DOE/GO/10148--1-Pt.2

SWITCHGRASS BIOMASS ENERGY STORAGE PROJECT FINAL REPORT

by

Gerald Miller
Alan Teel
Susan Brown

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Switchgrass Biomass Energy Storage Project

Final Report

IDNR Contract No. 93-6102-01
with Amendment 1

July 1, 1996

Submitted by:

Gerald A. Miller, Professor of Agronomy

Alan Teel, Extension Field Specialist

Susan S. Brown, Extension Program Specialist

Iowa State University Agronomy Extension
2104 Agronomy Hall
Ames, IA 50011

Table of Contents

Introduction and project background

The Chariton Valley Biomass Power Project, sponsored by the Chariton Valley RC&D Inc., a USDA-sponsored rural development organization, the Iowa Department of Natural Resources Energy Bureau (IDNR-EB), and IES Utilities, a major Iowa energy company, is directed at the development of markets for energy crops in southern Iowa. This effort is part of a statewide coalition of public and private interests cooperating to merge Iowa's agricultural potential and its long-term energy requirements to develop locally sustainable sources of biomass fuel. The four-county Chariton Valley RC&D area (Lucas, Wayne, Appanoose and Monroe counties) is the site of one of eleven NREL/EPRI feasibility studies directed at the potential of biomass power. The focus of renewable energy development in the region has centered around the use of switchgrass (Panicum virgatum, L.). This native Iowa grass is one of the most promising sustainable biomass fuel crops. According to investigations by the U.S. Department of Energy (DOE), switchgrass has the most potential of all the perennial grasses and legumes evaluated for biomass production. Appendix 3 is a summary and bibliography on the potential value of switchgrass biomass as a fuel source, based on research at Iowa State University and elsewhere.

The biomass project includes demonstration and development of all aspects of commercial biomass power. Production (establishment and management) of switchgrass is being demonstrated on public lands managed by the IDNR with assistance from Iowa State University Extension (ISUE) and the Natural Resources Conservation Service (NRCS). The NRCS and the Chariton Valley RC&D are working with local producers to create interest in switchgrass production on their released federal Conservation Reserve Program (CRP) acres. The Farm Service Agency (FSA) in Iowa has allowed for cost share assistance to producers on 4,500 targeted acres of CRP for conversion to switchgrass, to establish a pilot test-scale supply. Meanwhile, biomass grown in the IDNR demonstration areas is used to study technology for establishment, production, harvest, storage and processing of switchgrass as biomass fuel, as well as for other uses. In the final steps in the project, funds from the U.S. Department of Energy (DOE) will be used to establish two power generation demonstrations; a small gasification unit and co-firing switchgrass with coal.

From 1993 - 1996, ISUE, under contract to IDNR-EB, has carried out studies and demonstrations of switchgrass establishment, nutrient and weed management, harvest and storage. This report addresses the work items in that contract.

Rationale

In the Chariton Valley RC&D area, as in most of southern Iowa, the landscapes and soils are well suited to the production of forages and trees, but cannot compete with the rest of the state for grain production. The NRCS estimates that more than three quarters of all the cropland in southern Iowa is subject to excessive soil erosion when used for intensive row crop production. Deterioration of the region's soil and water resources, coupled with mandated application of conservation practices and forecast reduction of agricultural production incentives, necessitates the development of viable alternatives to row crops on highly erodible land.

Ten percent of the approximately 1.4 million acres of crop land in the four county Chariton Valley area is in the CRP and 64% of the farmland is classified as highly erodible. As the CRP contracts begin to expire (90,000 acres are set to expire in 1996), bringing these and other erodible acres into use for biomass production, rather than row crops, is a sustainable and potentially profitable option. Chariton Valley RC&D and other project participants have proposed the establishment of biomass power generation capabilities as an alternative market for forages.

Given recent farm program changes, and potentially the eventual end of the CRP, adding value and establishing long term markets for perennial forage crops is vital for southern Iowa's continued prosperity. Production of native grasses on marginal lands as perennial energy crops is also attractive from a long-term resource management perspective. Much of the targeted land area is in the watershed of Rathbun Lake which supplies 13 Iowa and Missouri counties and 21 cities with water through Rathbun Regional Water Association, one of the largest rural water systems in the United States. Benefits to water quality and the local economy would be significant.

