Switchgrass as a biofuel

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Brief report, moderate no. of references - for quick use / overview, mainly pointing out issues to study and develop, esp. for NM
(Put in pictures, graphs)

Quick introduction

Switchgrass (Fig. 1) is a perennial grass that can grow in most states of the US. Its attractiveness as an alternative energy source stems from its renewability, good net energy yield (see below), generally favorable impact on life-cycle greenhouse gas (GHG) emissions relative to fossil fuels, wide environmental tolerances, and harvestability with standard farming equipment. Its negative impacts include high land use per unit power provided (with consequent impacts on habitats and biodiversity), continuation of crop-derived water pollution, and some particulate air pollution, depending on mode of usage. One more impact, if the grass is grown in drier areas, is high consumption of water (relative to non-crop alternative of wind, solar, or nuclear power). The most promising avenue appears to be conversion of its cellulosic biomass to ethanol using advanced / synthetic enzymes. Some unique challenges exist in control of pests, diseases, weeds, and fire, while common agronomic practices might be adapted to deal with many of these. Another challenge is transportation cost, in energy and dollars, from point of growth to point of use. Biomass farms may be located at significant distances from conversion points as ethanol production facilities or powerplants.

Fig. 1. Stand of switchgrass. U.S. Govt. photo from Wikimedia Commons.

Biology and agronomic practices

Botany. Switchgrass, *Panicum virgatum*, is a warm-season perennial grass native to North America, growing from southern Canada into Mexico. The mature plant commonly attains a height of 60 to 150 cm (2 to 5 ft.), with extremes to 220 cm (8 ft). Before European settlement, it was a major component of many grassland ecosystems in these regions. Switchgrass tolerates a broad range of soils, doing best on better-drained soils that are neutral to slightly acidic (pH 5.5 - 7). It is deep-rooted and spreads slowly by belowground rhizomes. Contributing to its success in diverse conditions is that switchgrass has evolved many ecotypes that are adapted to local conditions. The ecotypes differ genetically and physiologically from each other, a factor that both requires and enables breeding programs for optimizing its performance. Stand establishment from seed is relatively rapid, in about 3 years, and stands persist at least 10 years in trials with artificial plantings.

Switchgrass has the C_4 photosynthetic pathway, in which a biochemical "pump" for CO_2 precedes the universal C_3 pathway of all photosynthetic vascular ("higher") plants. This pump enables C_4 plants to have higher efficiencies than C_3's in using sunlight, water, and nitrogen. It also makes them more cold-sensitive because the enzyme in the "pump" dissociates into inactive units at low but above-freezing temperatures. Consequently, the growing season varies from 3 months at the northern limits of its range to 8 months in the southern regions.

Productivity. The plant can achieve high annual productivity of raw aboveground biomass, ranging from 6.7 to 13.5 tonnes per hectare per year (6 to 12 tons per acre per 3 years) as dry mass in US trial plantings at sites with good rainfall of 855 to 1100 mm (33.7 to 43.7 in.) (Kaiser and Bruckerhoff, 2009. Higher yields, averaging 14.6 tonnes/ha, were reported in another study over a wider geographic area (McLaughlin and Kzos, 2005). In New Mexico, yields should be expected to be considerably lower unless irrigation is used. The species' adaptation to North American conditions makes many ecotypes tolerant of drought. Irrigation is not necessary for yield in most years, though highest yields are attained with irrigation.

Inputs. Initial trials have all been rainfed, without irrigation. Standard planting and hay-harvesting equipment is usable. Nitrogenous fertilizer is applied at rates that have varied widely between trials (Barnhart and Gibson, 2007) , with averages near 170 kg per hectare (150 lb per acre). This input much exceeds the N removed in plant material (0.5 to 1% N) in a typical harvest of 6.7 tonnes/hectare (6 tons/acre) The excess N, as with other crops, is lost to litter production (residues), denitrification (leading to production of N_2O, a greenhouse gas of increasing concern XXX0, and leaching to groundwater and ultimately to waterways and oceans (XXX). Fuel usage for planting, tillage, and harvesting are modest, as noted in the reports on energy yield discussed below (XXX). No-till agriculture is an option with switchgrass, which has also been used for soil conservation by virtue of the continuous cover it affords.

Hazards to productivity. As all plants, switchgrass is susceptible to pests, diseases, and weed competition. Fungal and viral disease are common but appear not to depress yield severely or spread as epidemics, at least in small-scale tests. There is as yet no experience with large-scale monocultures of limited genotypic diversity. Switchgrass is additionally susceptible to wildfire. Nonetheless, burning of residues after harvesting is a common practice (which is likely to be curtailed in large-scale deployment of the crop to met EPA regulations on airborne particulate matter). Wildfire potential in large-scale plantings under extreme weather conditions cannot yet be assessed.

Practicalities of use

As direct combustion feedstock. Dried harvested material can be pelletized and used for combustion, including as an adjunct to coal in large power plants. Adjustments are needed in operating conditions because the combustion temperature is lower than that of coal or other fossil fuels and the fuel-air ratio is higher. Some small-scale trials have been favorable (http://www.iowaswitchgrass.com/).

For synthesis of liquid fuels. The principal route tested to date has been fermentation of the cellulosic component to ethanol. One recent study indicates a very favorable life-cycle energy return for this route, discussed below. Note that highly efficient cellulose fermentation methods have not yet been shown beyond the demonstration stage - that is, not to the scale of pilot plants or production facilities.

While ethanol has been fitted into the gasoline distribution system, problems remain. Energy density is lower, giving fewer miles per gallon (higher consumption as liters per 100 km in the standard European measure). Ethanol has limited solubility in gasoline hydrocarbons. With absorbed water, it also corrodes standard pipelines, so that it requires on-site blending prior to tanker delivery. As an alternative to conversion to ethanol, plant biomass can be thermally converted to liquids that closely approximate hydrocarbon fuels (http://aiche.confex.com/aiche/2009/webprogrampreliminary/Paper171370.html). In this process of hydropyrolysis, significant inputs of either fossil or solar energy are needed. The methods are still in development and are not yet practical and cost-competitive.

Economics

Direct investments and returns. A number of studies are completed or in progress for switchgrass and other renewables, all with a number of uncertainties. A study by the Center for Agricultural and Rural Development at Iowa State University (Secchi et al., 2008) projected a price of about $35 per oven-dry ton of switchgrass, while a price of $100/ton would be needed to support substantial plantings (46,000 ha) in the Upper Mississippi River Basin. A University of Tennessee Study (http://www.25x25.org/index.php?option=com_content&task=view&id=156&Itemid=56) projected prices of $44 to $88 per ton. Multibillion-dollar subsidies would consequently be needed

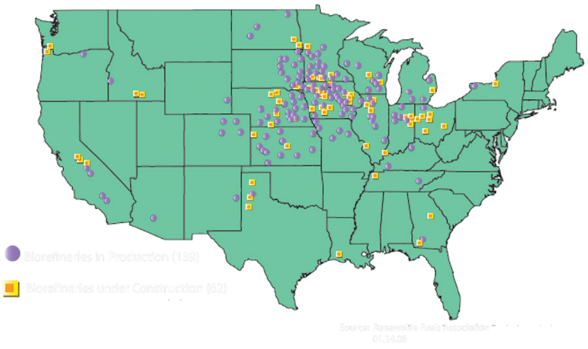
In contrast to market prices, the physical inputs on-farm are rather well quantified, from much experience in farming and energy conversion. Principal inputs are diesel fuel for planting, tilling, harvesting; nitrogenous fertilizer; process energy and amortized capital energy in constructing the conversion plant. The monetary costs of per unit of each of these inputs fluctuate, rendering a significant uncertainty in the total cost.

Another major cost is land rent. The land need not be of prime farmland quality but poorer land gives lower yields. Later in this report [make hyperlink XXX], the issue of land use for competing renewable energy technologies is explored.

Indirect economic effects. A consistent and large concern with all biofuel cropping is that it displaces food crops. Consequently it can raise the price of food, and globally as well as locally, given the globalization of grain markets (Miller, 2008). Switchgrass may have lower impacts on food prices than corn when either is used for biofuel production, but its displacement of crop area is not negligible (Secchi et al., 2008).

