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Second Harvest: Bioenergy from Cover Crop Biomass

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Executive Summary

Bioenergy made from sustainably harvested cover crops has the potential to build the country's renewable energy portfolio while conserving resources and increasing farmers' income. Cover crops, in spite of many benefits to farmers, are still underutilized, but the added benefit of a biomass harvest may help to scale up their use. Systems for producing biomass from cover crops must balance main crop yields, cover crop yields, and environmental benefits provided by the cover. This balancing act can be made easier with better public policies, and research is still under way on many aspects of sustainable cover cropping systems for biomass production.

Traditional cover cropping, a conservation technique in which farmers plant a second crop in coordination with a main crop, brings many benefits to farmers. Cover crops have been shown to improve water infiltration into the soil; reduce erosion, polluted runoff, and nutrient loss; fix nitrogen directly into the soil for future crops; suppress weeds; and add organic matter to build soil quality. Cover crops also capture and store carbon dioxide (CO_2) from the atmosphere, helping to mitigate climate change.

Despite all these potential benefits, most farmers still do not plant cover crops. Only 8 percent of farms were found to implement the practice in one study of four Midwest states. This is due in part to lack of knowledge and concern about payback. An additional benefit, the potential to grow biomass for bioenergy production, might give farmers the incentive they need to adopt cover cropping more widely.

If done carefully, cover crops harvested as feedstock for bioenergy production could provide extra income to farmers without significantly impacting the amount of land available to grow food crops. Creation of local biomass markets and greater access to incentives could raise adoption rates for the practice. However, second crop biomass will require careful evaluation of crop pairings, site-specific soil and climate conditions, and management practices in order to be successful, and trade-offs are inevitable.

This paper examines the benefits of using cover crops on agricultural land, the potential added benefits of harvesting biomass from cover crops, and the trade-offs that may be involved in harvesting cover crop biomass as a bioenergy feedstock versus leaving it on fields for other environmental services. Currently there are limited federal incentives that help farmers carefully integrate cover crops and biomass collection into their practices. We conclude with a discussion of existing policy incentives and how public investments could help drive adoption of sustainable cover cropping and biomass harvesting systems by U.S. producers.

Overview

Liquid biofuels have been hailed as an important part of the solution to our dependence on oil and the related threats to our economic, environmental, and national security. However, in light of spikes in food prices and studies linking biofuels to terrestrial carbon emissions from land-use change, biofuels are facing intense scrutiny. Long-standing concerns about the environmental impacts of conventional biofuels moved Congress to enact the Renewable Fuel Standard (RFS), which will cap first-generation biofuels at 15 billion gallons a year and require 21 billion gallons a year to come from "advanced" biofuels—those delivering at least a 50 percent reduction in greenhouse gas (GHG) emissions from a 2005 baseline—by 2022, including 16 billion gallons from biomass plant materials, also known as cellulose.

To achieve these volume mandates, the agricultural sector will need to transition toward growing biomass for energy while maximizing environmental co-benefits, minimizing food competition, and avoiding loss of valuable forestland and grasslands around the world. Perennial species like native grasses will likely provide the highest productivity and most environmental benefits as biomass feedstocks, but it may take some time for production to develop. Furthermore, concerns around indirect land-use change (ILUC) limit the types of land that are suitable for dedicated energy crops. Cover crops and similar types of conservation crop rotations, harvested as biomass by today's farmers alongside their current main crop, have the potential to improve conservation performance and generate additional revenue from biomass sales to local energy facilities.

In this paper, we explore the potential for cover crops to be part of the next generation of biomass feedstocks, both in the near term, while perennial biomass systems are undergoing research and development, and as an ongoing opportunity to co-produce food and biomass on the same acres while reaping environmental co-benefits. We also assess whether the addition of unharvested cover crops could make it possible for crop residues to be harvested for biomass at sustainable rates while increasing the environmental benefits of the overall cropping system.

BIOMASS POTENTIAL AND TRADE-OFFS

Early studies suggest that at present, cover crops could produce 2-3 tons per acre of biomass when harvested in an average year, and up to 5 tons with good weather and soil fertility.[1,2,3] If 10 percent of the nation's 220 million acres of field crop land were cover cropped and the biomass harvested, this would produce 44-110 million tons of biomass per year, the equivalent of 3.5-12.1 billion gallons of ethanol, depending on the efficiency of conversion. If incentives boosted cover crop adoption rates to 30 percent, we could expect 66 million acres of land to be cover cropped, yielding 132-330 million tons of biomass per year of biomass, or 10.6-36.3 billion gallons of ethanol.

Some farmers, especially organic operations, plant cover crops without harvesting biomass. In general, this is better for soil and water, since removing cover crop biomass may compromise environmental benefits. However, in most cases, carefully implemented cover cropping with biomass harvest will be better for the environment than no cover cropping at all. This is true especially for monoculture row crops found on the majority of agricultural lands today. Cover crops could help farmers who currently remove their main crop residue for biomass mitigate some of the environmental costs.

Other trade-offs that must be evaluated when assessing the environmental performance of cover crops as biomass include impact on main crop yields; impact on soil fertility, temperature, and moisture retention; and land-use change.

Our estimates of the life-cycle GHG emissions of biofuels made from cover crop biomass show an extremely wide potential range of emissions. The best-case scenario results in an 81 percent reduction in GHGs compared to gasoline. But the worst-case scenario results in a 115 percent increase in GHGs. The impacts on the yield of the primary summer crop is the most important factor, but assessments of the life-cycle environmental performance of cover cropping systems must also consider any resulting increases in fertilizer use (especially nitrogen), water use, and impacts on soil organic matter.

POLICY INCENTIVES FOR COVER CROPS

Policies can help drive adoption of cover crops, with or without harvesting for biomass. The 2008 Farm Bill contains several programs that provide incentives to farmers to plant cover crops:

- the Conservation Stewardship Program rewards farmers for improving natural resources on working lands and scores cover crops very well;

- the Environmental Quality Incentives Program shares the cost of establishing cover crops and similar practices;

- the new Biomass Crop Assistance Program offers farmers in project areas a yearly payment for five years, plus two years of matching payments when the biomass is sold, to stimulate biomass production in environmentally sound systems. Annual cover crops to be harvested for energy will be eligible, as will main crop residues managed with unharvested cover crops.

Unfortunately, none of these specifically focus on helping farmers carefully balance the trade-offs that are part of integrating cover crops into their farming systems and producing biomass.

CONCLUSION

Well-implemented cover cropping systems offer a potential source of biomass with many environmental and renewable energy benefits. More research is needed to determine where and to what extent cover cropping can be part of a long-term solution for bioenergy production. Research is also needed to determine what planting and harvesting practices will maximize environmental benefits in different cropping systems. Investment is needed to support the research, development, and demonstration projects that will help to identify best practices. Topics for research include how to integrate cover crop cultivation with main crops, breed better varieties of cover crops, and produce energy efficiently from different forms of biomass. Farmers will need to balance profit and environmental benefits for the system as a whole, so researchers must evaluate how to simultaneously optimize yield from the cover crop, yield from the main crop, and environmental benefits.

CHAPTER 1

Introduction to Cover Cropping

Cover cropping is the practice of planting of a second crop in coordination with a main crop to cover and bring environmental benefits to the soil. Cover crops can prevent wind and water erosion compared to fields left bare after harvest, reduce nitrogen leaching, and improve soil quality. Cover crops can be cultivated in a variety of ways: they can be grown all year as living mulch, planted as a post-harvest fall and winter cover, or "intercropped" with other plants. Typically, cover crops are not harvested, although they are sometimes grazed or mowed for forage, or plowed under the soil.

For example, some cover crops are called "green manures." These small grains or forage legumes are intended to increase soil fertility by adding organic matter to the soil and/or fixing nitrogen. Any cover crop can also be a green manure if enough of its biomass is left on the soil at the end of the season to increase fertility, rather than collected and removed from the field.

