# Growing alternative energy crops in West Central Minnesota

## A review done under an internship while part of the West Central Research and Outreach Center

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Alternative energy crops have the potential to provide sustainable and renewable energy while assisting in mitigating current global climate change.  Alternative energy crops convert the suns energy into usable energy through the process of photosynthesis, where they take sunlight, carbon dioxide, and water and convert it into oxygen and usable energy typically in the form of sugar or carbohydrates. These plants can then be harvested and used for conversion to energy helping offset the need for fossil fuels.  Alternative energy crops include short rotation woody crops, switchgrass, corn, miscanthus and other perennial plants.  When planting an energy crop it is important to match the local conditions with the energy crop that will be plant, this will help maximize yield while preserving the local habitat.

## Introduction

The rising price and negative environmental impacts of using fossil fuels has caused increased interest in using renewable forms of energy. Extensive research in renewable energy has found that an important source of energy will be converting biomass (any organic material coming from living matter) into energy. Many methods of converting biomass to energy have been identified, and currently some of these methods are being utilized. When biomass is grown for energy conversion, it is typically called a feedstock. Many potential feedstocks have been identified for conversion to energy; originally, emphasis was put on short rotation woody crops that would develop high amounts of renewable biomass over a short period of time. Scientist then transition the main focus of research to switchgrass and other perennial grasses, due to their high yield potential and relatively low input needs, currently research is focused on using specialty crops and agricultural residues (McLaughlin and Kszos, 2005).

This review was done by analyzing important characteristics of select alternative energy crops and comparing them for growth in west central Minnesota. The attributes being considered include establishment, yield, energy content, harvesting and environmental issues. Establishment is an important consideration because it will show what nutrients and water availability will be needed to establish the crop. Studying establishment will also help determine if local soil and weather conditions will have an effect on the growth of the biomass. Yield and energy content should be considered because it will be important to have sufficient biomass to continue energy conversion. Knowing the amount of biomass produced and the energy content of that biomass will assisting in estimating the amount of biomass that will be needed for an energy conversion facility. Environmental issues are a concern because planting an energy crop has the potential to change the local habitat which can then have an effect on local animals and plant populations.

Energy crops in this review include non-native crops, native crops and native prairies; they were reviewed for conversion to energy in west central Minnesota. The non-native energy crop that will be reviewed is miscanthus, a grass that is native to Asia. Miscanthus is being analyzed for its potential high biomass yields and low input needs (Lewandowski et al, 2003). The native energy crops that will be reviewed include switchgrass and big bluestem. The native crops are being analyzed because of the high energy contents, and ability to grow on marginal land (Hallam, Anderson, and Buxton, 2001). Native prairies will not be considered for planting for energy but rather for harvesting the biomass that is grown for conversion to energy.

An important part of growing an alternative energy crop is its sustainability (Reijnders, 2006). Sustainable energy requires energy crops that can be produced in a way that will not inhibit future production, but are capable of meeting the energy needs of the current generation. Current energy production is not sustainable because it is using a finite resource (fossil fuels) that has a negative effect on the environment. For the energy to be sustainable it is important to consider erosion, nutrient uptake, future quality of the soil and effect on local water supply (Reijnders, 2006).

The alternative energy crops studied for growth in west central Minnesota all have some important attributes in common. They are rhizomatous, meaning they spread by the growth of rhizomes. A rhizome is a horizontal stem of a plant that is usually found underground. Rhizomes often send out roots and shoots from their nodes, the places on the stem where buds form. They all utilize the $C_4$ photosynthetic pathway, meaning they have both the Benson-Calvin pathway and Kranz anatomy. Plants that utilize the $C_4$ photosynthetic pathway are referred to as warm season, and plants that utilize the $C_3$ pathway are referred to as cool season. The photosynthetic rate is two to threefold greater in warm season plants than cool season plants (Waller & Lewis, 1979). The higher photosynthetic rate is important because photosynthesis is the most important factor in plant production (Waller & Lewis, 1979). Plants with high photosynthetic rates, warm season plants, have the potential to produce more biomass and more effectively use water than plants with lower photosynthetic rates, cool season plants (Waller & Lewis, 1979), (Niu, Liu, & Wan, 2008). The $C_4$ pathway gives warm season plants competitive advantages over cool season plants in situations of drought, high temperatures and nitrogen or carbon dioxide deficiency (Waller & Lewis, 1979). The energy crops studied for this review are all perennial, meaning that they are planted once and continue to grow every year. This is important because the farmer will not have the cost of planting the crop.

### Crops 1.1

Miscanthus is an East Asian warm season grass that comes can grow up to 3.5 meters high. Miscanthus species are woody, rhizomatous, non invasive and originally ornamental in nature (DEFRA, 2007). The hybrid of miscanthus that has sparked interest in the agricultural sector is a triploid hybrid called *Miscanthus x Giganteus*. This hybrid form of miscanthus produces sterile seeds; because of this the hybrid has to be planted as rhizomes.

