Chapter 4

Using native warm-season grasses for biofuels

Since gasoline prices escalated in the early 1970s, interest has grown in finding cost-effective and environmentally friendly alternatives to address the transportation liquid fuel needs of the United States. A key area in developing renewable energy sources has been organic materials, such as wood, crop residues and dedicated perennial crops. Several years of research by the U.S. Department of Energy led to the identification of two particularly promising crops: hybrid poplars and switchgrass. A 10-year research program focused on establishment, fertilization and harvest management of switchgrass began in 1993.

Fig 4.1 Switchgrass has received considerable attention for its potential as a biofuel. Single harvests made after the first frost are generally recommended, but the possibility of using an initial harvest in mid- to late May for hay, then a final harvest for biomass is being evaluated.

More recent oil shortages and political instability in key oil-producing regions have brought these issues back into focus. Of the four major energy sources in the United States (petroleum, coal, natural gas and nuclear), petroleum is used most (> 39 percent) and is especially important for transportation, with 97 percent of all transportation fuels petroleum-based. Another issue with petroleum is that approximately 45 percent of all U.S. domestic consumption is imported (the U.S. is a net exporter of all other energy sources), accounting for a substantial portion of our foreign trade deficit. Further complicating the almost complete dependence of transportation in the U.S. on imported oil is the politically sensitive nature of that supply (Venezuela and the Arabian Gulf region).

The greatest potential for switchgrass as a biofuel, therefore, is as a liquid fuel in the form of ethanol. Ethanol has been demonstrated to work in modern engines and can be blended with gasoline, typically either at a low level, 10 percent (E10), or in nearly pure form, 85 percent (E85). Ethanol has been used successfully in the U.S. (corn-based) and most notably in Brazil, where 4.4 billion gallons of sugar cane-based production were used as a gasoline replacement in 2005, representing about 40 percent of that country's non-diesel fuels. Furthermore, ethanol produces fewer carbon emissions, making it less of a problem from a global climate change perspective.

Burton English

Fig. 4.2 This pyrolysis unit is responsible for converting plant matter into bio-oil using heat in the absence of oxygen.