"Double cropping" or "intercropping" is a form of cover that can include mixed stands of two varieties; alternating rows of different crops; strips running through the main crops; or relay planting of an early crop followed by a later catch crop for nutrient recycling.

Sometimes cover crops are part of a conservation crop rotation, a multiyear sequence of crops that includes crops planted for cover and nutrient enhancement, such as alfalfa hay.

Although distinctions among these categories of crops and their uses are important, for the sake of simplicity in this report we will refer to all secondary crops planted in coordination with regular-season crops for any of the above purposes as cover crops.

Grasses and legumes are the most commonly planted cover crops. Leguminous cover crops fix nitrogen, while grasses tend to increase organic matter in the soil more quickly than do legumes.[4] Some common cover crops include rye (annual and perennial), clover, alfalfa, oats, wheat, and hairy vetch. Others are millet, sudangrass, buckwheat, amaranth, sunflower, soybean, field peas, sorghum, annual medic, forage turnip, and oilseed radish.

Less common cover crops, such as triticale (a wheat-rye hybrid) and crotalaria (a tropical crop), show potential for producing biomass for bioenergy production and are the subjects of new research. Industrial hemp and plants formerly thought of as weeds, such as pennycress, are also being discussed as potential sources of biomass.

Since the advent of cheap chemical fertilizers, the practice of rotating crops and planting cover crops has largely gone out of favor with the majority of farmers. The notable exception is organic farmers, who use cover cropping to maintain nutrient cycles and whose certification requires them to implement soil-building crop rotations.

CHAPTER 2

Environmental Benefits of Traditional Cover Cropping

Typical commodity crops, such as corn and soy, cover the soil for only a few months of the year. After harvest and before the next spring planting, bare soils are exposed to erosive rains and wind for up to nine months. Even when crop residue (stems and leaves) is left on the field over the winter as part of a conservation tillage plan, soil erosion often occurs, reducing fertility and leading to sedimentation in waterways. Without vegetative cover in the off-season to take up nitrogen and prevent runoff, rain carries away more pesticides, herbicides, and fertilizers, worsening water pollution.

Vegetation helps hold carbon and moisture in the soil. The leaf canopy of cover crops shields the soil from rain and wind, provides habitat, and supplies green matter to either nourish the soil or be harvested. The crops' roots hold two-thirds of the carbon of the plant, and provide numerous benefits to soil quality. When fields are bare, these benefits are lost. Months without plant cover, combined with the need to replace lost nutrients with chemical inputs and heavy tillage in most field crop systems, means monoculture farming systems without cover cropping also generate large amounts of heat-trapping GHG emissions.

Cover crops perform many environmental functions, both above and below ground, which can help mitigate the adverse environmental impacts of monoculture farming systems and bare fields. The recognized benefits from cover cropping vary according to the crop, but include:

- **Improved infiltration of water into the soil.** Cover crops help keep soil clumped together in aggregates and prevent it from being broken down into smaller particles, which can seal the soil surface to water. The organic matter-building properties of cover crops (see below) also help improve infiltration, as do the roots of the crop and the worm communities they

BENEFITS OF COVER CROPS

- Improved infiltration of water into the soil
- Reduced erosion, runoff, and sedimentation
- Reduced nitrogen leaching
- Increased available nitrogen
- Weed and disease suppression
- Increase in beneficial insects
- Increased yield in subsequent crops
- Gain in soil organic matter
- Carbon sequestration

encourage. Grasses and other low-nitrogen covers tend to increase infiltration more effectively than do nitrogen-fixing leguminous crops.[5]

- **Reduced erosion, runoff, and sedimentation.** Cover crops protect the soil from wind and water erosion by providing a physical barrier, and can greatly slow water flow off the field after heavy rains. Improved infiltration helps the water that stays on the field be absorbed more quickly.[6] The erosion-reducing role of cover crops is particularly important in the Southeast and Midwest Corn Belt, where winter rains wash away topsoil unless winter cover crops are in place.[7] Where runoff is reduced, there is much less diversion of sediment, pesticides, and fertilizer into waterways. Biomass harvest of cover crops will have to be managed, both for height of cutting and time of harvest, to retain as much erosion reduction function as possible.

- **Reduced nitrogen leaching.** Nitrogen is heavily applied in many field crop systems and is highly mobile in some forms, being carried by water runoff and infiltration. Field crops such as corn take up nitrogen during the time that they are actively growing, but once dry, they leave mobile nitrogen in the soil free to be transported to surface water and groundwater.[8] Grasses and other non-leguminous cover crops can reduce this nitrogen leaching by taking up residual nitrogen and holding it in the roots and leaves between cash crop seasons.[9] Research in Washington State found that cover crops planted early enough in the fall took up and recycled more than 100 pounds of nitrogen per acre.[10]

- **Greater nitrogen availability.** Like soybeans, leguminous cover crops convert atmospheric nitrogen into a form of nitrogen that is stored in root nodules and in the soil for future crops to use, reducing the need for synthetic nitrogen fertilizer application. Historically, legume crops and animal manures were the closed-loop nutrient systems used by all farmers. In addition to fixing nitrogen on their roots, when the top growth of cover crops is incorporated into the soil or left on the soil surface at the end of the season, that biomass is mineralized by soil microbes into nitrate, which is then available for the cash crop that follows. The amount of nitrogen in the aboveground biomass of cover crops varies considerably, depending on the type of crop used, but some research has suggested that legumes can contribute anywhere from 60 to 200 pounds of nitrogen per acre. Not all of this nitrogen will be available to the regular-season crop in the first year, as it is released slowly over several years.[11]

- **Weed and disease suppression.** Cover crops can often suppress the germination and growth of weeds through competition and shading. When killed by either frost or herbicides and left on the surface, cover crops continue to suppress weeds by blocking out light.[12] If the right cover crops are chosen, they can also break disease cycles in the cash crop.[13] After biomass is harvested, this function may be reduced.

- **Increase in beneficial insects.** Cover crops provide habitat and sustenance for beneficial insects, particularly in no-till or conservation tillage systems, where more crop residue is left on the surface to host them.[14] Biomass harvest timing could affect this function.

- **Increased yields in subsequent crops.** There are a variety of perspectives on the impact of cover cropping on cash crop yields. While yield increases have certainly occurred, partly as a consequence of the additional nitrogen provided by a leguminous cover crop, there are indirect factors driving yield increases as well. Agronomists have been unable to isolate many of these indirect factors and instead refer to them collectively as the "rotation effect."[15] However, there is also evidence suggesting that cover crops may reduce yields under certain conditions such as dry weather in arid areas.[16]

- **Gains in soil organic matter.** Soil organic matter can improve the water infiltration capacity of the soil and increase nutrient availability. Organic matter also bolsters populations of soil microbes, improving the nutrient cycle. Moreover, organic matter captures and sequesters carbon in the soil, which has important benefits for the climate (see below).[17] Notably, different cover crops have different degrees of impact on organic matter content.

Grasses tend to increase organic matter more quickly than do leguminous crops because they have finer roots in larger root structures; more lignin, which breaks down very slowly; and lower nitrogen content.[18] Leguminous crops are broken down more quickly because their high nitrogen content drives microbial activity and mineralization.

- **Carbon sequestration.** Having vegetation growing year-round increases the amount of CO_2 fixed from the atmosphere during photosynthesis. In addition, by reducing erosion and preventing the soil from becoming exposed, cover crops help keep carbon sequestered in the soil. Cover crops can also contribute to carbon sequestration to the extent that they slow the decomposition of organic matter and carbon mineralization, when organic carbon is converted by soil microbes into CO_2.[19] As noted, when the aboveground biomass of a crop is left on the field and covers the soil, the roots decompose more slowly and carbon is retained in the soil.

Discussion

Evidence suggests that the capacity of cover crops to build organic matter is enhanced by the use of no-till or conservation tillage systems.[20] These practices conserve soil moisture and decrease soil temperature by keeping some biomass on the surface of the soil.[21] The ability of cover crops to build organic matter is also directly related to the amount of cover crop biomass that is left on the surface of the soil to decompose after the season has ended.