Planting and establishment of miscanthus can be difficult and time consuming. Miscanthus is a poor weed competitor in the first year of growth, because of this it should be planted in a field without weeds and weeds should be controlled. This means use of a herbicide is necessary for growth of miscanthus. Typically the fall before miscanthus is planted, as well as after miscanthus is planted a herbicide is applied. Forrest (2008) tested three different herbicides and found that 2,4-D, lumax, and attrazine could all be applied to a field and miscanthus shows no ill effect to any of them, while even the slightest application of Round-up has been shown to have a killing effect on miscanthus. Lewandowski et al (2000) found that miscanthus should be planted in the spring; this allows the most growth potential before a dormant season, meaning that the crop will be the most developed going into the dormant season. Defra (2000) found the most difficult aspect of planting miscanthus is that it must be planted either special equipment or a potato planter because both are time and labor intensive. With the available specialty equipment planting rates up to 20 ha $day^{-1}$ can be achieved, while potato planters can only achieve up to 3 ha $day^{-1}$. Defra (2007) found that when planting miscanthus it should be planted at density of approximately 12 plants per square meter, this is approximately 10,200 rhizomes per ha.

It will be important in the first 2-3 years after establishment of miscanthus to apply fertilizer, herbicide and possibly water as needed. Heaton, Voigt and Long (2004) found that water is the most important agent for continued growth of miscanthus, and the most important nutrient is nitrogen. Lewandowski et al (2003), Defra (2007) and Bullard (1999) found that miscanthus should not receive nitrogen fertilizer in during the establishment year and then found that addition of very little per year after that was needed (see table 1). Lewandowski et al (1999) found that after the first 3 years of growth there was very little response to addition of fertilizer, the authors also found that miscanthus did very poorly without the addition of nitrogen.

Harvesting of miscanthus is typically done between late February and early May, in west central Minnesota harvest at this time may not be feasible. Harvesting should be done in the spring to obtain the driest stems, which will increase the energy conversion properties of the biomass. When miscanthus is harvested in the spring the leaves will not be harvested because they will already have fallen off. Defra (2007) reported that harvesting the leaves of miscanthus is not necessary, due to the high volatile content, and large amounts of ash and tar produced when the leaves of miscanthus are converted to energy. Lewandowski et al (1999) found that allowing the leaves to return to the ground will also add soil organic carbon to the soil. When harvesting miscanthus for conversion to energy Defra (2007) found that a dry baled product is most desirable. A row independent device will be needed to harvest older stands of miscanthus where the original planting pattern has been lost due to the growth of rhizomes. Lewandowski et al (1999) reports field losses during harvesting maybe up to 10% or more. When miscanthus is harvested yields of up to 30 tonnes per ha have been recovered (Lewandowski et al, 2003). Typically harvested biomass yields of miscanthus will be between 10 and 20 tonnes dry matter per ha (Lewansdowski et al, 1999, 2003), (Bullard, 1999), (table 1).

Miscanthus has a variety of possible uses in west central Minnesota. These uses include: carbon sequestration, high end animal bedding, fiber, and conversion to energy. Clifton-Brown, Stampfl and Jones (2000) found in a study based off the assumption that 12Mha of agricultural land would be available in Europe to grow miscanthus, they found that if all of that land was used for miscanthus production the carbon sequestration and mitigation potential was 76 Megatons Carbon per year this is enough to meet the current Kyoto requirements. Sequestration may become increasingly important with the trading of carbon credits in Europe and the possible future trading in the United States. Miscanthus has been studied mostly for it's us as an energy crop. The energy density of miscanthus was found by Lewandowski et al (2003) to be 17.1-19.2 MJ/kg. This is very close to the energy density of switchgrass and corn cobs, but still less than half the energy density of coal. Defra (2007) found that the energy density comparison between miscanthus and coal was 5 tonnes miscanthus was equil to 2 tonnes of coal.

There are some potential issues that should be considered when planting miscanthus for conversion to energy. Of these issues is miscanthus low tolerance for cold weather. The first two to three years of growth miscanthus has a low tolerance for cold weather, and consequently a west central Minnesota winter can kill a majority of the planted miscanthus. The Department of Natural Resources (2008) reported the average temperature in winter is 13 degrees, and temperatures commonly drop below 0 degrees. Large amount of research have been done because of this and results have included: genetic selection, cover crops, planting a cover crop and using A-frames. Clifton-Brown and Lewandowski (2000) did an experiment where they studied different genotypes and how they reacted to cold weather and frost situations. They found that the hybrid *Miscanthus x Sinensis* generally had the best over winter survival rate, where *Miscanthus x Giganteus* had a low survival rate. Covering miscanthus with either an A-frame or covering with straw or mulch are not economically feasible. They are not economically feasible because of the amount of labor and tractor time and fuel cost that this would take. Lewandowski et al (1999) reported that growing a cover crop over miscanthus has increased survival rates.

