DRAFT

Conservation Issue Brief

Resource Effects of Biomass Energy Production

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Key Points:

- Biomass has the potential to help meet US energy needs but there are potential environmental trade-offs
- What, where and how biomass is grown will determine it's environmental impact
- Crop residues provide ecosystem services; their harvest could increase erosion and decrease soil organic matter.
- Switchgrass and other herbaceous perennial crops provide better wildlife habitat than annual crops
- Perennial biomass crops have erosion problems in their first year(s) but, with additional conservation measures, any negative impacts could be mitigated.
- Guidelines for biomass harvest are needed.

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Issue

Concerns about the security and sustainability of fossil fuel use are important drivers in the search for cleaner burning fuels that can be produced from renewable agricultural enterprises. Recent advances in biomass conversion technologies have increased interest in biomass feedstocks to produce fuels and electricity to partially meet US energy needs (Glassner et al., 1999). At present, biomass energy provides only about 4% of the total energy used in the US. By contrast, fossil fuels accounted for approximately 80% of US energy use in 2005.

Renewable energy from biomass has the potential to reduce dependency on fossil fuels. In the next few years, significant improvements in biomass fermentation are expected. Recent advances in fermentation technology allow cellulose and lignin (the primary components of plant stems, stalks and woody material) to be pretreated with specific enzymes for conversion to ethanol. Once technology is in place to produce ethanol from cellulosic materials, such as crop residues, switchgrass, or short-rotation tree species, it may be more efficient and cleaner feedstock than grain ethanol (Table 1). President Bush's 2006 State of the Union Address specifically targeted alternative sources for ethanol fermentation (wood chips, stalks and switchgrass) for practicality and competitive pricing within the next six years.

Table 1. Comparison of Corn Grain Ethanol and Corn Stover Ethanol.

Ethanol Feedstock	Net Energy Balance* (e_{EtOH} - $e_{production}$)	Percent reduction in GHG emissions/vehicle mile** E10	E85
Corn grain	25,000 Btu/gal	2%	25%
Corn stover	60,000 Btu/gal	9%	79%

*Net Energy Balance is estimated as the energy contained in 1 gallon of ethanol minus the energy required to produce it.
**Estimates of greenhouse gas (GHG) emissions from E10 (90:10 gasoline:ethanol) and E85 (15:85 gasoline:ethanol) as compared with conventional gasoline (Wang et al., 1999, as cited in DiPardo, 2000).

Natural Resource Trends

Three types of cellulosic feedstocks (crop residues, grasses and woody biomass) have a great deal of attention and interest by researchers, government and industry. The environmental trade-offs of increased use of these materials as bioenergy feedstocks depends on how they are grown and harvested, and where on the landscape they are produced.

CROP RESIDUES

The low-cost and abundance of harvesting crop residues make them competitive as gasoline additives. The eight leading U.S. crops produce more than 500 million tons of residue each year. Corn, and to a lesser extent wheat, is receiving the most attention as a potential biomass feedstock. This is due to its concentrated production area and because it produces 1.7 times more residue (or stover) than other leading cereals, based on current production levels (Wilhelm et al., 2004). There is also sufficient quantity to support commercial scale production (DiPardo, 2000). However, removing crop residues for bioenergy use can have a negative effect on natural resource quality. Crop residues perform many positive functions for agricultural ecosystems including:

- **Protecting soil from erosion**, thereby maintaining water and air quality by reducing runoff and sediment (via reduced water-induced soil erosion) and air-borne particulates (through decreased wind erosion).
- **Increasing or maintaining soil organic matter and nutrients**, leading to improved soil and water quality
- **Maintaining beneficial soil organisms and providing wildlife habitat**; and
- **Improving plant-available water and drought resistance,** potentially increasing yields (adapted from Hargrove, 1991).

It is widely recognized that improper residue removal has the potential to degrade natural resources (e.g., Wilhelm et al, 2004). Despite the broad recognition of the need for specific guidelines for residue removal to avoid environmental degradation, none yet exist. In a recent review, Mann et al. (2002) concluded that more information was needed on the long term effects of residue harvest, including its impact on: 1) water quality; 2) soil biota; 3) transformations of different forms of soil organic carbon (SOC); and 4) subsoil SOC dynamics. However, existing research and modeling tools can likely be used to guide practices to a great extent (Table 2), especially for corn stover harvest in the Corn Belt, where it has been studied most extensively. Current USDA-NRCS practice standards for residue management do not specify