There is significant debate in the research community over the relative importance of belowground and aboveground biomass to building soil organic matter. Roots may contribute fractionally more carbon than the aboveground portion of a plant under normal conditions. However, if the aboveground material is removed, the decomposition process of the roots could accelerate, leading to faster nitrogen mineralization rates and reduced organic matter accumulation.[22]

This dynamic is a key consideration in designing cover crop harvest options that optimize organic matter levels. Equally significant is the potential for cover crops to be used where main crop residue is being removed, whether for bioenergy production or other purposes. Similar outcomes may be achieved by either retaining crop residues and removing cover crop biomass, or harvesting crop residues and leaving cover crop biomass on the field.

Total carbon sequestration potential is a function of both soil and plant types. Grasses planted as cover crops increase organic matter more than leguminous crops, improving the soil's capacity to sequester carbon. Bicultures of rye and vetch (a legume) grown together have been found to sequester more carbon than do monoculture cover crops on comparison plots.[23] It is the interplay of how the main crop and cover crop are managed that determines how much biomass can be harvested while still increasing carbon storage in the soil. However, soil carbon sequestration is difficult to measure and verify and easily reversed, so any resulting climate benefits must be considered within the context of a farm's overall GHG emissions.

DESPITE MULTIPLE BENEFITS, ADOPTION OF COVER CROPPING HAS BEEN SLOW

The limited data available suggest that farmers are not utilizing cover crops at nearly the rates one might expect, given the on-farm and external benefits, let alone benefits to national renewable energy goals. Singer, Nusser, and Alf (2007) conducted a survey of 1,000 random producers in Illinois, Indiana, Iowa, and Minnesota in June 2006 to determine rates of cover crop use in the nation's Corn Belt. An estimated 18 percent of producers in the region reported having used cover crops at some point, 11 percent in the previous five years. Only 8 percent had planted cover crops during the fall preceding the survey.

The authors of the survey were unable to find national-level data on cover crop usage.[24] As a result, we can only extrapolate from these findings to estimate national use of cover crops. Anecdotal evidence from the Southeastern U.S. suggests that cover crop adoption in that region is similarly low.[25] According to the U.S. Department of Agriculture (USDA), approximately 220 million acres of cropland were planted in corn, cotton, winter wheat, sorghum, and soybeans in 2007. If we assume that 8 percent of that land was planted in cover crops between cash crop seasons, then our baseline is approximately 17.6 million acres of cover crops nationwide. At 11 percent utilization, our baseline is 24.2 million acres.[26]

The survey found that cost was not an insurmountable barrier to adoption. Fewer than 25 percent of respondents listed cost as their reason for not planting cover crops. Cost does, however, have some bearing, though: 56 percent indicated that they would plant cover crops if cost-share help were available. The authors estimate that the mean payment required as an incentive is approximately $23 per acre.

An even greater barrier to adoption was farmers' perception that cover cropping was too time-consuming or otherwise onerous. Roughly one-third of survey respondents believed that planting cover crops took too much time. Cover cropping may require producers to buy or contract equipment that they would not otherwise use (such as helicopter service to over-seed the cover crop into the growing field crop in midsummer).[27] The authors note that "finding ways to minimize the cost and time needed to establish and manage cover crops will support the expansion of cover crop use in all types of farming."

Farmers also were deterred by some of cover crops' negative qualities. A Maryland study found that because cover crops took up nitrogen during the winter and tied it up in the soil, additional spring-available nitrogen was required on some cash crops to bring yields up to the levels they would reach without a cover crop.[28] In northern regions, cover crops can slow warming and drying of the soil in the spring, which delays or hinders establishment of succeeding cash crops in the spring. This can have significant impacts on yields in these shorter growing seasons. In arid areas, cover crops can take too much moisture away from the main crop.

Finally, farmers lacked familiarity with the practice of cover cropping. The most common reason cited by farmers for non-adoption was that they did not know enough about cover crops to judge whether they were right for their farm. In Iowa, nearly 30 percent of respondents were not at all familiar with cover crops. This suggests that significant education will be needed to scale up cover crop use.

CHAPTER 3

Biofuels from Cover Crops Support U.S. Clean Energy Goals

Interest in biofuels stems from the need to achieve three primary goals: reducing American dependence on foreign oil, creating economic growth, and developing an alternative liquid fuel with reduced life-cycle GHG emissions compared to gasoline. First-generation biofuels—ethanol from corn and biodiesel from soybeans—were the starting point for alternative liquid fuels. Unfortunately, these biofuels have failed to deliver emissions reductions, drive up food prices, and, in many cases, increase water pollution, soil erosion, and pressure on forests and other ecologically valuable landscapes.

In 2007, Congress passed legislation aimed at encouraging a transition toward the next generation of biofuels made from cellulosic biomass. This includes corn stover, waste from wood operations, and cover crops. The Renewable Fuel Standard (RFS) increases the volume of renewable fuel required to be blended into gasoline from 9 billion gallons in 2008 to 36 billion gallons by 2022, but caps corn ethanol at 15 billion gallons. It requires 21 billion gallons to be "advanced" biofuels, including 16 billion gallons from plant-based biomass.

To achieve these volume mandates, farmers will need to shift to growing biomass for energy while maximizing environmental co-benefits, minimizing food competition, and avoiding the direct or indirect loss of valuable forestland and grasslands around the world. Cover crops fit these requirements because they are planted between cash crop seasons or alongside the cash crop, and if done right they preserve the food, feed, and fiber production on each acre.

Harvesting cover crops for biomass could not only increase revenues for farmers but also reduce the risk that biomass production will have adverse impacts on food production or increase competition for land. As a result, researchers have begun to explore the potential to harvest cover crop biomass as a biofuel feedstock.

FEEDSTOCKS SHOULD MATCH LOCAL ENERGY NEEDS

One subject of research is the qualities that bioenergy feedstocks will need in the future. BTUs per acre is and will likely remain the most important criterion, regardless of conversion process. While ethanol fermentation is the most familiar technology for producing energy, conversion research shows that gasification, pyrolysis, co-firing, biodiesel, hydrogen fuel cells, direct burning, anaerobic digestion, and other processes may all be fed by biomass. With any of these processes, the final energy products might vary: ethanol, butanol, biogas, biodiesel, electricity, heat, hydrogen, and even fertilizer are all possible end products.

In order to maximize benefits, biomass produced from cover crops should match the demands of local energy facilities. Some systems use wet, green biomass, while others need large bales or pellets of dried material. Some utilize a mix of feedstocks, while others require uniform inputs. The most desirable qualities of biomass will depend on the local context.

For individual farmers, this will mean finding profitable biomass markets not too far from their farms in order to minimize transportation costs. It is thus likely that projects will evolve in one of two ways: either energy facility developers will select conversion processes and feedstocks based on the ability and willingness of local farmers to grow and supply that feedstock, or energy developers will site projects where locally available feedstocks match their chosen technology. This highlights a certain “chicken or egg” problem that policy can help overcome: providing incentives for renewable bioenergy facilities in coordination with incentives to local feedstock growers.