Because miscanthus is a non-native plant, questions have been raised about how west central Minnesota habitats will adapt to miscanthus. Jodl et al (1998) found that miscanthus stands tend to contain more large animals (mammals, birds) than other herbaceous crops, possibly because of the greater diversity of canopy structure. The Organisation for Economic Co-Operation and Development (2003) reported that the height and structure of miscanthus share similarities with other tall perennial grasses, such as reed beds, and may therefore provide suitable habitats for birds that are adapted to reed beds and dense herbaceous vegetation. There is still little known about how west central Minnesota animal and plant communities will respond to miscanthus and because of this more research is needed.

Miscanthus has high potential for use as an energy crop, though little potential in west central Minnesota. Miscanthus has a high potential because of the high yields, low amount of inputs needed and high amounts of carbon that can be sequestered. Miscanthus growth in west central Minnesota has low potential for use because of the over poor overwinter ability, poor ability to adapt to cold weather and low amounts of moisture during the growing season.

### Crops 1.2

Native alternative energy crops are being researched for conversion to energy in west central Minnesota due to their high yield potential, low input needs, and ability to adapt to local conditions. West central Minnesota was comprised of mostly tallgrass prairie land where grasses such as big bluestem and switchgrass dominated the region before it was converted to agricultural use. Now there is interest in growing these grasses in monocultures for conversion to energy as well as other uses

### Crops 1.2.1

Switchgrass is a perennial warm season grass that is native throughout most of the United States. The Species is deep rooted and rhizomatous, with the ability to produce seeds in excess of 700 pounds per acre (NCRS, 2007). Uses for switchgrass include: conversion to energy, forage, hay, conservation, and erosion control. Reasons for researching switchgrass include: high dry matter yields, high energy content, and the ability to produce biomass on marginal land.

The establishment of switchgrass grown for energy has become an important topic in alternative energy research. Planting of switchgrass should be done on packed soil either with a seed drill or by broadcast under low or no till practices. Schmer et al. found in 2005 that broadcasting resulted in inferior seedling development conditions and contributed to low initial switchgrass stand. McLaughlin (2005) reported that in the first year of switchgrass growth it is important to apply a herbicide, because switchgrass is a poor weed competitor. Mulkey, Owen and Lee (2006) reported nitrogen is should not be added during the first year of growth, this is because the nitrogen will have a more beneficial effect on local weed populations than switchgrass. Paine et al. (1996) reported switchgrass is a very efficient nutrient scavenger and will spend the first year putting down a deep tap root that will provide future nutrient and water uptake. Switchgrass also possesses efficient nutrient utilization; this efficiency assists in high biomass production.

Management of switchgrass in west central Minnesota relies on allowing the switchgrass to properly be established, weed control and proper nutrient addition. During the first year of growth the above ground biomass that is produced is a small enough amount that even to a trained eye it may be unnoticed. The second year there is little production of switchgrass, in some studies they found that up to half of the possible biomass yield was grown, but in most cases there will be little aboveground biomass growth. The reason for such little aboveground growth in the first 2 years is the large amount of underground growth that takes place. In the third year there will be a sufficient amount of growth to harvest. In years were switchgrass is harvested the addition of nitrogen fertilizer will be required. Heaton, Voigt and Long (2004) found that the most important nutrient for continued switchgrass growth was nitrogen. Table 1 gives nutrient recommendations for growth of switchgrass in both establishment year and years following.

Switchgrass, in west central Minnesota, should be harvested once a year in the fall after the first killing frost (Mulkey, Owens, & D.K., 2006). Cuomo et al (1996) found that two or three harvests per year exhausted the plants rhizomes much faster than does harvesting once per year. Anderson and Matches showed in 1983 that harvesting switchgrass 3 times per year reduced yields 34-60% in the second year. Cuomo et al found in 1996 when switchgrass was harvested once annually the yields increased over three years, but when harvested three times annually the yield decreased after the second year. Cuomo et al also found that when switchgrass was harvested once annually the yields where increased by 750 Kg $ha^{-1}$ over three years while harvesting three times per year led to yield increases of only 50 Kg $ha^{-1}$ over three years, and the yield from one annual harvest was much greater than that of either 2 or 3 harvests annually. Hallam, Anderson and Buxton (2001) found that when switchgrass is harvested that typically yields of between 9-15 tons per ha can be produced.

West central Minnesota uses for switchgrass include: conversion to energy, forage, haying, erosion control, wildlife plantings and decorative planting. McLaughlin and Kszos (2005) reported the energy density of switchgrass to be 18.4 GJ per tonne; this is more than half the energy content of coal. There has been interest in growing switchgrass for conversion to energy this interest includes co firing with coal, conversion to ethanol and firing switchgrass to heat a boiler.

There is high potential for biomass production of switchgrass in west central Minnesota. This is because the relatively high yield potential as well as the high energy content. Switchgrass should be planted due to the efficient scavenging of nutrients, as well as efficient uptake. The efficiency in scavenging and taken nutrients assist in the high yield expected when growing switchgrass, as well as limiting the amount of nutrients that have to be added when switchgrass is fertilized.