Water as a potential issue of cost and availability in our area. Irrigation water has not been supplied in trials to date, which have been done in areas with notably higher rainfalls than lower-elevation areas of New Mexico. Arid areas offer longer growing seasons and perhaps multiple crops per year, thus, higher annual yields. However, irrigation water would be a necessity for practical yields. Even though irrigation water is priced very low, its availability in the arid SW is very dubious.

Transportation of the biomass to a plant for combustion or for conversion to liquid fuel is another significant cost, one that plagues most renewables (crops, wind, many solar technologies) that are generated primarily in rural areas far from points of final use by consumers. There is one biorefinery in New Mexico, under construction (Fig. 2; the NM site is listed erroneously as in operation).



Source: Renewable Fuels Association
01.24.08

Fig. XXX. Biorefineries in the US. From Secchi et al. (2008). Purple = operational, yellow = under construction

Need for new economic analyses and regulatory clarifications. Before switchgrass is considered for New Mexico or other areas of the arid SW, it is imperative to generate new economic analyses suited to our sites. In all areas of the US, it is still foreseen that economic subsidies will be needed for all biofuels, including switchgrass (see earlier). One may argue that this is useful, given that fossil fuels have many indirect subsidies, such as the costly operation of the US Seventh Fleet to support oil supplies. Nonetheless, the subsidy provisions remain uncertain for the future and across states they present a patchwork. So also do mandates for the fraction of energy from biofuels. The lack of a national energy policy, which would stabilize these subsidies and mandates, is seen as a hindrance to investment by primary energy producers, energy processors, and electrical utilities. These uncertainties may be more challenging to deal with than uncertainties in the costs of inputs and production.

One element in energy policy that is favorable to energy crops such as switchgrass, both economically and politically, is a new regulatory framework that requires life-cycle accounting for total greenhouse gas impacts (http://www.ucsusa.org/news/press_release/new-renewable-fuel-standard-favorable-review-from-UCS-0345.html) . The elements of GHG impacts are described in some more detail later in this report. What is important for economic viability is that the regulations also count indirect impacts. Perhaps chief among these is land conversion that must be done elsewhere to replace food crops that were displaced to grow the energy crops. These impacts are markedly lower for cellulosic ethanol production or hydropyrolysis of biomass, compared with current ethanol production from corn with fermentation of only the starches. Another regulatory consideration, that of airborne particulates released in energy use, may affect the use of pelletized dry switchgrass biomass in powerplants (or homes). In large powerplants, particulates are fairly readily controlled, but in some envisioned smaller plants serving local demand, this is less clear (literally). Favorable to biomass vs. coal but not yet in regulations is the much lower release of mercury per unit energy produced.

Meeting demands for life-cycle energy return and GHG reduction

***Energy* per se**. Simulations show favorable local energy returns from growing and processing switchgrass, under the assumption of high conversion of cellulosic biomass to ethanol (0.34 L per kg of dry biomass). Nonconvertible lignin in the biomass is used for process heat, such as in final distillation. For switchgrass, the on-farm use of fossil energy for farm machinery and the pre-farm energy use in making nitrogenous fertilizer is less than half that for corn raised for ethanol production from starch, and still superior to that for corn raised for cellulosic ethanol. A recent study (Schmer et al., 2008) indicates that each unit of energy used to raise and process switchgrass for ethanol yields 5.4 units of energy in the final ethanol product. Also favorably, this same study used a more conservative estimate of biomass yields and final energy yields.

Energy per land area. The intensiveness of land use for energy cropping has been noted earlier. A more quantitative analysis may be pursued. Because all energy sources compete to a large extent, it is worth comparing the land use of energy crops such as switchgrass with land use of other renewable energy technologies. A simplified comparison is readily derived for solar photovoltaics. These have a high capital cost, which is declining (and markedly, recently - CSM? Science?XXX). Their efficiency varies by type, mainly crystalline vs. amorphous silicon. We can conservatively take 10% as a "first-law" efficiency, that is, electrical energy (enthalpy) out relative to incident solar energy. This is at the collector. Collectors may cover 80% of an installation. There is a further need for land area dedicated to energy storage of some type, to even out energy delivery during day and night and cloudy and sunny times. If this takes an equal area, then the energy yield on a total-land basis is down to about 4%. In the Appendix, I estimate that the annual average energy efficiency of growing switchgrass in mid-continental areas to make ethanol is 0.24%.

The energy figures are not simply comparable, because liquid fuels and electrical energy are used differently. Consider then use for transportation. The most energy-efficient use of biomass for transportation is actually combustion in a central power plant. In Appendix II, I estimate that the effective efficiency of converting biomass to drivetrain energy is about 24%, in a hybrid vehicle. In Appendix I, I estimate that the efficiency of capturing solar energy to biomass energy with switchgrass is 0.48%. Thus, from solar energy to drivetrain energy, the net efficiency is about 0.24*0.0048 = 0.12%. For solar photovoltaics, the 4% efficiency at the plant output must be reduced, just as for bioenergy in Appendix II, to account for transmission line losses (10%) and battery charge/discharge efficiency (75%). The net figure is then about 2.5%. This is a factor of over 20-fold higher (2.5%/0.12%) than that for switchgrass. Consequently, the same amount of energy for transportation requires more than 20 times as much land when switchgrass is used vs. solar photovoltaics. Using switchgrass for ethanol doubles this figure, to 40-fold greater use. Note that the land-use figures for wind farms are also highly favorable (not presented here). Fossil fuels are even better than solar and wind energy as land-sparing energy technologies, as energy yield per unit of land disturbed. We may conclude that there is a serious need to consider how much value we place on the convenience of liquid fuels vs. the investment that enables electric vehicle use. In any event, we are committed, by the realities of our energy future, to use much more land for energy production.

GHG impacts. Renewable fuel legislation is now being abetted by regulations that account for GHG production or amelioration. Biofuels have long been expected to reduce the emission of greenhouse gases, particularly CO_2, methane, and N_2O. The realities are complex, as several reports have noted (Melillo et al., 2009), including candid reports from university consortia funded by the largest biofuels-promoting fossil-fuel corporation, BP (Davis et al., 2009). Biofuels largely recycle CO_2 emitted in use of any fuel, fossil or bio-, but some fossil fuel is used in cropping and sometimes in processing. Consequently, biofuel use has a direct impact of increasing atmospheric CO_2, but not as much as direct use of fossil fuels. In the study cited earlier (Shmer et al., 2008), the reduction is to a factor 1/5.4, or about 18%.

There are two major qualifiers to the immediate favorability of biofuels for GHG emissions, both of these being discussed in the reports just cited. First is indirect land use. If other (food) crops are displaced in current agricultural areas by biofuel crops, then new land will be put into cultivation for food crops elsewhere. This land must be cleared of existing vegetation, causing the release of CO_2 and perhaps N oxides when the vegetation is burned or simply decomposed. Forest clearance, as in some South American farms, presents the worst case, with emissions as large as 90+ years of fuel use. Second is production of N_2O and, less so, of methane. Some fraction of applied nitrogenous fertilizers always undergoes denitrification in the field or in waterways. This produces N_2O, a greenhouse gas with 300 times the greenhouse effect of CO_2, per unit mass on a 100-year basis (its residence time in the atmosphere is about 120 years). Fortunately, the N:C ratio in switchgrass is low, about 1:40, and the fraction of applied fertilizer N released as N_2O is low, such that N_2O accounts for perhaps 10-20% as much impact as CO_2 (http://opencarbonworld.com/wiki/greenhouse-gas.html).

Other environmental impacts of biofuel production that play in the structure of regulations, current and future. The largest environmental impacts derive from the expansion of land use for (biofuel) crop growth. This necessarily entails further loss of habitat for native plants and animals. In turn, items of value to humans are adversely affected. Wild species have been characterized extensively as providing recreation (hunting, birding, etc.), breeding stock for crops (native plants, particularly outside the US), ecosystem services (flood control by riparian plants, pollination by insects, control of insect pests by birds and bats, etc.), other values as biodiversity (e.g., sources of medicines), and simple amenity value. Some but not all of these values can be monetized; others, including intrinsic human appreciation of nature (biophilia) must be accounted non-economically but realistically. Economic analyses of these environmental impacts are in various stages of completion and with various premises. In any event, policies will ultimately derive from such studies (Groom et al., 2007) and must be watched closely during the development of switchgrass and other bioenergy technologies.

