere. Through the natural process of photosynthesis, cover crops absorb carbon dioxide from the atmosphere and use the carbon to develop biomass. Plants will also draw carbon down through their roots and place carbon into the soil. In one field test, bell bean, a winter cover crop, added 2.7 tons of carbon per acre and sunn hemp, a summer cover crop, added 2.1 tons of carbon per acre. By maintaining plant presence on the soil for as long as possible, cover crops maximize the opportunity to use land to reduce greenhouse gas concentrations in the atmosphere. In more humid and warm climates like those found in the South and Southeast, adding a cover crop to a conservation tillage system nearly doubles the rate of soil carbon sequestration.[19] Carbon is a vital component to soil health and is greatly benefited by the presence of cover crops.

Keys for Maximizing Benefits from Cover Crops

- Reduce the amount of time soil lays barren by planting cover crops as soon as possible after harvest, and in some cases, cover crops may be planted before harvest.
- Plant cover crops suited for your climate, soils, and ecosystem.
- To maximize the nutrient carrying capacity of soil, plant cover crops high in biomass.
- To maximize the carbon sequestration (and increase in soil carbon), allow cover crops to grow as long as possible in between commodity crop cycles.
- Various wildlife species use agricultural areas and cover crops differently. Plant the cover crop that best suits the needs of the targeted species.
- Consistent use of cover crops builds up soil structure to help grow commodity crops while also consistently addressing other environmental issues.

Conservation Tillage

Conservation Tillage—*a range of cultivation techniques designed to minimize disturbance of the soil only to areas necessary for seed placement. Undisturbed soil and organic matter from the previous crop help protect the soil from erosion. Conservation tillage is the broader term for a range of techniques, including minimum till, strip till, and no-till. Benefits include reduced erosion, reduced equipment, labor, and fuel costs for farmers, improved water quality, and increased carbon sequestration.*

Photo courtesy of USDA NRCS

Conservation tillage such as these soybeans planted using zero, or no, till protect natural resources while maximizing farm profitability.

Throughout human history, societies have relied on farmers to produce food. Historical leaps in economic, social, and cultural growth can be tied to technological advancements in food production. The moldboard plow, which broke native sod with relative ease, provided one of these leaps in the ability of farmers to produce large amounts of food. When coupled with tractors, farmers became extremely productive in defeating plant species in competition with commodity crops and in breaking open native lands to expand agricultural production. The plow helped farmers achieve "clean tillage," a cultivation approach in which all competing plants were removed, making the field entirely void or clean of residue. America experienced vast increases in food supply from these innovations.

Over time, however, people began to notice the unintended consequences of clean tillage. The tragic events of the 1930s Dust Bowl first taught the nation about erosion resulting from intensive soil disturbance associated with clean tillage. By the 1980s, some farmers began to notice years of losing topsoil on intensively cultivated lands led to nutrient deficiency, and in some cases, outright infertility in fields that had just a generation earlier provided ample bounty. Conservation tillage, or reducing tillage intensity, has gained growing acceptance as a way to prevent soil erosion and maintain soil fertility. The practice jumped from use on 26 percent of U.S. cropland in 1989 to 41.5 percent by 2008.[20] In Tennessee, for example, over 87 percent of all row crops were planted using conservation tillage in 2010.[21]

Repeated intensive tillage can affect the soil's ability to retain water through reducing pores in the soil as well as impairing the soil's ability to bind together. These two functions facilitate water drainage as well as water retention. Intensively tilled soils have a reduced ability to drain water down through the soil profile, causing increased runoff. The ability for the land to absorb water is also reduced, which makes it dry out faster. [22] Conservation tillage allows for more water absorption; increasing soil organic matter by just 1 percent increases water retention by 2.5 percent.[23] Consequently, crops grown using

THE HIGH COSTS OF EROSION AND RUNOFF

Erosion of soil by wind or water creates problems and costs for farmers, whose fields have lost soil and nutrients, and for the regions in which they live. States must pay to clear sediment from ditches and culverts. Municipalities in erosion-heavy areas often require special equipment and incur additional expense purging sediment from drinking water. Similarly, taxpayers bear the costs of dredging to remove excess sediment from ports and barge traffic channels.[24] Each year, businesses and taxpayers incur billions of dollars in indirect costs due to erosion and sedimentation.

Soil erosion also contributes to increased financial burdens associated with flooding. In fact, researchers attribute over half a billion dollars of annual flooding costs directly to erosion.[25] Eroded sediment is often deposited in lower flow areas of rivers, contributing to bottleneck problems. Moreover, decreased water infiltration rates caused by conventional land management practices coupled with the loss of thousands of acres of wetlands have reduced the land's ability to absorb rainwater. As a result, severe flooding of waterways becomes more frequent. A study conducted at Stanford University concluded that reducing runoff from agricultural lands by just 10 percent could reduce flood peaks by up to 50 percent. This process would dramatically reduce the costs associated with flood prevention and damage.[26] By implementing practices such as conservation tillage and cover crops on their land, farmers help to reduce flooding in their watersheds and downriver.

Clean tillage resulting in wind erosion.

Photo courtesy of USDA NRCS

conservation tillage methods are better able to withstand both intense wet periods as well as extended dry periods.[27]

Improved water management through conservation tillage provides economic benefits for society at large and farmers choosing to implement the practice. Every year, the U.S. loses between $21 billion and $69 billion annually in costs due to erosion.[28] Increasing water retention and percolation can significantly reduce surface runoff from agricultural lands.

By improving percolation, conservation tillage decreases the time needed for water to enter into the soil profile, which reduces erosion, runoff, and sedimentation. No-till, one version of conservation tillage, reduces the time needed for one inch of water to infiltrate the soil from over 14 minutes with conventional till to less than two minutes.[29] In 10 minutes' time, rainwater that falls on conventionally-tilled fields will hit the ground, loosening and carrying soil and nutrients to nearby streams and rivers. During the same 10 minutes in a neighboring field managed with conservation tillage, rainwater will infiltrate the soil profile, become absorbed by organic matter, and become available for plants to use through the next few days. This increased ability to absorb precipitation rather than allowing moisture to run off across the surface can contribute to flood management and prevention systems. As a proven example, a project to increase conservation tillage on 57,000 farmed acres in the Pine River Watershed allowed the city of Richland Center, Wisconsin to reduce peak discharge of a 100-year flood by 15 percent.[30] Other water management techniques, like pasture and hay land planting, timber stand improvement, stream bank protection, and wildlife upland habitat management also contributed to the decline in runoff and severity of flooding.

WATER ABSORPTION AND RUNOFF RATES OF CLEAN AND NO TILL SYSTEMS[31]

	Time needed for 1 inch of water to infiltrate into the soil
Native soil	Less than 1 minute
No-till	Less than 2 minutes
Conventional (clean) till	Over 14 minutes

Undoubtedly, conservation tillage is valuable to farmers' bottom line. Numerous studies comparing conventional and conservation tillage practices show that farmers who employ conservation tillage typically have higher profit margins compared to their conventional counterparts.[32] By addressing erosion and improving water retention, conservation tillage practices reduce nutrient loss from farm fields, reducing the need to add nutrients through fertilizers. While conservation tillage can sometimes result in increased use of herbicides, it nonetheless eliminates the intensive seedbed preparation that defines conventional or clean tillage, eliminating between three and seven trips across each field. By reducing the number of trips across a field, farmers can reduce fuel, equipment, and labor costs substantially while increasing income. One study shows farmers saved between $7.67 and $71.42 per acre by implementing conservation tillage.[33] Furthermore, farmers with irrigation systems will find they do not have to irrigate as much after implementing conservation tillage on irrigated lands, which improves their profit margins.[34] Finally, farmers who switch from clean to conservation tillage experience improved yields, all the while reducing costs.[35]

FUEL COSTS OF VARIOUS CULTIVATION METHODS[36]

Tillage System	Fuel Use per Acre	Carbon Emissions from Fuel Use
Clean Tillage	3.31 gallons per acre	33.2 kg CO_2/acre/year
Conservation Tillage	2.91 gallons per acre	29.1 kg CO_2/acre/year
No Tillage	.93 gallons per acre	9.3 kg CO_2/acre/year

ANNUAL COST REDUCTIONS OF CONSERVATION TILL (COMPARED TO CLEAN TILLAGE)[37]

Labor	$1.00–$7.74 per acre
Fuel	$1.45–$7.63 per acre
Machinery Repairs	$1.12–$11.30 per acre
Equipment Ownership	$4.10–$44.75 per acre
Total Reduced Costs	$7.67–$71.42 per acre

Conservation tillage has a proven track record of increasing wildlife populations by reducing soil disturbance. Highlighting the effect disturbance has on wildlife, a study in Canada found a direct correlation between duck nesting success and reduced disturbance.[38] Wildlife and biodiversity benefits are maximized as tillage operations are minimized, especially during the nesting season. Retaining as much crop residue as possible after harvest similarly

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Oklahoma Farmers, Conservationists and Electric Cooperative Improve Farm Profitability, Stream Quality and Global Climate

A cereal rye cover crop grows through recently harvested wheat. Stacy Hansen, Oklahoma Conservation Commission

Farmers, conservationists and an electric cooperative in western Oklahoma discovered a way to improve farm profitability, restore streams and remove carbon dioxide from the atmosphere. Farmers in Blaine and Canadian counties are earning about $20.40 per acre for the water quality benefits and carbon dioxide storage they are providing on their farms by converting to no-till farming. This farming method replaces intensive cultivation of farm fields with practices that leave most of the soil undisturbed and applies slight tillage in narrow seed bed strips at planting time.

Participating farmers achieved these benefits by transitioning a total of 8,700 acres of their land to no-till production and storing 3,485 metric tons (roughly .4 tons per acre) of carbon dioxide annually in the process.

Their use of no-till farming benefits Oklahomans by reducing pollution to the North Canadian River, which improves water quality and fish habitat. The Western Farmers Electric Cooperative (WFEC) is working with the Oklahoma Association of Conservation Districts to purchase carbon credits from the farmers for sequestering the carbon dioxide. In addition, participating farmers qualified for Oklahoma's 319 water quality program, implemented by the Oklahoma Conservation Commission, which provided some cost-share to offset the costs of transitioning to no-till.

> Farmers in Blaine and Canadian counties are earning about $20.40 per acre for the water quality benefits and carbon dioxide storage they are providing on their farms by converting to no-till farming.

PROFITABILITY:

Farmers earned $19 per acre per year for three years of no-till production. The carbon sequestered earned them carbon credits which the Oklahoma Association of Conservation Districts (OACD) purchased for $3.50 per ton. The OACD aggregated and sold these carbon credits to the Western Farmers Electric Cooperative for the same price. The Oklahoma Conservation Commission (OCC) provided verification of the carbon sequestration. Shanon Phillips, Director of Oklahoma Conservation Commission's Water Quality Division, found the Western Farmers Electric Cooperative's "voluntary purchase of carbon credits was a way for the Co-Op to reward their customers for conservation practices that protect water quality and sequester carbon." The Oklahoma Conservation Districts participating in this pilot project purchased a no-till drill, which they rented to farmers to help them convert to no-tillage production without buying equipment.

ENVIRONMENTAL BENEFITS:

Oklahomans benefit from improved water quality thanks to implementation of no-till farming. In the nearby Lake Creek, fish species diversity and the number of fish doubled due to similar efforts. No-till production reduces erosion, which keeps surface waters cleaner. Also, no-till enables the ground to build up soil carbon and organic matter, which improves the soil's ability to absorb nutrients and release them to plants. In six watersheds where the Oklahoma Conservation Commission worked with farmers to plant riparian buffer zones, transition to no-till and improve livestock management, the United States Environmental Protection Agency (EPA) certified that the watersheds, formerly polluted, now meet water quality standards. The EPA has recognized these achievements by ranking Oklahoma in the top five states in the country for reducing phosphorous and nitrogen pollution.