POTENTIAL VOLUME OF COVER CROP BIOMASS

The potential to scale up the use of cover crops on U.S. farms for the purpose of producing biomass will depend on the type of cover crops ultimately adopted. Most crops currently used as cover are not chosen for their usefulness as a bioenergy feedstock, nor are they grown with harvesting in mind. Very little research is available on their yield potential.[29]

It is likely that cover crops adopted specifically for biomass production would be of a different variety, and research into the best varieties is just now beginning. For example, triticale, a hybrid of wheat and rye, is currently being explored as a crop that could provide significant aboveground biomass while also reducing erosion and limiting nitrogen leaching. One study finds that triticale cover-cropped on Midwest corn and soybean land yields 2.8-3.6 tons per acre of biomass when harvested.[30] With good weather and soil fertility, it can yield as much as 5 tons per acre.[31] However, there are few agronomic guidelines for producing triticale in the Midwest.[32] Ongoing studies in the Southeast using rye, oats, and/or wheat as a cover crop have seen yields of 2-3 tons per acre on average.[33]

Using our previously determined baseline of 17.6 million acres of cover crops (8 percent of field crop land), we could assume that if this land were cropped with triticale or a comparable cover crop in conditions similar to those in the above studies, producers might harvest 50-64 million tons of biomass annually. If incentives boosted cover crop adoption rates from the current estimate of 8 percent to 30 percent, we could expect 66 million acres of land to be planted in cover crops, yielding 185-238 million tons per year of biomass at current yields. A higher long-term adoption rate of 50 percent would yield 308-396 million tons per year. This is enough for roughly 24,600-31,600 million gallons of biofuel, assuming approximately 80 gallons can be produced from every dry ton of biomass.

We can expect that research and development could improve the biomass yields of cover crops while also optimizing environmental performance. Assuming a yield of 5 tons per acre, at a 30 percent adoption rate, producers could expect to harvest 330 million tons per year of cover crop biomass. At a 50 percent adoption rate, 550 million tons could be harvested each year.

These estimates, however, are extrapolated from a small number of studies; actual yields and estimates will likely vary widely for different crops and regions. Ongoing university-based research will help to answer some of these questions. Additionally, as noted above, one high priority for USDA agronomists is the production of state and regional inventories of current and projected cellulosic feedstocks and the expansion of USDA-National Agricultural Statistics Service (NASS) databases to include crop model–based predictions for cellulosic biomass production.[34]

CHAPTER 4

Benefits and Challenges of Harvesting Cover Crops for Biomass

In assessing and seeking to maximize the potential benefits of cover cropping for biomass harvest, it is important to look not at a single variable or single crop, but rather at the system as a whole. There are many possible combinations of cash crops and cover crops in a crop rotation. Any assessment should include various options for spatial and temporal sequencing of crops and multiple management and harvest techniques.

Monetizing a single variable such as yield has the potential to exacerbate negative environmental impacts—for example, resulting in increased nitrogen fertilizer use. New markets for biomass, which add new financial incentives for implementing yield-maximizing cover crop management practices, may therefore reduce the potential benefits of cover cropping in terms of water quality and soil health and result in a system with poorer environmental performance. A holistic approach that considers the way residues of both the main and cover crop are managed is critical to any evaluation of the environmental performance of the overall crop rotation system.

In almost all cases, harvesting biomass from cover crops and other cropping systems will diminish environmental benefits compared to planting cover crops and not removing any biomass. Nevertheless, harvested cover crops can add significant environmental benefits to a row crop system even if they are harvested. The literature documents several potential trade-offs associated with the use of cover crops in a cash crop system. In the small body of literature that compares harvesting cover crop biomass for energy production with growing but not harvesting, some key areas are worth highlighting.

MANAGING FOR MAXIMUM YIELD MAY REDUCE ENVIRONMENTAL BENEFITS

Cover crops vary in their ability to deliver environmental benefits. Some build organic matter more quickly, while others fix nitrogen or suppress pests. Producers decide which crop to plant by identifying the most important goal on the farm and selecting the crop best suited to that goal.[35] If incentives are put in place to promote the production of biomass for commercial harvesting, it is reasonable to expect producers to make management decisions aimed at maximizing yields.

However, the cover crop or mix of crops that yields the greatest amount of aboveground biomass may not maximize environmental benefits to the water or soil. One agronomist consulted for this report suggested that crops being harvested for biomass should not be called "cover crops" because the term applies only to crops that are planted specifically for the purpose of providing cover to the ground to prevent erosion and runoff. Others disagree, noting that regardless of the end use of the cover crop, it would still fulfill its role of "covering" the ground during the winter months.

A singular focus on maximizing yield may result in increased synthetic nitrogen fertilizer use, which can have negative effects on water quality and GHG emissions. Managing for maximum yield may also preclude other co-benefits, significantly reducing the overall environmental performance of the system. Researchers will have to evaluate how to simultaneously optimize three factors: yield from the cover crop, yield from the main crop, and environmental benefits. Significant research is needed in this area to identify the best crop mixes and to develop best management practices based on location, soil type, climate, and other factors.

HARVESTING COVER CROPS WILL IMPACT THE REST OF THE SYSTEM

A system in which cover crops are harvested for biomass will look quite different from the traditional cover crop system, and will have an appreciable impact on cash crop outcomes.[36]

For example, in a typical corn-soybean rotation where cover crops are used, the main crop is harvested in early fall, and cover crops are planted after harvest. The cover crops generally have only a short time to establish themselves before low temperatures cause them to go dormant for the winter. The cover crops grow again for a brief period in the spring and are then killed (either mowed and left on the ground, harvested, plowed under to build soil organic matter, or sprayed with an herbicide); the field crop is then planted in mid-to-late spring.

In order for Midwestern farmland to provide enough biomass for harvesting, cover crops would have to stay on the field longer so that enough growth could be achieved in the spring to yield sufficient returns. The cover crop might be aerially seeded by helicopter over the growing corn or soybeans in late August to put on a flush of growth after harvest. The following spring, the main crop would have to await planting until after cover crop harvest. This might mean delaying planting, with diminished moisture to germinate the corn seed near the surface when the plants are young and roots are shallow. The drier weather and later planting date would impact corn grain yields, increasing their variability.[37]

Alternatively, corn crops would have to be harvested earlier so that cover crops would have time to accumulate adequate biomass before the weather became too cold.[38] This could be feasible if the corn were to be harvested for silage or sweet corn rather than for grain, but not if the goal was to harvest the corn for grain, which would be underdeveloped or too moist if harvested too early. One analyst suggests that this system could work well if there were dairy cattle or local bioenergy operations able to utilize the high-moisture biomass and then cycle the nutrients back to the land in the form of manure or captured waste from the facility.[39]

Preliminary research in Iowa suggests that while the total biomass yield (cover crop plus corn silage) from a corn/triticale double-cropping system could be as much as 25 percent greater than in a conventional corn-only system, grain yield in the corn crop would be reduced by about 20 percent.[40] This system could work well for an individual producer who is able to market the corn for silage, but widespread adoption could result in an aggregate decline in grain production, and risk driving corn production onto previously fallow or marginal lands.

The Renewable Energy Assessment Project (REAP) of the Agricultural Research Service includes research on sustainable residue removal rates and the trade-off with carbon sequestration.[41,42] Other researchers in the Southeast see greater potential to plant and harvest cover crops for biomass in that region, as warmer weather allows for growth throughout the winter months.

Researchers are also investigating the potential of using new breeds of corn that can be planted later and harvested earlier and still maintain grain yields. This may ultimately be the best way to provide sufficient biomass without dramatically reducing the amount of corn grain available for food and feed. Nevertheless, some yield impact would still be expected. Ultimately, it appears that researchers and producers will need to find an arrangement that maximizes profits and environmental benefits from the system as a whole, rather than maximizing output from each separate piece of the system.[43] The correct policy incentives can help ensure this outcome.

COVER CROP BIOMASS FOR BIOFUELS: IMPACT ON LIFE-CYCLE GHG EMISSIONS

In their analysis of GHG emissions from indirect land-use change (ILUC), Searchinger et al. (2008) concluded that the diversion of corn from feed to fuel results in substantial emissions from the clearing of land around the world. This land is cleared, Searchinger argued, to bring the supply and demand for crops back toward equilibrium. According to Searchinger's modeling, corn ethanol is responsible for life-cycle emissions that are nearly twice those of gasoline when these ILUC impacts are accounted for.

Some have questioned the inputs and assumptions of this analysis, as well as the concept of including economically mediated impacts in life-cycle emissions analysis. Nonetheless, the notion that supply and demand market dynamics will increase clearing of natural landscapes if biofuels increase the competition for arable land is now well accepted. Indeed, federal law requires the U.S. Environmental Protection Agency (EPA) to include ILUC emissions as part of the life-cycle assessment used to determine the eligibility of different renewable fuels under the RFS.