An impact with more immediate policy implications is runoff of excess N and P fertilizers to rivers and onward to coastal waters. A fraction of all applied fertilizer gets into surface waters directly or indirectly after leaching into groundwaters that supply springs that feed rivers. The fertilizer runoff from agriculture in the Mississippi River Basin to the Gulf of Mexico is enormous (XXX). In the Gulf, the nutrient input supports algal blooms, which, upon dying, create a large "dead zone"temporarily devoid of most sea life, including important food fish and crustaceans. The size of the zone, commonly over 20,000 km^2 each year, is correlated with the fertilizer runoff. The US EPA has a task force working implementing a range of corrective actions, some of which may constrain fertilizer use and crop choice. Switchgrass cropping moderately reduces the N and P flux to the Gulf (Secchi et al., 2008), but the indirect impact of needing more food cropland elsewhere may exacerbate the dead zone problem and drive additional policy initiatives.

particulates
dead zone
        Benefits
            Ecosystem services
                Crop pollination
                Flood control
            Game animals
            Crop breeding stock
            Amenity value - and not just economic

On water supply and water quality (long-term salinization via irrigation)
On nutrient runoff
On land use and habitat conversion - basically, we're pissed away low-land ff's
On soil tilth and erosion
    No-till is possible
    No-rotation cropping?
    Soil pH changes from use of N fertilizer
On plant diseases, esp. in extensive monocultures
    Genetic diversity
    Breeding programs - up to the challenge?
On biodiversity
    Partial alternative: LIHD
On air quality (esp. vs. coal)

Consider also field-burning of residues as an impact; will it be allowed by PM10, PM2.5 regulations?
Again, direct and indirect impacts
Regulatory implications of impacts - current and future

Relative impacts
Coal mining and use
Even in direct combustion - lower Hg emissions
Oil extraction and use
Solar PV or solar thermal
Land use - more use, better quality land, no use on buildings
Poplar plantations (the best rated biofuel)
Algal biofuels

Life-cycle

Overall - What do investors need? What does the public need and what legislative support is likely to be offered?

Use this outline as hyperlinks, so that the issues are presented compactly but can be explored in more depth at will

Check U. Ill. Website for info

From wikipedia:

Switchgrass

Scientific classification Kingdom: Plantae
(unranked): Angiosperms
(unranked): Monocots
(unranked): Commelinids
Order: Poales
Family: Poaceae
Genus: *Panicum*
Species: ***P. virgatum***
Binomial name ***Panicum virgatum***
L.

Panicum virgatum, commonly known as **switchgrass**, is a perennial warm season grass native to North America, where it occurs naturally from 55°N latitude in Canada southwards into the United States and Mexico. Switchgrass is one of the dominant species of the central North American tallgrass prairie and can be found in remnant prairies, in native grass pastures, and naturalized along roadsides. It is used primarily for soil conservation, forage production, game cover, as an ornamental grass, and more recently as a biomass crop for ethanol, fibre, electricity, and heat production and for biosequestration of atmospheric carbon dioxide. Other common names for switchgrass include *tall panic grass*, *Wobsqua grass*, *blackbent*, *tall prairiegrass*, *wild redtop*, *thatchgrass*, and *Virginia switchgrass*.

Contents

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[edit] Properties

Root system of switchgrass grown at The Land Institute

Switchgrass is a hardy, deep-rooted, perennial rhizomatous grass that begins growth in late spring. It can grow up to 2.7 m high but is typically shorter than Big Bluestem grass or Indiangrass. The leaves are 30-90 cm long, with a prominent midrib. Switchgrass uses C$_4$ carbon fixation, giving it an advantage in conditions of drought and high temperature.[1] Its flowers have a well-developed panicle, often up to 60 cm long, and it bears a good crop of seeds. The seeds are 3-6 mm long and up to 1.5 mm wide, and are developed from a single-flowered spikelet. Both glumes are present and well developed. When ripe, the seeds sometimes take on a pink or dull-purple tinge, and turn golden brown with the foliage of the plant in the fall. Switchgrass is both a perennial and self-seeding crop, which means farmers do not have to plant and re-seed after annual harvesting. Once established, a switchgrass stand can survive for ten years or longer.[2] Unlike corn, switchgrass can grow on marginal lands and requires relatively modest levels of chemical fertilizers.[2] Overall, it is considered a resource-efficient, low-input crop for producing bioenergy from farmland.

[edit] Background

Much of North America, especially the prairies of the Midwestern United States, was once prime habitat to vast swaths of native grasses, including Switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*), Eastern Gamagrass (*Tripsacum dactyloides*), Big Bluestem (*Andropogon gerardii*), Little Bluestem (*Schizachyrium scoparium*), and others. As European settlers began spreading west across the continent, the native grasses were plowed under and the land converted to crops such as corn, wheat, and oats. Introduced grasses such as fescue, bluegrass, and orchardgrass[3] also replaced the native grasses for use as hay and pasture for cattle.

[edit] Distribution

Switchgrass is a versatile and adaptable plant. It can grow and even thrive in many weather conditions, lengths of growing seasons, soil types, and land conditions. Its distribution spans south of latitude 55°N from Saskatchewan to Nova Scotia, south over most of the United States east of the Rocky Mountains, and further south into Mexico.[4] As a warm-season perennial grass, most of its growth occurs from late spring through early fall, becoming dormant and unproductive during colder months. Thus, the productive season in its northern habitat can be as short as three months, but in the southern reaches of its habitat the growing season may be as long as eight months, around the Gulf Coast area.[5]

Switchgrass is a diverse species, with striking differences between plants. This diversity, which presumably reflects evolution and adaptation to new environments as the species spread across the continent, provides a range of valuable traits for breeding programs. Switchgrass has two distinct forms, or "cytotypes": the lowland cultivars, which tend to produce more biomass, and the upland cultivars, which are generally of more northern origin, more cold-tolerant, and therefore usually preferred in northern areas. Upland switchgrass types are generally shorter (≤ 2.4 m, tall) and less coarse than lowland types. Lowland cultivars may grow to ≥ 2.7 m, in favorable environments. Both upland and lowland cultivars are deeply rooted (> 1.8 m, in favorable soils) and have short rhizomes. The upland types tend to have more vigorous rhizomes, so the lowland cultivars may appear to have a bunchgrass habit, while the upland types tend to be more sod-forming. Lowland cultivars appear more plastic in their morphology, produce larger plants if stands become thin or when planted in wide rows, and they seem to be more sensitive to moisture stress than upland cultivars.[6]

In native prairies, switchgrass is historically found in association with several other important native tallgrass prairie plants, such as big bluestem, indiangrass, little bluestem, sideoats grama, eastern gamagrass, and various forbs (sunflowers, gayfeather, prairie clover, and prairie coneflower). These widely adapted tallgrass species once occupied millions of hectares.[7]

Switchgrass' suitability for cultivation in the Gran Chaco is currently studied by Argentina's INTA.[8]

[edit] Establishment and management

Switchgrass can be grown on land considered unsuitable for row crop production, including land that is too erodible for corn production as well as sandy and gravelly soils in humid regions that typically produce low yields of other farm crops. No single method of establishing switchgrass can be suggested for all situations. The crop can be established both by no-till and conventional tillage. When seeded as part of a diverse mixture, planting guidelines for warm-season grass mixtures for conservation plantings should be followed. Regional guidelines for growing and managing switchgrass for bioenergy or conservation plantings are available. Several key factors can increase the likelihood of success for establishing switchgrass. These include:[9]

- Planting switchgrass after the soil is well warmed during the spring.

- Using seeds that are highly germinable and planting 0.6 - 1.2 cm deep, or up to 2 cm deep in sandy soils.
- Packing or firming the soil both before and after seeding.
- Providing no fertilization at planting to minimize competition.
- Controlling weeds with chemical and/or cultural control methods.