**Crops 1.2.2**

Big bluestem is a native warm season grass that is a dominate grass in native tall grass prairies. Big bluestem is a rhizomatous tallgrass that is native to the Great Plains area (Midwest United States). Big bluestem is being examined due to its potential for high yields, efficient nutrient uptake and water usage, which allows bluestem to be drought tolerant. There has been a lot of research over time about big bluestem and consequently there is a lot known about the production, uses and management of big bluestem. The main uses for big bluestem include: forage, pasture planting, erosion control, conversion to energy and hay.

The establishment of big bluestem in west central Minnesota is similar to the establishment of switchgrass. Big bluestem is typically planted either with a seed drill or it is broadcasted. This is usually done on firm soil. Hallam, Anderson and Buxton report that in the first year nitrogen addition is not typically recommended, though if later in the season, typically late July to early August if weeds are controlled then big bluestem can benefit from an addition of nitrogen. Big bluestem is also a poor weed competitor in the first 2-3 years of growth, and consequently a herbicide is typically recommended in production.

Management of big bluestem is important when it is being harvested for conversion to energy. Big bluestem should not be harvested in the first or second year, due to the low amounts of biomass produced and so as to not hinder future productivity. In years after the establishment year it will be important to add nitrogen to the soil to increase and sustain biomass growth, it was found by Lewandowski et al (2003) that nitrogen was the most important nutrient for continued growth of big bluestem. Because of the importance of biomass removal in years when biomass is not harvested, the aboveground biomass should be burned.

Harvesting of big bluestem is also much like the harvesting of switchgrass; it should be done only once a year and harvested late in the year. Vogel and Bjugstad (1968) found that reduced yields can be caused by summer clipping while increased yields can be caused by clipping during the seed ripening and dormant stages of the big bluestem life cycle, Vogel and Bjugstad suggest that fall and winter clipping on shallow droughty soils. Dwyer, Elder, and Singh (1963) showed that pure stands of big bluestem grown on a deep loam soil greatest sustained yields were obtained by cutting every year in July. Even in this case it is recommended to harvest big bluestem in the fall after a killing frost; this is to ensure that all wildlife has moved out. Hallam, Anderson and Buxton (2001) found that typically yields of between 8 and 12 tonnes per ha can be achieved when harvesting big bluestem.

Uses for big bluestem include forage, haying, conversion to energy, medicinal uses, landscape, erosion control and wildlife plantings. Big bluestem is a high protein grass making it good for forage and feed for horses and cattle. Chippewa Indians used the root of big bluestem to alleviate stomach pains, while extracts of the leaf blades were used as a wash for fevers. Due to the rapid underground biomass growth and spreading of big bluestem it has been used for erosion control on soil with medium to high drainage. Big bluestem also can be used as a wildlife planting, as it provides a home to many species of song birds, as well as many insects.

When considering planting an energy crop, it is important to consider a variety of things. These things include: effect on local habitat, survival ability, yield, energy content, and known ability to grow on marginal soils and input needs. The non-native crop analyzed, miscanthus, has an unknown effect on local habitat, poor winter survival rates during establishment, which can be a problem in west central Minnesota. Where native grasses have a known effect on local habitat, high survival potential, high yield, high energy content, well know ability to grow on marginal soils and require low inputs. When considering planting an energy crop west central Minnesota a native crop such as switchgrass or big bluestem should be planted.

### Crops 1.3.1

Interest has been raised in using native prairie land, and high diversity grass mixtures for biomass production. It is important to distinguish between virgin native prairies and restored native prairies. Virgin native prairies are native prairies that are original, that have not been tilled. Restored native prairies are prairies that are being planting, and grown in effort to restore the land to its original state. Native prairies were self sufficient and home to large amounts of biodiversity. The Department of Natural Resources (2008b) found that one third of the land of the United States was prairie land this represents 741,000,000 acres, they estimated that less than three percent of that land remains virgin native prairie and most of that land is segmented into small sections.

Native prairies are a fire based ecosystem. An important reason native prairies rely on fire is the fire removes biomass. Burning also removes vegetation allowing the sun to heat the soil earlier in the year which raises soil temperatures and encourages the growth of $C_4$ (warm season) grasses. When prairie land is burned ash, the byproduct of the burn, goes right to the soil, adding small amounts of nutrients and cations to the soil and assisting in pH buffering. Burning biomass is currently a standard management tool for land managers, and is done on a two to five year rotation, but can be an expensive management practice, with costs including time, labor, equipment, training, paper work and mobilization. Estimates cost to burn prairies is $30 per acre (Tallaksen, 2008).

