Agronomic Suitability of Bioenergy Crops in Mississippi

MISSISSIPPI STATE UNIVERSITY EXTENSION

In Mississippi, some questions need to be answered about bioenergy crops: how much suitable land is available? How much material can that land produce? Which production systems work best in which scenarios? What levels of inputs will be required for productivity and long-term sustainability? How will the crops reach the market? What kinds of infrastructure will be necessary to make that happen?

This publication helps answer these questions:

- Which areas in the state are best for bioenergy crop production?
- How much could these areas produce sustainably?
- How can bioenergy crops impact carbon sequestration and carbon credits?
- How will these crops affect fertilizer use and water quality?
- What kind of water management is needed to maintain a productive crop?

The answers to these questions will help supporting institutions across the state to improve land assessment and agronomic management practices for biomass production.

In the last decade, energy supply has become a worldwide problem. Bioenergy crops could supply energy in the future. Bioenergy crops are plants, usually perennial grasses and trees, that produce a lot of biomass that can be converted into energy. Bioenergy crops can be grown for two energy markets: power generation, such as heat and electricity, or liquid fuel, such as cellulosic ethanol. These resources could reduce petroleum dependency and greenhouse gas production. Woody plants and herbaceous warm-season grasses, such as switchgrass, giant miscanthus, energy cane, and high yielding sorghums, could be major sources of biomass in Mississippi.

Land Suitability for Bioenergy Crops

Any land being considered for bioenergy crops should have environmental limitations. Environmental limitations may include protected areas (CRP), biodiversity hotspots, agricultural areas, and population centers. The land should also be assessed using a land resource inventory. The land resource inventory should include information about climate, soils, and landforms. In Mississippi, there are over 8.3 million acres of agricultural land that could grow bioenergy crops (Table 1). Land that can grow food crops should be saved for food crops. Use marginal lands for energy production, as long as energy production will not cause erosion or otherwise harm the environment.

There are four production systems that could work well and be sustainable in Mississippi. These systems could include perennial grasses, such as switchgrass, giant miscanthus and energy cane, and annual grasses, such as sweet sorghum and forage sorghum.

Mississippi's land and climate lend themselves to the growth of many crops that could be used for energy – both traditional biomass (corn) and cellulosic biomass (switchgrass and miscanthus). But there is research to be done. First, Mississippians must determine realistic production and profit goals. Research should also focus on the productivity of different bioenergy crops in different regions, the energy content of bioenergy crops produced in Mississippi, the impact of bioenergy on soil and water quality, and logistical issues, such as transportation to biofuel processing facilities. Research should also assess the long-term effects on carbon sequestration and greenhouse gas emissions.

Table 1. Agricultural land[1] use by category in Mississippi and portions potentially available for bio-energy production (2007 U.S. Census of Agriculture).

Land use category	Total area (acres)	Area assumed usable for bioenergy crop production
Cropland		
Harvested cropland[2]	4,223,708	3,378,966 (80%)
Cropland used only for pasture and grazing	741,307	481,850 (65%)
Other cropland		
Cropland idle or used for cover crops or soil improvement but not harvested and not pasture or grazed	473,000	354,750 (75%)
Cropland in which all crops failed or were abandoned	56,816	51,134 (90%)
Cropland in cultivated summer fallow	35,994	34,194 (95%)
Conservation practices[3]	1,107,406	555,703 (50%)
Pasture		
Permanent pasture and rangeland	2,100,000	1,785,000 (85%)
Woodland		
Woodland pastured	561,225	448,980 (80%)
Woodland not pastured[4]	3,049,766	1,219,906 (40%)
Total Agricultural land[5]	12,351,222	8,310,483 (67%)

[1] Excludes special uses, such as farmsteads, buildings, livestock facilities, ponds, roads, and wasteland.
[2] Includes corn, cotton, soybean, sorghum, oats, barley, wheat, rice, hay crops.
[3] Includes land in Conservation Reserve, Wetlands Reserve, Farmable Wetlands, or Conservation Reserve Enhancement.
[4] Excludes land in forest, parks, and other special uses.
[5] Excludes land in other uses such as fruit, vegetable, and minor crop production.