Mowing and properly labeled herbicides are recommended for weed control. Chemical weed control can be used in the fall prior to establishment, pre-plant and post-plant. Weeds should be mowed just above the height of the growing switchgrass. Hormone herbicides such as 2,4-D should be avoided as they are known to reduce development of switchgrass when applied early in the establishing year.[10] Plantings that appear to have failed due to weed infestations are often wrongly assessed, as the failure is often more apparent than real. Switchgrass stands that are initially weedy commonly become well established with appropriate management in subsequent years.[9] Once established, switchgrass can take up to three years to reach its full production potential.[11] Depending on the region, it can typically produce 1/4 to 1/3 of its yield potential in its first year and 2/3 of its potential in the year after seeding.[12]

After establishment, switchgrass management will depend on the goal of the seeding. Historically, most switchgrass seedings have been managed for the Conservation Reserve Program in the US. Disturbance such as periodic mowing, burning, or disking is required to optimize the stand’s utility for encouraging biodiversity. Presently, increased attention is being placed on switchgrass management as an energy crop. Generally, the crop requires modest application of nitrogen fertilizer as it is not a heavy feeder. Typical nitrogen (N) content of senescent material in the fall is 0.5% N. Fertilizer nitrogen applications of about 5 kg N/hectare (ha) applied for each tonne of biomass removed is a general guideline. More specific recommendations for fertilization are available regionally in North America. Herbicides are not often used on switchgrass after the seeding year, as the crop is generally quite competitive with weeds. Most bioenergy conversion processes for switchgrass, including those for cellulosic ethanol and pellet fuel production, can generally accept some alternative species in the harvested biomass. Stands of switchgrass should be harvested no more than twice per year, and one cutting often provides as much biomass as two. Switchgrass can be harvested with the same field equipment used for hay production and it is well-suited to baling or bulk field harvesting. If its biology is properly taken into consideration, switchgrass can offer great potential as an energy crop.[9][13]

[edit] Uses

Switchgrass can be used as a feedstock for biomass energy production, as ground cover for soil conservation and to control erosion, for forages and grazing, as game cover, and as feedstock for biodegradable plastics. It can be used by cattle farmers for hay and pasture and as a substitute for wheat straw in many applications, including livestock bedding, straw bale housing, and as a substrate for growing mushrooms.

Panicum virgatum 'Heavy Metal', an ornamental switchgrass, in early summer

Additionally, switchgrass is grown as a drought-resistant ornamental grass in average to wet soils and in full sun to part shade.

[edit] Bioenergy

Switchgrass has been researched as a bioenergy crop since the mid-1980s, because it is a native perennial warm season grass with the ability to produce moderate to high yields on marginal farmlands. It is now being considered for use in several bioenergy conversion processes, including cellulosic ethanol production, biogas, and direct combustion for thermal energy applications. The main agronomic advantages of switchgrass as a bioenergy crop are its stand longevity, drought and flooding tolerance, relatively low herbicide and fertilizer input requirements, ease of management, hardiness in poor soil and climate conditions, and widespread adaptability in temperate climates. In some warm humid southern zones such as Alabama it has the ability to produce up to 25 oven-dry tonnes per hectare (ODT/ha). A summary of switchgrass yields across 13 research trial sites in the United States found the top two cultivars in each trial to yield 9.4 to 22.9 t/ha, with an average yield of 14.6 ODT/ha.[14] However, these yields were recorded on small plot trials, and commercial field sites could be expected to be at least 20% lower than these results. In the United States, switchgrass yields appear to be highest in warm humid regions with long growing seasons such as the US Southeast and lowest in the dry short season areas of the Northern Great Plains.[14]

The energy inputs required to grow switchgrass are favorable when compared with annual seed bearing crops such as corn, soybean, or canola, which can require relatively high energy inputs for field operations, crop drying, and fertilization. Whole plant herbaceous perennial C4 grass feedstocks are desirable biomass energy feedstocks, as they require fewer fossil energy inputs to grow and effectively capture solar energy because of their C4 photosynthetic system and perennial nature. One study cites that it takes from 0.97 to 1.34 GJ to produce 1 tonne of switchgrass, compared with 1.99 to 2.66 GJ to produce 1 tonne of corn.[15] Another study found that switchgrass uses 0.8 GJ/ODT of fossil energy compared to grain corn's 2.9 GJ/ODT.[16] Given that switchgrass contains approximately 18.8 GJ/ODT of biomass, the energy output-to-input ratio for the crop can be up to 20:1.[17] This highly favorable ratio is attributable to its relatively high energy output per hectare and low energy inputs for production.

Considerable effort is presently being expended in developing switchgrass as a cellulosic ethanol crop in the USA. In George W. Bush's 2006 State of the Union Address, he proposed using switchgrass for ethanol;[18][19][20] since then, over $100 million USD has been invested into researching switchgrass as a potential biofuel source.[21] Switchgrass has the potential to produce up to 380 liters of ethanol per tonne harvested.[22] However, current technology for herbaceous biomass conversion to ethanol is about 340 liters per tonne.[23] In contrast, corn ethanol yields about 400 liters per tonne.[24] The main advantage of using switchgrass over corn as an ethanol feedstock is that its cost of production is generally about 1/2 that of grain corn and more biomass energy per hectare can be captured in the field.[17] Thus, switchgrass cellulosic ethanol should give a higher yield of ethanol per hectare at lower cost. However, this will depend on whether the cost of constructing and operating cellulosic ethanol plants can be reduced considerably. The switchgrass ethanol industry energy balance is also considered to be substantially better than that of corn ethanol. During the bioconversion process, the lignin fraction of switchgrass can be burned to provide sufficient steam and electricity to operate the biorefinery. Studies have found that for every unit of energy input needed to create a biofuel from switchgrass, four units of energy are yielded.[25] In contrast, corn ethanol yields about 1.28 units of energy per unit of energy input.[26] A recent study from the Great Plains [27] indicated that for ethanol production from switchgrass, this figure is 5.4, or alternatively, that 540% more energy was contained in the ethanol produced than was used in growing the switchgrass and converting it to liquid fuel. However, there remain commercialization barriers to the development of cellulosic ethanol technology. Projections in the early 1990s for commercialization of cellulosic ethanol by the year 2000[28] have not been met. The commercialization of cellulosic ethanol is thus proving to be a significant challenge, despite noteworthy research efforts.

Thermal energy applications for switchgrass appear to be closer to near-term scale-up than cellulosic ethanol for industrial or small-scale applications. For example, switchgrass can be pressed into fuel pellets that are subsequently burned in pellet stoves used to heat homes (which typically burn corn or wood pellets).[11] Switchgrass has been widely tested as a substitute for coal in power generation. The most widely-studied project to date has been the Chariton Valley

Project in Iowa.[29] The Show-Me-Energy Cooperative (SMEC) in Missouri[30] is using switchgrass and other warm-season grasses along with wood residues as feedstocks for pellets used for the firing of a coal-fired power plant. In Eastern Canada, switchgrass is being used on a pilot scale as a feedstock for commercial heating applications. Combustion studies have been undertaken and it appears to be well-suited as a commercial boiler fuel. Research is also being undertaken to develop switchgrass as a pellet fuel because of lack of surplus wood residues in Eastern Canada,[31] as a slowdown in the forest products industry in 2009 is now resulting in wood pellet shortages throughout Eastern North America. Generally speaking, the direct firing of switchgrass for thermal applications can provide the highest net energy gain and energy output-to-input ratio of all switchgrass bioconversion processes.[32] Research has found that switchgrass, when pelletized and used as a solid biofuel, is a good candidate for displacing fossil fuels. Switchgrass pellets were identified to have a 14.6:1 energy output-to-input ratio, which is substantially better than that for liquid biofuel options from farmland.[16] As a greenhouse gas mitigation strategy, switchgrass pellets were found to be an effective means to use farmland to mitigate greenhouse gases. Using farmland to produce switchgrass pellets could mitigate 7.6-13 tonnes per hectare of CO2. In contrast, switchgrass cellulosic ethanol and corn ethanol were found to mitigate 5.2 and 1.5 tonnes of CO2 per hectare, respectively.[33]

Historically, the major constraint to the development of grasses for thermal energy applications has been the difficulty associated with burning grasses in conventional boilers, as biomass quality problems can be of particular concern in combustion applications. These technical problems now appear to have been largely resolved through crop management practices such as fall mowing and spring harvesting that allow for leaching to occur, which leads to fewer aerosol-forming compounds (such as K and Cl) and N in the grass. This reduces clinker formation and corrosion and enables switchgrass to be a clean combustion fuel source for use in smaller combustion appliances. Fall harvested grasses likely have more application for larger commercial and industrial boilers.[34][35][36] Switchgrass is also currently being used to heat small industrial and farm buildings in Germany and China through a process used to make a low quality natural gas substitute.[37]

[edit] Biodegradable plastics production

In a novel application, US scientists have genetically modified switchgrass to cause it to produce polyhydroxybutyrate, which accumulates in beadlike granules within the plant's cells.[38] In preliminary tests the dry weight of plant's leaves were shown to contain up to 3.7% of the polymer.[39] Such low accumulation rates do not presently (2009) allow for commercial use of switchgrass as a biosource.