Farmers adopting no-till in Oklahoma store on average 0.4 metric tons of carbon dioxide per acre per year. Approximately half the carbon an annual plant removes from the atmosphere through photosynthesis is stored in the soil. No-till protects carbon stored in the soil. There are about 177 million acres of row crop farmland in the United States that could be no-tilled, and if every acre sequestered an average of .4 metric tons of carbon dioxide, over 1% of the United States' annual greenhouse gas emissions would be stored.

MORE RESOURCES:

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Precision Agriculture

Thanks to advancements in global positioning systems, remote sensing data, and real-time soil sensing equipment, precision agriculture is developing into an effective system for maintaining or increasing yield with reduced inputs. Through precision agriculture, farm implements are guided by GPS, reducing operator error and field pass overlap. Data from sensing technology, such as yield monitors and on-the-go sensing electrical conductivity, combined with remote sensing data from satellites are all drawn together to correlate production yields to soil characteristics. Armed with such information and new technology that allows for fine-tuned metering of inputs such as seed, fertilizer, and pesticides, farmers using precision agriculture have the opportunity to reduce inputs while maintaining yield.[39] This precision leads to reduced emissions from fuel use and volatilization of over-supplied nitrogen. Additionally, precision agriculture shows promise in reducing nutrient runoff by matching nutrient application to site-specific soil need.[40] Further development is still needed for precision agriculture technology to become widely implementable. As it currently stands, precision agriculture requires significant investment in expensive equipment, yet this rapidly advancing field offers great promise.

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maximizes benefits to wildlife by providing vital food and cover, especially during winter and early spring.

Crops grown using conservation tillage methods are better able to withstand both intense wet periods as well as extended dry periods.

Conservation tillage fields provide stable nesting areas for wildlife and encourage higher populations of beneficial soil organisms that provide food for wildlife and improve soil structure vital to crop production.

Photo courtesy of USDA NRCS

Water erosion from clean tillage.

Abundance of non-pest insects has been shown to be greater in no-till fields than in those that are clean tilled.[41] The importance of the effects of tillage on insect abundance and wildlife populations is illustrated in a study in which quail chicks gained weight when foraging for insects in no-till fields but lost weight when foraging for insects in tilled fields.[42] No-till fields can attract greater diversity of bird species and lead to better nesting success than clean tilled fields.[43]

In fact, under clean tillage, up to 80 percent of soil organic carbon is lost over 40 to 50 years of cultivation.

In addition to preventing soil erosion, improving water management and wildlife habitat, and decreasing production costs for farmers, conservation tillage practices can also play a role in addressing climate change. The practice sequesters carbon into the soil and plants, locking it away for an extended period of time. This stands in stark contrast to clean tillage methods which sequesters carbon through plant growth, but then releases that carbon back into the atmosphere when the soil is intensively tilled on an annual basis. For example, each spring in Iowa the atmospheric carbon concentration rises as farmers conduct their spring tillage. Additionally, clean tilled land will lose soil organic carbon

Photo courtesy of USDA NRCS

Sedimintation from erosion.

over time due to the continued release of carbon without efforts to counterbalance those losses. In fact, under clean tillage, up to 80 percent of soil organic carbon is lost over 40 to 50 years of cultivation.[44]

Farmers can sell their greenhouse gas benefits from conservation tillage on carbon markets. Various estimates place carbon sequestration of conservation tillage between .2 and .3 tons per acre per year.[45] At this rate, if 200 million acres of conventional tillage were replaced with conservation tillage, up to 60 million tons of carbon would be sequestered every year. Farmers gain an additional revenue source, and the nation benefits from improved water quality, improved wildlife habitat, and biodiversity.

Keys for Maximizing Benefits of Conservation Tillage

- Coupling conservation tillage with cover crops increases soil building, erosion and flood prevention, and field productivity benefits while reducing costs to farmers.
- Conservation tillage widely implemented across a watershed can significantly mitigate flooding.
- Conservation tillage provides the best benefits if implemented consistently.
- Transitioning to conservation tillage with cover crops currently presents a difficult barrier for many farmers.

Organic Management

Organic farmers use techniques that rely on biological systems to replace synthetic chemical inputs. These techniques include the use of cover crops, advantageous crop rotations, and manure and compost nutrient sources to produce diverse products. The term "organic farming" derives its name from soil organic matter, a key indicator of soil biological health. The United States Department of Agriculture (USDA) certifies products from these farms. Consumers are increasingly attracted to products labeled organic, often due to a perception of health benefits from those products. Between 1997 and 2007, sales of organic food and beverages grew from $1 billion to over $24 billion.[46] Despite double digit growth rates, certified organic production still represents a relatively small percentage of market demand and production acreage.

Farmers who use organic methods profit more per acre than those who use conventional farming methods.

For farmers, organic production can be more profitable. A 22-year study conducted at the Rodale Institute compared conventional corn-soy production with an organic corn-soy rotation and an organic corn-soy-pasture rotation. The results showed that the organic systems had higher profit per acre. The conventional corn-soy rotation earned an average of $72 per acre while the organic corn-soybean rotation earned, on average, over $89 per acre.[47] Numerous studies conducted at land grant universities further substantiate the conclusion that farmers who use organic methods profit more per acre than those who use conventional farming methods.[48] These studies indicate the profit advantage of organic production through reduced input costs alone. Adding the price premium for these products would further increase the profit advantage of organic production. Moreover, organic systems enjoy more stable profit margins with fewer years of losses. In separate studies conducted by researchers at Iowa State University and the University of Nebraska, the organic systems had a higher average annual profit compared to continuous corn, and they posted a profit every year of the 10 and 8 year studies. Conventional

Organic Management—*An agricultural system that promotes and enhances biodiversity and biological cycles through practices that work with ecological processes while minimizing the use of off-farm inputs. Benefits include elimination of chemical inputs, improved soil health, increased wildlife habitat, and increased farm profitability.*

corn, however, experienced a net loss roughly one out of every four years.[49] The 2007 Census of Agriculture found that organic farms had an average profit of $46,000 and non-organic profited $25,000.[50]

One of the reasons organic farmers enjoy more stable and increased profit margins is organic agriculture's focus on biological systems that reduces energy use. Organic agriculture has on average 60 percent less direct energy use compared to conventional production practices.[51]

Organic agriculture has on average 60 percent less direct energy use compared to conventional production practices.

In addition to reducing emissions through less energy use, organic agriculture builds up carbon and other nutrients in the soil at impressive rates. The farming method utilizes practices that maximize soil organic matter, which uses carbon sequestered from the atmosphere to improve soil nutrient holding and delivery capacity. Each time soil is exposed to the air, the carbon in SOC volatizes and escapes into the atmosphere. This volitization is particularly extensive with the cultivating or breaking of lands in native ecosystems—lands which have had years to build up carbon in the soil. Major differences in soil, biological and environmental characteristics occur between fields with low SOC and those managed to maximize soil organic carbon. Fields with high SOC retain and make nutrients available for subsequent crops, resist erosion, and exhibit better percolation. Increasing SOC makes more water available to crops to better survive droughts while reducing the impact and incidence of flooding by more effectively directing excess water into the ground rather than across the surface landscape.[52] A nine year study conducted by John Teasdale at the Beltsville, Maryland Agricultural Research Service compared the carbon sequestration ability of minimum till organic systems to no-till production. Examining these systems in corn, soybean, and wheat production, the organic system was found to build more soil organic carbon (SOC) than no-till methods.[53] The organic system added organic matter to the soil and reduced inputs that destroy living matter.[54] Building healthy soil allows organic farmers to experience more consistent yields without having to rely on inputs such as fertilizer and other soil amendments that can often experience rapid price volatility.

Further facilitating more stable production with reduced dependence on off-farm inputs, organic farming maximizes beneficial organisms in the soil, which play important roles in facilitating nutrient exchange and managing pests. Earthworms, for instance, play a vital role in aerating soil, which increases root growth, facilitates water infiltration and redistributes nutrients throughout the root zone.

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Can Organic Provide?

Many scientific studies indicate organic agriculture can match and sometimes exceed production from non-organic agriculture.[55] However, in the first years of organic production, also known as the transition period during which soil health builds, farmers often experience lower production. This results from nitrogen deficiency which occurs when inorganic fertilizers that provide short term boosts in nitrogen are no longer applied. Nitrogen from organic sources requires more time to establish and build up in the soil. After the transition, which takes roughly two to five years, organic agriculture can consistently match or out-produce conventional agriculture.

Three studies comparing conventional and organic production provide valuable insight into the issue of organic farming. In one of the longest running agricultural trials in England comparing conventional and organic systems, the organic system produced 1.4 tons of wheat per acre while the conventional system produced 1.38 tons per acre. In Pennsylvania, the Rodale Institute completed a 22-year study comparing conventional and organic production systems. After a transition period for organic agriculture, both corn and soybean yields were equivalent for years 6 through 22 of the study.[56] In a 17-year study in Minnesota, rotations using organic methods had higher alfalfa, oats, and corn production.[57] Because organic systems build up soil fertility and increases future productivity, there is little question that organic can produce as much as conventional agriculture.

CASE STUDY

The Next Generation of Farmers Grows on an Organic Grain Farm in Massachusetts

Loaves of bread at Wheatberry Bakery, grown, harvested and eaten in Amherst Massachusetts.

Source: Ben and Adrie Lester

Ben and Adrie Lester are young farmers using organic practices that improve their profitability, remove greenhouse gases from the atmosphere and provide habitat for local wildlife. Ben and Adrie are not your typical farmers—while the average American farmer is 57 years old, Ben and Adrie just turned 30. Secretary of Agriculture Tom Vilsack called for 100,000 new farmers, and the couple is happy to step up to the plate. The Lesters represent not just youth, but a new awareness in farming. Ben says, "every young grower I know is motivated by concerns about climate change and other environmental problems."

The Lesters grow grain, eggs and wool organically on 4.5 acres in the Pioneer Valley of western Massachusetts. They will grow grain in an extended rotation of corn followed by oats followed by winter wheat, followed by about 3 years of perennial grass, followed by a legume like dry beans. He plants rye, oats, and clover as a cover crop during the winter season between the summer annual grain crops. The Lesters' sell their products directly to the local community.

PROFITABILITY:

By selling directly to the local community, the Lesters are able to increase their profit margin, receiving $3-5 per pound of grain and $7 per pound of local organic bread, rather than the $.10 per pound of grain or $4 per pound of bread the farmers might receive in the commodity market. The young organic farmers sell their products in two ways. First, the Lesters manage a Community Supported Agriculture program in which 119 members pay $375 at the start of the growing season to the couple and three other local grain farmers. In return, the members get a 'share' of the grain harvest, which varies depending on yields in a given year. In 2010, each customer paid around $3.50/pound for heirloom beans, wheat, spelt, rye, buckwheat and heritage grain corn. Second, the Lesters operate Wheatberry Bakery in downtown Amherst, where they sell local bread and vegetables.

Perhaps a future farmer? Source: Ben and Adrie Lester

ENVIRONMENTAL BENEFITS:

The people of western Massachusetts benefit from the Lesters' farming practices. No herbicides or pesticides, which can kill and mutate amphibians and fish, are present in waters leaving the couple's farm. Their reduced tillage reduces soil erosion, keeping local waterways free from excess sediment. Reduced tillage also increases the population of soil biota like earthworms, which provide another food source for wildlife like birds. Furthermore, the increased diversity of crops on the Lesters' farm and their preservation of natural and semi-natural areas provide habitat and food for beneficial insects. Studies have found wildlife species richness on organic farms increased by an average of 30%, and wildlife populations increased by an average of 50%.

Organic farms in the northeast like Ben and Adrie's have been shown to store about two metric tons of carbon dioxide per acre. Through diverse crop rotations, planting perennial crops and cover crops, and adding nutrients for soil health, organic farmers sequester carbon in many ways. Plants remove carbon dioxide from the atmosphere through photosynthesis. They store about half that carbon in the soil, where they give the carbon, in the form of sugar, to soil organisms in exchange for nutrients and water. Each kind of crop has its own set of soil organisms it connects with, so by maximizing crop diversity, organic farmers maximize the number of carbon rich soil organisms. Perennial crops grow during a longer portion of the year than annual crops, and divert more carbon to their roots where it is more easily stored for longer periods or put into the soil for even longer storage. Cover crops give carbon to soil organisms in exchange for nutrients and water during times of year when nothing else would be growing. By practicing minimum tillage, Ben and Adrie reduce disturbances to soil organisms and carbon stored in the soil. They are interested in future experimentation with other cutting edge farming practices with climate benefits, such as burning biomass in a low oxygen environment for energy, and then using the resulting biochar as a fertilizer. This willingness to experiment may be crucial in identifying tomorrow's profitable future friendly practices.