Biofuels are increasingly considered key to any strategy for energy independence. To be practical, bioenergy crops must compete successfully both as crops and as fuels. Perennial bioenergy crops could displace annual row crops that are more expensive and time-consuming. Owners of cropland will produce bioenergy crops only when they anticipate an economic return that is at least as much as the returns from the most profitable conventional crops, such as corn, soybeans, and cotton. When conventional crops have unstable returns, owners may decide to use their land to produce bioenergy crops instead. As the market price of conventional crops increases, the cost to produce bioenergy crops is likely to increase. Geographical variation in the costs of producing these crops and the opportunity costs of land are likely to make the economic viability of cellulosic biofuels differ across locations and the available land resources.

Establishing Bioenergy Crops

Policy makers need to know more about Mississippi's potential for bioenergy development and the best places for bioenergy crop production. Using the best agricultural management practices will favor a long-term sustainable use of the natural resources.

Monocultural production of bioenergy crops seems to be problematic for most producers due to erratic establishment. A producer should expect slow establishment due to high seed dormancy in species such as switchgrass, Indiangrass, little blue stem, and eastern gammagrass.

On the other hand, giant miscanthus and energy cane are usually established through sprigs or canes planted in the spring or fall. The techniques used to plant sprigs or canes are similar to those used to plant bermudagrass sprigs or sweetpotato slips. Poor moisture could cause the sprig to desiccate and reduce establishment success. Because of the slow establishment, these grasses will take three years to become productive. Weed competition, severe winter temperatures, encroachment of perennial forbs, and warm-season grasses can also slow establishment. Since most of these second-generation bioenergy crops can have an effective lifespan of well over 10 years, they may have a place in long rotations to build soil and renovate infertile farmlands.

Fertility Requirements for Bioenergy Crops

Research suggests that some of the bioenergy crops can be grown and maintain productivity even on soils with low fertility and low fertilizer inputs. This is because the carbon and nitrogen in the shoots recycle to the below-ground parts (roots and crown) at the end of the growing season. There is evidence that fertilizer might be necessary within the first five years of establishment. After that, switchgrass and giant miscanthus have developed a deep root system (3 to 10 ft.) that could provide a good nutrient reserve (Lemus et al., 2008). Other strategies that could reduce dependence on commercial fertilizer include maintaining a legume component and incorporating manure. However, tropical grasses, such as sorghums and energy cane, do not recycle nutrients to roots and therefore require fertilizer applications.

Harvest and Feedstock Quality

Switchgrass, giant miscanthus and forage sorghum could be harvested with conventional haying equipment after the top growth has completely died. The best time to harvest sweet sorghum for high quality juice is around mid-dough stage. In Mississippi, harvest will occur from mid- to late November. Late season harvests are important to maintain low nitrogen, low lignin, and high cellulose content, key characteristics for high quality ethanol feedstock. High nitrogen content can reduce the conversion efficiency of biofuel and pollute air after conversion. Studies have found that a single harvest of switchgrass in late fall or early winter results in the highest sustainable biomass yields and best stand persistence from year to year (Parrish and Fike, 2005).

Moisture of the bioenergy crops should be at 15 percent or less to facilitate quick bailing, easier transportation, and higher feedstock quality. Bioenergy crops used for co-firing are commonly used at 12 to 13 percent moisture (Lemus and Parrish, 2009).

Cutting each species to the ideal height is also important. Keeping enough residual biomass could help maintain enough ground cover to protect the root crowns from winter kill. Also, bale size has a major impact in transportation cost, storage, and processing at the plant. To reduce costs, develop a standard bale size that can be handled by most processing plants.

Herbaceous Biofuel Feedstock Candidates

Switchgrass (Panicum virgatum L.)