[edit] Soil conservation

Further information: Mine reclamation, Restoration ecology, and Revegetation

Switchgrass is useful for soil conservation and amendment, particularly in the United States and Canada where switchgrass is endemic. Switchgrass has a deep fibrous root system – nearly as deep as the plant is tall. Since it, along with other native grasses and forbs, once covered the plains of the United States that are now the Corn Belt, the effects of the past switchgrass habitat have been beneficial, lending to the fertile farmland that exists today. The deep fibrous root systems of switchgrass left a deep rich layer of organic matter in the soils of the Midwest, making those mollisol soils some of the most productive in the world. By returning switchgrass and other perennial prairie grasses as an agricultural crop, many marginal soils may benefit from increased levels of organic material, permeability, and fertility, due to the grass's deep root system.

Soil erosion, both from wind and water, is of great concern in regions where switchgrass grows. Due to its height, switchgrass can form an effective wind erosion barrier.[40] Its root system, also, is excellent for holding soil in place, which helps prevent erosion from flooding and runoff. Some highway departments (for example, KDOT) have used switchgrass in their seed mixes when re-establishing growth along roadways.[41] It can also be used on strip mine sites, dikes,[40] and pond dams. Conservation districts in many parts of the United States use it to control erosion in grass waterways because of its ability to anchor soils while providing habitat for wildlife.

[edit] Forages and grazing

Switchgrass is an excellent forage for cattle; however, it has shown toxicity in horses, sheep, and goats[42][43][44] through chemical compounds known as saponins, which cause photosensitivity and liver damage in these animals. Researchers are continuing to learn more about the specific conditions under which switchgrass causes harm to these species, but until more is discovered, it is recommended that switchgrass not be fed to them. For cattle, however, it can be fed as hay, or grazed.

Grazing switchgrass calls for watchful management practices to ensure survival of the stand. It is recommended that grazing begin when the plants are about 50 cm tall, and that grazing be discontinued when the plants have been eaten down to about 25 cm, and to rest the pasture 30 – 45 days between grazing periods.[45] Switchgrass becomes stemmy and unpalatable as it matures, but during the target grazing period, it is a favorable forage with a relative feed value (RFV) of 90-104.[46] The grass's upright growth pattern places its growing point off the soil surface onto its stem, so leaving 25 cm of stubble is important for regrowth. When harvesting switchgrass for hay, the first cutting occurs at the late boot stage – around mid-June. This should allow for a second cutting in mid-August, leaving enough regrowth to survive the winter.[47]

[edit] Game cover

Switchgrass is well-known among wildlife conservationists as good forage and habitat for upland game bird species such as pheasant, quail, grouse, wild turkey, and song birds, with its plentiful small seeds and tall cover. Depending on how thickly switchgrass is planted, and what it is partnered with, it also offers excellent forage and cover for other wildlife across the country. For those producers who have switchgrass stands on their farm, it is considered an environmental and aesthetic benefit due to the abundance of wildlife attracted by the switchgrass stands. Some members of Prairie Lands Bio-Products, Inc. in Iowa have even turned this benefit into a profitable business by leasing their switchgrass land for hunting during the proper seasons.[48] The benefits to wildlife can be extended even in large-scale agriculture through the process of strip harvesting, as recommended by The Wildlife Society, which suggests that rather than harvesting an entire field at once, strip harvesting could be practiced so that the entire habitat is not removed, thereby protecting the wildlife inhabiting the switchgrass.[49]

[edit] See also

- Algae fuel
- Big Bluestem
- Brachypodium distachyon
- Cellulosic ethanol
- Energy crop
- Proceedings of the National Academy of Sciences
- Wood pellets

[edit] References

1. ^ Silzer, Tanya (January 2000). "Panicum virgatum L., Switchgrass, prairie switchgrass, tall panic grass". *Rangeland Ecosystems & Plants Fact Sheets*. University of Saskatchewan Department of Plant Sciences. http://www.usask.ca/agriculture/plantsci/classes/range/panicum.html. Retrieved 2007-12-08.
2. ^ a b Secter, Bob. "Plentiful switch grass emerges as breakthrough biofuel". The San Diego Union-Tribune. http://www.signonsandiego.com/uniontrib/20061221/news_lz1c21grass.html. Retrieved 2008-05-24.
3. ^ Ernst Seed Catalog Web Page (2007). "Switchgrass and Warm Season Grass Planting Guide". Ernst Conservation Seeds. http://www.ernstseed.com/switchgrass_planting_quide.htm. Retrieved 2007-12-08.
4. ^ "PLANTS Profile for Panicum virgatum (switchgrass)". United States Department of Agriculture, Natural Resources Conservation Service. http://plants.usda.gov/java/profile?symbol=PAVI2. Retrieved 2008-05-21.
5. ^ Ball, D.M.; Hoveland, C.S., and Lacefield, G.D. (2002). *Southern Forages* (3rd ed.). International Plant Nutrition Institute. p. 26. ISBN 0-9629598-3-9. http://www.ipni.net/e-catalog/BOOKS/95-1033/sf.HTM.
6. ^ Establishing and Managing Switchgrass as an Energy Crop, Forage and Grazinglands, 2008.
7. ^ Switchgrass as a Bioenergy Crop, ATTRA - National Sustainable Agricultural Information Service, 2006.
8. ^ "Aprovechamiento de recursos vegetales y animales para la produccion de biocombustibles" (in Spanish). INTA. 26 June 2008. http://www.inta.gov.ar/iir/investiga/proyectos/pebiocombustibles.pdf.
9. ^ a b c [1] David J. Parrish, John H. Fike, David I. Bransby, Roger Samson. Establishing and Managing Switchgrass as an Energy Crop. Forage and Grazinglands. 2008
10. ^ http://nmsp.css.cornell.edu/publications/factsheets/factsheet20.pdf
11. ^ a b Samson, R. (2007). "Switchgrass Production in Ontario: A Management Guide" (PDF). Resource Efficient Agricultural Production (REAP) - Canada. http://www.reap-

canada.com/library/Bioenergy/2007%20SG%20production%20guide-FINAL.pdf. Retrieved 2008-05-24.