Source: Ben and Adrie Lester

MORE RESOURCES:

The Greenhorns:
http://www.thegreenhorns.net/

National Young Farmers Coalition
http://www.youngfarmers.org/

Photo by Andy King, USDA Natural Resources Conservation Service

Bats can be sensitive to pesticides while also providing alternative means of insect control for farmers worth billions of dollars every year.

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Populations of these worms can be as much as twice as abundant in soils of farms that use organic management compared to conventional tillage methods.[58]

Organic production provides numerous benefits to farmers and society, as well. Through the use of biological systems, crop rotations, cover crops and other methods to manage weeds and pests and increase soil health, organic farming lowers costs placed upon society by more input-intensive systems. For example, organic agriculture replaces the use of chemical herbicides like atrazine with non-synthetic or biological alternatives. Because it is highly effective and relatively cheap, atrazine is one of the most commonly used herbicides on non-organic farms, which has led to contamination of waterways in farm communities. In sampling conducted by the U.S. Geologic Survey, 97 percent of streams in agricultural areas had atrazine present. Atrazine was the most frequently detected chemical and at the highest concentrations in water samples from agricultural areas. In total, almost 10 percent of streams in agricultural areas had chemical concentrations above the human health benchmarks established for water by the Environmental Protection Agency.[59] Even at low levels, atrazine in water can cause hermaphroditism in amphibians, affecting their reproductive capacity.[60]

Some wildlife are so sensitive to pesticides they can become sick and even die simply by ingesting plants covered with the chemicals. Once animals become sick from pesticide exposure, they are more likely to die if exposed again.[61] Less use of agriculture chemicals allows a greater variety of plants and insects to develop in and around farmed lands, increasing plant diversity and insect populations vital to wildlife and resilient ecosystems.

Organic farms have a higher abundance and species richness of bats and birds, both of which provide excellent means of controlling insect populations.[62] By employing alternative pest management methods, organic farming reduces negative impacts to beneficial insects and wildlife.[63] Meanwhile, the development of balanced natural ecosystems and food chains provide a check on agricultural pests, allowing for farm production to not only continue, but thrive.

Keys for Maximizing Benefits of Organic Farming

- Organic farming requires 60 percent less energy use compared to conventional production.
- When implemented with a crop rotation, organic farming can consistently produce yields similar to conventional production.
- Reduced fluctuation of input costs, coupled with more stable production, results in more consistent, and often higher profit for farmers.
- Transitioning to organic production requires farmers to incur upfront costs before they enjoy the long-term benefits.

Grassland and Pasture Management

Grassland and rangeland management— *applying plant and animal management techniques on pastures and other animal grazing areas to maximize plant health and diversity while increasing animal carrying capacity of the land. Benefits include reduced erosion, reduced chemical and fertilizer applications and runoff, increased carbon sequestration, and increased farm profitability.*

Before European settlement of North America, six million bison roamed the lands, adding nutrients and pushing biomass into the ground by grazing large sections of grasses. With this huge herd of grazers, water quality and soil health was excellent. Periodic fires swept through the landscape, returning nutrients to the soil. Modern management of grasslands prevents adequate cycling of nutrients while inhibiting carbon sequestration, biomass production, and wildlife habitat. However, grassland and pasture management can be optimized to provide more of the benefits provided by native prairie while continuing to provide grazing to cattle.

One of the most commonly used grazing practices is known as continuous grazing, which allows animals to graze the same field or area for months at a time. This practice limits plant growth and recovery, producing a homogenous grass community of single species able to survive perpetual harvest. Weeds and invasive species are more likely to out-compete native grasses under continuous grazing, reducing forage production and wildlife habitat in the process. In many cases, continuous grazing reduces the total productivity of the plant community.

Abe Collins

Dairy cows mob grazing a small portion of a pasture after it has been given ample time to regrow.

Some farmers are turning to rotational and mob grazing to address these issues and increase production and farm profitability. Rotational grazing, also known as Management Intensive Grazing (MIG), limits the amount of land available to animals at any one time, and entails moving animals to new fields every two to five days. Pasture sections are then given adequate time to recover and regrow a healthy stand of grass mixtures and native plants. By allowing the land adequate time to rest, grass re-growth improves significantly. Mob grazing involves an even faster rotation than rotational grazing. Rather than moving every few days, most mob grazers move their animals daily or a few times a day, keeping the animals packed closely together.

Farmers can see tremendous benefit from improved grassland management. Rotational grazing increases the

Management of native grasses such as this switchgrass in Union County, Iowa, maximize farm profit and environmental services.

Photo courtesy of USDA NRCS

total volume of plant biomass produced on grazed acres, allowing farmers to increase herd size while operating on the same number of acres. Additionally, rotational grazing often extends the growing season for grazed grasses, allowing farmers to increase the length of time animals may graze in an area. This decreases farmers' need to purchase or produce feed for the offseason. Because feed is often the largest cost to dairy and meat farmers, this can represent significant cost savings for them. More diverse fields, particularly those with native grasses, can more ably exclude exotic invasive and weed species, reducing and sometimes eliminating herbicide and fertilizer costs. These native plants also provide improved nutritional value to grazing animals. Some farmers report that the improved nutritional value of diverse native grasses reduced their need for providing nutritional supplements to their herds.[64]

In beef and dairy markets with tight profit margins, lower costs can determine the difference between a profit and loss for a year. On Greg Judy's Green Pastures Farm in Rucker, Missouri, 20 miles northwest of Columbia, high intensity grazing allowed him to double his beef animal production per acre while cutting his seed costs by $5,000 per year. Additionally, by returning his land to native ecosystems, whitetail deer, quail, wild turkey and songbirds returned to the land. This provided a new revenue stream from hunting leases, not to mention the enjoyment of experiencing nature and wildlife first-hand on a daily basis. For that Missouri farmer, high intensity grazing made the difference from having to sell his farm in bankruptcy to now succeeding as a profitable grazing operation.[65]

When farmers manage grasslands well, they provide many benefits to everyone. Effective management of grasslands can improve water supply and water quality and reduce flooding. Increased grass cover and soil structure also improves water infiltration and storage. Rain that falls on well-managed pastures quickly enters the soil (infiltration) and stays safely in groundwater for longer periods of time (storage), reducing runoff while recharging groundwater sources. Improved infiltration and absorption over many grassland and rangeland acres can affect surface water levels miles from the managed areas. By mitigating wind and water erosion and associated nutrient loss, improved grassland management also helps reduce dead zones in bodies of water. Grasslands with excellent plant growth derived through improved grazing practices and the use of native grasses will see increases in soil organic carbon. The extra carbon improves the soil's ability to absorb water and hold onto it longer, attenuating flooding conditions down river.

By mimicking the natural systems that maximize the growth of native grasses, improved grassland and rangeland management can reduce the need for chemical and nutrient applications. Historically, farmers and ranchers have turned to chemical herbicides to limit weeds. Some farmers implementing rotational grazing methods report halving or eliminating their use of fertilizer and herbicides.[66] Better grazing techniques and more suitable mixtures of native grasses prove effective in making it harder for weeds to take root. Scaling back chemical and nutrient applications reduces chemicals in run-off, improves water quality and wildlife habitat of nearby water bodies, and saves farmers money. .

> *Grasslands with excellent plant growth derived through improved grazing practices and the use of native grasses will see increases in soil organic carbon. The extra carbon improves the soil's ability to absorb water and hold onto it longer, attenuating flooding conditions down river.*

Tailoring rotational grazing systems around native ecosystems can improve habitat for local wildlife while maintaining the productive capacity of the land.[67] For example, farmers can design a rotation that avoids disrupting bird nesting habitat during the nesting season. Once birds have raised their broods, grazing animals may return to that area without causing harm to young bird populations. In fact, well-managed native rangelands have higher levels of bird diversity than unmanaged rangelands. Diverse grazing practices create the full gradient of vegetative structures needed to maintain many grassland bird species.[68]

Farmers adopting these improved grazing management techniques build up soil organic carbon and enhance soil health. These practices also help to address climate change through carbon sequestration. Typically, farmers using these techniques will see carbon sequestration rates between .1 and 2.5 tons of carbon per acre per year.[69] With these improved carbon sequestration rates, grasslands could reduce total domestic emissions by over one percent per year.

Increasing plant diversity on grasslands and pastures will also result in improved land carrying capacity, carbon sequestration and climate change adaptation. Research suggests grasslands with more diverse groups of grass species have a three-fold benefit. First, plant diversity feeds and encourages diverse soil biota which more ably store carbon than in a monoculture. Second, animals that eat these diverse mixes enjoy a more nutritional diet, which they are better able to digest, improving overall herd health and reducing the amount of methane these animals directly release.[70] Third, by incorporating more diverse mixtures of native grasses, grasslands and pastures are better able to withstand changes in climate, allowing for continued production in an uncertain climate future. Gene Goven, a North Dakota beef rancher and wheat producer, sees these benefits firsthand. Gene often seeds ten different species at once. He mixes legumes, tall grasses, and warm-season and cool-season grasses to fill all the niches in the ecosystem. Coupled with a transition to high intensity rotational grazing, Gene has better soil health, with a four percentage point increase in soil organic carbon. The beef rancher also has increased his herd size, which increases his profitability.[71]

Keys for Maximizing Benefits from Grassland and Pasture Management

- Mixed species of grasses and plants that replicate original ground cover often provide the most benefit to landowners through increased production and wildlife habitat. Downstream residents also benefit from better water management and water quality, and the environment benefits through increased carbon sequestration.
- Increasing the grazing rotation and reducing the amount of time an area is grazed will increase plant regrowth, lessen the opportunity for weeds to establish, and allow for healthier soils and plants and increased herd sizes.
- Grassland and pasture management that restricts grazing or harvesting during peak bird nesting periods will dramatically increase the benefits to wildlife.
- Rotational grazing and native plant mixtures typically increase farm profitability.

CASE STUDY

New Mexico Rancher Cultivates More Cows, Profit, and Environmental and Climate Benefits

Source: Peggy Cole, www.holisticmanagement.org

Kelly Boney raises cattle in western New Mexico. Her ranch, 13 miles south of Bard in Quay County, has been in her family since 1907. She has a typical western cow/calf operation, breeding beef cattle for sale to feedlots and consumers. Kelly has been able to increase her herd to 1.25 animals per 100 acres from an initial amount of just .66 animals per 100 acres by concentrating her animals and increasing the rotation or movement frequency. The animals are concentrated in a paddock for a short period of time, from 12 hours to 3 days, and then that area is given 80 or more days to recover before regrazing. Kelly, like many mob grazers, uses the rule that half of the grass should be grazed, and half should be trampled into the ground by the animals in order to promote soil health and improved grass regrowth. In the parts of her ranch where she implemented this practice, Kelly observed increases in grass production and diversity and less bare soil. Like innovative ranchers around the country implementing mob grazing, Kelly Boney has simultaneously increased production and profits while removing carbon dioxide from the atmosphere and improving biodiversity.

PROFITABILITY:

Boney doubled the amount of cattle she produces with minimal increases in costs, significantly boosting her profitability. The rancher's mob grazing requires careful planning of paddock layout and rotation strategy. Creating a mob grazing plan enables her to concentrate her animals in each paddock to ensure a beneficial impact on soil and grass. The strategy also includes plenty of time for that paddock to regrow, typically around 80 days, depending on rainfall. She needs to allow enough regrowth so that when her cows return, they have plenty of grass to eat and trample into the soil. Kelly increases animal concentration using cheaper portable electric fencing. By combining portable electric wiring with her existing fencing infrastructure, Kelly is able to create many small paddocks within one large one. These smaller paddocks enable her to achieve the animal concentrations she needs to improve the health of her soil, the quality of her grass and the number of animals she can graze.