IES Utilities is participating in the project to study the feasibility of using a dedicated supply of southern Iowa biomass as a fuel source for a power generation facility. A proposed biomass gasification/electric generation plant with a capacity of 35 megawatts would need an estimated 30,000 to 40,000 acres of switchgrass for dedicated supply. Land currently in CRP is a natural candidate, as well as other highly erodible land in the area.

Local project cooperators include the four county Soil and Water Conservation Districts, FSA county committees, and other local groups supportive of the RC&D initiative. The Iowa Farm Bureau Federation is committed to recruiting farmers for biomass production and to developing a post-CRP industry. Technical assistance has been provided by the John Deere Ottumwa Works, which houses their forage research unit. Several local hay producers have assisted with field work on an in-kind basis.

Project activities

In Iowa, experience with switchgrass has shown that annual production can vary from two to six dry tons per acre. Establishment, management, and harvesting techniques are similar to other grass species, however optimum methods need to be determined and subject to cost/benefit analysis to support projections for the large scale production of switchgrass as a biomass fuel. In 1992 the Chariton Valley RC&D established a demonstration area for switchgrass production on a field trial scale of over 300 acres (see map, Appendix 1) at the state conservation farm on the north shore of Lake Rathbun, Appanoose County. The farm is managed by the Iowa Department of Natural Resources (IDNR). ISUE was contracted to provide a field specialist in crops and forages to coordinate the demonstration and study of switchgrass establishment, nutrient management, production costs, transportation, BTU and dry matter yield, and storage effects.

In fall of 1992, existing stands were harvested as large round bales for a storage study, and other areas received soil tests. In spring of 1993, several new areas were seeded, and a nitrogen (N) fertility trial begun on existing stands. In 1994 and 1995, the N trial was also conducted on the newly seeded plots. Results of these demonstrations are described below. From a producer's standpoint, is has become clear that management for biomass production is somewhat different than for an animal forage product and would require some changes in assumptions and practices.

Switchgrass establishment and N fertility results

Converting old stands: All of the established switchgrass on IDNR land around Lake Rathbun was the variety Blackwell. This was a very acceptable variety choice ten years ago for vigor and ground cover. However, it was not intended for maximum productivity. The project evaluated the potential for increasing the productivity of these old stands with additional management practices, including burning and additional N fertilizer application. Results of this effort suggest that increasing yield from older switchgrass stands is not a useful option, and new seedings with improved varieties will be needed.

Old Blackwell stand areas were burned and N fertility plots established in the spring of 1993. A total of 40 test plots was established in three different locations. Rates of N used were 0, 30, 60, and 90 or 120 lbs/A. One area of approximately 10 A. was designed with plots measuring 50 x 330 feet for farm-sized equipment, with four replications of each N rate. The other two plot areas were designed with 9 x 21 foot plots in a block, with three replications.

The 1993 growing season was very wet and problems began showing up late in the growing season. Blackwell is very susceptible to rust, and additional N fertilizer plus excess rainfall provided ideal conditions to foster a high level of infestation. While the rust disease slowed the growth of the switchgrass, the opportunist weed population flourished, capturing the ample supply of N and further reducing switchgrass production by competition.

The N treatments were repeated in the spring of 1994. Although the growing season was much better than for 1993, the problem of weed competition continued to increase. By the fall of 1994 the small plot areas no longer contained enough switchgrass to provide useable data. The larger plots also had excessive weed invasion, but were harvested to complete the data set (Table 1). Yields were low, and in some plots as much as 60 - 75 per cent of the dry matter harvested from the plots came from weeds, and variability in weights reflects weed populations rather than switchgrass production.

This work was abandoned in 1995. Project recommendations are that rejuvenating old stands of switchgrass variety Blackwell by adding N fertilizer is unlikely to be cost effective, due to 1) the susceptibility of Blackwell to rust and 2) potential for invasion by weedy species.