12. ^ Bransby, David (2005). "Switchgrass Profile". Bioenergy Feedstock Information Network (BFIN), Oak Ridge National Laboratory. http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html. Retrieved 2008-05-24.
13. ^ [2] Samson, R., Bailey-Stamler, S., & Ho Lem, C. Optimization of Switchgrass Management for Commercial Fuel Pellet Production (Final report prepared by REAP-Canada for the Ontario Ministry of Food, Agriculture and Rural Affairs (OMAFRA) under the Alternative Renewable Fuels Fund). 2008
14. ^ *a* *b* McLaughlin, S.B., Kzos, L.A. Development of switchgrass (Panicum virgatum) as a bioenergy feedstock in the United States. Biomass and Bioenergy. Volume 28. 2005. 515-535.
15. ^ [3], Dale, B., Kim, S. Cumulative Energy and Global Warming Impact from the Production of Biomass for Biobased Products. Journal of Industrial Ecology. Volume 7, Number 3-4. 2004. 147-162.
16. ^ *a* *b* [4], Samson, R. et al. The Potential of C4 Perennial Grasses for Developing a Global BIOHEAT Industry. Critical Reviews in Plant Science. Volume 25. 2005. 461-495.
17. ^ *a* *b* Samson, R. et al. Developing Energy Crops for Thermal Applications: Optimizing Fuel Quality, Energy Security and GHG Mitigation. In Biofuels, Solar and Wind as Renewable Energy Systems: Benefits and Risks. D. Pimental. (Ed.) Springer Science, Berlin, Germany. 2008. 395-423.
18. ^ Adrienne Mand Lewin (2006-02-01). "Switchgrass: The Super Plant Savior?". ABC News. http://abcnews.go.com/GMA/Business/story?id=1566784.
19. ^ "Switch Grass: Alternative Energy Source?". National Public Radio. 2006-02-01. http://www.npr.org/templates/story/story.php?storyId=5183608.
20. ^ Dana Bash, Suzanne Malveaux, et al. (2006-02-01). "Bush has plan to end oil 'addiction'". CNN. http://www.cnn.com/2006/POLITICS/01/31/bush.sotu/.
21. ^ "Since that mention in the 2006, investment in switch grass has exploded, thanks in large part, experts say, to the president's speech. Venture capitalists have poured over $100 million into private companies that are exploring the technology necessary to convert switchgrass into fuel, and large publicly-owned companies are also directing their research dollars into biofuels."Jessica Yellin, Katie Hinman, Nitya Venkataraman (2007-01-23). "What Happened to Bush Call for Switchgrass?". ABC News. http://abcnews.go.com/Nightline/story?id=2814511&page=1.
22. ^ "Switchgrass: Native American Powerhouse?". Renewable Energy Resources. http://www.prognog.com/driving/ethanol/switchgrass:__native_american_powerhouse.html. Retrieved 2007-01-05.
23. ^ [5] Iogen Corporation, 2009.
24. ^ Farrell, A.E. Ethanol Can Contribute to Energy and Environmental Goals. Science. Volume 311. 2006. 506-508.
25. ^ "Switch Grass: Alternative Energy Source?". NPR. http://www.npr.org/templates/story/story.php?storyId=5183608. Retrieved 2007-01-05.
26. ^ Wang, M., Wu, M., & Huo, H. Life-cycle energy and greenhouse gas emission impacts of different corn ethanol plant types. Environmental Research Letters. Volume 2. 2007. 1-13.

27. ^ Schmer, M. R., Vogel, K. P, Mitchell, R. B., and Perrin, R. K. Net energy of cellulosic ethanol from switchgrass. PNAS. 105. 2008. 464-469
28. ^ Lynd, L. R., Cushman, J. H., Nichols, R. J., and Wyman, C. E. Fuel Ethanol from Cellulosic Biomass. Science. Volume 251, Number 4999. 1991. 1318 – 1323
29. ^ http://www.iowaswitchgrass.com/
30. ^ http://www.goshowmeenergy.com
31. ^ Bailey Stamler, S., R. Samson and C. Ho Lem. Biomass resources options: Creating a BIOHEAT supply for the Canadian greenhouse industry. Final report to Natural Resources Canada, Ottawa. 2006. 38 pages
32. ^ [6] Samson, R., and S. Bailey Stamler. Going Green for Less: Cost-Effective Alternative Energy Sources. C.D. Howe Institute Commentary 282. Economic Growth and Innovation. 2009. 25 pages
33. ^ [7] Samson, R., Bailey-Stamler, S., & Ho Lem, C. Optimization of Switchgrass Management for Commercial Fuel Pellet Production (Final report prepared by REAP-Canada for the Ontario Ministry of Food, Agriculture and Rural Affairs (OMAFRA) under the Alternative Renewable Fuels Fund). 2008
34. ^ "Samson et al. 2007": http://www.reap-canada.com/online_library/feedstock_biomass/The%20Emerging%20Agro-Pellet%20Industry%20in%20Canada%20(Samson%20et%20al.,%202007).pdf R. Samson, S. Bailey and C. Ho Lem. The Emerging Agro-Pellet Industry in Canada. 2007
35. ^ "Samson et al., 2008": In regions where the potassium and chlorine contents of switchgrass cannot be successfully leached out for thermal applications, it may be that biogas applications for switchgrass will prove more promising. Switchgrass has demonstrated some promise in biogas research as an alternative feedstock to whole plant corn silage for biogas digesters.
36. ^ "Frigon et al. 2008 http://www.gtmconference.ca/site/downloads/2008presentations/5B3%20-Frigon.pdf J.C. Frigon, P. Mehta, S.R. Guiot. The bioenergy potential from the anaerobic digestion of switchgrass and other energy crops. National Research Council Canada. Growing the Margins Conference: Energy, Bioproducts and Byproducts from farms and food sectors. April 2-5 2008, London, Ontario
37. ^ "plentiful_switchgrass"
38. ^ *Biomass Combo*, Chemical & Engineering News, **86**, 33, 18 Aug. 2008, p. 13
39. ^ *Plant Biotechnology Journal*, **2008**, 6, 663
40. ^ *a* *b* "Plant Fact Sheet, Panicum virgatum (switchgrass)" (PDF). United States Department of Agriculture, Natural Resources Conservation Service, Plant Materials Program. 2006-05-06. http://plants.usda.gov/factsheet/pdf/fs_pavi2.pdf. Retrieved 2008-05-21.
41. ^ "KDOT Bid Tabs". Kansas Department of Transportation. http://www.ksdot.org/burConsMain/bidtabs/bidtab.asp?yr=2008&id=08034232. Retrieved 2008-05-20.
42. ^ Lee, S.T.; Stegelmeier, B.L.; Gardner, D.R.; Vogel, K.P. (2001). "The isolation and identification of steroidal sapogenins in switchgrass". *J Nat Toxins* **10** (4): 273–81. http://www.ncbi.nlm.nih.gov/pubmed/11695816. Retrieved 2008-05-24.
43. ^ Johnson, A.L.; Divers, T.J.; Freckleton, M.L.; McKenzie, H.C.; Mitchell, E.; Cullen, J.M.; McDonough, S.P. (2006). "Fall Panicum (Panicum dichotomiflorum)

Hepatotoxicosis in Horses and Sheep". *Journal of Veterinary Internal Medicine* **20** (6): 1414–1421. doi:[1414:FPPDHI2.0.CO;2 10.1892/0891-6640(2006)20[1414:FPPDHI]2.0.CO;2]. http://www.jvetintmed.org/perlserv/?request=get-abstract&doi=10.1892%2F0891-6640(2006)20%5B1414%3AFPPDHI%5D2.0.CO%3B2. Retrieved 2008-05-24.

44. ^ Stegelmeier, B.L.; Elmore, S.A.; Lee, S.T.; James, L.F.; Gardner, D.R.; Panter, K.E.; Ralphs, M.H.; Pfister, J.A. (2007). "Switchgrass (panicum Virgatum) Toxicity In Rodents, Sheep, Goats And Horses". *Poisonous Plant Global Research and Solutions* **19**: 113–117. http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=186737. Retrieved 2008-05-24.
45. ^ Ball, D.M.; Hoveland, C.S., and Lacefield, G.D. (2006). "Table 28. Guidelines for rotational stocking of selected forage crops". *Forage Crop Pocket Guide*. International Plant Nutrition Institute. http://www.ipni.net/e-catalog/BOOKS/32-0001/pg.HTM.
46. ^ Ball, D.M.; Hoveland, C.S., and Lacefield, G.D. (2006). "Table 33b. Total Digestible Nutrients (TDN) and Relative Feed Value (RFV) Ranges for Various Forage Crops". *Forage Crop Pocket Guide*. International Plant Nutrition Institute. http://www.ipni.net/e-catalog/BOOKS/32-0001/pg.HTM.
47. ^ Wolf, D.D.; Fiske, D.A. (1995). "Planting and managing switchgrass for forage, wildlife, and conservation" (PDF). *Virginia Cooperative Extension Publication*: 418–013. http://www.ext.vt.edu/pubs/forage/418-013/418-013.pdf. Retrieved 2008-05-24.
48. ^ Hipple, Patricia C.; Duffy, Michael D. (2002). "Farmers' Motivations for Adoption of Switchgrass". in Jules Janick, Anna Whipkey (PDF). *Trends in New Crops and New Uses*. Fifth National Symposium, New Crops and New Uses, Strength in Diversity. Alexandria, Virginia: American Society for Horticultural Science. pp. 252–266. ISBN 0097075655. http://www.hort.purdue.edu/newcrop/ncnu02/pdf/duffy-252.pdf. Retrieved 2008-05-23.
49. ^ Bies, Laura (2006-11-01). "The Biofuels Explosion: Is Green Energy Good for Wildlife?". *Wildlife Society Bulletin* **34** (4): 1203–1205. doi:[1203:TBEIGE2.0.CO;2 10.2193/0091-7648(2006)34[1203:TBEIGE]2.0.CO;2].