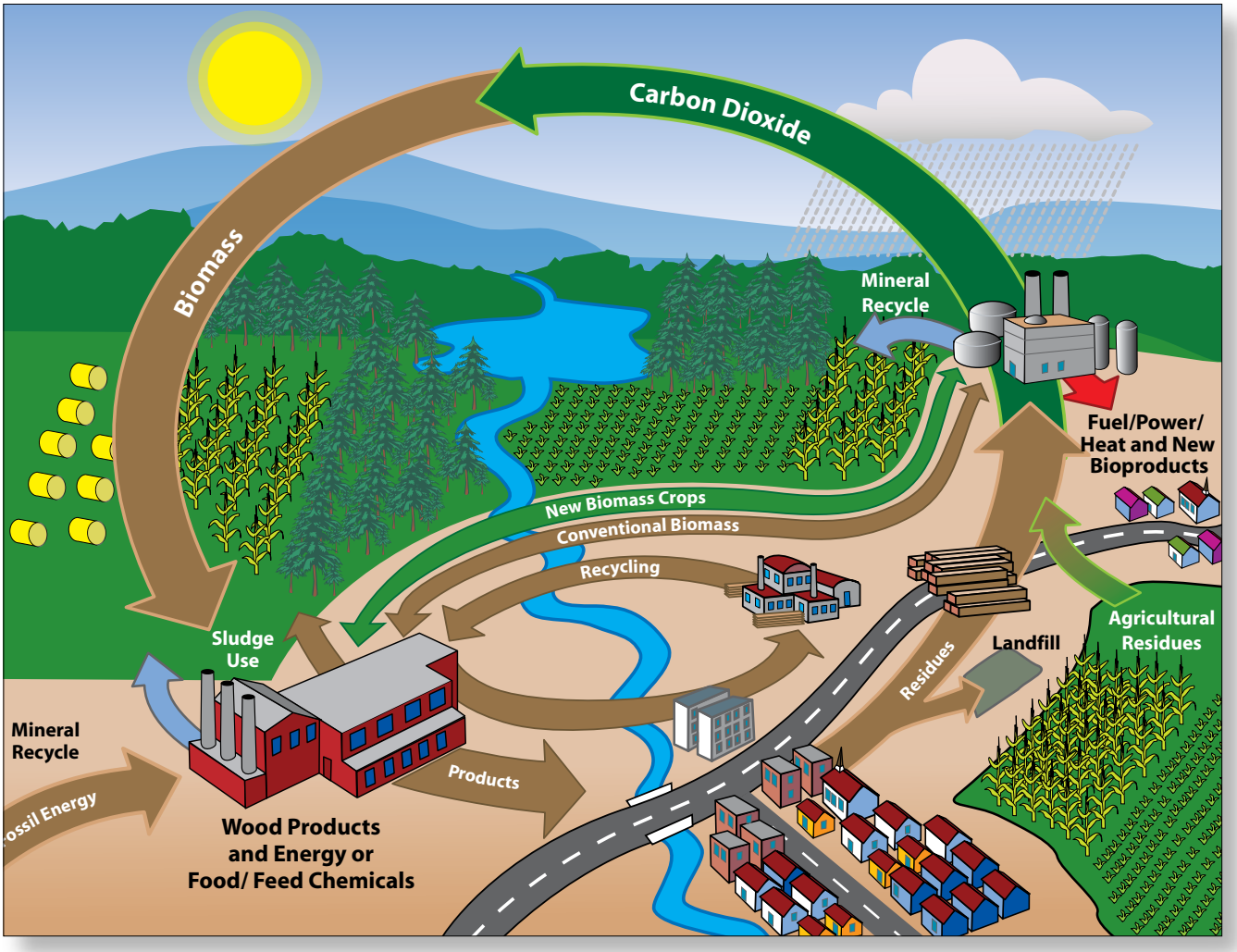

Image adapted from the US Department of Energy.

Fig. 4.3 In a robust bioeconomy, agricultural feedstocks join with municipal residues as energy sources, while sludges are used to feed agricultural crops.

A recent Department of Energy study conducted at Oak Ridge National Laboratory evaluated U.S. supplies of biofuel feedstocks to determine if there were enough to replace 30 percent of our current petroleum consumption. That goal, set by a Congressional panel, would require the production of 1 billion tons of dry matter on an annual basis. Published in 2005, this study identified numerous sources of possible biofuels from forestlands that would account for 368 million dry tons per year and about 1 billion tons from agricultural lands, all without compromising current food production levels. Much of the agricultural contribution (428 million dry tons) would come from crop residues, but a substantial portion (377 million dry tons) would come from dedicated perennial crops, most notably switchgrass. This same report concluded about 55 million acres of cropland would need to be converted to produce that much switchgrass. Another study indicated that if the nation were to achieve 25 percent renewable energy by the year 2025, 105 million acres of dedicated energy crops might be needed, requiring nearly 1.2 billion tons of cellulose, corn grain and soybeans as feedstocks for energy production.

Despite the focus on ethanol, switchgrass can also be used for energy generation through direct combustion. Typically, baled or pre-processed switchgrass would be burned along with coal, natural gas or other primary fuels. In some cases, an entire plant could run off switchgrass with another fuel source as back-up. This area has not received as much attention as cellulosic ethanol because of transportation costs, potential impacts on plant operations, storage issues and the fact that there are sufficient supplies of coal within the nation. However, at a small scale in plants less than 250 megawatts, co-firing of biomass with coal may be feasible. For instance, smaller cogeneration facilities (< 100 tons per year) at existing industrial sites are exploring switchgrass as an alternative to coal and natural gas.

Production of switchgrass for biofuels

Switchgrass has been considered an excellent species for biofuels production because of its wide adaptation, low inputs, ability to grow on poor soils, limited problems with pests and relatively high biomass yield. During the 1990s, much was learned about switchgrass production through extensive studies across the species' range. Numerous varieties were examined for production potential, with a lowland variety developed in Texas (*Alamo*) considered best because of high yields (5 – 8 dry tons per acre based on a 1992 study with 18 field sites in 13 states). *Alamo* grows well throughout most of the South, though it may suffer damage from extreme cold in the central Appalachians and upper parts of the Corn Belt. In the Mid-South, this is rarely a problem. Although best adapted to alluvial soils, *Alamo* does well on upland sites and, like all varieties of switchgrass, is very drought-tolerant. *Alamo* exhibits little problem with seed dormancy, a serious concern with *Cave-in-Rock*, another upland variety with high yields that can be used in more northerly climates where cold hardiness is a concern.