Table 1. Established Switchgrass, Blackwell Variety - Nitrogen Fertility Results					
Field Number	Average Tons Dry Matter per Acre* (* Includes excessive dry matter from weeds.)				
	0 lbs N/A.	30 lbs N/A.	60 lbs N/A.	90 lbs N/A.	120 lbs N/A.
1993 Field 7 (n=3)	1.79	2.61	2.65	2.76	nd
Field 17 (n=3)	1.62	2.66	3.28	2.92	nd
Field 10 (large plots, n=4)	0.76	1.38	1.42	nd	1.83
Overall Average	1.33	2.14	2.35	2.84	1.83
1994 Field 10 (only)	1.05	1.92	2.24	nd	2.27

No-till switchgrass establishment on crop ground: The project also demonstrated no-till establishment of switchgrass on both crop ground and in established sod. Work on this objective began in the spring of 1993. The very wet season made timing of various operations a challenge.

On crop ground, one burndown application was made of one quart of glyphosate, one pint of 2-4,D and 2% ammonium sulfate just prior to seeding on 6/1/93. Five lbs. aged, pure live seed (PLS) per acre, variety Cave-In-Rock, was planted using a no-till drill. Continuing rain made it impossible to apply any other type of weed control, and foxtail and fall panicum grassy weeds appeared to be a problem. Mowing, and/or an application Pursuit would have been done if weather conditions had allowed.

The switchgrass grew well despite the competition and by fall there was an exceptional stand on two fields, an acceptable stand on one field and a marginal stand on one field. It appears that the soil characteristics in the least acceptable field played a definite role in reducing the stand. The field was very flat and pocked and had standing water during much of the spring.

In early March of 1995 the field with the least desirable stand was frost seeded, again with five pounds PLS/A., resulting in a very acceptable stand. Weed control was not a problem on this field. One seedsman in the area has been recommending the frost seeding procedure for several years, apparently with a great deal of success.

During 1996, plans are in place to use a no-till drill to seed the variety Cave-in-Rock into the fields now in Blackwell. The fields were burned in early May, and the same weed control chemical application described above will be applied. At this time no other chemical applications are being planned. The stand will be evaluated for weed competition later in the season and mowed if necessary.

No-till switchgrass establishment, conversion of cool season sod: Since most CRP fields are planted with cool season grasses, the conversion of these areas to switchgrass is an important aspect of the project demonstration. Guidelines were developed as shown in Table 2. These practices are being used during 1996 to establish switchgrass in cooperating producers' CRP fields. The fall applications were made in 1995 and evaluation of those fields in late April indicated an excellent kill of existing vegetation. However, the spring weather in 1996 has been unusually cool, and the timetable listed in the guidelines may need to be extended.

The guidelines shown in Table 2 will be the basis of an extension publication, to be completed during FY97. These procedures are being recommended to producers in the special study area who are receiving cost share to convert their CRP acres.

Nitrogen fertility trials on new seedings: Twelve large (50' x 550') plots were established in the spring of 1994 to study the response of switchgrass to three levels of N fertilizer. The area was a part of the new seeding established in 1993. The site is on a very broad ridge top and is relatively flat, resulting in very slow surface drainage and poor internal drainage through the soil profile. Input N levels were 0, 30, 60 and 90 lbs/A., with three replications of each. Two replicates of each treatment were in field 9 and one in field 6 (Map, Appendix 1). The N levels were selected based on consideration of the need to determine an economic optimum, rather than a physiological maximum, recommendation for switchgrass fertilization due to the relatively low value of the biomass product, and the low inherent productivity of area soils.

Plots were harvested 10 days after the first killing frost by cutting a 7 foot swath from the center of each plot and baling with a large round baler. The bales were weighed and core samples taken to determine percent moisture. Dry matter yields in tons per acre were calculated (Table 3).

The project plan was to continue the N plots a second year, however, extremely wet conditions during the 1995 growing season prevented the timely application of N. The plots were harvested in November, later than planned, due also to weather conditions. The John Deere Company cooperated in the harvest. The low moisture content in this older material (average 10.6%) was of interest, for reasons discussed below. Ninety large bales were removed from the plots. Forty of these bales were loaded on a flatbed truck and the balance were stored in a hay shed. The remaining biomass in the plots was harvested into smaller, 4 x 4 x 8 foot, bales. Twenty-five of these bales were sent to a co-firing project in Wisconsin and the balance were stored.

Table 2.

Guidelines For Converting Cool Season To Warm Season Species Using No-Till.