Switchgrass is a fast-growing, higher-yielding low-land type perennial. It is a warm-season grass native to Mississippi. Switchgrass is useful for either forage or bioenergy. It is a good bioenergy crop because it has demonstrated high productivity across various environments, suitability on marginal and erosive land, relatively low water and nutrient requirements, and positive environmental benefits. It is excellent for erosion control and soil improvement because of its extensive, deep root systems and fine-root turnover, which also provides for carbon sequestration and soil stabilization. Newer varieties of switchgrass with improved biomass yield and chemical composition have been released, but their productivity and suitability has not been fully tested in Mississippi.

Yields can range from 3.0 to 7.0 tons DM ac-1 (Table 2). Switchgrass can be grazed through mid-July and harvested for bioenergy in fall, making switchgrass part of a flexible bioenergy system. In the South, second- or third-year stand becomes available for grazing around mid-April. It could be used for stocker cattle production early in the season (30 to 90 days grazing period) and then grown for biofuel.

Table 2. Biomass yields of nine switchgrass varieties in 2007 and 2008[1,2] at Starkville, MS (Lang, 2010).

Variety	2007	2008
	DM Yield (tons ac-^{1})	
Alamo	5.6	6.4
Cave-in-rock	4.1	3.3
Kanlow	4.0	4.9
NA Shawnee	3.5	4.2
NF/GA-991	7.0	6.7
NF/GA-992	6.4	6.1
NF/GA-993	6.9	6.9
NF/GA-001B	8.1	6.3
NFSG05-1	6.0	7.5
Mean	5.7	5.8
$LSD_{0.05}$	1.7	2.0

[1] Plots were fertilized in 2007 and 2008 with 448 and 335 lb/ac of 15-5-10, respectively.
[2] Plots were harvested in December of both years.

Giant Miscanthus (Miscanthusx giganteus)

Giant miscanthus is a perennial warm-season grass with very little forage potential because of its morphology. Unlike Miscanthus sinensis, which produces viable seed and is becoming a prevalent weed in the Carolinas, Kentucky, Tennessee, and Pennsylvania, giant miscanthus produces no viable seed. It has a good cold tolerance and is winter hardy. Similar to switchgrass, giant miscanthus has a low requirement for N fertilizer because it efficiently translocates N between aboveground biomass and belowground structures. Giant miscanthus can grow from April to November and be harvested in early winter when moisture content and alkali levels are reduced.

A disadvantage of using giant miscanthus as a bioenergy crop is that it is propagated via cane or rhizome cuttings and therefore not productive until the second or third year. The recommended planting is usually on three-foot centers, but 30-inch centers can increase canopy closure. Variety trials in Mississippi have indicated that giant miscanthus could produce higher biomass than switchgrass (Table 3).

Table 3. Comparison of giant miscanthus and Alamo switchgrass yields in Southeast USA for plots planted in 2002 (Baldwin, 2008)

		Yield (tons ac^{-1})				
Herbaceous crop	**Harvest Regime[1]**	**Year**				
	-days-	2003	2004	2005	2006	2007
Giant miscanthus	1-90	6.1	15.0	19.0	–[2]	–[2]
	91-180	1.7	2.5	3.3	11.2	14.3
	1-180	10.4	10.2	22.5	21.7	14.2
Switchgrass	1-90	8.7	13.0	14.5	–[2]	–[2]
	91-180	2.5	3.2	3.7	8.5	11.2
	1-180	12.7	9.6	16.9	17.2	8.4

[1] Harvest regimes are listed as two, 90-day cycles (1-90 representing the first harvest and 91-180 representing second harvest), and 1-180 representing a single full-season (180-day) harvest.
[2] No first harvest was taken.

Giant Reed (Arundo donax)

Giant reed is also known as reedcane, fibercane or energygrass. Plants are bamboo-like; they have hollow stems that may reach 10 to 18 feet and produce large flowers. They do not produce viable seeds in temperate areas of the Southeast, such as Mississippi (Duke, 1983). Giant reed can grow in a range of soils, from heavy clays to sands, but it is most productive in well-drained soils with abundant moisture.