ENVIRONMENTAL BENEFITS:

New Mexicans benefit from the hard work of ranchers like Kelly Boney. By covering bare soil, increasing grass cover and increasing carbon, mob grazing helps to build stable soil that more effectively holds water. Boney uses long rest periods to encourage grass growth and diversity while lowering the amount of bare ground on her ranch. In dry regions like New Mexico, having more grass growing means she can store more rainfall and carbon in the soil. The average rainfall in Quay County, where her ranch is located, is only around 10 inches per year. Continuously

A rancher and his son examine the signs of animal impact during a grazing class at the Ford Ranch near Brady, Texas May 3, 2011.

grazed land leaves bare soil exposed, allowing the occasional rainstorms that sweep through the Southwest to cause damaging erosion. This erosion process threatens food security as productive land becomes barren. Erosion also damages lakes and streams as they become increasingly clogged with sediment.

Additionally, increased ground cover improves wildlife habitat, especially for vital species such as the sage grouse. The animal is facing declining habitat because of suburban sprawl, increased oil and gas production and competition from invasive species as a result of poor land management.

Ranches in nearby west Texas managed with mob grazing like Boney's have recorded carbon sequestration rates of 1.5 metric tons of carbon dioxide per acre per year over sequestration rates from continuous grazing. As perennial grasses store most of their carbon underground, they can produce significant carbon storage. There are approximately 410 million acres of rangeland in the United States, if every acre achieved this sequestration rate, the carbon sequestered would offset about 10 percent of the United States' annual greenhouse gas emissions.

RESOURCES:

Holistic Management International:
www.holisticmanagement.org

Burleigh County Soil Conservation District:
http://www.bcscd.com

Natural Resources Conservation Service: Practice Standard, Animal Enhancement Activity: Ultra high density grazing system to improve soil quality.
http://www.nrcs.usda.gov/programs/new_csp/2011/animal-pdfs/ANM30_Ultra_high_density_grazing_system_to_improve_soil_quality.pdf

5

Sustainable Forest Management

Forests are under increasing threats from insect infestation, fire, and reduced plant and animal biodiversity. In 2009, forest stakeholders highlighted the negative trends affecting the nation's forests, including a decline in forest health, increases in conversion to non-forest uses, and increasing dependence on private lands and foreign imports to meet needs. Typically, these sources do not experience the same level of management to maintain forest health in light of increased demand. To address these negative trends, a number of forest stakeholders have identified the importance of conservation and sustainable management of the nation's forests.[72]

Forest management—*planning and administration of forest resources for sustainable harvest, multiple use, regeneration, and maintenance of a healthy biological community. Benefits include increased wildlife habitat, carbon sequestration, wood production, water filtration, and ecosystem resilience.*

Forest management is vital not only to forest health, ecosystem resilience, wildlife, and water quality, but it is a vital management technique to maximizing timber production. Many current problems are linked to overstocking and excessive accumulation of woody material.[73] Selective thinning is one forest management technique commonly used to correct overcrowding and boost growth of remaining trees for the benefit of the forest and wildlife.[74] Thinnings can then be used for biomass energy operations to displace fossil fuel use.

Photo courtesy of USDA NRCS

White fir is thinned from a stand of timber under a forest management practice in Arriba County, New Mexico.

Forest management plays an important role in maintaining forest health, increasing biodiversity, and improving wildlife habitat. Through selective harvesting, understory plant species and young trees gain opportunities for growth throughout a forest ecosystem. Variation in understory and canopy structure, as well as age of plant species, create wildlife habitat opportunities not present in forest ecosystems dominated by a single

How Clear Cutting Forests Leads to Carbon Emissions

Forest clear cutting leads to carbon emissions from the soil.[79] When forest soil is exposed to sunlight, the heat rapidly speeds up decomposition of forest floor material, releasing carbon stored in the soil. Clear cutting a forest can release between 2-8 tons of carbon per acre for up to 20 years after the cutting. In many situations, this carbon release can exceed the carbon sequestration rates of the growing timber stand.

age of plant species.[75] A layered forest that includes tree canopy, dead "snags," young trees, understory plants and leaf litter is central to the sustainability of many species. This tree and understory species diversity in various locations and sizes throughout a forest ecosystem maximize wildlife habitat options.

Diversifying plant species and spatial arrangement offer further benefits to ecosystem health. Fostering biodiversity contributes resistance to disease that can decimate less diverse forests. Additionally, species and age diversity can help forests withstand and recover faster from severe wind and other extreme weather events that are becoming more common with climate change.[76] Selective thinning can be used to manage fuel buildup, limiting the severity and risk of wildfire. In all three of these potentially destructive situations (disease, wind-down, and fire) carbon stored in either the biomass or the soil will be released. Species-diverse and age-diverse stands are most capable of resisting such destruction and massive carbon releases.

Less sustainable management methods like patch clear cutting lead to forest fragmentation, or the segmentation of a whole forest into smaller forest sections interspersed with non-forest areas such as grasslands. This results in a significantly negative impact on forest wildlife and biodiversity. Fragmentation dramatically decreases the habitat for some sensitive species. In fragmented forest situations, sensitive species such as the scarlet tanager become much more vulnerable to predators. Fragmentation can result when large, contiguous forests are divided by development or forest conversion to other uses, such as to pasture or other agricultural production. Fragmentation can also result from clear cutting blocks of mature forest, creating sizeable areas of edges between cleared areas and remaining forest. Edges create excellent perch locations for predators, greatly reducing the survivability of sensitive species. To protect at-risk species, fragmentation should be avoided. Moreover, disturbance should be concentrated along existing edges while maintaining a diverse understory.[77]

Globally, forests sequester an estimated three billion tons of carbon each year. The multiple levels of vegetation within a forest—ranging from forest canopy to understory and forest floor—maximizes the photosynthetic and carbon sequestering capacity.[78] In the U.S. alone, forests store the equivalent of over 165 billion tons of carbon dioxide–nearly 27 times the amount of CO_2 emitted in the U.S. each year through consumption of fossil fuels.[80] The carbon already banked by forests in the United States is an investment worth maintaining and enhancing as a vital component to any plan designed to address climate change.

In the U.S. alone, forests store the equivalent of over 165 billion tons of carbon dioxide–nearly 27 times the amount of CO_2 emitted in the U.S. each year through consumption of fossil fuels.

Forest management methods are best tailored to the unique ecosystem characteristics and needs of a particular site. In many forest types, proper management of native ecosystems can enhance plant growth and carbon storage. The sustainable management of mature forests that reach carbon equilibrium can actually lead to increased carbon sequestration, while unmanaged forests may face a carbon sequestration plateau.[81] Mature trees can later be selectively harvested to provide growth opportunity for younger trees to renew the forest, as well as provide the forest owner with income. Late-successional tree species are able to accumulate higher levels of soil carbon than pioneer tree species, which often exhibit faster rates of growth at earlier ages.[82] Sustainable management maximizes the mix of older and younger trees, improving long term carbon storage as well as wildlife habitat and other additional benefits. Diverse stands can sequester as much and sometimes more carbon than monoculture stands of fast growing tree species.[83]

Forest owners accrue many benefits from implementing a forest management plan that optimizes carbon sequestration, wildlife habitat, and biodiversity. Increased wildlife can lead to increased recreational opportunities, including hunting, fishing and wildlife viewing—which may also provide additional income through hunting leases. Through sustainable forest management, landowners can increase long-term profits from periodic and sustainable timber harvests compared to clear cutting. The regularity of harvest in a sustainable manner will yield consistent income while maintaining the health of the forest to ensure future income, all the while maintaining carbon sequestration capacity and other ecosystem services.

Keys for Maximizing the Benefits of Forest Management

- Maximizing plant diversity through forest management increases tree growth, timber production, and carbon sequestration.
- Trimmings from managed forests may be used as a biomass source for energy.
- Wildlife benefits of managed forests are maximized by maintaining large blocks of forest.
- Managing understory plants is an important component of ensuring a strong forest ecosystem.
- Managed forests with mixed species will mitigate better against climate change.

Steve Hillebrand, USFWS

Clear cutting forests such as this clear cutting in Oregon will result in erosion, carbon emissions, and dramatic loss of wildlife habitat.

Anaerobic Digesters

Anaerobic digestion—*a process in which micro-organisms break down organic material in the absence of oxygen, with methane resulting from the process.*

On farm anaerobic digester located at Five Star Dairy in Elk Mound, Wisconsin.

Anaerobic Digester—*an enclosed tank and associated equipment in which organic material such as manure or food scraps are broken down by microorganisms with the resulting methane collected and burned to create electricity or heat. Benefits include: improved water quality, reduced greenhouse gas emissions, considerable elimination of odor, reduced threat of pathogens entering the water supply, reduced need for fertilizers, as well as the provision of distributed electricity and heat to offset fossil fuel-based energy sources.*

As livestock farms increase in size, they face the challenge of managing larger quantities of animal waste. When waste management systems become overburdened, the nutrient-rich waste can cause considerable odor, as well as water and air quality issues. These factors can threaten human health and ecosystem health. Meanwhile, animal manure in large concentrations emits methane, a greenhouse gas that is 23 times more potent than carbon dioxide. When manure is stored in liquid lagoons, the waste from each dairy cow produces an estimated five tons of carbon emissions equivalents each year.[84] Increased awareness of these issues, coupled with improved technology, is leading to growing interest in anaerobic digesters. Anaerobic digesters offer a robust solution to problems arising from waste management as well as new revenue and cost reduction opportunities for farmers.

Anaerobic digesters use natural biologic processes to extract methane from animal waste.

Anaerobic digesters use natural biologic processes to extract methane from animal waste. Rather than sit in an open lagoon, liquid animal waste is pumped into the digester's large sealed tank. Digesters are heated to encourage growth of microorganisms. These microorganisms, which are already present in manure, play the important role of breaking down the waste. That process creates methane gas that rises to the top of the digester and is collected and cleaned of sulfur. Once the chemical is removed, biogas, the cleaned version of methane, behaves much like natural gas. In fact, natural gas is 87 percent methane. After the biogas has been separated from the waste, digesters destroy the methane by burning it with a flare or in an internal combustion engine.

Farmers can also use biogas to help power their farm. When fueling an engine, biogas can be used to create electricity. Farmers can then sell that electricity to the grid, adding another income stream, or use it on-farm, reducing the need to purchase electricity. By producing electricity, anaerobic digesters can offset, or reduce, the amount

(continued on page 37)

Five Star Dairy, Elk Mound Wisconsin

Anaerobic digester at Five Star Dairy.

Tucked into the rolling hills of western Wisconsin, Five Star Dairy unites modern technology with agrarian stewardship. Lee Jensen, Operations Manager and co-owner, combines his considerable experience in agriculture with a sustainable vision for dairying. Four years ago, he added an anaerobic digester to the 10 year old, 900-head facility. In a unique partnership with the local electric cooperative, Five Star Dairy owns the digester. The gas scrubber, engine, generator, and associated electrical equipment are owned by the electric cooperative. The entire process is managed off-site by the digester equipment installer. This partnership maximizes expertise while spreading the risk among multiple stakeholders.

Manure collected in the freestall barns is pumped into a small storage tank. Every 18 minutes, manure is pumped from that tank to the digester. At the same time, additional waste oils and greases, which are stored in a separate tank and brought in from off-farm sources, are also pumped into the digester to maximize methane production. In the complete mix digester, material is stirred constantly to help microorganisms produce methane. Methane collected at the top of the tank is scrubbed and then directed to the engine to generate electricity. Meanwhile, digested material located at the top of the liquid surface in the tank flows to a solids separator. The separated solids (now pasteurized from the digester) are used as bedding, reducing costs as well as consumption of other

This lagoon gas collection system at Five Star Dairy prevents additional greenhouse gases from reaching the atmosphere.