1. Test soil for P, K and pH the year before seeding. Apply P and K if necessary to medium (M) test level, and lime if necessary to pH 6.5 or higher. Plan to retest fields every three years.

2. The year before seeding, mow the area to be reseeded to less than three inches in height between August 1 and August 15, and allow a four to six inch regrowth.

3. After September 15, when the grass has regrown to a height of four to six inches, and before the first frost, kill the existing sod by spraying with glyphosate (Round-up) at the rate of 1 qt/A., plus 1 pt/A. 2-4,D, 2% ammonium sulfate (17 pounds per 100 gallons of water) and a surfactant.

4. Between April 1 and April 20 of the seeding year, evaluate the effectiveness of the vegetative control. If the sod is not dead repeat step 2. If annual plants are a problem, spray 2 pt/A. gramoxone (Paraquat) with a non-ionic surfactant.

5. Between April 15 and May 30, seed five lbs. PLS per acre of variety Cave-in-Rock switchgrass that has a dormancy rate of 10% or less (seed must be checked specifically for dormancy as opposed to just germination). SEED NO DEEPER than 1/4 inch. Use "aged seed" harvested in the second calendar year prior to the seeding year.

6. To aid in the control of grassy and certain broadleaf weeds, a post emergence application of four ounces per acre of Pursuit, using a non-ionic surfactant and 2% ammonium sulfate (17 pounds per 100 gallons of water) in seven to ten gallons of water per acre may be recommended.

7. Do not apply nitrogen fertilizer in the seeding year.

In early March of 1996, eight additional plots were set up in the newly-established switchgrass area, and red clover was frost seeded into the plots at 10 and 15 lbs/A. The purpose of this trial is to demonstrate the potential for legumes to replace the need for purchased N. Trial data from Iowa State University has demonstrated this ability under forage production management conditions. It is uncertain how this technique will work under biomass management conditions.

A response to N is clearly indicated in yield data from 1993, and little or no apparent residual effect in 1994 when no additional fertilizer was applied (Table 3). The project target, thought to be needed for economic biomass production, is 4.5 to 5 tons/A. dry matter. Yields in the second year after seeding (1994) were below this target even at the highest N input level. However, more mature stands with additional management such as adjusting the P and K levels are likely to meet the goal. Presently the project is recommending an annual application of 60 lbs/A. N for economic switchgrass production. However, up to 90 lbs/A./yr may be appropriate depending on higher yielding varieties, land values and other costs, and available prices for the biomass product.

Table 3. Switchgrass Biomass Nitrogen Rate Plot Results					
Field Number	Tons Dry Matter per Acre				%H_2O at cut
	0 lbs N/A.	30 lbs N/A.	60 lbs N/A.	90 lbs N/A.	
1994 Field 9W	2.21	3.24	3.27	4.19	
Field 9E	3.57	2.18	2.96	3.57	
Field 6	1.51	1.97	3.22	3.78	
1994 Average	2.42	2.46	3.15	3.84	21.75%
1995* Field 9W	2.25	2.63	2.74	3.18	
Field 9E	3.29	2.77	3.22	2.35	
Field 6	2.59	2.82	2.46	2.35	
1995 Average * - No N applied in 1995.	2.71	2.74	2.80	2.62	10.6%

Harvest and storage trials

The logistics of moving switchgrass biomass from the field to the end user at various times during the year was also investigated by the project. Twelve large round bales, average size 1,030 lbs at 90% dry matter, were harvested from existing switchgrass stands on 10/28-29/92. Total yield from the old field was low, at approximately 1.5 tons/A. The bales were weighed, core sampled, and moved to four storage treatments with three replications of each. The treatments were off ground/no cover; off ground/covered; on ground/no cover; and inside a barn at the conservation farm. Bales were moved approximately 1/2 mile on flatbed trucks.

The intention was to sample and weigh bales at 30 day intervals through 90 days, and then less frequently over a longer period in storage. Problems were soon encountered when it was found large round bales were unsuitable for such handling. Bales were weighed with a pair of log chains around them, which worked well on new bales. However, by the second weighing bales were breaking up and a large amount of material being lost just due to the weighing procedure. Also, bales were gaining moisure. Three weighings were made, with inconsistent results, before, in March of 1993, IDNR staff burned the area and accidentally included the bales stored outside, ending the study.