Tix and Charvat (2005) found that harvesting of native prairie land can be an alternative to burning biomass.  When considering harvesting prairie land considerations include future species diversity, wildlife, and future biomass growth.  Harvesting of biomass in native prairies has been shown to favor native forbs and legumes.  Tix and Charvat (2005) found that removal of biomass has also been shown to maintain diversity in native prairie lands.  The Department of Natural Resources (2007) set up recommendations for best management guidelines in native prairies when harvesting biomass for conversion to energy.  They recommend that part of the field should not be harvested, thus providing winter cover for wildlife such as resident game birds and prairie invertebrates.  They also recommended harvesting late in the year when most birds have already fledged.  Foster and Lovett found in 2003 that even harvested prairies would benefit from burning, because it is important for some species in the prairie for the prairie to be burned, because otherwise they can be crowded out by dominate prairie grasses and weedy non-native grasses.  Tix and Charvat found in 2005 growth of biomass will not be affected by harvesting of biomass, and removal of biomass prevents encroachment of woody species. They also found that mowing biomass without removing it was not an effective management practice. Tallaksen (2008) found that biomass can, from a practical and economic standpoint is successfully harvested from native grasslands. They also found that harvesting biomass as a management practice shows promise as a beneficial and cost effective tool versus the expense of a prescribed burn.

Typically, prairie restoration is done on marginal land enrolled in the Conservation Reserve Program (CRP), or owned by the DNR or Fish and Wildlife services.  Currently land is being pulled out of the CRP and being put into corn and soy bean production.  Land enrolled in CRP is marginal land, which is land that is either highly erodible or land that is sensitive.  Typically marginal land is unsuitable for crop production, because of lack of nutrients in soil, and high erodibility.  Examples of marginal land include land with low moisture, land with steep slopes, and land around moving water, land with extremes in pH, and nutrient depleted land.  Tillman et al (2006) did a study growing low input and high diversity (LIHD) native mixtures on marginal soil, researchers estimated that $5 \times 10^8$ ha of agriculturally abandoned and degraded land could produce biomass with the potential energy content of 90 GJ $ha^{-1}$ $yr^{-1}$. Controversy has been raised about the conclusions of the Tilman et al study. Russelle et al (2007) argued that LIHD plantings could not provide a sustainable source of harvestable biomass because when biomass is harvested all nutrients are removed from soil. Although legumes can replace nitrogen, nutrient replacement will be an important requirement for acidic marginal soils. Limestone additions would be required to maintain nitrogen fixation on soils with poor pH buffering. The amount of worldwide biomass production estimate was also questioned.

Native prairies provide habitats for many animals, some of these animals include the black tailed jackrabbit, common snipe, coyote, prairie chicken, prairie dog and pronghorn antelope. Many of these animals can no longer be found in Minnesota due to the lack of natural habitat, when native prairies are restored the DNR (2008b) found that some of these animals will return to the prairie area, but the area needs to be secluded. When planting a biomass crop in west central Minnesota, it is important to consider the habitat that biomass will provide for local animals.

Native prairies could become an important part in converting biomass to energy. Native prairies are a habitat that are beneficial for many animals in the west central Minnesota, they are well adapted to local conditions, have potential to produce biomass, sequester carbon, are already being restored throughout the West Central , and require biomass to be removed as a management practice. Native prairies can also help improve future soil quality, by increasing soil organic matter, as well as helping prevent erosion. Native prairies are especially important on soil that is considered marginal, as they provide a use for the soil that will not deplete soil quality any further.

## Considerations 2.1

When growing alternative energy crops for energy in west central Minnesota it is important to consider location.  Different locations have different attributes and these attributes affect biomass growth and what alternative energy crop will be most productive each specific location.  Attributes to consider include water availability, drought, soil type, and erosion.  Water availability and drought has the potential to cause problems when an area is relying on production of biomass, because drought and lack of water will result in lower yields of biomass.  Soil type is important because different biomass respond differently to different soil types and mixtures.  Erosion is important because it can affect amount of productive soil.

### Considerations 2.2

Water availability is an important consideration when planting an alternative energy crops. Briggs and Knapp (1995) found water is commonly a limiting agent in plant growth, meaning when the plant can no longer obtain water it will not grow beyond that point until adequate water is supplied. Water is important because it acts as a solvent for biochemical reaction; it is a key part in photosynthesis, helps transport nutrients, provides turgor pressure and is part of important biochemical reactions in the plant.  Photosynthesis is the conversion of sunlight carbon dioxide and water into oxygen and energy.  Turgor pressure is important because it is the pressure of the cell against the cell wall, it assists the plant in standing erects as well as keeping form which is important for the purpose of catching water and sunlight.  Water can also increase nutrient uptake, by helping flow of nutrients and providing a medium for flow of nutrients.