Table 2. General Guidelines for sustainable residue harvest:

Sustainable harvest amounts will vary by:	Residue harvest rates should DECREASE with:	Recommendations for sustainable residue harvest:
Management practice	Increased soil disturbance	Use no-till with cover crops
Crop & yield	Lower yield or lower C:N	Harvest high residue crops and only in good yield years
Climate	Warmer, wetter climate	Residue harvest in the US SE is high-risk
Soil type	Coarser soil texture	Heavy clay, poorly drained soils are good candidates
Topography	Greater slope	Use a variable rate harvester or keep off hillsides and eroded knolls

residue quantities but do suggest the use of the RUSLE2 model for guidance (USDA-NRCS, 2005). In the future, specific guidelines for residue harvest could be developed to prevent soil degradation resulting from over-harvest of crop residue, partially based on modeling results from RUSLE2 and the Soil Conditioning Index (SCI).

GRASSES

Biomass derived from forage grasses, such as switchgrass, could provide a valuable source of feedstock for renewable energy. Switchgrass is a sod-forming native perennial with a wide geographic distribution and high potential yields (see Figure 1). Other species such as big and little bluestem, indiangrass, Illinois bundleflower and perennial mixtures also show promise as biomass feedstocks.

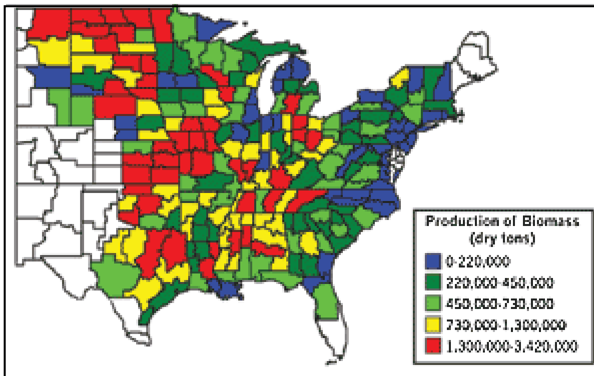


Figure 1. US Energy Crop potential for dryland switchgrass production.
Walsh et al., 1999. Available online at: bioenergy.ornl.gov/papers/wagin/index.html

Switchgrass was commonly planted in Conservation Reserve Program (CRP) fields and buffers in the Midwest because of its availability, demonstrated effectiveness at filtering agricultural contaminants, and anticipated wildlife benefits. In addition to these benefits, switchgrass has the potential to store significant amounts of soil C due to its extensive and deep root system. Research has shown that approximately 5 years after establishment, 19 to 31% of the existing soil organic carbon stores were derived from new carbon inputs from switchgrass (Garten and Wullschleger 2000). Properly managed CRP fields can also provide critical habitat for grassland wildlife (Heard et al., 2000).

With interest in harvesting switchgrass for bioenergy production, which is not currently allowed under CRP, questions arise about the effects on wildlife. Establishment, maintenance, and harvest procedures of switchgrass fields established for maximum biomass production would differ somewhat from switchgrass fields managed for multiple purposes. Switchgrass fields established for production of biomass fuels would: have heavier recommended seeding rates; need annual applications of nitrogen with occasional applications of phosphorous, potassium, lime and herbicides,; and require careful management with respect to harvest timing, harvest heights, and plant moisture content at harvest. These changes could potentially affect soil and water quality as well as wildlife habitat.