Realizing that for biomass use the "package" needs to be of a more consistent density and able to be moved at least twice after leaving the field without loss of bale integrity, the project began looking at large rectangular bales in the fall of 1995. The John Deere Company cooperated in the harvest, using a prototype of a new machine that makes large rectangular bales (32 x 32 inches x 8 feet). A local commercial hay producer also participated. Approximately 160 large rectangular bales were made. Some have been sent out of state to various biomass-utilization projects, and others are now in storage or on a truck ready to be shipped. These bales are clearly the best option at present for packaging switchgrass biomass. The economics of transportation are also in favor of rectangular bales because of their greater ease of handling.

Other management considerations - timing of harvest: The harvest process has been a concern to farmers considering biomass production because of the large number of acres that must be dealt with in a biomass operation, conflicting with their harvest of more valuable crops. However, a fortuitous discovery in the fall of 1995 has suggested a resolution. When weather delayed the harvest, the switchgrass moisture content had fallen dramatically. It now appears that waiting 2-3 weeks or longer after a killing frost may allow the biomass to dry sufficiently (to 10-15 % moisture) that it can be windrowed and baled immediately. Since the material is used for fiber only, it's nutritional value is not an issue as it would be for forage crops, and the only matter to investigate is whether an excess amount of biomass may be lost if the crop stands longer in the field.

Harvesting biomass crops later in the year would make economic use of labor and equipment resources. Because the is usually little dew at night during fall and winter, baling could potentially continue 12-18 hours per day. Further, at this time of year custom hay producers have excess time and idle equipment. The project harvested switchgrass during November, December and April in FY96. There were many other times that conditions were suitable for harvest during that November-April time frame. Further evaluation is needed of the opportunities to harvest switchgrass biomass during the winter months.

Biomass applications

By 1995 the project had begun consulting with a number of potential commercial biomass "endusers". Examples of applications research and prototype development cooperating with the biomass project include:

- Development of planting and harvesting equipment. The John Deere Ottumwa works has been the main cooperator in this area, as previously described.

- Processing of biomass into fuel pellets. For any fuel application the switchgrass must be extruded into pellets. Thus far many plants have had difficulty with this step, but John Redden of Northwest Missouri State University is successfully producing pellets in various sizes from the Chariton Valley Biomass Project material.

- Technology for efficient burning. Several makers of wood pellet- and corn-burning stoves have come to the project for materials to test. Chiptek, a Vermont-based maker of gasifier technology for smaller scale (schools and manufacturers) power generation is also testing materials from the project.

- Private sector energy. This commercial application of the biomass product is likely to be realized in the near future. The Iowa State University McNay Research Farm will be burning switchgrass pellets for it's boilers in winter 1996-1997, and a private farm machinery shop at Moravia will be using them in it's woodstove.

- Public sector energy generation. IES Utilities is participating in the project to study the feasibility of using a dedicated supply of southern Iowa biomass as a fuel source for a power generation facility. They are looking at both biomass gasification and co-firing with coal as options for an electric generation plant in the area.

- Substitution in fiber-based products. This is another application outside the original energy-based concept of the project which is likely to be successfully commercialized in the near term. ISU New Products Technology laboratory is developing methods of fiberboard manufacture from the switchgrass materials, and both HON (an office products company) and Masonite are testing materials from the project.

- Animal bedding. While switchgrass has generally not been used for this purpose, it is an economic option based on the cost of production numbers generated by the project, and several local livestock producers are interested.

Economic results

Early indications are that biomass crop yields on marginal lands relative to local land values and transportation costs support the choice of the southern Iowa for biomass production. Costs of production for switchgrass in the demonstration area has been calculated by the extension specialist, in cooperation with the contract hay producers who assisted with field operations (Appendix 2). Cost per ton estimated for the highest projected yield, 5 tons/A., is approximately $68. The $70/A. land cost in the table reflects the present rental cost of CRP land, and may be a high estimate. Other costs are derived from actual inputs and operations.

Although only the highest yields look economically viable for switchgrass biomass production at this time, in future yield is not the only factor that will determine feedstock viability. Assuming that variable costs are unchanged, land valued at $350/acre producing 5 tons per year of biomass will have lower production costs than land valued at $2000 per acre producing 10 tons per year. Property taxes, opportunity costs and competing uses will all add to the cost on high valued land more rapidly.