Drought can have a substantial impact on local habitats and agricultural in the affected region. A drought is an extended period of time where an area has a deficiency in water supply due to below average amounts of precipitation (Knapp, 1985).  The major agricultural effect of drought is reduced crop yield, which can lead to a number of things, including erosion, desertification and death of livestock. When a drought occurs typically $C_4$ grasses, such as switchgrass, big bluestem, have a high drought tolerance and survival rate because they relocate nitrogen as well as other nutrient to their rhizomes (Heckathorn and DeLucia 1994). Miscanthus is been found to be less tolerant to drought situation, but survival rate has been shown to be high, (DEFRA 2007) meaning typically the year of the drought miscanthus will have low yield but in subsequent miscanthus will survive. Big bluestem has been found drought tolerant to a point and anywhere past the point big bluestem will relocate nutrient to the rhizomes so as to protect future growth. Switchgrass has been shown to have a worse drought tolerant than big bluestem but will still survive some drought situations. Switchgrass will also relocate nutrients to the rhizomes to protect future growth. On area's were drought is known to be a concern it is important to considered what crop will be planted.

### Considerations 2.3

Energy crops react differently to different soil types. There are four main soil types, silt, clay, sand and loam. Sand is soil that is coarse or gritty, silt is a finer soil that is typically smooth and slippery to the touch. Clay soil is finest soil, and is typically made up of only clay particles. Loam is soil that is a mixture of more than one type of soil, it is typically the main soil type then loam, for example sandy loam, would be a soil that is not sand, but the main component is sand. The differences in the soil types are dealing with the size of the particles in the soil. Typically a soil will not be only one size of particle, but a mixture of two or more sizes.

Sandy soil can be difficult to grow alternative energy crops in due to the high drainage and low nutrient retention. Sandy soils do however have good aeration; this means that air can easily reach the roots of the plant. This is important because plants need air to reach the roots to survive. Sandy soils can however produce biomass large amounts of biomass if adequate nutrients and water are supplied.

The water supply needs to be frequent. If alternative energy crops are grown on sandy soil it is possible for the soil organic matter to increase and make the soil more fertile.

Silt soils can be good sites to grow alternative energy crops in due to high nutrient retention, and water holding capacity. Silt soils can however have problems with slow drainage during times of heavy rain, and silt soils also have poor aeration. Silt usually is found around moving water because silt is eroded rock that is moved a lot in water. Silt soils can also have poor aeration, but can store air in the soil for the plants roots to use. Typically silt soils will require less fertilizer and water to be added, due to the high retention.

Clay soil can be difficult to grow most crops but typically alternative energy crops can survive and produce high yields in clay. This is because of the development of a tap root system that goes deep enough and is rugged enough so that the roots do not break up due to soil texture. Alternative energy crop can be a good way to improve the clay soils because the root system will help break up the soil and improve aeration and poor drainage. To help growth of alternative energy crops on clay soil addition of organic matter is typically recommended.

### Considerations 2.4

When considering planting an alternative energy crop it is important to consider the potential of erosion. In 1995 Pimentel et al found that during the previous 40 years nearly a third of the world's arable land was lost to erosion and continues to be lost at a rate of more than 10 ha per year. There are many agents of erosion, including: wind, water, tectonic activity, ice and gravity. Limiting factors to erosion are texture of soil, gradient of slope, cover of vegetation, underground biomass, rocks, and land use. Above and belowground biomass are important considering preventing erosion because the underground biomass can help hold soil in place, while aboveground biomass can help protect the soil from erosion agents by limiting wind and water that reaches the soil. On an area that is erosion prone, a biomass that develops a large amount of underground biomass as well as a canopy of biomass is important. Kort, Collins and Ditsch (1998) found that using herbaceous perennial species, especially grasses, helps provide year-round protection and minimal soil erosion. They also found that growth improves soil productivity by increasing soil organic matter and improving soil structure by increasing soil water and nutrient holding capacity.

### Summary

All of the biomasses reviewed have the potential to produce high biomass it yields, while given relatively low inputs. It was found that the range for yield of miscanthus is between 20-40 tonnes per ha, the yield potential for switchgrass was 8-14 tonnes per ha, and the yield potential for big bluestem was 6-10 tonnes per ha. Typically all of the biomass reviewed produce lower yields on marginal soil, but will still have potential produce high amounts of biomass.

All of the biomasses were found to be able to produce biomass with low inputs. Many studies showed that miscanthus showed no response to nitrogen addition, but that miscanthus was more reliant on water. In these studies it was still recommended that miscanthus receive an addition of nitrogen. Switchgrass and big bluestem were more reliant on nitrogen to maintain biomass production, and could still produce biomass when little water was available.

Habitat was found to be one of the biggest differences amongst the energy crops studied. Miscanthus being a non-native crop raises question as to the effect on local habitat, it has been hypothesized that local animals will treat miscanthus plantations as a reed habitat, but there has not been enough study to substantiate that hypothesis. While the effect of switchgrass, big bluestem and native prairies on a location is well know. It is known to have a positive effect on local biodiversity, by providing a native habitat for both vertebrates and invertebrates. When considering habitat growing a biomass that is native to the location, such as switchgrass big bluestem and native prairie, has been shown to be constructive to the local animal community.