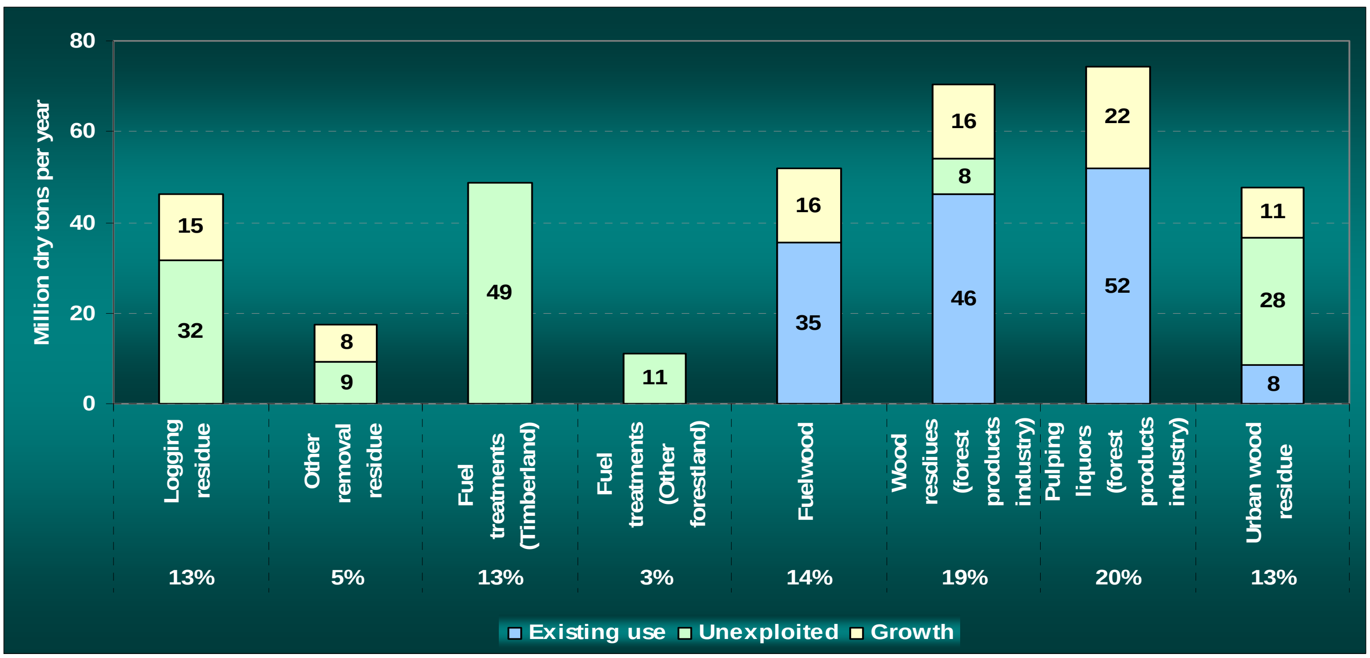
Studies of birds in Midwestern CRP have documented use of switchgrass fields by many birds of conservation concern. An assessment of how harvesting switchgrass cover from CRP fields affected breeding grassland birds, determined that total abundance of birds was similar in unharvested, partial and complete harvest treatments. However, the abundance of individual species did vary among treatments. For example, birds that prefer shorter, sparser vegetation, were most abundant in fields that were completely harvested. Conversely, species that prefer relatively dense vegetation were more abundant in unharvested fields. Although the overall rate of nest failure exceeded 50 percent, the researchers projected that nesting success in harvested switchgrass fields was adequate to support stable populations of grassland birds.

Grasslands are disturbance-adapted systems. In the absence of disturbance, such as fire or harvest, the attractiveness and productivity of fields for grassland-dependent wildlife declines. Conversely, frequent or poorly- timed disturbances may limit bird use of grasslands. Research indicates that a landscape that includes harvested switchgrass would support a diverse grassland bird community. Harvest of switchgrass outside of the nesting season minimizes risks to nesting birds, but may reduce winter cover for some species (e.g., pheasants).

WOODY BIOMASS

Woody biomass is increasingly being grown for energy and biomass products. Most often this implies the use of short-rotation, dedicated plantations of rapidly-growing forest crops such as hybrid poplar, willow, sweetgum or eucalyptus. Even though single-species tree crops of an even age may lack the diversity of natural forests, research shows that they can support a diverse assemblage of bird species. However, other research indicates that short-rotation woody crops may result in high erosion and runoff rates during the first year(s) of establishment.

Figure 2. The Sustainable Forest Resource Potential Is Nearly 370 Million Dry Tons Annually



Presented by Bryce Stokes (2005) – USDA FS R&D "Based on Billion-Ton Vision Report"

Woody biomass is a very low value product compared to lumber, veneer, pulpwood and poles. Transportation for delivering from the supply site to the wood combustion or processing unit is the primary expense of woody biomass. Therefore, alternative forest biomass including harvesting and thinning residues, thinning from hazardous fuel reduction and habitat improvement and other ecosystem restoration projects, totaling 370 million dry tons annually (Figure 2), could also be considered for biomass feedstock production. Normal residue harvesting practices remove only portions of the branches and tops, leaving sufficient biomass in the forest to conserve soil organic matter and nutrients as well as maintain yields. Thus, in practice, biomass harvesting may be no less environmentally sustaining than conventional harvesting.