Lagoon covers such as this one at Five Star Dairy not only reduce emissions, but prevent rainwater from filling up the lagoon, reducing operating costs.

materials. The remaining liquid flows to a lagoon to be stored until it can be applied to crop fields. To further reduce greenhouse gas emissions, Lee installed a rubber cover, as well as a gas collection system under the cover. This system collects the methane and burns it with a flare.

The on-farm benefits of Five Star Dairy's digester truly add up. Once the solids are separated out of the waste, digestate is more easily applied to the land through an injection process, reducing runoff and volitization risks while improving the fertilizing capacity of the digestate, and thus reducing fertilizer needs. Lee hopes to see increased soil health through years of adding digestate. The lagoon cover not only keeps in methane, but prevents 1.2 million gallons of rainwater from entering the lagoon each year, reducing the need to run pumps and trucks to empty the lagoon. Because the digestate does not get diluted, Five Star Dairy can incorporate more of the fertilizing material into each acre of cropland, reducing the need for adding nutrients through fertilizers.

CASE STUDY

Wisconsin Dairyman Grows Profits While Reducing Air and Water Pollution

John Vrieze's family has farmed their land near Baldwin, Wisconsin for 104 years, and John has been part of the operation his whole life. He feels, "our dependence on foreign sources of energy is the Achilles heel of the United States." John would prefer to use renewable energy produced in the United States rather than importing a vital resource. In addition, throughout his time on the farm, he has observed winters getting shorter and milder, providing concrete observations that justify his concern about climate change. For all these reasons, John has installed two anaerobic manure digesters, which captures methane gas emitted from his dairy cows' manure. The gas is cleaned so that it can be burned to produce local renewable electricity and heat. The Wisconsin farmer sells the electricity to a utility and uses the heat for a vegetable-producing greenhouse. John also sees increased benefit from the digested material, which provides more nutrient value to his corn fields and increases his yields. John Vrieze is producing home grown energy, saving money and increasing profits while reducing greenhouse gas emissions and protecting water quality on his dairy farm. He has eliminated methane emission from manure, reduced nitrous oxide emissions from fertilizer and is storing carbon dioxide in his soil.

PROFITABILITY:

John's manure digesters will pay for themselves in about seven years, and thereafter they will provide$186,000 in annual profit. Each digester costs a little over $1.3 million and handles waste for 1,300 cows. Digesters capture methane that is naturally released from manure and turns it into biogas, which can be used to produce electricity. John currently uses one digester to generate electricity purchased by a utility at an average rate of around 7.5 cents per kilowatt hour. Vrieze is using the biogas from the second digester to heat a 27,000 square foot greenhouse. The produce grown in the greenhouse provides more profit than generating and selling electricity at the going rate. In finding a more profitable avenue for the biogas, John has dramatically sped up the return on investment and he is on track for that digester to fully pay for itself in four or five years.

In addition to adding new income streams for the Wisconsin dairy farmer, the digesters increase the value of manure for John's farming operation. When digested, manure is altered by micro-organisms, making the nutrients easier for plants to consume. Vrieze injects his corn fields with digested manure, and has been able to totally eliminate commercial fertilizer, saving an average of $75 per acre. John also saw yield increases on the fields where he applies the digested manure. On one corn field, yields increased from 125 bushels per acre to 175 bushels per acre. At $6 per bushel of corn, this is a value of $300 per acre.

Numerous funding sources are available to assist farmers in implementing digesters. The Rural Energy for America Program currently provides grants of up to 25% towards the costs of an anaerobic digester. The Environmental Quality Incentives Program also provides technical and cost-sharing assistance for on-farm digesters. By burning methane, digesters reduce greenhouse gas emissions. Those reductions can be sold as credits on greenhouse gas emissions markets in the Northeast and California, bringing in additional income.

ENVIRONMENTAL BENEFITS:

John's manure treatment not only helps reduce emissions, but it also reduces threats to human health. Raw manure contains dangerous pathogens, so any accidental leak or spill can make local water unsafe for people. Digesting manure kills those pathogens, greatly reducing the potential for contaminants to enter water supplies from an accidental manure spill or manure run off from farm fields. Also, large quantities of raw manure can release toxic odors and volatile organic compounds that exceed air safety standards. Anaerobic digestion removes most of these compounds from the digestate. Wisconsinites enjoy cleaner air and water thanks to farmers like John Vrieze.

Vrieze's use of anaerobic digesters to treat his animals' manure nearly eliminates methane emissions from his manure storage facilities. Manure is typically stored in uncovered lagoons, which produce large amounts of methane, a greenhouse gas 23 times more potent than carbon dioxide. Methane emissions from manure are eliminated because the anaerobic digester extracts and uses the methane to produce thermal or electric energy.

By injecting the digested manure into the soil, John causes a climate benefit of about 1 metric ton of carbon dioxide equivalent per acre per year. This comes from carbon dioxide stored in the soil (.8 metric ton) due to manure additions and reductions in nitrous oxide emissions (.2 metric ton). Nitrogen in synthetic fertilizer or manure applied to crop fields can volatize to release nitrous oxide, a greenhouse gas that is about 298 times more potent than carbon dioxide. Agricultural fields are the single largest source of nitrous oxide emissions in the United States. Replacing synthetic fertilizer with injected manure typically avoids nitrous oxide emissions equivalent to about .2 metric tons of carbon dioxide emissions per acre per year. This is because the nutrients in the manure are not exposed to the air, and are thus less likely to volatize into nitrous oxide.

MORE RESOURCES:

AgSTAR
www.epa.gov/agstart

Innovation Center for U.S. Dairy
www.usdairy.com

Vrieze Farm
www.afuturefarm.com

(Continued from page 33)
of electricity produced by fossil fuels. Moreover, exhaust heat from the engine can also heat farm buildings, further decreasing a farm's consumption of fossil fuels. Anaerobic digestion can eliminate over one ton of indirect carbon dioxide emissions per cow per year.[85]

Digesting manure can lower risks to farmers of litigation or fines brought on by a manure spill or an over application of manure to fields. Animal waste can enter waterways through storm water runoff, when lagoons overflow, or when waste is accidentally released during transportation for land application. When animal waste enters waterways, bacteria in the waste quickly consume large amounts of dissolved oxygen from the water. This consumption uses up all of the oxygen in the water, which suffocates fish and leads to massive fish kills that affect both aquatic and land ecosystems.[86] Waste that has been through a digester, on the other hand, is essentially pasteurized of bacteria that would cause this high biological oxygen demand, dramatically reducing the threat of fish kills. Some studies show up to a 97 percent reduction in the biological oxygen demand of digestate.[87] Therefore, in the event of a digestate spill, the threat of a fish kill is greatly reduced.

Waste that has been through a digester, on the other hand, is essentially pasteurized of bacteria that would cause this high biological oxygen demand, dramatically reducing the threat of fish kills.

In addition to avoiding fish kills in the event of manure entering waterways, anaerobic digesters can also help to decrease the hazards livestock waste poses to human health. Normally, a number of diseases and bacteria reside in animal manure, including E-Coli, Salmonella, fecal coliforms, and Cryptosporidium. These dangerous microorganisms can survive for extended periods, creating the risk of contaminating drinking water sources, especially if manure enters surface waters. High temperatures between 100 and 120 degrees Fahrenheit in methane digesters lead to a reduction in fecal coliforms by 99.9 percent and over 95 percent of other pathogens are completely eliminated.[88] Dairy wastes can sometimes lead to expensive human health damages. For example, in 1993, over 400,000 Milwaukee, Wisconsin residents were sickened by drinking water contaminated with the bacteria Cryptosporidium. This cost residents over $31 million in medical bills and businesses over $65 million in lost productivity.[89] Researchers attribute the source of the bacteria to dairy farm runoff that overwhelmed the drinking water treatment process. Digesters provide a wise solution to this problem with additional benefits to farmers, nearby towns and cities, and nature, as well.

Anaerobic digestion provides multiple environmental and agronomic benefits. Not only do digesters destroy methane, the offensive odor from manure is also eliminated. Methane, after all, is the main source of manure odor. The more complete process of decomposition improves the nutrient availability of the digestate, making it more useful for crops. Typical manure contains nutrients useful for plant growth. However, much of that nutritional value is locked in forms plants cannot use. Instead, plants must rely on soil organisms to convert nutrients to useable forms. Often, the nutrients get washed away before the soil organisms can convert them for plant use or the growing season is completed before the nutrients become available, making obsolete much of the nutritional value provided by manure. Microorganisms in anaerobic digesters provide that same nutrient conditioning service as soil microorganisms, but much more rapidly and completely under ideal conditions.

The conversion of nutrients to a more useable form provides significant environmental benefits. First, farmers using digestate as a crop nutrient source often experience reduced need for synthetic fertilizers. Some farmers have even reported complete elimination of fertilizers, greatly reducing their operating costs and improving their carbon footprint. Additionally, by applying more useable forms of nutrients, plants can take up the nutrients faster, increasing nutrient use efficiency and reducing the threat of nutrient runoff into waterways. Soil organisms can take over two years to fully process all of the nutrients in animal waste. When plants are not growing, or are not even present, which is typical under clean tillage, nutrients have nowhere else to go but into the air through volatilization, into surface water through runoff, or into ground water through leaching.

Keys for Maximizing Benefits from Anaerobic Digesters

- Digesting manure provides more nutrient value to crops, reducing fertilizer needs.
- Electricity generation from digesters creates local energy from a waste source.
- Digesting manure greatly reduces the threat of fish kills if the digestate enters waterways.
- Digested manure reduces pathogen content.
- Digesters decrease methane emissions from livestock facilities.

Protecting and Restoring Land to Native Ecosystems

Native ecosystem—*an ecosystem which remains in its original, unaltered state or is returned to its original or near original condition. Benefits include increased biodiversity, optimized carbon sequestration, and maximized wildlife habitat and ecosystem stability.*

It would be foolish to suggest a return of all lands to pre-settlement conditions. However, challenges to habitat and biodiversity loss can be addressed through innovative solutions that also meet our food, fiber, fuel, carbon sequestration and other ecosystem service needs. Within this context, there are land management options that can maximize the provision of resources. Biodiversity and wildlife habitat can be incorporated into agriculture while maintaining production and contributing to carbon sequestration. However, retaining existing native ecosystems and native plant communities represent the best means of ensuring biodiversity and wildlife habitat while also maximizing carbon sequestration. To take full advantage of environmental benefits, ecosystem restoration should occur in ways consistent with sound soil and water conservation as outlined in Natural Resources Conservation Service (NRCS) Standards and Specifications.[90]

Photo by Scott Bontz permission from The Land Institute.

Preserving native ecosystems such as this tallgrass prairie provide multiple benefits.

Restoring marginal cropped lands to native ecosystems through the Conservation Reserve Program stands as the most effective means of protecting and increasing native ecosystems and the services they offer.

Retaining areas of native ecosystems, as well as restoring marginally productive land to native systems, takes on great importance when considering the overwhelming loss of major ecosystems in the coterminous United States since settlement began. Between pre-settlement times and the start of the 21st century, 30 ecosystems lost 98 percent of their area. In Iowa, for example, less than 30,000 acres of tall-grass prairie remain from over 29 million acres that originally covered the state.[91] A tremendous loss of biodiversity and carbon sequestering

A 30 acre wetland restoration project in Minnesota provides water filtration, flood mitigation, wildlife habitat and recreation opportunities.

Photo source: USFWS

capacity occurs when native ecosystems are diminished or eliminated. The loss of wildlife and biodiversity is also a legacy lost for future generations.