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Fig. 4.4 The only way to get an accurate estimate on biomass, whether for biofuels or hay, is to weigh several bales on certified scales and get an average. Guessing the weight of hay bales is usually erroneous (most often to the positive side!).

Establishment of switchgrass is straightforward and can be readily accomplished by following the guidelines presented in Chapter 5. Because a basic goal of stands established for biofuels is to maximize tonnage, seed should be drilled at 8 pounds PLS per acre. Minor increases or decreases in planting rate will not affect yield appreciably.

Once switchgrass is established, little management is needed over the life of the stand. Evidence suggests stands should last at least 15 years with proper fertilization and harvest. About 60 pounds per acre of N applied early in the growing season will provide high yields. However, if the stand is not well-established, no more than 40 pounds of N should be applied. Because of the growth habit of switchgrass (typical of all nwsg), there is a high rate of below-ground biomass accumulation (five tons per acre during the first 10 years post-establishment). This high amount of soil organic matter may reduce required N fertilization in more mature stands. Nitrogen should not be applied in the establishment year (or during the fall prior to establishment) as discussed in Chapter 5. During the second year, N may be applied, but only if competition is under control, and at a reduced rate (no more than 40 pounds per acre).

Harvesting switchgrass for biofuels

Most work on switchgrass harvest regimes for biofuel production indicates there should be only one annual cutting. More frequent cuttings tend to reduce stand vigor and reduce yields in subsequent years. Frequent cuttings also require increased harvesting, handling and storage costs versus a single-entry system for little or no improvement in yield. The single harvest should occur post-dormancy, because carbohydrate and mineral content, especially N, is reduced as they have translocated back to the root system, resulting in higher-quality feedstocks with fewer processing concerns. Elevated N and mineral content associated with a mid-summer initial harvest is another reason why two-cut systems are less desirable for biofuel production. Moisture content is also reduced in post-dormancy harvests, making transportation and storage easier.

Although timing the single cut after the first frost is desirable, there are trade-offs in delaying harvest even as late as the following spring. While biomass decreases over the winter, mineral (and therefore ash) and moisture contents decline also. It is worth noting that the loss of biomass is mostly a result of the grasses falling over and being missed during harvest. Nonetheless, producers can delay harvest for several months beyond the first frost if there are storage or time constraints, market conditions are more favorable later and/or maintaining wildlife cover over the winter are important considerations.

Where dormant-season harvests are implemented, cutting height is not as critical as with forage stands (see Chapter 3). Once all carbohydrate reserves have moved back into the root system and active photosynthesis has ceased, there is little production benefit to higher cutting heights

needed for growing-season harvests. Nonetheless, retaining stubble heights greater than 6 inches during winter harvests can provide shoot protection for stands that may be grazed the following summer.

Square baling is the preferable harvest method, because it allows more efficient loading, greater density and reduced transport costs. However, a square baler is more expensive than a round baler. Tradeoffs between large round bales and square bales need to be considered carefully. Research is examining ways to reduce bulk through compression of bales or in-field chopping. Limited space at conversion facilities may require storage of harvested switchgrass, either on the farm or at satellite concentration yards, not unlike those used by the pulp and paper industry for pulpwood.

Alternative management strategies

Because of the current uncertainties regarding future biofuels markets for switchgrass, producers should remain flexible. The ability to manage native grass for forage and biofuels, wildlife habitat and biofuels, or perhaps all three is most desirable. One of the attractive aspects of planting native grasses is the possibility to manage for a variety of objectives within the same stand. Therefore, producers should consider a few options before stand establishment.

Fig. 4.5 Value for wildlife is much greater in a mixed stand of native grasses and forbs than a monoculture grass stand. In 2006, a study in Minnesota (Tillman and others 2006) suggested biomass generated from a mixed native grass stand was greater than that from pure switchgrass stands.