Woody biomass use could cause an increase in the area of plantation forests. This is generally considered to be acceptable if plantations are created from agricultural land, but if converted from natural forests, would alter wildlife habitat and other environmental benefits associated with forests. With conservation in mind, the use of wood for energy can be efficient, economical and environmentally sustainable.

Conservation Measures

HARVEST GUIDELINES

Because crop residues and perennial crops perform important ecosystem services, sustainable harvest rates are critical, which can be accomplished through site specific management. To maintain farmer economic requirements, a component of sustainability, most agree that one-pass harvest for grain and stover must become a reality (DOE, 2003). One-pass harvesters (Figure 3) must also allow for variable harvest rates to account for changing conditions within the field, like hillsides, to avoid increased soil erosion, organic matter loss and reduced wildlife use of croplands. For perennials crops, harvest times and amounts will need to include wildlife habitat considerations, such as nesting seasons, to enhance or maintain wildlife populations.


Figure 3. One-pass harvester for corn grain and stover. G.R. Quick, Iowa State University

ADDING CONSERVATION PRACTICES

Including additional conservation practices that control erosion and increase soil organic matter will help alleviate negative effects of crop residue harvest. Cover crops, in particular, can protect soil from erosion and add organic matter and nutrients while potentially offsetting any negative effects of residue harvest or perennial crop establishment. During the first year(s) of establishment, perennial crops often have elevated soil erosion rates. Even perennials crops would benefit from additional conservation practices, such as planting crops??, using mulches and installing buffers to reduce erosion during establishment.

OPTIMIZING INPUTS

Applying nutrients should be done by following soil test recommendations and following a nutrient management plan. Pesticides should be applied following a pest management plan using mitigation for any high risk pesticides. Optimizing or minimizing application of fertilizers and herbicides will benefit wildlife as well as soil, water and air quality. Although the benefits of fertilizer application for switchgrass production are clear, the resulting tall, dense stands may reduce use by some grassland birds. Monocultures of switchgrass (or other grass species) would reduce their attractiveness for many birds of conservation interest but are likely to be necessary to produce quality bioenergy feedstock. Monocultures will probably be maintained by application of broad-leaf herbicides. Over-application of fertilizers or pesticides will also degrade soils and potentially reduce water and air quality, regardless of crop grown.

PERIODIC MONITORING

Regardless of the residue removal practice chosen, fields should be carefully monitored for visual signs of erosion or crusting. Periodic checks of soil carbon as part of soil testing are also recommended. Removal rates should be adjusted in response to adverse changes: if erosion increases or carbon decreases, removal rates must be reduced to maintain soil quality. Similar monitoring efforts for targeted wildlife species may be useful in perennial cropping areas to determine if adjustments to harvest timing and stubble height are needed.

Figure 4. Growers in switchgrass field. Photo: Warren Gretz, NREL

GROWING PERENNIAL CROPS

In the long term, perennial crops are likely to be a more viable option than crop residues as biomass feedstocks. Dedicated perennial energy crops can improve soil quality by reducing disturbance and increasing soil organic matter via their extensive root systems. Perennials typically use less energy than row crops because they need less fertilizer and pesticide and fewer field passes. These benefits translate to improvements in water and air quality via reduced water erosion and runoff and less wind erosion and overspray. Longer potential harvest windows may allow avoidance of nesting or breeding seasons, which can benefit wildlife.

CHANGING LAND USE

Increased use of perennial crops dedicated for use as energy crops could unintentionally increase the overall area of cropland. Such increases in the demand for land could mean conversion of natural forests, wetlands or native prairie to crop production and negatively alter wildlife habitat and other environmental benefits associated with those ecosystems. On the other hand, if biomass can be grown on existing agricultural land, especially on marginal lands, such as highly erodible land (HEL), poorly drained soils or areas used for wastewater reclamation, pressure on existing crop acreage would be reduced. In fact, Paine et al. (1996) recommended growing these crops on such land, avoiding competition with food crops and effectively increasing the amount of arable land. A large amount of land in the Corn Belt is classified as HEL (Wilhelm et al., 2004), presumably making this land unsuitable for residue removal but potentially viable for dedicated energy crop production. Also changes in the provisions of CRP, allowing for commercial harvest of perennials, would facilitate biomass production without net gain of farmed acreage.