One great way to preserve plants and animals for future generations is linking disconnected wildlife areas to create larger ecosystems and wildlife habitats. When small habitats are connected via wildlife corridors, the benefit of the connected area is greater than the sum of the benefits of the connected parts. Increased connectivity allows for animal and pollinator movement that can strengthen the health and total population of both plants and animals.[92] One way to create wildlife corridors in an agricultural system would be by utilizing buffers appropriately. Converting two million miles of existing conservation buffers into forest riparian buffers, where ecologically appropriate, would sequester 1.5 million metric tons of carbon per year while creating many of the wildlife corridors necessary to connect ecosystems.[93]

Another avenue of maximizing the wildlife habitat and biodiversity capacity of agricultural lands includes planting windbreaks along field edges. By planting five percent of field area to windbreaks in the north central U.S., where ecologically appropriate, not only would wildlife experience increased habitat opportunities, but these windbreaks would sequester over 2.9 million metric tons of carbon per year and protect farmland from erosion.[94]

Restoring marginal cropped lands to native ecosystems through the Conservation Reserve Program stands as the most effective means of protecting and increasing native ecosystems and the services they offer. Re-establishing other specific ecosystems, such as grasslands and wetlands, through land easements or federal programs such as the Grassland Reserve Program and Wetland Reserve Program, also present effective avenues for protecting native ecosystems and the multiple benefits they provide to society.

Loss or degradation of native ecosystems can occur through converting land to agricultural production, introducing forest plantations onto native prairie or other naturally tree-less areas, clear cutting native forest and planting a monoculture of exotic or non-native tree species, or draining a wetland or peatland for development or agriculture. The introduction of exotic plants can be particularly detrimental to ecosystems by displacing the native species.[95] The introduction of genetically modified native species could pose even more problems because so little is known about how these altered plants will affect the native plant community or the ecosystem as a whole.

To maximize ecological benefits, land restoration should incorporate native plant species most suited to the ecosystem in which the land is located and with as many plant species as possible. Soil type should determine the species of plants used in the restoration, with trees restricted to woodland or transitional soils and grasses/forbs to prairie or transitional soils. Additionally, existing native ecosystems must be protected to ensure adequate habitat for wildlife.

Restoring wetlands, especially within agricultural areas, can provide an often overlooked benefit to society. Wetlands exhibit a remarkable ability to filter agricultural runoff, proving much more effective than other processes at removing common agricultural chemicals, particularly the herbicide atrazine. The slow water movement of wetlands allows for sediment to settle, providing a natural catchment of material and chemicals from surface runoff. Numerous studies have shown wetlands speed up the atrazine degradation process to less than 70 days, while it may take years for similar atrazine destruction to occur in open bodies of water. Conventional water treatment processes typically remove less than 15 percent of atrazine, leaving millions of people susceptible to ingesting atrazine found in their drinking water. Considering the high mobility and recalcitrance of the herbicide, wetlands can play a vital role in greatly reducing the common chemical from farmland runoff before it enters lakes and waterways where it experiences little breakdown, persisting for years in large bodies of water such as the Great Lakes.[96]

> *Losing peatlands causes the loss of some of the best and cheapest water filtration and flood mitigation systems available, resulting in more localized flooding, lower water quality, and more expensive water treatment.*

Since European settlement, one-half of U.S. wetlands have been lost to urban sprawl or draining for agricultural use. This conversion of wetlands has greatly diminished lowland areas' ability to absorb excess water and regulate its release into lakes and rivers. A number of studies have quantified the water management value of wetlands, including the value of water retention and flood mitigation, between $121 per acre per year for South Dakota seasonal wetlands and $9,500 per acre per year near metropolitan areas.[97] More recent analysis places the value of wetlands much higher, as scientists become more aware of the ability of wetlands to regulate water flows.[98]

The Climate and Environmental Benefits of Peatlands

Peatlands are wetland areas that contain a considerable buildup of plant material. Due to permanent water saturation, plant material decays very slowly. The peat that accumulates sequesters a considerable quantity of carbon. Peatlands cover only three percent of the earth's land area, yet they store over 550 gigatonnes of carbon, twice as much as the amount of carbon stored in the world's forests.[99] Additionally, peatlands filter and maintain large amounts of water, with the organic material acting like a sponge to soak up excess water and then slowly release it in drier conditions. Peatlands also provide unique habitat not found in any other setting. Because of their sponge-like characteristics, peatlands are often inaccessible for larger predatory animals, making them vital habitat for bird species such as the Kestrel, Red Grouse, and Golden Plover.

Unfortunately, the United States has been losing important peatlands since the 19th century. Remaining peatlands must be protected. Currently, significant quantities of peat are mined for use in gardening. Peatland losses also result from suburban sprawl and conversion to agricultural lands, particularly in the Florida Everglades and throughout the plains. These losses result in considerable carbon emissions as the carbon-rich plant material oxidizes once water is drained from the area. In 2008, peatland losses in the U.S. resulted in over 70 million metric tons of greenhouse gas emissions while also reducing the lands' ability to sequester carbon.[100] Additionally, losing peatlands causes the loss of some of the best and cheapest water filtration and flood mitigation systems available, resulting in more localized flooding, lower water quality, and more expensive water treatment.

Longleaf Pine Reforestation Proving Worthwhile

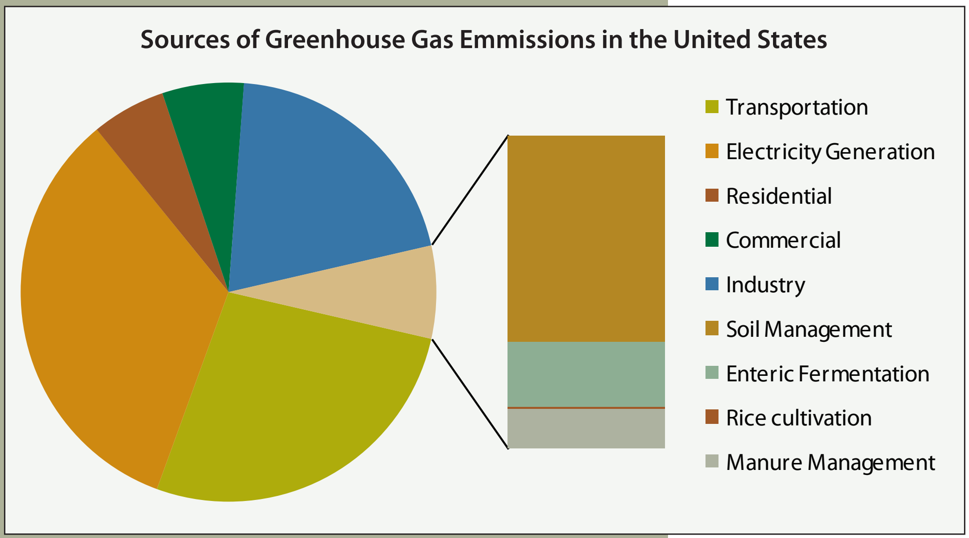
The ecological gains accruing from longleaf pine restoration efforts in the Southeastern United States provide an excellent example of the multiple benefits that can be provided through ecosystem restoration. Of the nearly 94 million acres in the Southeast that were once covered by longleaf pines, less than 3 million acres remain.[101] Unlike the forests that replaced the original ecosystem, longleaf pine trees are more resistant to disease and insects, are easily maintained through prescribed fire, are inexpensively renewed by natural regeneration and support an understory of native grasses and forbs. Longleaf pine trees continue to grow and sequester carbon even after 150 years, long after other trees have stopped growing and sequestering carbon. In addition, the growth form of the tree (tall and straight) and density of the wood makes longleaf pine more suitable for use in wood products such as pilings and poles, which are higher value products compared to the pulpwood market typical of other southern pines. Although managed on a wider spacing (i.e. fewer per acre), the stumpage value can be 50 percent greater than for other southern pines. Importantly, longleaf pine ecosystems are among the most biodiverse ecosystems outside of the tropics and support 140 plant species and wildlife such as the eastern wild turkey, gopher tortoise, red-cockaded woodpecker and others. Restoring longleaf pine forests can play a vital role in restoring ecosystem health to the Southeastern United States while also increasing economic opportunities for landowners in the region.

Mixed age long leaf pine

Keys for Maximizing Benefits through Ecosystem Retention and Restoration:

- Avoid conversion of remaining native ecosystems, such as forests, prairies and wetlands.
- Restore native ecosystems on marginally-productive agricultural land.
- Utilize only native plants suited to the soil type and ecosystem.
- Maximize restoration benefits by connecting with other native areas.
- Management is necessary to maintain the long-term health of the ecosystem.
- Consult a resource professional before restoring or managing native plant communities.

Agricultural and Land Management Carbon Offsets Opportunities



Agriculture practices emit roughly six percent of all greenhouse gas emissions in the United States.[102]

Breaking new ground, or converting natural landscapes of grasses and forests into row crops has a particularly large carbon impact. In the first year after the soil is broken, between 60 and 75 percent of the carbon originally stored in the ground is released into the atmosphere.

Most people are aware that carbon is released into the atmosphere by burning fossil fuels in cars for transportation and in power plants for electricity. However, few people are aware that carbon can be released into the atmosphere from land as well. This can happen in several different ways. When plant matter is not returned to the soil, or is burned, the carbon that was once absorbed by plants is released back into the atmosphere. Furthermore, when the rich ecosystem that lives in soil is disturbed, like when the earth is tilled, the dying soil microorganisms and plant matter are broken down into carbon dioxide. Such releases comprise a significant portion of total global carbon emissions. Finally, breaking new ground, or converting natural landscapes of grasses and forests into row crops has a particularly large carbon impact. In the first year after the soil is broken, between 60 and 75 percent of the carbon originally stored in the ground is released into the atmosphere.[103] In fact, deforestation and land use change from agriculture and sprawl account for 20 percent of all anthropogenic carbon dioxide emissions around the world. Carbon is not the only loss here—once native grass-lands are broken, wildlife habitat is lost and the ecosystem can never be fully restored back to its natural state.[104]

Many agricultural production practices create additional greenhouse gas emissions. Synthetic fertilizers, often derived from natural gas, along with chemicals for pest and weed management and fuel for tractor and equipment operation, all add to the carbon footprint of agriculture. Nitrogen, a vital ingredient for plant growth, can turn into a gas once applied to the land if it is not absorbed by plants or held by organic matter in the soil. This process emits nitrous oxide, a greenhouse gas with 298 times the heat trapping ability of carbon dioxide. Because nitrogen is applied to croplands in single, large doses, on average over half is lost to the atmosphere.[105] Emissions can be reduced when row crop farmers plant nitrogen fixing cover

Lagoon on Georgia hog farm. Photo courtesy of USDA NRCS

crops that lower or entirely eliminate dependence on fossil fuel-based fertilizers.

Deforestation and land use change from agriculture and sprawl account for 20 percent of all anthropogenic carbon dioxide emissions around the world.

Livestock production is another agricultural practice that produces significant greenhouse gas emissions. The direct release of methane by cattle, called enteric fermentation, contributes 25 percent of all methane emissions in the U.S.[106] Manure storage and field application contribute an additional eight percent of methane emissions. While there is some opportunity to lessen emissions from enteric fermentation through changes in diet, the big opportunities for emissions reductions, along with providing additional benefits, are in addressing manure management techniques. Livestock producers using manure storage facilities have the opportunity to implement technology that not only eliminates much of the methane emissions from waste storage facilities, but can actually be used to displace fossil fuels used to produce electricity.

Just as agriculture can lose carbon to the atmosphere, improved agricultural practices increase the amount of carbon removed from the atmosphere and sequestered into the earth. Soil carbon provides substantial benefits to environmental, plant, and soil health, ultimately yielding numerous benefits to society and to farmers and landowners in particular. Increasing the amount of carbon in the soil also provides a number of advantages for crops. Soil carbon increases the ground's ability to hold onto nutrients and provide them to growing crops. Soil carbon also improves soil structure, which helps soil to hold onto water longer, making it available for crops through dry periods. Soil carbon also helps soil shed excess water down farther into the ground, allowing crops to better survive extended wet periods while also reducing the threat of flooding for communities. Increasing soil carbon not only helps offset

CASE STUDY

Intermittent Flooding of Rice Reduces Water and Energy Use While Lowering Methane and Carbon Dioxide Emissions

Earl Kline is a rice farmer who reduced his irrigation costs by $15 per acre, lowered greenhouse gas emissions by about .92 metric tons carbon dioxide equivalent per acre, and cut pesticide run-off by 60%. He and his uncle farm rice, soybeans and corn near Cleveland, Mississippi. Earl reduced his water use by over one third by replacing the traditional practice of maintaining rice fields in a constantly flooded condition with the practice of intermittent flood management regime. This change in practice increases rainfall capture and reduces over-pumping, so less water is used. Through this practice, Earl saves about $15 per acre, and rice yield and milling quality are not affected by intermittent flooding. He says he is saving water so that his sons can "have the same opportunities I have had, if they choose to farm."