Selection of grass species other than switchgrass can enhance the forage and wildlife habitat value of the stand. A recent study indicated mixed species stands produced more net energy than switchgrass monocultures, albeit their study focused on relatively poor sites unlikely to be used for agriculture. In addition, species such as big bluestem and indiangrass may actually yield more than switchgrass in terms of net energy production, because they may be easier to convert to ethanol through existing digestion processes. Furthermore, recent developments in the production of ethanol from cellulose suggest processes can be developed that will not require single-species feedstocks for conversion. Together, these notions suggest that not only may mixed stands be acceptable, but they may even be preferable. At this point, there is some question about which ethanol conversion process will be developed and how that may be able to handle mixed-species stands. Also, more work is needed to determine the acceptable range of variation in feedstocks for firing in cogeneration applications. A high degree of consistency is usually needed, but to what extent, including whether a second or third species of grass in a feedstock will vary the firing properties of the feedstock, is not known.

Producers should consider developing integrated management approaches that allow flexibility to shift production between livestock forage and biofuels in response to markets or seasonal needs (such as drought years when cool-season grass hay is unavailable). As discussed in Chapter 3, nwsg, including switchgrass, can produce high-quality forages. Early-season production (late April–mid-May for switchgrass) produces the highest-quality forage and can be easily diverted for forage either through haying or controlled grazing. The later the forage is harvested, the greater reduction there will be in the final biofuel harvest for that season. Most biomass accumulation in switchgrass occurs during the first half of the growing season. Harvests approaching July 1 will result in substantial reductions in a final post-dormancy harvest. Obviously, delaying the forage harvest too late (past late-boot stage) would be counterproductive for forage production because of deterioration in forage quality in the maturing stand.

Unlike dormant-season harvests, these early-forage harvests (haying or grazing) should leave a minimum 6- to 8-inch residual height to ensure rapid regrowth and an adequate final biofuels harvest. Past research has indicated two-cut systems tend to reduce total biomass production in switchgrass stands over time. However, these studies have generally evaluated a relatively late first harvest and may not have left appropriate residual heights, which resulted in reduced regrowth. Some studies have also shown an increased yield under two cuts. A study is being imple-

Fig. 4.6 Although not nearly as bad as perennial cool-season grasses, the structure at ground level of a pure stand of switchgrass is relatively poor for brooding quail and turkeys. A lack of forbs really minimizes the value of these stands for wildlife.

mented at the University of Tennessee to address some of these questions. In any case, depending on biofuel markets and forage needs, a modest total reduction in yield may not be a problem. With a two-cut system, application of N should be split: half applied per the recommendations above and half 2 – 3 weeks after the first harvest.

For producers interested in wildlife, strategies to enhance wildlife habitat in a biofuel production stand include delayed winter harvest (to retain winter cover) and rotating harvest so that some fields or portions of fields

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Fig. 4.7 If left standing through winter before cutting, switchgrass grown for biofuel can provide winter cover for several wildlife species. .

are harvested only once per 2 – 3 years. Annual entire fall harvests leave no winter or nesting cover; whereas, partial or rotational harvests retain some cover for wildlife. Other methods to enhance wildlife habitat value include leaving buffers and/or fallow strips within and/or around fields and possibly grazing or haying. The important thing for producers to recognize is **high density and largely forb-free grasses provide only marginal wildlife habitat (similar to rank fields of tall fescue)**. This certainly applies to biofuel stands. For more information on incorporating wildlife habitat in nwsg, see Chapter 2.

The future

It is important to realize that while the area of biomass-based fuels seems very promising, those markets have not yet developed in any appreciable way outside of the Corn Belt where ethanol production has become established. While conversion of corn and sugar cane to ethanol is fairly straightforward, commercial-scale processes for conversion of cellulosic materials to sugar have not yet been developed. On the other hand, there have been some promising breakthroughs at the laboratory scale, and in 2007-08, a pilot-scale cellulosic ethanol plant will be built in East Tennessee. Direct-combustion markets will likely remain viable only at smaller-scale, co-generation facilities in the near term. Existing larger facilities would need substantial capital modifications for storage, handling, pre-processing and combustion to handle appreciable amounts of biofuels. Until substantial and cost-effective feedstocks are available, it is unlikely such capital investments will be made.

This combination of the substantial potential and currently non-existent markets suggests producers begin to move into native grass production at this time at a modest scale. The most logical pathway into production over the next few years is to gain experience establishing and managing native grasses, while using the material produced as forage for beef cattle. This would shift the harvest strategy from a single late-season harvest to one focused on optimal forage production (see Chapter 3 for details on forage harvesting). As biofuel markets develop, some or all of the forage could be diverted into that use.