Searchinger's analysis provides a few values that can help us develop an illustrative example of the trade-offs that must be considered for all feedstocks that might be used to make biofuels, and specifically for cover crops. Using the Food and Agricultural Policy Research Institute (FAPRI) model from the Center for Agricultural and Rural Development at Iowa State University, the authors calculated that for every acre of corn that is diverted from feed to fuel, after considering the distiller grains fed to livestock, substitutions, and yield variability, 0.85 new acres on average is cleared. When an acre of corn is diverted to a crop that does not produce any feed co-products, they estimated that 1.27 acres are cleared. Drawing on a Woods Hole Research Center database of the types of land cleared for agriculture around the world in the 1990s and the aboveground and belowground carbon stored in each, the authors calculated that the clearing of the weighted-average acre results in the release of the equivalent of 4.7 megagrams of CO_2 during the first 30 years of cultivation.

Using these values, we can look at various scenarios for cover crops. Depending on how much biomass they yield, how much fuel we can produce from each ton of biomass, how they impact the yield of the summer crop, and how they change the inputs needed to grow both crops, we can show theoretically how the life-cycle GHG emissions from the resulting fuel compare to those from gasoline. The table below summarizes a range of scenarios based on a corn/triticale system, with cover crop biofuels resulting in life-cycle GHG emissions that range from 81 percent lower than gasoline in the best case, to 115 percent greater than gasoline in the worst case. In this analysis, the most significant factor in increasing the life-cycle GHG profile of cover crop biofuels is depressed summer crop yields. For more details see Appendix A.

Table 1: Cover Crop Biofuels Life-Cycle GHG Scenarios

Scenario summary (based on a corn/triticale system)

	Best Case	Good	Poor	Worst Case	No Yield Reduction
Cover crop yield (tons/acre)	5	4	3	2	3
Conversion efficiency (gallons etoh/dry ton)	110	100	90	80	100
% Reduction in summer corn crop yield	10%	15%	20%	30%	0%
Ag stage emissions (g CO_2 eq/acre)	400,000	556,833	611,527	720,917	392,749
% Change in life-cycle GHG emissions	–74.4%	–49.6%	–7.9%	115.0%	–81.3%

Potential impacts of harvesting cover crops for bioenergy production include:

- ***Greater fertilizer use.*** The capacity of cover crops to take up nutrients during the off-season is beneficial, but some researchers believe that harvesting the cover crops—whose nutrients would otherwise return to the soil as they decompose—could deplete soil fertility. Further research is needed to consider nutrient needs for the cover crop, succeeding crop, and for long-term soil fertility.

  One study found that harvesting the biomass from a triticale cover crop in a triticale/corn system increased nitrogen, phosphorus, and potassium extraction by 82 percent, 30 percent, and 347 percent, respectively, compared with a system in which cover crops were neither grown nor harvested.[44] While this may be positive from the perspective of removing excess nutrients that could otherwise leach or wash away from the field, it is negative if the intent is to preserve the nutrients for the next crop. Unless there is some way to recycle nutrients contained within the harvested biomass, producers may increase synthetic fertilizer applications in order to keep yields high, resulting in greater GHG emissions. Because there is no need for bioenergy products to contain potassium, phosphorus, and nitrogen, ways to recover and recycle these nutrients after processing should be the subject of ongoing research. Ash, biochar, digestate from anaerobic digestion, and other by-products of energy production could contain carbon as well as nutrients and be returned to the soil in a closed-loop system.

  Producers may also apply nitrogen fertilizer to the cover crop if they feel the expense is worth the biomass yield increases. Currently, producers try to minimize costs in cover cropping systems since they are not being paid to grow the cover crop. Thus, fertilizer and pesticide use on cover crops is extremely low. If cover crops become another cash crop, that practice could change.

  There is ongoing research into the role of nitrogen management in the corn crop and the cover crop and nitrogen's contribution to the life-cycle GHG emissions of the resulting ethanol. This is a critical issue for further exploration in the context of using cover crop biomass as a bioenergy feedstock. Any increase in the amount of fertilizer—especially nitrogen—applied to either the summer or cover crop must be accounted for in assessing the environmental impact of bioenergy produced from cover crops.

- ***Increased demand for water resources.*** Like all crops, cover crops will take up water as they grow and may require additional water to maximize yield. In water-limited areas, this could strain available resources and necessitate greater use of irrigation water on the cash crop. Moving the cash crop planting date to after spring rains in the Midwest could also raise water demand in the regular season.[45] It is critical to match the cover crop to local water availability.

- ***Reduced soil organic matter.*** Additional research is needed to determine the impact on soil organic matter of harvesting the aboveground biomass from cover crops for bioenergy production.[46] Harvesting biomass, particularly from sloped fields, may increase the risk of erosion. Research is needed to investigate the organic matter content of the soil in a variety of biomass production and harvesting scenarios, compared with fields in which cover crops are instead left as green manures.[47]

- ***Greater or smaller life-cycle GHG emissions.*** The direct GHG emissions resulting from the cultivation and transportation of cover crops (not including any ILUC emissions) will depend on a number of factors: whether the chosen cover crop builds soil organic matter and/or fixes nitrogen, or requires a large amount of synthetic fertilizer to boost yield. Also important to the life-cycle GHG emissions calculation is the cover crop's nutrient requirement, the proximity of the biomass processing plant to the field where the cover crop is grown, and whether the nutrients that remain after processing can be returned to the field.[48] Both modeling and field studies are needed in order to understand these factors and their interactions.[49]

CELLULOSIC CROPS SHOULD BE PRIORITIZED ACCORDING TO SUSTAINABILITY

Regardless of the type of biomass—be it cover crop biomass, collection of regular-season crop residue, replacement of traditional crops with perennial prairie grasses, or some other source—cellulosic crops should be prioritized according to their sustainability.

- Perennial crops with mixed species are preferable to single species, if measures are taken to avoid triggering ILUC emissions.
- Crop rotations that include two or more years of perennials and are grazed may be preferable to traditional feed grain production.
- Annual crops using a cover crop and/or no-till are preferable to annual crops using minimum tillage (in strips or ridges) or annual crops using conservation tillage.

Individual farmers need to understand the trade-offs that apply to their specific agronomic and economic situation so they can make a decision on cover crops that will maximize both sustainability and economic benefits.[50] Policy incentives and stewardship requirements can weigh positively into that calculation.

CHAPTER 5

Policy Incentives to Scale Up the Use of Cover Crops

The right adoption incentives can encourage use of cover crops in a manner that increases systemwide sustainability. Today, many producers do not associate cover crops with reduced labor or cost savings. Producers have not yet seen a market for biomass feedstocks and are unfamiliar with many of the environmental benefits associated with the practice.[51]

The 2008 Farm Bill offered numerous incentives for cover crop use through new rules and ongoing implementation of a variety of programs. These incentives support the incorporation of cover cropping into existing working-landscape programs. Programs encouraging these improvements include the Conservation Stewardship Program (formerly known as the Conservation Security Program), the Environmental Quality Incentives Program, and elements of the Conservation Reserve Program. They reward farmers for implementing beneficial practices on working farmland. A new Biomass Crop Assistance Program was also enacted. In addition, the RFS, passed as part of the 2007 Energy Independence and Security Act (EISA), sets life-cycle GHG emissions performance standards for biofuels, encouraging the use of more sustainable biomass feedstocks such as cover crops.

CONSERVATION STEWARDSHIP PROGRAM

The Conservation Stewardship Program (CSP) is a comprehensive green payments program designed to reward working lands for protecting and improving natural resources and the environment. The previous version, the Conservation Security Program, enrolled 16 million acres under the 2002 Farm Bill to provide financial and technical assistance to farmers and ranchers, both for previous conservation accomplishments and for new conservation activities. Although extremely popular with those who could get in, the old CSP was inhibited by limited funds and complex rules, and enrollment was restricted to specific watersheds.