Establishment must be by propagation from vegetative material, such as shoots, canes, or rhizomes. One disadvantage is that giant reed cannot be harvested with conventional hay equipment. However, giant reed can be established and harvested with sugarcane production equipment or silage equipment. Nitrogen fertilization recommendations range from 35 to 50 lb N ac-1 yr-1 (Bransby et al. 2004). Yields typically increase from the first through the fourth year after establishment (Angelini et al., 2005).

Sorghums (Sorhum vulgare)

There are different types of sorghums that could be used to produce bioenergy or cellulosic ethanol. They include grain, forage, and sweet sorghums. Most sorghum species are relatively drought- and heat-tolerant and can grow on marginal land. The sorghums can be grown on soils ranging from heavy clays to light sands, with a pH above 5.8 preferred (Vermerris et al., 2008). They are very water-efficient and can produce high biomass yields averaging 10.7 tons DM ac-1 (Table 4).

Forage sorghum can be used as a dedicated bioenergy crop. Grain and sweet sorghum can be used for ethanol production because of their sugar and starch content. Varieties with higher juice production (Table 4) will be desirable, but those varieties yield less.

Under optimum environmental conditions, sorghums could be harvested for biomass several times throughout the season. They can also be planted late in the season and produce an acceptable biomass yield. One major disadvantage is that sorghum has to be planted every year, which increases the cost of production; the land tillage decreases its erosion control value.

Table 4. Biomass yield production of eleven sweet sorghum cultivars in Mississippi in 2007 (Horton, 2011 and Horton et al., 2008).

Variety	Yield[1] (Ton ac^{-1})	Juice Production[2] (percent)
Bale All	9.6	41.7
Bundle King	11.8	40.1
Dale	12.8	46.3
Della	10.2	44.3
Keller	11.2	45.6
M81-E	11.0	55.8
Simon	2.3	-
Sugar Drip	5.7	47.5
Sugar Top	16.1	47.9
Theis	10.3	32.8
Topper	13.6	48.1
Mean	10.4	45.0

[1]Yield includes grain and stalk biomass from the 2007 growing season.
[2]Two-year mean collected at the end of the season.

Energy cane (Saccharum spp.)

Energy cane is a perennial crop. It is a hybrid of domestic sugarcane and a cold-tolerant relative. Energy cane produces more fiber than sugarcane and therefore, less sugar, but like all other crops, cellulose in the fiber is valuable for conversion to energy. It is adapted to a large range of soils, from sandy to heavy clay soils.

Energy cane is currently being evaluated in test plots at Mississippi State University, at both Starkville and Raymond, in conjunction with USDA-ARS Sugarcane Research Unit. The energy cane's initial use was to be for ethanol production, with a projected yield of 900 to 1,100 gallons. (In contrast, sugarcane produces about 800 gallons.) This value is derived from conversion of both juice and fiber in the stalks. The life expectancy of energy cane is seven to eight years. Average yields are expected to be 7.1 tons DM ac-1 (Table 5), but that varies by latitude (lower yields are expected farther north) and the variety (some are more cold hardy than others). Typically, September-planted canes lay on their sides in a furrow. Energy cane produces a harvestable yield the following October, after 13 months of growth. Nitrogen recommendations range from 60 to 80 lb N ac-1.

Bioenergy crops offer opportunities to develop new markets for co-firing, biofuels, and biomaterials. An advantage of using forage crops for bioenergy is that farmers are familiar with their management and already have the capacity to grow, harvest, store, and transport them. Perennial crops dedicated to biomass feedstock production seem to be ideal because there would be no annual reestablishment costs and no need for annual tillage, reducing inputs, costs, and soil erosion. The crops would also provide a permanent vegetative cover that could conserve soil and protect water quality. Ethanol has been one of the prime biofuel options, and the commercial sector can now convert biomass to petroleum-like products. However, the demand on biofuel from the industry is still placed on biomass. With its long growing season, Mississippi can help meet the national goal of producing biomass to meet the US's future energy needs. This longer growing season could also allow feedstock growers to grow a diverse number of bioenergy crops that could provide a continuous supply of both sugar and ligno-cellulosic based products to biorefineries and power plants in the area. The infrastructure for power plants and biorefineries across the state is still in the early developmental stages with interest from different national companies to place plants strategically to increase efficiency and decrease transportation costs.