Economic Considerations

The effects of residue removal on short-term yields are well-studied, while long-term effects are less understood. If crop residue removal results in increased erosion, reduced SOM and nutrient levels, and lower biotic activity, yield is very likely to be suppressed as well (unless inputs are increased, thereby reducing profits and increasing pollution risk). Other potential economic trade-offs to residue removal, include higher fertilizer costs and higher fuel costs with more field passes. Storage and transportation costs of the residue to processing sites also must be considered. Reduced soil quality and SOM may also preclude participation in carbon trading markets and in some USDA conservation programs, such as Conservation Security Program, which uses SOM trend as a gatekeeper for participation. Both short and long-term effects need to be considered when making a determination about residue removal.

On a larger scale, the economic value of any potential environmental degradation due to the harvest of residue for alternative fuel use has to be weighed against the value of the potential environmental and economic benefits realized by fossil fuel offsets and new markets for biomass. One environmental benefit is that cleaner burning fuels reduce the amount of carbon monoxide from vehicle emissions that are a concern for global warming.

For dedicated, perennial energy crops, the key economic consideration from the producer perspective is market demand. Uncertaintly in the market poses great risk for the producer. However, if switchgrass is harvested from marginal land already in set-aside programs, financial risk will be reduced. Potential environmental benefits gained through use of these crops for bioenergy production, coupled with the potential economic gain realized by producers, make their use attractive.

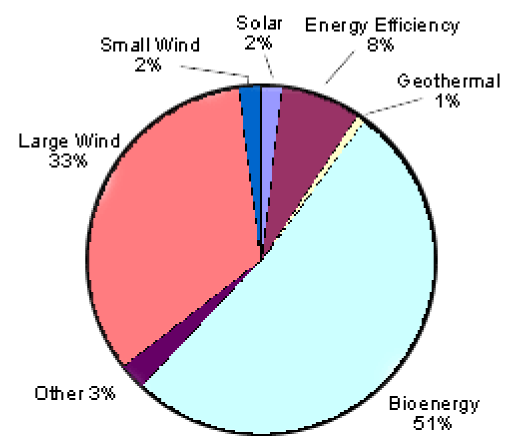
The costs of converting any feedstock to a usable fuel is a major hurdle. At this time, it does not appear that it is economical for a fuel production facility to procure, collect, transport, store, and convert these feedstocks into usable fuel products. Currently, industry seems to favor crop residues because is the most readily available at the lowest cost. From a social perspective, it would be desirable if all options be reviewed for their potential to yield the greatest total environmental AND economic benefits for society.

Funding

The Energy Title of the 2002 Farm Bill authorized $23 million in annual mandatory funding for Section 9006, a program to help farmers, ranchers and rural small businesses offset some of the costs of renewable energy and energy efficiency projects (Figure 5). The US Department of Agriculture (USDA) is also funding a number of projects under the Biomass Research and Development Initiative (a joint effort DOE and USDA) that specifically target harvest, pre-treatment or related issues for bioenergy production. The DOE, through both their portion of the Initiative and well as their 'SynGas' and 'Sugar' research platforms, is funding or leading a number of projects examining novel conversion technologies for cellulosic materials. However, very few of these projects consider the natural resource conservation implications of their work.

Figure 5.

Breakdown of Section 9006 Funding, 2003-2004



Union of Concerned Scientists, 2005

Challenges

These biomass feedstocks are attractive in that they not only produce an alternative energy source, but also may lessen dependence on foreign oil, spur rural economies, and (in some cases) improve the environment. Considering the size of the potential bioenergy market, a considerable land base could be affected. On balance, perennial energy crops seem to have a primarily positive effect on the environment, while harvesting crop residues have greater potential for resource degradation. All biomass options have two main challenges:

1) **development of sustainable harvest strategies** (emphasizing appropriate rates and timing) and 2) **application of additional conservation practices** to offset erosion and loss of organic matter and nutrients.

Because crop residues and perennials perform important ecosystem services, their sustainable use will only be accomplished through the use of site-specific production and harvest guidelines. For crop residues in particular, sustainable removal rates will vary by factors such as management practice, crop yield, climate, topography, soil type and existing soil quality. Therefore, a simple decision tool could be developed to help determine harvestable rates. Tools like RUSLE2, WEQ, and the Soil Conditioning Index (SCI) are likely to be the most practical ways to predict safe removal rates. An expert system could be developed based on model runs using simple user inputs such as zip code, crop, soil texture, and slope. (However, any guidelines based on models should be validated by field observations.) For perennials, guidelines must consider erosion control and wildlife management. Guidelines, developed or endorsed by USDA, that outline these conservation measures would help to ensure that natural resource quality is not sacrificed in the name of renewable biomass energy.

Data Sources

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