## Conclusion

This review found that that in different situations different biomasses should be planted. In west central Minnesota, it was found that a native biomass should be used due to the harsh winter conditions, adapted state of the native crops, known effect on local habitat and potential high yield on marginal land. It was found that miscanthus does very poorly surviving the first winter and in central Minnesota, because of the harsh winters. Where the native crops, such as big bluestem and switchgrass, were able to survive over winter. It was also found that harvesting native prairies could be a positive management choice for marginal land throughout west central Minnesota. This is because it would boost local habitat, provide a habitat for endangered and diminishing animal populations, sequester carbon from the atmosphere, help increase soil quality and provide protection for highly erodible soils.

When planting an alternative energy crop west central Minnesota, it is important to consider conditions of the immediate area. In most cases it was found that growing switchgrass was a good management practice as well as a good environmental crop. On highly erodible sandy soil it was found that growing big bluestem would be a good management practice. It is possible in areas further south, than west central Minnesota growing miscanthus as an energy crops would be advisable, but it will be important to first do studies on effect on local habitat before planting.

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## Table 1 Harvesting and growing information for three energy crops.

| | Study | Yield (t/ha) | Highest yield (t/ha) | Nitrogen Establishment Year (kg/ha) | Nitrogen Harvest Years (kg/ha) | Herbicide | Lime kg/ton | Harvest time | Location |
|---|---|---|---|---|---|---|---|---|---|
| **Switchgrass** | Epplin | 9 | 11 | 0 | 56 | 1.68 2,4-D | 0 | July-December | OK |
| | Ugarte | 11.86 | 14.83 | 0 | 22.4 (Kg $DT^{-1}$) | 1.12 2,4-D | 2.24 | Late Summer | MI, MN, WI |
| | Lewandowski | 14.75 | 15.4 | 0 | 50-100 | 2,4-D | 0 | After first Frost | Midwest/Lake States |
| | Hallam | 10.5 | 15.3 | 0 | 140 | 12L/ha Atrazine | 0 | October | IW |
| | Muir | 14.8 | 16.1 | 0 | 168 | 2,4-D | 0 | Late Summer | Texas |
| **Big Bluestem** | Hallam | 8.86 | 12.4 | 0 | 140 | 12 L/Ha Atrazine | 0 | October | IW |
| **Miscanthus** | Lewandowski | 20 | 30 | 60 | 50-70 | 2,4-D | .8-1 | March-April | South Europe |
| | DEFRA | 16 | 18 | 0 | Minimal | Broad spectrum | 0 | Late February-early May | Southern Europe |
| | Bullard | 18 | 24 | 103.9 | 80 | glyphosate | 0 | Mid February-Late March | Various Sites Europe |

## Table 1 Harvesting and growing information for three energy crops.

| | Study | Yield (t/ha) | Highest yield (t/ha) | Nitrogen Establishment Year (kg/ha) | Nitrogen Years Harvest (kg/ha) | Herbicide | Lime | Harvest time | Location |
|---|---|---|---|---|---|---|---|---|---|
| Switchgrass | Epplin | 9 | | 0 | 56 | 1.68 2,4-D | 0 | July-December | OK |
| | Ugarte | 11.86 | 14.83 | 0 | 22.4 (Kg $DT^{-1}$) | 1.12 2,4-D | 2.24 | | MI, MN, WI |
| | Lewandowski | 14.75 | 15.4 | 0 | 50-100 | 2,4-D | 0 | After first Frost | Midwest/Lake States |
| | Hallam | 10.5 | 15.3 | 0 | 140 | 12L/ha Atrazine | 0 | October | IW |
| | Muir | 14.8 | | 0 | 168 | 2,4-D | 0 | Late Summer | Texas |
| Big Bluestem | Hallam | 8.86 | 12.4 | 0 | 140 | 12 L/Ha Atrazine | 0 | October | IW |
| Miscanthus | Lewandowski | 12.1 | 16.2 | 60 | 50-70 | 2,4-D | .8-1 kg/ton | March-April | South Europe |
| | DEFRA | 16-Dec | 16 | 0 | Minimal | Broad spectrum | 0 | Late February-early May | Southern Europe |
| | Bullard | 24-Dec | 24 | 103.9 | 80 | glyphosate | 0 | Mid February-Late March | Various Sites Europe |

# References

Briggs J.M., Knapp A.K. 1995. Interannual Variability in Primary Production in Tallgrass Prairie: Climate, Soil Moisture, Topographical Position and Fire as Determinates of Aboveground Biomass. American Journal of Botany 82:1024-1030

Bullard M. 1999. Miscanthus Agronomy for Fuel and Industry Uses. Technical Report NF0403

Clifton-Brown J.C., Lewandowski I. 2000. Overwintering Problems of Newly Established Miscanthus Plantations can be Overcome by Identifying Genotypes with Improved Rhizome Cold Tolerance. New Phytologist 148: 287-294

Cuomo G.J., Anderson B., Young L.J., Wilhelm W. 1996. Harvest Frequency and Burning Effects on Monocultures of 3 Warm-Season Grasses. Journal of Range Management 48:157-162

DEFRA. 1999. Planting and Growing Miscanthus. http://www.defra.gov.uk/erdp/pdfs/ecs/miscanthus-guide.pdf