Table 5. Biomass of different energy cane (Saccarum spp.) accessions at Starkville, MS (Baldwin, 2010).

	Year		
Accession	**2008**	**2009**	**Mean**
	—Yield (ton ac^{-1})—		
HO 00-9611	3.4	2.3	2.9
HO 96-9881	2.3	4.1	3.2
L 99-2331	1.9	1.8	1.9
H_O 01-07	2.1	11.5	6.8
H_O 02-144	2.4	10.1	6.2
H_O 02-147	2.8	20.8	11.8
H_O 06-9001	2.5	21.3	11.9
H_O 06-9002	2.3	15.4	8.9
H_O 72-114	3.2	20.0	11.6
Mean	2.6	11.9	-

[1]Accessions are sugarcane checks.

References

Angelini, L.G., L. Ceccarini, and E. Bonari. 2005. Biomass yield and energy balance of giant reed (Arundo donax L.) cropped in central Italy as related to different management practices. European. J. Agron. 22(4):375–89.

Baldwin B. 2008. Cultured Feedstocks. Annual Report. Sustainable Energy Research Center (SERC), Mississippi State University.

Baldwin, B. 2010. Giant Miscanthus variety trials. Mississippi State University.

Bransby, D.I., H. Gu, J.R. Duke, G.A. Krishnagopalan, and H.T. Cullinan. 2004. An update on giant reed and mimosa for energy, fiber, and other uses. In: Annual Meeting of the Association for the Advancement of Industrial Crops/New Uses Council Joint Annual Meeting: Industrial Crops and Uses to Diversify Agriculture, 19–22 September 2004, Minneapolis, MN.

Census of Agriculture. 2007. National Agricultural Statistic Service. United States Department of Agriculture.

Duke, J.A. 1983. Arundo donax L. Purdue University Center for New Crops and Plants Products.

Horton, S.D., J.R. Rushing, and B.S. Baldwin. 2008. Sweet sorghum, a better source of ethanol. In: AAIC 20th Annual Meeting, 7–11 September 2008, College Station, TX.

Horton, S.D. 2011. Evaluation of sweet sorghum cultivars as a potential ethanol crop in Mississippi. Thesis. Mississippi State University

Lang, D. 2010. Switchgrass variety trials. Mississippi State University.

Lemus, R. and D.J. Parrish. 2009. Herbaceous crops with potential for biofuel production in the USA. CAB Reviews 4, N0. 057:1-23. DOI: 10.1079/PAVSNNR20094057

Lemus, R., D.J. Parrish, O.A. Abaye. 2008. Nitrogen-use dynamics on switchgrass grown for biomass. Bioenergy. Res. 1:153–162. DOI 10.1007/s12155-008-9014-x

Parrish, D.J. and J.H. Fike. 2005. The biology and agronomy of switchgrass for biofuels. Crit. Rev. Plant Sci.24:423–59.

Vermerris, W., C. Rainbolt, D. Wright, Y. Newman. 2008. Production of Biofuel Crops in Florida: Sweet Sorghum. Publication No. SS-AGR-293. University of Florida Cooperative Extension Service, Tallahassee, FL. p. 4.

Publication 2713 (POD-12-19)

By **Rocky Lemus**, PhD, Extension and Research Professor, Plant and Soil Sciences; **Brian Baldwin,** PhD, Professor, Plant and Soil Sciences; and **David Lang,** PhD, Professor, Plant and Soil Sciences.

Produced by Agricultural Communications.

Extension Service of Mississippi State University, cooperating with U.S. Department of Agriculture. Published in furtherance of Acts of Congress, May 8 and June 30, 1914. GARY B. JACKSON, Director