[edit] External links

- Switchgrass Production in Ontario: A Management Guide
- Vermont Grass Energy Symposium
- Switchgrass for Bioheat in Canada (agriwebinar presentation)
- A Management Guide for Planting and Production of Switchgrass as a Biomass Crop in Europe
- Establishing and Managing Switchgrass as an Energy Crop
- Optimization of Switchgrass Management for Commercial Fuel Pellet Production
- Management Guide for Biomass Feedstock Production from Switchgrass in the Northern Great Plains
- Management Guide for the Production of Switchgrass for Biomass Fuel in Southern Iowa
- Switchgrass as a Bioenergy Crop
- Switchgrass Variety Choice in Europe
- Warm Season Grasses in Pennsylvania

- Planting and Managing Switchgrass as a Dedicated Energy Crop 2009
- Switchgrass Fuel Yields Bountiful Energy
- "Switchgrass: A Living Solar Battery." Roger Samson (Online reprint)
- http://bioenergy.ornl.gov/papers/misc/switchgrass-profile.html
- Economics of switchgrass production
- USDA Studies Switchgrass for Ethanol and Energy Production
- Switchgrass as an Alternative Energy crop - European Union study on Switchgrass feasibility.
- Switchgrass for Bioethanol and Other Value-Added Applications: A Review by D. R. Keshwani & J. J. Cheng in *Bioresource Technology* 100 (2009) (pdf)
- Switchgrass images - Archive of Central Texas Plants
- Switchgrass images - Has closeup photos of spikelets
- Switch Grass Information Repository - General information repository on switch grass usage and feasible application as an alternative energy
- "Grass Makes Better Ethanol than Corn Does" - Scientific American article on the potential use of switchgrass for biofuels
- Study Shows Great Potential of Switchgrass as Biofuel Feedstock
- Taxonomic description in GrassBase

[hide]

v • d • e

Bioenergy

Biofuels	Algae fuel • Bagasse • Babassu oil • Biobutanol • Biodiesel • Biogas • Biogasoline • Cellulosic ethanol • Corn stover • Ethanol fuel • Stover • Straw • Vegetable oil	
Energy from Foodstock	Hemp • Maize • Rapeseed • Sorghum bicolor • Soybean • Sugarcane • Sunflower	
Non-food Energy Crops	Arundo • Big bluestem • Chinese tallow • Duckweed • Jatropha curcas • Miscanthus giganteus • **Switchgrass** • Pongamia pinnata • Wood fuel	
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Concepts	Cellulosic ethanol commercialization • Energy content of biofuel • Energy crop • Energy forestry • EROEI • Food vs. fuel • Sustainable biofuel	

From: http://www.mail-archive.com/ecolog-l@listserv.umd.edu/msg04466.html

Re: switchgrass concerns & fire

Henebry, Geoffrey
Tue, 06 Feb 2007 09:01:16 -0800

Mike Palmer observed:

>"There is also the problem of fire.
>Vast fields of switchgrass present a very different fire risk landscape
>than fields of corn or soy."

>Yes, I agree with Geoff. Anyone who has set, managed, or fought fires
>in switchgrass can attest to this, and fire danger must be considered.
>However, it is a little bit of a red herring. A hay meadow (with
>switchgrass as one component) will be mowed late in the season, so
there
>will not be a lot of standing fuel when there is the most fire risk.

I think, Mike, you underestimate the scope of the fire risk problem. Certainly, it is unlikely that there will be vast fields of dry switchgrass overwintering poised to receive spring's lightning strikes. However, is that the only period of high fire risk?

Linda Wallace observed earlier in an allied thread:

>The use of switchgrass as a biofuel feedstock is not as environmentally
>benign as one would hope. It does take land from other uses (food,
range, >livestock, native prairie) and these new varieties of
switchgrass have very >low root/shoot ratios. This means that this crop
will need more irrigation >and fertilization than its wild cousin.

Substantial differences in the rooting habits and/or root-to-shoot ratios of the selected varieties could yield significant different vertical distribution of carbon and nutrients and water in the soils that could affect the belowground biotic communities. Were these planted switchgrass communities more susceptible to growing season dry periods (and drought), there could be a significant quantity of dried/senesced material accumulated in the still-green canopies. This fuel would increase the fire risk during the growing season.

Further, it is common agricultural practice for many grain and forage crops to dry the crops in the field to reduce to the water content. Drying grain in storage is energetically expensive. Transporting the moist heavy harvest is also energetically expensive. Thus there is likely to be significant periods of drying switchgrass at the end of the growing season.

Roadside fires in the country are a common occurrence during late summer. Passing vehicles toss out an ignition source, it lands amid sufficiently dry fuel, and the wind does the rest. But these wildfires along grassy roadsides usually stop at the edge of the cropped field because there is insufficient fuel at ground level to carry the fire farther. This scenario is quite different in areas with extant prairie: the fire carries from the roadside into the field until it reaches a firebreak, consumes available fuel, changing meteorological conditions stop the fire spread, or humans intervene.

Even green switchgrass is quite flammable, especially in the face of a raging prairie wildfire.

Mike also observed:

>Also, the greatest fire danger in the SC Great Plains is the abandonment
>of existing grasslands, leading to dominance of Juniperus virginiana.
>These trees are extremely flammable, and have characteristics that lead
>to very rapid spread of fire. They are also one of the biggest dangers
>when fighting fires.

Certainly, these areas of native species expansion in the absence of periodic fire present a current fire risk. These are also the lands that may well be converted into biofuel plantations, if the economics are favorable.

Geoff Henebry
South Dakota State University

- Re: switchgrass concerns & fire Henebry, Geoffrey
    - Re: switchgrass concerns & fire Palmer, Mike
- Reply via email to

Ag practices, pests, diseases, yields, …: see ~/job/switchgrass/ag200.pdf

See also ~/job/switchgrass/AgronomyTechNote35.pdf,
  from http://efotg.nrcs.usda.gov/references/public/IA/AgronomyTechNote35.pdf

New Renewable Fuel Standard, Which Sets First Heat Trapping Emissions Requirements for Biofuels, Gets Favorable Review From UCS

EPA Analysis Demonstrated That Without Additional Support, Cleanest Biofuels Will Fail to Meet Targets

Washington (February 3, 2010) – The Environmental Protection Agency's (EPA) new rules for the Renewable Fuel Standard, the nation's primary biofuels program, got a favorable review from the Union of Concerned Scientists (UCS). The science group praised the agency for a transparent process that accurately accounted for biofuels' lifecycle heat-trapping emissions by including so-called "indirect-land-use emissions." The new rules reflect the fact that advanced and cellulosic biofuels deliver substantially greater pollution reductions than today's biofuels, such as corn ethanol.

"We now have a yardstick to measure the global warming pollution from different biofuels," said Jeremy Martin, a senior scientist in UCS's Clean Vehicles Program. "EPA should be congratulated for having an open process on this rule that involved scientists, farmers and the ethanol industry."

Despite intense pressure from the corn ethanol industry to exclude emissions from indirect-land-use change, the EPA found that such emissions are a major source of heat-trapping pollution from corn ethanol and other food-based biofuels. This finding affirms the view of 200 scientists and economists with relevant expertise who sent a letter to the EPA in September 2009 arguing that "grappling with the technical uncertainty and developing a regulation based on the best available science is preferable to ignoring a major source of emissions." The EPA also issued an analysis examining the scientific uncertainty involved in calculating emissions from indirect-land-use change and plans to ask the National Academy of Sciences to look at the issue.

Indirect-land-use-change emissions also have been the focus of recent analysis by the California Air Resources Board, as well as peer-review scientific articles, which concluded that using food crops to produce fuel increases worldwide demand for those crops, prompting farmers to clear previously untouched land to grow new crops. Clearing land, especially tropical forests, releases massive amounts of heat-trapping gases into the atmosphere.