The new CSP has a nationwide, continuous sign-up, which means farmers can apply at any time in any year. The program has 10 years of mandatory funding, with a total budget of over $12 billion. Nearly 13 million acres are being enrolled each year, apportioned out to the states according to the amount of agricultural land they have. The program's goals include addressing local watershed and regional resource concerns; improving soil, water, and air quality as well as biodiversity and habitat; sequestering carbon to mitigate climate change; and conserving energy and water.

USDA's Natural Resources Conservation Service (NRCS) periodically selects the highest performing applicants and pays them according to the environmental performance of their existing and newly added conservation practices. The streamlined structure has universal five-year contracts and a single $40,000-per-year payment limit. Retained from the original program is a focus on rewarding current and new efforts and innovative use of a conservation measurement tool to score performance. Payments are based on costs, forgone income, and environmental outcomes as measured by various indices.

Cover crops and continuous cover crops (which follow all annual crops in a rotation) are among the highest performing and highest paid practices in CSP. Participating farmers must first have a sufficient level of baseline environmental performance data to qualify and compete for ranking. For a farmer to improve his or her prospects for selection and enrollment in CSP, one option is to use the Environmental Quality Incentives Program (EQIP) first to help with planting cover crops. Farmers who already meet baseline requirements could propose adoption of cover crops to achieve higher outcomes and increase the likelihood of being selected for CSP payments. The new CSP includes an additional supplemental payment for farmers willing to adopt resource-conserving crop rotations that include cover crops, forages, green manures, catch crops, and other crop mixes that enhance soil quality, reduce erosion, increase diversity, and improve soil, water, pest, nutrient, and disease management. This supplemental payment could be a primary incentive for farmers to integrate cover crops for biomass. On-farm research and demonstration participation, which can help build the body of research on cover crops and raise awareness about the practice among other farmers, also results in additional payments.

Recommendations: *Congress should continue to maintain support for full funding to implement the commitment to continue enrolling 13 million acres a year in CSP. NRCS should continue to assess the annual list of new enhancements to ensure that biomass harvest is encouraged in concert with high conservation performance.*

ENVIRONMENTAL QUALITY INCENTIVES PROGRAM (EQIP)

The Environmental Quality Incentives Program (EQIP) is the largest conservation cost-sharing program offered by USDA. EQIP provides cost-share payments of up to 75 percent for a huge array of conservation practices, including cover crops. In addition to sharing planting costs at a set local rate, EQIP will also pay up to 100 percent of forgone income, which may cover any loss of main crop yields caused by the cover crop. The 2008 Farm Bill provided EQIP with $16 billion in mandatory funding over 10 years.

EQIP standards for each practice are outlined in the National Handbook of Conservation Practices. The Handbook includes considerable leeway on how cover crops are to be managed, depending on the specific objectives of the farmer. For example, if the objective is to produce forage, the cover crop may be hayed or grazed. If weed suppression is desired, cover crop residues must be left on the soil. While the objective of enhancing biomass production opportunities is mentioned, management standards may need to be revised to give clear guidance on exactly when and how much cover crop may be harvested.

Farmer access to EQIP is complicated by the fact that conservation priorities are set nationally, while state and county NRCS offices determine exactly which practices will be offered. Each year, the list of eligible practices and payment rates is set at the state level, from which local-level NRCS officials select what EQIP will cover in their county. For example, in 2008 only a fourth of Iowa's counties offered cost share for cover crops, with a typical payment rate of $31.50 per acre per year for three years. Even more significant is the tremendous competition for EQIP dollars. Even with strong growth in overall funding, only about 15 percent of applicants are selected. Nevertheless, the program offers the potential to significantly assist farmers in adopting cover crops and crop rotations.

Conservation practices other than cover cropping could also earn financial incentives for farmers attempting to integrate biomass crops into their fields and crop systems. These include: conservation crop rotations, contour buffer strips, crosswind trap strips, filter strips, grassed waterways, herbaceous wind barriers, riparian herbaceous cover, sinkhole area treatment, strip cropping, and vegetative barriers. Practices that entail woody species include alley cropping, hedgerows, multistory cropping, and windbreak/shelterbelt establishment. However, in order to benefit from EQIP support, each of these must be designated as an eligible practice in the county of the participating farmer. While other conservation goals such as wildlife habitat must also be maintained, harvest for biomass could be possible as part of these practices.

Recommendations: *Congress should maintain full funding for EQIP. NRCS should conduct a review of the practice standards for cover crops and other practices to clarify under what conditions biomass harvest for energy would be supported. Special consideration should be given to how a cover crop might relate to crop residue harvest for bioenergy to ensure maintenance of soil carbon levels over the long term. NRCS state and local offices should be encouraged to put locally appropriate cover crops on their lists of offered practices for cost share. Technical assistance to help farmers implement cover crops in a way that maximizes benefits and minimizes trade-offs should be made available to all farmers, regardless of whether they are using EQIP or other programs. Training on biomass harvest is also needed for NRCS staff.*

BIOMASS CROP ASSISTANCE PROGRAM (BCAP)

The 2008 Farm Bill created the Biomass Crop Assistance Program (BCAP) to provide incentives for farmers to establish and harvest new biomass crops for conversion to any type of bioenergy. The program's stated goal was to promote the cultivation of "crops that show exceptional promise for producing highly energy-efficient bioenergy or biofuels," and to help develop those new crops and cropping systems in a manner that preserves natural resources and avoids competition with the production of food and animal feed. Under the program, all crop residues and all crops with the exception of subsidized commodity crops (corn, soybeans, wheat, cotton, rice, etc.) and invasive or noxious plants are eligible. Biomass from virtually all cover crops is eligible, as well as the residue from the main crop. Projects are to be selected by USDA from applications made by groups of farmers together with a proposed biomass conversion facility.

Participating farmers can receive annual payments for five years for harvest of either annual or perennial biomass, and 75 percent cost share for establishment of perennials. Alternatively, the program will match up to $45 per ton of biomass sold for two years to help with the cost of biomass collection, harvest, storage, and transport to the facility, in effect greatly increasing the price earned for biomass. To qualify, participants must have an approved individual conservation or forest stewardship plan.

While BCAP could be a valuable incentive for trying out appropriate cover crop and crop rotation options for biomass, its success in launching sustainable biomass cropping is yet unknown. USDA handed the program to its Farm Service Agency (FSA), which got off to a rocky start when it launched only the matching payments part of BCAP without environmental review and few controls. After suspending the program in early 2010 and finalizing a rule later in the year, FSA is getting ready to re-launch the entire program. Participants will be required to submit conservation plans, but standards governing who will approve the plans are not yet known. Unfortunately, FSA's environmental review is poor for establishment and annual payments and still missing altogether for matching payments. With only two years of funding remaining, the program will be fully reconsidered as part of the 2012 Farm Bill.

Recommendation: *All BCAP participants should submit conservation plans for approval before receiving any funds. NRCS should be designated as the responsible agency for setting plan standards and approving plans according to its usual conservation planning standards. Congress should eliminate the subsidy for biomass collection and transport, on which FSA has already spent far more than Congress envisioned. The vast majority of available financing has gone towards subsidizing existing biomass feedstocks, thereby siphoning scarce resources intended to help establish new energy crops.*

Congress should also consider shifting implementation authority from FSA to NRCS to re-ground the program in its primary purpose of stimulating the establishment of sustainable biomass cropping systems. Funding should be extended only if the purposes of BCAP are being effectively achieved.

COOPERATIVE CONSERVATION PARTNERSHIP INITIATIVE (CCPI)

The 2008 Farm Bill set aside 6 percent of CSP, EQIP, and Wildlife Habitat Incentive Program funds to focus on local and regional conservation projects. NRCS State Conservationists will have roughly $90 million per year at their disposal for CCPI (and other) projects that they select to involve producers in implementing conservation programs. NRCS's national headquarters will have roughly $10 million for the same purpose.