Department of natural Resources. 2007. Optimizing Native Prairie Seed Harvest and Replanting on State-Owned Lands. http://files.dnr.state.mn.us/aboutdnr/reports/pspb_report.pdf

Department of Natural Resources. 2008a. Climate. http://www.dnr.state.mn.us/faq/mnfacts/climate.html

Department of Natural Resources. 2008b. Prairie Restoration. http://www.dnr.state.mn.us/prairierestoration/index.html

Forrest L. 2008 Feasibility of Growing Miscanthus in Minnesota. Personal Communication

Foster J., Lovett J. 2003. Haying Effects on a Restored Prairie Plant Community in Northeastern Kansas. Transactions of the Kansas Academy of Science 106:198-206

Gustafson D.J., Gibson D.J., Nickrent D.L. 2004. Competitive Relationships of *Andropogon Gerardii* (Big Bluestem) from Remnant and Restored Native Populations and Select Cultivated Varieties. Functional Ecology 18:451-457

Hallam A., Anderson I.C., Buxton D.R. 2001. Comparative Economic Analysis of Perennial, Annual and Intercrops for Biomass Production. Biomass and Bioenergy 21:407-424

Heaton E., Voigt T., Long S.P. 2004. A Quantitative Review Comparing the Yields of Two Candidate $C_4$ Perennial Biomass Crops in Relation to Nitrogen, Temperature and Water. Biomass and Bioenergy 27:21-30

Heckathorn, Scott A; DeLucia, Evan H. 1994. Drought-Induced Nitrogen Retranslocation in Perennial C4 Grasses of the Tallgrass Prairie. Ecology 75:1877-1886

Knapp A.K. 1985. Effect of Fire and Drought on the Ecophyisology of Andropogon Gerardii and Panicum Virgatum in a Tallgrass Prairie. Ecology 66:1309-1320

Kort J., Collins M., Ditsch D. 1998. A Review of Soil Erosion Potential Associated with Biomass Crops. Biomass and Bioenergy 14:351-359

LaGory K.E., LaGory M.K., Perino J.V. 1982. Response of Big and Little Bluestem (*Andropogon*) Seedlings to Soil and Moisture Conditions. Ohio Journal of Science 82:19-23

Lewandowski I., Clifton-Brown J.C., Scurlock J.M.O. & Huisman W. 2000. Miscanthus: European experience with a novel energy crop. Biomass and Bioenergy 19:209-227.

Lewandowski I., Scurlock J.M.O., Lindvall E., Christou M. 2003. The Development and Current Status of perennial rhizomatous Grasses and Energy Crops in the US and Europe. Biomass and Bioenergy 25:335-361

Mann L., Tolbert V., Cushman J. 2002. Potential Environmental Effects of Corn Stover Removal with Emphasis on Soil Organic Matter and Erosion. Agriculture, Ecosystems and Environment 89:149-166

McLaughlin S.B., Kszos L.A. 2005. Development of Switchgrass (*Panicum Virgatum*) as a Bioenergy Feedstock in the United States. Biomass and Bioenergy 28:515-535

Mulkey V.R., Owens V.N., Lee D.K. 2006. Management of Switchgrass-Dominated Conservation Reserve Program Lands for Biomass Production in South Dakota. Crop Science 46:712-720

Mulkey V.R., Owens V.N., Lee D.K. 2008. Management of Warm-Season Grass Mixtures for Biomass Production in South Dakota USA. Bioresource Technology 99:609-617

NCRS. 2007. Switchgrass Biomass Trials in North Dakota, South Dakota and Minnesota. USDA

Paine L.K., Peterson T.L., Undersander D.J., Rineer K.C., Bartelt G.A., Temple S.A., Sample D.W., Klemme R.M. 1996. Some Ecological and Socio-Economic Considerations for Biomass Energy Crop Production. Biomass and Bioenergy 10:231-242

Reijnders L. 2006. Conditions for the Sustainability of Biomass Based Fuel Use. Energy Policy 34:863-876

Russelle M.P., Morey R.V., Baker J.M., Porter P.M., Hans-Joachim, Jung G. 2007. Comment on “Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass” Science 316:1567

Schmer M.R., Vogel K.P., Mitchell R.B., Moser L.E., Eskridge K.M., Perrin R.K. 2005. Establishment Stand Thresholds for Switchgrass Grown as a Bioenergy Crop, Crop Science 46:157-161

Tallaksen J. 2008. West Central Research and Outreach Center, Morris MN

Tilman D., Hill J., Lehman C. 2006. Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass. Science 314:1598-1600

Vogel W.G., Bjugstad A.J. 1968 Effects of Clipping on Yield and Tillering of Little Bluestem, Big Bluestem and Indiangrass. J. Range Manage. 21:136-140

Weaver J.E., Hougen V.H. 1939. Effect of Frequent Clipping on Plant Production in Prairie and Pasture. American Midland Naturalist 21:396-414