PROFITABILITY:

By using less irrigation water and diesel fuel to run the water pumps Earl saved $15 per acre. Typically, rice farmers spend about 10% of their budget on energy for irrigation. Reducing energy costs for irrigation is an exciting opportunity for farmers to offset rising costs for fertilizer and seed. Rice farmers in Mississippi commonly apply 36 to 40 inches of irrigation water per acre of rice. With an intermittent flood management regime, Earl applies 22 inches of water per acre, and in the relatively wet 2009 season, he used only 15 inches on several fields. Pumping less water enables Kline to reduce his diesel fuel use by about 9 gallons per acre. The rice farmer saved $27 per acre at current diesel prices due to his 14 acre-inch reduction in irrigation water use. He spends about $12 per acre on materials and labor to implement this system, for a net savings of approximately $15 per acre. Earl worked with Mississippi State University Agronomist Joe Massey to ensure this technique would maintain his crop yields.

ENVIRONMENTAL BENEFITS:

The farming techniques Earl applies benefits his wallet and the health and well-being of everyone in Mississippi. Pesticide run-off from his fields is reduced by 60%, as the water he applies to his land soaks into the ground, reducing runoff into surface waters. This reduction in chemical runoff improves habitat conditions for local populations of fish and amphibians. Additionally, the rice farmer reduced his water use by 30%. As the alluvial aquifer under Mississippi provides water for much of the south, Kline's water conservation enables future generations to enjoy water for drinking and irrigation.

Joe Massey

Rice irrigation.

By using intermittent flooding, Earl Kline reduced his greenhouse gas emissions by .92 metric tons of carbon dioxide equivalent per acre. This comes from reductions in carbon dioxide emissions due to reduced diesel use and from reductions in methane emissions caused by saturated ground conditions. Rice production is a significant source of methane gas globally, as flooded rice fields typically produce conditions where methane is released. Methane is produced by bacteria that thrive in the absence of oxygen. Draining rice fields allows oxygen to reach the soil, reducing the amount of methane produced. Preliminary measurements have found methane reductions of approximately 30% over conventional rice flooding. These reductions in methane emissions are equivalent to about .83 metric tons of carbon dioxide equivalent. In addition to the reduced methane emissions, there are also lower emissions from reduced diesel fuel used for irrigation. For every inch of water not pumped on an acre of rice, the burning of about 0.7 gallon of diesel fuel is avoided. By reducing his water use by 14 acre-inches, Earl has achieved reductions of approximately .09 metric tons of carbon dioxide emissions per acre from reduced diesel use.

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Photo courtesy of USDA NRCS

The accumulation of dark soil in the rootzone of grass on land in Minnesota enrolled in the Conservation Reserve Program provides visual evidence of the carbon sequestration process.

greenhouse gas emissions, but it also plays a significant role in helping crops withstand more extreme weather, which is becoming more common with climate change.

Properly managed forests provide increased carbon sequestration, as well as timber production and improved wildlife habitat.[107] Forests accounted for 84 percent of carbon sequestered in the United States in 2008.[108] Forests also play a role in climate maintenance through evapo-transpiration, or the release of water vapor, and associated cloud formation. Both processes help cool the earth.[109] Healthy, biodiverse forests also provide tremendous benefits to wildlife.

Conventional land management and agricultural production practices frequently result in environmental problems that were not recognized when such practices were developed. Years of intensive cultivation of the land led to considerable soil erosion and with it nutrient loss from fields into America's lakes and rivers. Vital nutrients and agricultural chemicals often travel with the soil, creating additional problems in local drinking water sources as well as in distant bodies of water. Additionally, pests have developed resistance to numerous chemical controls relied upon in conventional agricultural production. New land management and agricultural practices can play a major role in addressing many of the environmental issues we face today: gulf zone hypoxia, water quality, water availability, pest resistance to chemical controls, air quality, the greenhouse gas problem, and wildlife habitat loss. However, it can be quite difficult for farmers to transition away from old production methods since many are heavily invested in conventional agricultural production equipment. Helping farmers switch to these future friendly production techniques will be vital to achieving the many benefits provided by new agricultural production and land management techniques.

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THE BENEFITS OF CARBON SEQUESTRATION TO FARM AND FOREST OWNERS

In many ways, carbon sequestration addresses a range "of environmental issues. Through years of intensive tillage and other management techniques, America's agricultural lands lost soil organic carbon (SOC), which is the sequestered form of carbon dioxide. SOC is a key ingredient to sustained soil fertility. Soils with high SOC are more able to retain and make nutrients available for subsequent crops, resist erosion, and exhibit better percolation. Increasing SOC makes more water available to crops to better survive droughts while reducing the impact and incidence of flooding by more effectively directing excess water into the ground rather than across the surface landscape.[110]

By encouraging and rewarding particular carbon sequestering practices, society will accrue numerous environmental benefits including cleaner water, increased biodiversity, cleaner air, and an increased abundance of wildlife. These positive effects will be long-lasting, and will ripple out into other areas of society as well. For instance, vibrant natural resources will lead to increased recreational opportunities, which will boost struggling economies. Consumers will see an even more stable food supply with healthier food while witnessing a dramatic shift toward less fossil fuel consumption in the food production process. Farmers can reduce operating costs while improving their long-term food production capacity and ability to overcome weather variations. Finally, through changes in land management that result in carbon sequestration, lands will increase water percolation, resulting in a dramatic reduction in the impact and incidence of flooding of downstream areas, particularly urban centers located near waterways. While these changes will not occur overnight, these investments offer long-term economic and environmental returns.

PROBLEMATIC CARBON SEQUESTRATION PROPOSALS/TECHNIQUES

While most carbon sequestration activities provide additional benefits, there are also carbon sequestration options that could result in negative environmental consequences, damaging water quality or quantity, biodiversity, or wildlife habitat. While projects such as afforestation of non-forest land and monoculture grasses offer verifiable carbon sequestration projects at a relatively low upfront cost, a deeper look into their environmental impacts show that such projects may actually cause an overall detriment to ecosystem health and society. These short-sighted projects, such as afforestation of non-forest land and the use of monoculture systems, should be avoided.

AFFORESTATION OF NON-FOREST LAND

Afforestation—*Artificial establishment of forest on lands that previously did not carry forest within living memory.*

Reforestation—*returning tree species to lands that previously hosted forest ecosystems.*

Carbon sequestration incentives that fail to fully consider the other impacts of sequestration practices could result in properly incentivizing reforestation, but also improperly incentivizing afforestation.[111] Such scenarios could lead to inappropriate changes in land use while causing carbon emissions leakage, or forcing carbon emitting practices onto other lands resulting in no total reduction in carbon emissions. In such a scenario, grasslands, wetlands, and other natural ecosystems could become threatened by afforestation, reducing those ecosystems and the ecosystem services they provide.

Changing land use from its native cover has lasting consequences that impact more than just wildlife habitat. Studies show that foresting lands that never held forests results in soil salinization and increased soil acidity.[112] When forest plantations are planted on grasslands or shrublands, the increased water demand decreases in-stream flow by approximately 38 percent.[113] Reforesting flood plains once dominated by savannah forests, however, can make a beneficial use of the increased water demand. Not only would vital habitats be returned to their original condition, but these reforested flood plains would provide better flood mitigation while improving the water filtering capacity.[114]

Wildlife such as the Western Meadowlark are pushed out of their native areas when grasslands are inappropriately converted to forest or row crops.

Afforestation that results in conversion or fragmentation of prairie would be a particular detriment to biodiversity and wildlife habitat that has already been subjected to considerable decline.

Afforestation that results in conversion or fragmentation of prairie would be a particular detriment to biodiversity and wildlife habitat that has already been subjected to considerable decline. Since pre-settlement times, the Great Plains of North America has experienced tremendous loss of native landscape. Tall grass prairie declined by 96 percent, mixed-grass prairie by 64 percent, and short-grass prairie by 79 percent.[115] Grassland birds associated with these ecosystems show greater and more geographically widespread declines than any other guild of North American bird species. Breeding bird surveys from 1966 to1993 indicated that nearly 70% of the 29 grassland bird species surveyed had negative population trends.[116] The great prairie systems of North America are highly diminished due to historic conversions to agriculture and suburban sprawl, making it all the more imperative to conserve remaining prairie and associated biodiversity, including wildlife such as the prairie chicken, western meadowlark, lark sparrow and others. Native prairie plants, when left alone in diverse stands, can continue to sequester carbon at rates that rival the sequestration rates of introduced plantations, all the while requiring few inputs. It makes little sense to replace these natural systems with land cover that offers slightly increased carbon sequestration rates at the price of causing an immediate release of carbon from the soil, reduced water quantity, degraded soil health, and loss of biodiversity and wildlife habitat.

Photo courtesy of USFWS

Prairie chickens and other wildlife lose vital habitat areas when monocultures replace diverse native ecosystems.

MONOCULTURE

Monoculture—*any land area dominated by a single perennial or annual plant species and lacking natural ecosystem characteristics.*

Many researchers and developers studying biofuels target single, high biomass producing species as the best means of achieving a fast growing, high-yielding crop that can be readily converted to transportation fuel. Likewise, carbon sequestration researchers are searching for fast growing, easily established plantations that create verifiable carbon sequestration. Such developments often fail to consider the broader environmental consequences establishing these plantations. Monocultures in either a grass species for biofuels or tree species for carbon sequestration can have considerable negative impacts. When compounded with the use of non-native, invasive, or genetically altered species, the threat of damages only rise.

Large areas of land put into monocultures dramatically alter wildlife habitat. Plants play an obvious role in providing food and shelter to wildlife, and plant diversity is critical for providing wildlife habitat. Conversely, monocultures essentially create large swaths of area lacking in any plant species diversity, and thus, monocultures provide very little habitat for wildlife. The interdependent relationships formed among most species means that once one type of species—whether plant, animal, or microorganism—is forced out of an area, the remaining species will see an indirect decrease in habitat value due to the loss of that directly affected species. If top predators are forced out of an area, prey populations sometimes explode, destabilizing their own food resources and leading to a cascade of ecological effects.[117] In monoculture agricultural systems, the exodus of prey species encourages the growth of pests, causing subsequent problems.[118] Similarly, if the habitat can no longer support a certain species the effects will trickle all throughout the food web, nutrient cycle and ecosystem.[119]

Monocultures such as this plantation restrict biodiversity and are more susceptible to disease and pest infestation.

As species diversity declines, natural systems are thrown out of order.[120] Even introduced monoculture species face increased difficulty because a lack of natural predators may result in increased attacks from pests. Within natural ecosystems where no one species dominates, biodiversity provides natural barriers that inhibit pests and viruses from spreading throughout entire ecosystems.[121] Plantations with dense stands of a single plant species lack these natural boundaries, resulting in greater vulnerability to disease and pest problems. Non-native and invasive species destabilize ecosystem balances when the ecosystems they enter lack a natural predator system for keeping the new species in check, increasing the need for non-natural chemical inputs into the system. In such circumstances, pests can develop resistance to chemical controls. Already, there are over 200 reported cases of resistance to various herbicides. Relying on such inputs to control pest populations can have impacts on non-target species, increasing the chaos brought about by human attempts to manipulate the ecosystem.[122]

Native, biodiverse ecosystems can sequester as much or more carbon and produce more biomass with fewer inputs than any current monoculture crop variety.[123] The symbiosis that occurs among species maximizes plant growth and nutrient cycling without requiring inputs. Moreover, natural ecosystems with considerable biodiversity have a much better ability to maintain system balance in the face of outside forces such as climate change. In fact, as biodiversity increases, multiple species can play similar roles in the ecosystem, ensuring that each role will be provided if some species experience declines.[124] Therefore, even though monoculture plantations offer an easy means of implementing rapid carbon sequestration projects, the negative effects outweigh the positive.