With USDA's permission, program rules can be modified for participants to achieve unique objectives, as long as basic rules are maintained. For example, cover crops and crop rotations could be designated for EQIP in the project area. There can even be preferential enrollment in CSP, EQIP, and CRP for partnership participants. Biomass production from cover crops to feed into a local bioenergy facility should be a high priority in determining eligibility for CCPI.

Recommendation: *NRCS should continue to use CCPI to encourage projects that implement cover crops for biomass harvest and other similar cropping systems on row crops, and to organize farmers to cooperate with researchers to develop practices that maximize ecosystem benefits and minimize trade-offs. CCPI projects could be paired with BCAP projects so that the biomass incentives and conservation incentives could be combined.*

CONSERVATION COMPLIANCE

Conservation compliance requirements have been in place since the 1985 Farm Bill, requiring all who receive crop subsidies and many other USDA benefits to reduce erosion to a minimum level on their highly erodible commodity crop acres. Indeed, a quarter of the nation's cropland is covered by this requirement to have an individual conservation plan on file in the local NRCS office. Until a decade ago, compliance drove a significant reduction in erosion, but little progress has been made since then. Unfortunately, the program has been plagued by loopholes and lack of enforcement and will require serious reform, according to the Government Accountability Office (GAO-03-418). However, if rules and enforcement were bolstered, there would be a strong incentive for farmers to use cover crops and crop rotations to meet their erosion objectives and adopt practices that minimize the trade-offs inherent in harvesting for biomass.

Recommendations: *Congress should consider extending the reach of conservation compliance to cover excessive erosion on all crop acres and require that NRCS identify the regions, conditions, and practices that would allow cover crops for biomass production to provide erosion control, similar to other best practices. The use of "alternative conservation systems" should be rejected in favor of specific performance limits. Congress should require more inspections and drastically cut down on the number of waivers, now given to 80 percent of violators, and stop USDA payments to farmers in violation of the law. In addition, nutrient management should be required on all cropland receiving subsidies and insurance benefits. Any new biomass incentives should include conservation compliance (as the new BCAP does).*

COMPREHENSIVE CONSERVATION PLANNING

Though rarely used, conservation plans are effective tools for all farmers looking to improve the environmental performance of their lands. Conservation plans look simultaneously at soil, water, air, plants, and people to develop an integrated and profitable farming system adapted to the particular site in question. NRCS provides technical assistance to farmers wishing to develop such a plan, regardless of whether they participate in conservation incentive programs. Farmers and ranchers can receive technical and financial assistance for the development of a comprehensive conservation plan under CSP, or they can receive payment under EQIP for their planning activity and use the plan the following year to improve their application for CSP.

Recommendation: *NRCS should require comprehensive conservation plans for all farmers undertaking biomass production. CSP and EQIP, as well as technical assistance, should support such planning efforts by farmers. Conservation planning for biomass production can also be encouraged by requiring biomass conversion plants to obtain proof of an approved conservation plan from every farmer who sells them biomass. Private agronomists and crop advisors should be offered USDA training and certification so they can help farmers create conservation plans.*

OTHER INCENTIVES FOR COVER CROP BIOMASS FOR BIOENERGY PRODUCTION

The RFS is a major driver for the production of agricultural feedstocks for ethanol, biodiesel, and other biofuels to be blended into gasoline and biodiesel. Though much depends on aggressive implementation and enforcement by EPA, the RFS includes foundational sourcing safeguards and life-cycle GHG standards that aim to exclude the most damaging feedstocks and practices. However, to drive the adoption of biomass production practices that generate broad ecological benefits will require additional standards and incentives.

The biofuels industry currently reaps major financial incentives in the form of a blender's tax credit for corn ethanol and production tax credits for cellulosic biofuels, but these are blunt volume-based incentives that pay for production and not for the environmental benefits produced. Access to these incentives should be predicated on a broad set of minimum sustainability requirements, and payments should be directly based on environmental performance. Options should be explored for tasking feedstock buyers with purchasing only feedstocks produced in a sustainable manner. Requiring biofuel producers to obtain proof from supplying farmers of an NRCS-approved conservation plan before purchasing biomass feedstocks would be a step in the right direction. More narrowly, farmers could be required to disclose the rate of residue removal from their fields or report on their Soil Conditioning Index score as calculated by NRCS. The requirements should be feedstock neutral, so that farmers can work out the optimal production system for biomass on their farm.

Other options include paying farmers the net value of corn production for shifting to a less corn-intensive rotation, which could include the adoption of cover crops.[52] This policy would cushion producers from a steep drop in income and would allow them to ease into cellulosic production while the growing, transport, and processing issues are being resolved. However, land-use change could result if this system were widely adopted.

The concept of a nitrogen cap-and-trade program, in which farmers would be allowed a certain nitrogen quota and could sell any unused amounts, has also been discussed as a way of reducing the overall environmental impacts of agricultural production and encouraging the adoption of nitrogen-reducing practices such as the planting of leguminous cover crops. Some analysts emphasize that research on incentives should go hand-in-hand with research on cover crop utilization—as bioenergy, animal feed, or for other remunerated uses—because the utilization potential will serve as an incentive to adoption.[53]

Finally, if the adoption of cover crops results in concrete savings to the producer from reduced pesticide or herbicide needs, and/or if these crops can be managed in a way that results in increased yields in the regular season crop from better soil quality, the promise of higher overall income could act as an incentive. One study in Iowa looked at adding alfalfa, red clover, or other perennial forage species to corn/soybean rotations and found that a five-year rotation of corn-soybeans-oats/alfalfa-alfalfa-alfalfa resulted in a 24 percent net income gain to producers, both from input savings and from increased yield in the corn and soybean crops, compared with a five-year rotation of corn-soybeans.[54] If biomass prices reach anywhere near the value of hay for feed, the profit potential will be the same for biomass. The improved rotation looks different from the traditional cover crop system that is the focus of this report, but it is another example of a system that could provide environmental benefits as well as traditional food and feed crops.

CHAPTER 6

Research Priorities

Research dollars can be used to identify existing and new cover crops, crop mixes, or rotations with enhanced yield, environmental benefits, and energy conversion efficiency. They can also be used to develop best practices for cover cropping, to explore the environmental impacts of those practices under various conditions (especially the carbon-capture sequestration potential of various cropping systems), and to find ways to reduce farmer implementation costs.[55]

It is clear from farmer surveys such as those conducted by Singer et al. that a great deal more information about the benefits of cover cropping and the best means of implementation will have to be made available before producers will feel comfortable adopting the practice on a large scale. Long-term interdisciplinary research projects will be necessary to explore the interconnected and cascading effects on crop and soil communities.

OUTSTANDING RESEARCH QUESTIONS

A literature review and conversations with researchers working in the field yielded a number of critical topics for future research. They include:

- The establishment of a baseline for cover crop use in the United States;
- Research into sustainable, site-specific guidelines and practices for biomass removal that do not compromise the environmental/agronomic performance of the system;
- Research into the GHG emissions impact of different cover crop varieties, mixes, rotations, and management strategies, including research into the optimal harvest amounts of aboveground biomass from cover crops to avoid compromising soil organic matter and carbon sequestration potential;
- Further research into optimal biomass-producing cover crop varieties, crop mixes, or rotations and associated best management strategies;
- Research into the impact of cover crop harvesting on cash crop yields;

- Research into agronomic systems that reduce biomass production costs;
- Development of policy strategies to encourage farmers to adopt cover cropping;
- Development of models to estimate adoption potential and yield potential of cover crops and other cellulosic sources;
- Research into the development of products such as biofuels and animal feed from cover crops;
- Study of system-level effects, both economic and environmental, of cover crop production, including land-use changes;
- Development of a research clearinghouse so there is nationwide exchange of information, research, and demonstration experience. All research should have strong extension and outreach components and involve farmers as much as possible.