The Renewable Fuel Standard, enacted in 2005, requires fuel suppliers to blend a higher percentage of renewable fuels, such as ethanol and biodiesel, into motor vehicle fuels over time. In 2007, Congress passed the "Energy Independence and Security Act," which expanded the standard's overall volume requirement from 7.5 million gallons by 2012 to 36 billion gallons by 2022, and significantly increased the requirement for low-carbon cellulosic biofuels. It also required the EPA to establish independent volume mandates for different fuel categories. Each category was to be defined by its lifecycle heat-trapping emissions compared with conventional gasoline. The categories include: renewable fuel (20 percent less emissions than gasoline), biomass-based diesel (50 percent less), advanced biofuels (50 percent less), and cellulosic biofuels (60 percent less).

Corn ethanol facilities that were operating or under construction in 2007 are exempt from meeting the emissions-reduction requirements. The EPA projects that new corn ethanol facilities coming on line in 2022 could meet the 20 percent heat-trapping emissions reduction threshold for renewable fuels. However, this analysis is based on projected increases in crop yields and improvements in ethanol production technology and is not an analysis of the performance of today's corn ethanol facilities.

UCS experts say cellulosic ethanol, derived from grass, wood chips and other waste material, is a better option. According to EPA analysis, ethanol made from corn residue, or stalks and cobs, could reduce emissions by more than 90 percent compared with gasoline, in part because it would not necessarily displace land used to grow food crops and therefore would not trigger significant indirect land use emissions.

Cellulosic fuel production, however, has fallen short of the EPA target. The 2007 energy law required suppliers to produce 100 million gallons of cellulosic fuel in 2010. But current cellulosic ethanol production stands at only 6.5 million gallons. Therefore, the EPA announced today that it is waiving 93.5 million gallons of the 100 million gallon requirement.

"Achieving energy security and tackling climate change will require a big contribution from cellulosic fuels," said Martin. "Just setting a goal isn't good enough in this economy. We need investment policies that help this industry get off the ground."

According to UCS, the most important thing federal legislators could do to meet the Renewable Fuel Standard's goals would be to support investment in building commercial-scale cellulosic biofuel facilities across the country. An investment in this essential clean energy technology would jumpstart rural economies and expand the economic benefits of biofuels production

M. R. Schmer, K. P. Vogel, R. B. Mitchell, and R. K. Perrin. 2008. Net energy of cellulosic ethanol from switchgrass. Proc. Nat. Acad. Sci. USA 105: 464-469.
J. Kaiser and S. Bruckerhoff. 2009. Switchgrass for biomass production by variety selection and establishment methods for Missouri, Illinois, and Iowa. Technical Note 35, USDA Iowa State Office, Ames, IA, USA.
L. Gibson and S. Barnhart. 2007. Switchgrass. Report AG 200, Iowa State Univ., Ames, IA, USA.
S. B. McLaughlin and L. A. Kzos. 2005. Development of switchgrass (*Panicum virgatum*) as a bioenergy feedstock in the United States. Biomass and Bioenergy. Vol. 28. pp. 515-535.
http://aiche.confex.com/aiche/2009/webprogrampreliminary/Paper171370.html - hydropyrolysis
D. Miller. 2008. A note on rising food prices. Policy Research Working Paper 4682, World Bank, Washington, DC, USA.
J. M. Melillo,J. M. Reilly, D. W. Kicklighter, A. C. Gurgel, T. W. Cronin, S. Paltsev, B. S. Felzer, X. Wang, A. P. Sokolov, and A. Schlosser. 2009. Indirect emissions from biofuels: How important? Science 326: 1397-1399.
S. C. Davis, K. J. Anderson-Teixeira, and E. H. DeLucia. 2009. Life-cycle analysis and the ecology of biofuels. Trends Plant Sci. 14: 140-146.
M. J. Groom, E. M. Gray, and P. A. Townsend. 2008. Biofuels and biodiversity: Principles for creating better policies for biofuel production. Conserv. Biol. 22: 602-609.

dead zone:
http://www.nola.com/news/index.ssf/2009/09/post_31.html

80% sunlight availability
average 234 W m-2 → (from 4.5 kWh m-2 d-1 → → 188 W m-2 - close)

Appendix I. Efficiency of using solar energy input in growing switchgrass

What is the solar energy input at places where switchgrass trials have been done?

See the map at http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/serve.cgi

4.5 kWh m^{-2} d^{-1}, or 16.2 MJ m^{-2} d^{-1}. Per year, this is 5.91 GJ m^{-2}

Assume the biomass yield averaged about 14 tonnes/ha, or 14 Mg/ha, which is 1400 g m^{-2}.

The embodied energy in biomass for combustion in air is closely 20 kJ g^{-1}. The 1400 g per m^2 then represents an energy value of 28 MJ m^{-2}.

This energy is converted to final fuel energy with about 50% efficiency [1 kg of dry biomass with an energy content of ca. 19 MJ, yields about 0.34 L of ethanol, with an energy content of 10 MJ], giving us an annual energy yield per ground area of 14 MJ m^{-2}.

The energy efficiency is the ratio between this figure and the total solar energy, or
14/5910 = 0.0024 = 0.24%.

Note that the highest one-crop energy conversion (to biomass only) ever observed was 6.6% in sugarcane in Hawaii. The average efficiency of earth's vegetation in capturing energy in sunlight is 0.30%.

The low efficiency for switchgrass as an ethanol source derives in good part from its short growing season and the need to convert it to ethanol.

Appendix II. Ultimate energy efficiency of using biomass for vehicular transporations, as liquid fuel vs. for electricity generation

Gasoline as a liquid fuel is converted to mechanical energy in an automobile engine at an average rate commonly quoted as approximately 18% at the beginning of the drivetrain (http://www.fueleconomy.gov/FEG/atv.shtml). The figure varies considerably with the degree of urban vs. highway driving. Regenerative braking in a hybrid vehicle recoups energy and raises the effective efficiency projected to the beginning of the drivetrain by about 1/3, to about 24%.

Assuming the same efficiency for ethanol use in an engine, and 50% energy conversion from plant biomass to ethanol, and a multiplier of 0.9 to account for energy use in distribution, the overall efficiency from biomass to drivetrain is about 11%. This assumes use of the fuel in a hybrid vehicle.

Electricity generation from biomass to electric power in a coal-fired power plant ranges from 35 to 45%. The lower figure would apply to a power plant using biomass extensively at lower combustion temperatures. Transmission line losses average about 7% nationally; we might inflate this to 10% for longer lines linking biomass power plants to sites of use.

Consider use of the electricity in an electric or plug-in hybrid vehicle. The charge/discharge cycle of the vehicle's batteries has an efficiency ranging from 60 to 90%, depending on the type of battery (various sources) so that the net energy efficiency from biomass to battery-delivered energy in an electric vehicle is about 0.35*0.9*0.75 = 24%. Electric motors operate over a wide range of energy efficiencies, from zero at dead start up to 90% at full operating speed. In a vehicle, we might assume 75% as an average (http://www.fueleconomy.gov/Feg/evtech.shtml). We then credit the regenerative braking by multiplying the effective drivetrain efficiency by 4/3, giving us a final energy efficiency equivalent to 24%, more than twice that for using biomass to make ethanol for a comparable vehicle.

These calculations do not account for the significant capital energy in making the batteries for electric vehicles, either plug-in hybrid or pure electric. Nor do they account for the lower load-carrying capacity of electric vs. liquid-fueled vehicles that may affect the number of vehicles needed nationally.

Another biofuel water study:
http://www.farmfoundation.us/news/articlefiles/401-Final_version_Farm_Foundation%20feb%2020%2009.pdf#page=105

http://www.card.iastate.edu/presentations/
Biofuels and Water Quality in the Midwest: Corn vs. Switchgrass 4.21 MB
Silvia Secchi, Philip W. Gassman, Manoj Jha, Lyubov Kurkalova, and Catherine L. Kling
Presented at the Iowa Water Conference, Ames, Iowa (February 2008), and the Ecological Society of America Biofuels Conference, Washington, DC

Pros and cons of biofuels:
http://www.economist.com/world/international/displayStory.cfm?story_id=E1_TQSTDQGJ (need paid subscription)