The interdependent relationships formed among most species means that once one type of species—whether plant, animal, or microorganism—is forced out of an area, the remaining species will see an indirect decrease in habitat value due to the loss of that directly affected species.

Recommendations for Increasing the Adoption of Future Friendly Farming Practices

The seven practices described in this report provide benefits to soil, water, wildlife, as well as farmers' bottom lines. Unfortunately, a number of barriers exist that limit the ability of these agricultural and forestry practices to become widespread. For some landowners and farm managers, simple unfamiliarity with the discussed techniques prevents adoption. Similarly, lack of knowledge of the impacts of current techniques prevents farmers and land managers from seeking out new methods. Additionally, there can be a long transition period to these more sustainable practices. In these times of uncertain profit margins, few farmers and land managers are willing to consider options that do not offer an immediately evident profit potential. A number of solutions exist that can begin to address these diverse barriers towards adoption of future friendly farming. These options include: government cost share or environmental value incentive programs, tax incentives, carbon markets, and education.

INCENTIVE PROGRAMS

Federal programs that incentivize future friendly farming practices can provide an effective aid to overcoming any transition period. There are a variety of well-established, voluntary USDA conservation programs that address soil, water, wildlife and air quality concerns. The practices incentivized through these programs also result in significant carbon sequestration while also improving the long-term profitability for farm and forest owners.[125] These programs, like the Environmental Quality Incentives Program, Conservation Reserve Program, Wetlands Reserve Program, Grasslands Reserve Program, Healthy Forests Reserve Program, and Conservation Stewardship Program, have been successful at helping farmers protect natural resources while implementing profitable farming techniques. An expansion of funding for these programs to allow enrollment of the backlog of applications would increase the opportunity for farmers to transition to future friendly farming practices while providing significant benefits to taxpayers through protection of soil, water, air and wildlife.

The Conservation Reserve Program (CRP) pays farmers annual rental payments through 10 or 15 year contracts to set aside marginal land and provides cost-sharing for up to half of the cost of establishing natural covers on these lands to protect soil, water and wildlife. Taking marginal, often carbon-depleted farmland out of production and putting it into grasses or forest cover sequesters significant quantities of carbon in soil and vegetation. This also eliminates the need to fertilize or use other agricultural inputs on these unproductive lands, reducing greenhouse gas and emissions and water pollution. Farmers will see an improvement in profit by enrolling marginal and unproductive lands in CRP while at the same time improving the environment. USDA has recently modified how it ranks potential offers from landowners to enroll in the program, placing greater weight on certain practices that sequester carbon, such as installing vegetative covers and planting bottomland hardwood trees.

There are a variety of well-established, voluntary USDA conservation programs that address soil, water, wildlife and air quality concerns. The practices incentivized through these programs also result in significant carbon sequestration while also improving the long-term profitability for farm and forest owners.

The Wetland Reserve Program (WRP) assists participating farmers in restoring, protecting, and maintaining wetlands on their property. Lands restored under WRP are marginal, high risk, flood-prone areas that are often difficult to farm, providing marginal and sometimes no profit to farmers. The WRP enables landowners to take these places out of production and restore them to their original wetland condition. Restoring wetlands also provides benefits to the public through improved water storage, filtration, carbon sequestration, wildlife habitat and recreational opportunities.

The Grassland Reserve Program (GRP) enables landowners to restore or protect native grasslands on portions of their property through 10 or 20 year rental contracts or long term easements. Maintaining and restoring these grasslands helps to preserve a declining ecosystem while ensuring the use of the land for grazing, which can often provide higher profit margins for farmers. Restored grasslands provide numerous benefits including improved water quality, water management, carbon sequestration, and wildlife habitat. Unfortunately, program funding is extremely limited at this time, hampering the effectiveness of the program in keeping grasslands in grazing rather than getting converted to row crop production.

The Environmental Quality Incentives Program (EQIP) provides financial and technical assistance to farmers and ranchers to implement conservation practices on their farm or ranch. The program pays up to 75 percent of the cost of installing eligible conservation practices. The activities described in this report are eligible for EQIP funding.[126] Focusing EQIP on the practices outlined in this report can maximize farmer implementation by helping to overcome an initial barrier of upfront cost.

The Wildlife Habitat Incentives Program (WHIP) provides financial and technical assistance to landowners volunteering to implement practices that improve the wildlife habitat quality of their land for targeted species. Like other conservation programs, WHIP may focus on a particular benefit, but additional environmental benefits are provided by the activities designed to increase wildlife habitat. Such activities include adding particular ground cover suitable for habitat for targeted species, increasing the biodiversity of plant species to better reflect natural ecosystems, and providing fish passages in waterways. WHIP may cover up to 90 percent of the cost to install wildlife habitat practices in long-term agreements. Transitioning lands to operate within nature, and less against it, reduces costs over the long term for landowners while making farms more resilient to increasingly extreme weather brought on by climate change.

Conservation Technical Assistance (CTA) provides landowners including farmers, ranchers, city, county, and state governments, and citizens groups with assistance in developing conservation plans for a wide range of property sizes from individual properties up to entire communities or watersheds. These conservation plans guide landowners in implementing conservation practices that provide multiple benefits to the landowner and the environment including water quality, flood mitigation, carbon

Transitioning lands to operate within nature, and less against it, reduces costs over the long term for landowners while making farms more resilient to increasingly extreme weather brought on by climate change.

sequestration and greenhouse gas emissions reductions. Additionally, CTA provides inventories and evaluations of soil, water, animal, plant, and other resources to help landowners make the most informed decisions in choosing land management strategies and conservation plans. CTA does not provide financial or cost-sharing assistance. However, by providing technical assistance to develop a conservation plan, Conservation Technical Assistance provides a vital component in initiating the first step in getting more conservation and future friendly farming implemented on the ground.

The Conservation Stewardship Program provides financial and technical assistance to farmers, ranchers and forest owners to help them address resource concerns on their land and continue conservation practices already in place. Through five year contracts, participants can receive annual payments based on their conservation performance. Supplemental payments are also available for resource conserving crop rotations. Nearly all of the activities mentioned in this report would qualify for the CSP program.

The Healthy Forests Reserve Program assists landowners in restoring, enhancing and protecting forestland resources on private lands through easements, 30-year contracts and 10-year cost-share agreements. The objectives of the program are to promote recovery of endangered and threatened species, improve plant and animal diversity, and to enhance carbon sequestration. This program helps forest owners establish management practices that increase long-term wood production and profitability of their forests. Unfortunately, the program has very limited funding and is only available in a few states.

There are numerous smaller programs available through various federal agencies, such as the State and Private Forestry program of the U.S. Forest Service and the

Partners for Fish and Wildlife Program of the U.S. Fish and Wildlife Service. Conservation Technical Assistance from the Natural Resources Conservation Service or certified Technical Assistance Providers can also help landowners draft conservation plans. Increasing the numbers of Technical Assistance Providers would help many farmers overcome the first barrier to implementing more future friendly farming, namely establishing a plan and guidance for transitioning to new management practices.

> *Increasing the numbers of Technical Assistance Providers would help many farmers overcome the first barrier to implementing more future friendly farming.*

TAX INCENTIVES

Landowners who donate conservation easements on their land are eligible for federal income tax deductions and may be eligible for estate tax benefits. Additionally, many states and localities offer tax benefits for conservation easements. Conservation easements can help secure the numerous services provided by natural ecosystems by ensuring the land stays in its natural state into the future.

CARBON MARKETS

Providing incentives for practices that sequester carbon into the soil is one way to incentivize future friendly farming practices which have each been identified as providing carbon sequestration or emissions reductions. Greenhouse gas emissions markets use the power of free markets to achieve reductions in greenhouse gas emissions far more cheaply than direct government regulations. There currently exists no mandatory federal market for greenhouse gas emissions. Nonetheless, there are regional and state level markets that provide farm and forest owners with opportunities to sell carbon credits earned through improved management practices. Tremendous opportunity exists to sequester carbon and avoid greenhouse gas emissions from agricultural production and forestry, improve profitability for landowners, and provide so many other valuable benefits to society.

There are two major greenhouse gas emissions markets in the United States. In the northeast, ten states have created the Regional Greenhouse Gas Initiative. In the west, the state of California passed AB 32, a bill to create a greenhouse gas emission market which will come into effect in 2012. In both markets, greenhouse gas emissions from large point sources are regulated. These entities may purchase carbon credits from farmers who implement greenhouse gas emissions reductions projects. The Regional Greenhouse Gas Initiative accepts emissions reductions credits from sequestration due to afforestation and avoided methane emissions from animal manure operations in the participating northeastern states. Two future friendly farming practices that qualify include reforestation and anaerobic digesters. Starting in 2012, farmers across the country will be able to sell greenhouse gas emissions credits to California companies that must meet emissions reductions requirements. Carbon credits may provide an added financial incentive that can help farmers transition to future friendly farming practices.

EDUCATION

For some farm and forest managers, simple unfamiliarity with future friendly farming practices prevents adoption. Many have training and experience in more common or conventional management techniques. Even if other barriers are addressed through policy, calling on farm and forest managers to shift away from those comfortable and familiar techniques in favor of the unfamiliar will nonetheless result in little change. New efforts must be developed to train existing farmers through extension and other continuing education opportunities. Additionally, we must prepare future farmers through 4-H programs, Future Farmers of America, and other agricultural education efforts at the secondary and post-secondary level to increase their knowledge and comfort with agricultural practices that offer stronger, more consistent profit potential with lower input costs while benefiting the air, water and wildlife around us.

Research and demonstration farms can offer more research on future friendly farming practices and approaches, allowing farmers to feel more comfortable with these techniques. Finally, agriculture and forestry support networks, including crop and forest advisors, agricultural credit lenders, animal nutritionists and others can play a role in advancing future friendly farming practices. These stakeholders can promote these efforts by becoming more comfortable with these practices so they may provide more effective and insightful advice and services to farm and forest managers seeking to implement them. Agricultural and forestry publications can profile successful adoption of future friendly practices and help make landowners and managers more aware of these options that have been shown to improve profit margins, provide more consistent returns for farmers, and reduce vulnerability to increasing extreme weather events.

CONCLUSION

Through the seven techniques described in this report, farmers and forest owners can increase their productivity and income while addressing multiple environmental threats, from water and air quality degradation to biodiversity loss to climate change. Agriculture has a real opportunity to play a role in addressing all of these issues. A number of agriculture and land management strategies offer true win-win opportunities for land owners and the environment. There are numerous land management techniques, from reforestation to conservation tillage to cover crops and others that can play significant roles in addressing environmental problems while offering increased profits to land owners. To maximize implementation of these techniques we recommend:

- Developing further research on all land management techniques regarding their impact on water quality, water management, air quality, wildlife habitat, climate change, and biodiversity.
- Developing better analysis quantifying the direct and indirect costs and benefits of different land management techniques.
- Expanding outreach programs to educate farmers and others in the agricultural industry about the multiple benefits of future friendly farming practices.
- Expanding programs to assist farmers in transitioning to practices with multiple benefits. Federal working land conservation programs such as the Environmental Quality Incentives Program's organic crossover provides one example of such transition assistance.
- Increasing funding for the Conservation Reserve Program, Wetland Reserve Program, and Grassland Reserve Program, which help landowners protect vital native ecosystems and the multiple benefits they provide.
- Establishing market systems and parameters to reward farmers who implement positive land management techniques that provide solutions to multiple environmental issues.
- Expanding efforts to develop credit trading markets for environmental benefits such as carbon sequestration, biodiversity enhancement, water quality improvement, and wetlands protection and creation.
- Placing minimum "do no harm" provisions on all carbon sequestration projects, preventing actions that cause harm to the ecosystem or wildlife, such as afforestation of lands that should not be forested.

The choice is ours to make. We can either ignore the problems we face and accept the consequences of continued environmental degradation or we can develop, reward, and implement future friendly agriculture and land management techniques that provide multiple solutions, all the while increasing landowner income and reducing costs to businesses, consumers, and tax payers, while protecting the health of the planet and the ability of future generations to provide for their needs.

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