When research yields findings such as new plant varieties or cellulosic enzymes, these should be kept in the public domain, so that the public can benefit from publicly funded research without excessive licenses and technology fees.

CHAPTER 7

Conclusion: Cover Cropping Done Right and the Potential for Better Bioenergy

Traditional cover cropping has the potential to deliver multiple important conservation benefits. The presence of cover crops on land that would otherwise be bare could have large and positive impacts on factors such as soil erosion and nitrogen leaching. If done carefully, cover cropping also has the potential to provide biomass for bioenergy production without significantly impacting the availability of land to grow food and feed crops. However, second crop biomass will require careful evaluation of crop pairings, site specific soil and climate conditions, and management practices in order to be successful, and trade-offs are inevitable.

Our research suggests that the prospect of harvesting cover crops for biomass could provide the incentive needed to drive widespread adoption of sustainable cover cropping practices, under the right conditions and with significant investment into the research and development of sustainable systems. If conservation programs elevate and streamline access to financial and technical assistance for farmers to adopt cover crops and other rotations, this will help encourage farmers to consider sustainable biomass harvest.

However, how cover cropping is implemented is critical to the life-cycle environmental performance of a cropping system as a whole. It is important that a holistic approach be taken when assessing the costs and benefits of planting and harvesting cover crops. For example, if cover crops are managed only on the basis of maximizing yields, the practice could result in a net environmental loss. Scaling up the use of cover cropping as part of a multifunctional agricultural system will require a better understanding of the benefits and drawbacks of various cropping scenarios, the potential to develop new, innovative crop mixes and management techniques, and the policies needed to carefully manage the trade-offs.

Cover crops could be an important part of the portfolio of future alternative-energy options, if they are done right. The tools to ensure positive outcomes are, at this moment, still evolving. In certain parts of the country—for example, the Southeast, where warmer weather makes it easier to generate biomass from cover crops during the winter—harvesting cover crops could likely be done reasonably well even with today's technologies. In other regions, substantial innovation will be needed for cover crops to be cultivated and harvested sustainably without significantly impacting food, feed, and fiber production. This type of innovative research is well under way, but a major public investment in research and pilot projects is still needed.[56]

APPENDIX A

Estimating GHG Emissions for Cover Crop Scenarios

As discussed in the body of this report, double cropping for biomass may well lead to a reduction in yield from the summer crop. Furthermore, growing a winter crop for biomass yield is likely to result in more intensive management of the winter crop, possibly leading to higher GHG emissions per ton of biomass.

To make a ballpark estimate of the life-cycle GHG emissions of a corn/triticale pairing purely as an illustrative example, let us assume that the winter triticale crop will yield 3 tons of biomass per acre, that biofuel conversion technology will convert that fuel into 100 gallons of ethanol per ton, and that cultivating the winter crop has a GHG intensity similar to that of cultivating switchgrass. Let us also assume that cultivating the winter crop for biomass results in a reduction in the summer corn crop yield of 20 percent without any reduction in the GHG intensity of the summer crop. These values are chosen primarily for ease of calculations. They are not likely to be directionally wrong, but no one should assume that they are accurate.

The biomass crop is responsible for the emissions involved directly in its own cultivation, the emissions caused indirectly as land is converted due to increased pressure on supply from the reduction in yield of the summer crop (20% * 1.27 acres cleared per acre diverted * 4.7 Mg CO_2 equiv = 1.2 Mg CO_2 equiv per acre), and the increase in GHG intensity of the summer crop (20% * 2.7 Mg CO_2 equiv per hectare = 0.54 Mg CO_2 equiv per hectare). The table on the following page presents these values and the results. The bottom line is that in this example, the resulting 300 gallons of ethanol per acre would reduce GHG emissions by about 17 percent, compared with gasoline.

Table 2: Summary of Land-Use Change GHG Emissions Assumptions and Results

Baseline assumptions	Value	Unit	Source
Summer crop GHG intensity	2,703	kg CO_2 eq/ha	EBAMM 1.1
Gasoline GHG displacement rate	7,376	g CO_2 eq/gal etoh	GREET 1.7
Ethanol refinery stage emissions	70	g CO_2 eq/gal etoh	EBAMM 1.1 - 106 g/L coproduct benefit included
Values from Searchinger et al.	**Value**	**Unit**	**Source**
Displacement rate for corn to nonfood crop	1.27	acres cleared/acre of corn diverted	Searchinger et al.
Cleared land emissions rate	4,740,579	g CO_2 eq/acre (1/30 of 30-year value)	Searchinger et al.
Assumption for example corn/triticale	**Value**	**Unit**	**Source**
Winter crop GHG intensity	970.50	kg CO_2 eq/ha	EBAMM 1.1
Winter crop yield	3	dry tons/acre	
Conversion efficiency	100	gallons etoh/dry ton	
Summer crop yield reduction	20%		
Resulting emissions per acre	**Value**	**Unit**	**Notes**
Ag stage	611,527	g CO_2 eq/acre	= winter crop intensity + % summer crop yield reduction * summer crop intensity
Land use change	1,204,107	g CO_2 eq/acre	= % summer crop yield reduction * displacement rate for corn to nonfood * cleared land emissions rate
Refinery stage	20,943	g CO_2 eq/acre	
Gross fuel emissions	1,836,577	g CO_2 eq/acre	
Avoided gasoline emissions	–2,213,090	g CO_2 eq/acre	
Net emissions	–376,513	g CO_2 eq/acre	
% Change in life-cycle GHG emissions	–17%		

Building off this approach, we can explore a range of scenarios. For instance, under a best-case scenario, a farmer would harvest 5 tons of biomass per acre, displace only 10 percent of the summer crop yield, achieve very low overall crop GHG intensity, and the feedstock would be converted to 110 gallons per dry ton. This scenario would result in a 74 percent reduction in life-cycle GHG emissions, compared with gasoline. Conversely, in a worst-case scenario, a farmer would harvest only 2 tons of biomass per acre and displace 30 percent of the summer crop, and the conversion process would produce just 80 gallons per dry ton. This would result in an increase of 115 percent in life-cycle GHG emissions, compared to gasoline. The table on the next page presents a range of values from different scenarios, but the lesson is clear: a system in which cover crops are harvested for biomass could range from extremely beneficial to highly detrimental on a GHG basis, depending on how such a system is implemented.

Table 3: Summary of Land Use Change Emissions Assumptions and Results

Scenario summary (units the same as table on page 28)

	Best Case	Good	Poor	Worst Case	No Yield Reduction
Cover crop yield (tons/acre)	5	4	3	2	3
Conversion efficiency (gallons etoh/dry ton)	110	100	90	80	100
% Reduction in summer corn crop yield	10%	15%	20%	30%	0%
Ag stage emissions (g CO_2 eq/acre)	400,000	556,833	611,527	720,917	392,749
% Change in life-cycle GHG emissions	–74.4%	–49.6%	–7.9%	115.0%	–81.3%

As these tables illustrate, the summer corn crop displacement rate is by far the most important variable in this model. This is in part because displacement of the summer crop through reduced yield makes the cover crop responsible for a portion of the summer crop's GHG intensity. It is possible that this factor could be addressed through careful and innovative cropping practices that reduce the GHG intensity of the two crops—the cash crop and the cover crop—together as a system.

However, the larger role of displacement is in causing ILUC as the agricultural market tries to reach equilibrium again. This suggests that if we include ILUC emissions in our life-cycle analysis and assume that the Searchinger et al. analysis is accurate, we should utilize the combined winter and summer crop system more intensively in order to reduce the system's impact on summer crop yields. Many might counter that the water and soil quality impacts of intensification should be factored in and would argue for accepting slightly higher life-cycle GHG emissions for the resulting fuel in exchange for lower impacts in these other areas. As discussed in the body of this paper, understanding these trade-offs and developing crops and cropping practices that minimize trade-offs and maximize benefits should be priority research areas for public and private funding.

Endnotes

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