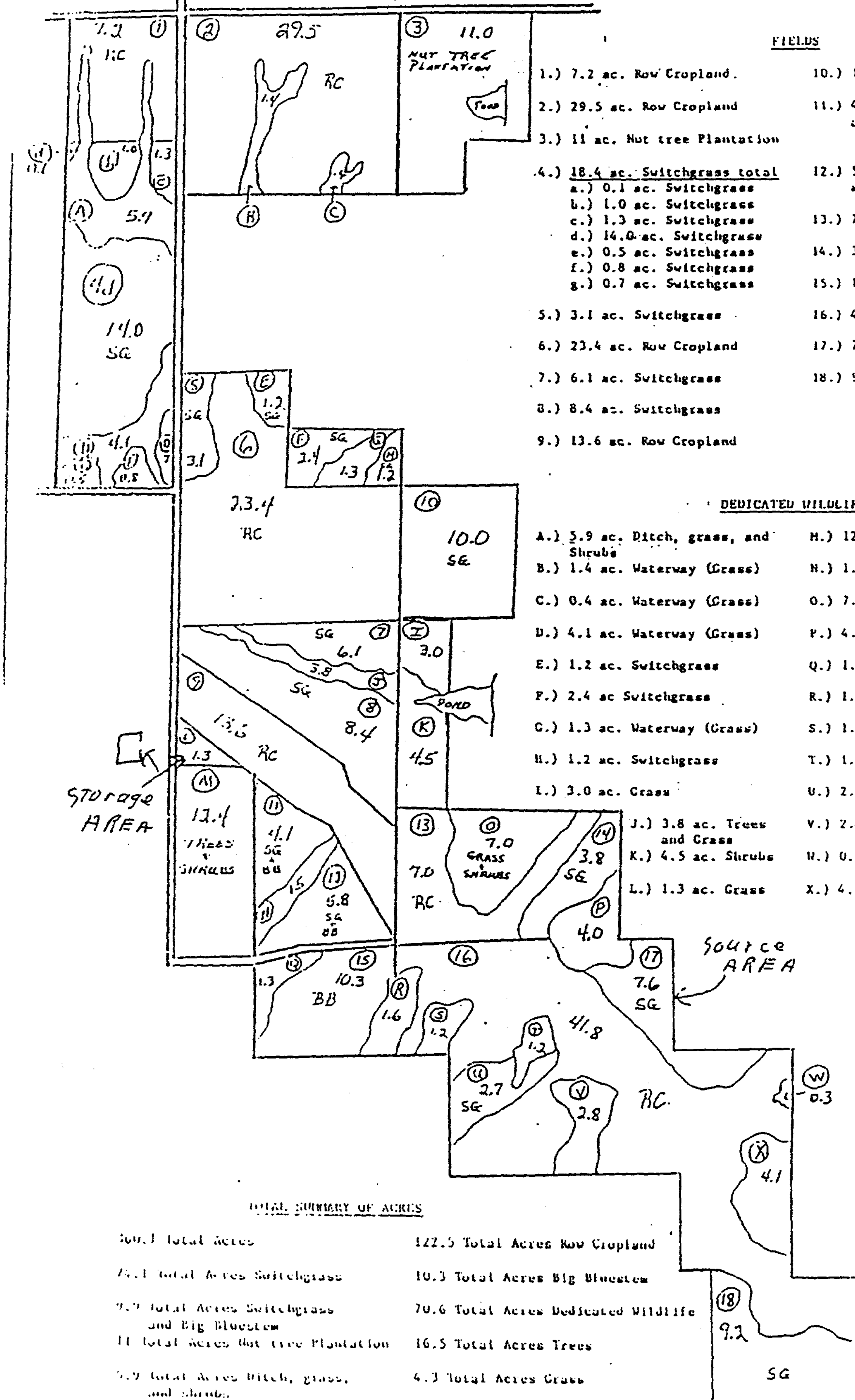
Meetings and presentations

The ISUE project specialist participated in the following meetings and workshops:

Date	Meeting	Results
1-25-93	NRCS Project Review	Clarification of project goals and setting short term objectives. Attendance 7
9-21-93	Clean Water Action Alliance, Winona, MN	Presented information regarding the biomass project. Attendance 50+ News coverage, Appendix 4.
7-6-94	Field review for IDNR Energy Bureau	Review project activities. Attendance 10
11-29-94	Iowa Forage and Grassland Council annual meeting	Inform public about the project gain public support. Attendance 86
1-25-95	IDNR project review	Review progress of the project. Attendance 7
7-27-95	IDNR energy field day at project site	Describe and demonstrate project activities, biomass issues. Attendance 8
11-29-95	Clean Water Action Alliance	Presented project accomplishments, networked with other biomass projects. Attendance 88

Summary

It is apparent that the production of switchgrass as a biomass product requires some management considerations different from those methods used for producing an animal forage product. Results of this project suggest that switchgrass production in southern Iowa is economic as a biomass energy fuel crop within present cost projections, but marginally so and not for older, established stands. Increasing economic yields will require further work on establishment of improved varieties, and on nutrient management. There will be other cost considerations, however. One is the opportunity for off-season harvest, which would add value to existing equipment and labor resources for producers and contractors. Harvest and storage handling as a biomass crop will also require more robust bales than the large round bales typically used for large forage operations. Initial work with large rectangular bales is promising, but storage studies must be repeated on this material. Cooperation must also be continued with the many organizations and businesses interested in biomass applications. Since various processes are under development, energy generation may not be the first or ultimately the most profitable use for a switchgrass product.



FIELDS

1.) 7.2 ac. Row Cropland.

2.) 29.5 ac. Row Cropland

3.) 11 ac. Nut tree Plantation

4.) 18.4 ac. Switchgrass total
- a.) 0.1 ac. Switchgrass
- b.) 1.0 ac. Switchgrass
- c.) 1.3 ac. Switchgrass
- d.) 14.0 ac. Switchgrass
- e.) 0.5 ac. Switchgrass
- f.) 0.8 ac. Switchgrass
- g.) 0.7 ac. Switchgrass

5.) 3.1 ac. Switchgrass

6.) 23.4 ac. Row Cropland

7.) 6.1 ac. Switchgrass

8.) 8.4 ac. Switchgrass

9.) 13.6 ac. Row Cropland

10.) 10 ac. Switchgrass

11.) 4.1 ac. Switchgrass and Big Bluestem

12.) 5.8 ac. Switchgrass and Big Bluestem

13.) 7.0 ac. Row Cropland

14.) 3.8 ac. Switchgrass

15.) 10.3 ac. Big Bluestem

16.) 41.8 ac. Row Cropland

17.) 7.6 ac. Switchgrass

18.) 9.2 ac. Switchgrass

DEDICATED WILDLIFE AREA

A.) 5.9 ac. Ditch, grass, and Shrubs

B.) 1.4 ac. Waterway (Grass)

C.) 0.4 ac. Waterway (Grass)

D.) 4.1 ac. Waterway (Grass)

E.) 1.2 ac. Switchgrass

F.) 2.4 ac Switchgrass

G.) 1.3 ac. Waterway (Grass)

H.) 1.2 ac. Switchgrass

I.) 3.0 ac. Grass

J.) 3.8 ac. Trees and Grass

K.) 4.5 ac. Shrubs

L.) 1.3 ac. Grass

M.) 12.4 ac. Trees & Shrubs

N.) 1.5 ac. Waterway (Grass)

O.) 7.0 ac. Grass & Shrubs

P.) 4.0 ac. Trees

Q.) 1.3 ac. Trees

R.) 1.6 ac. Trees

S.) 1.2 ac. Trees

T.) 1.2 ac. Trees

U.) 2.7 ac. Switchgrass

V.) 2.8 ac. Trees

W.) 0.3 ac. Trees

X.) 4.1 ac. Trees

TOTAL SUMMARY OF ACRES

300.1 Total Acres

74.1 Total Acres Switchgrass

9.9 Total Acres Switchgrass and Big Bluestem

11 Total Acres Nut tree Plantation

5.9 Total Acres Ditch, grass, and shrubs

7.[illegible] Total Acres Waterway (Grass)

122.5 Total Acres Row Cropland

10.3 Total Acres Big Bluestem

70.6 Total Acres Dedicated Wildlife

16.5 Total Acres Trees

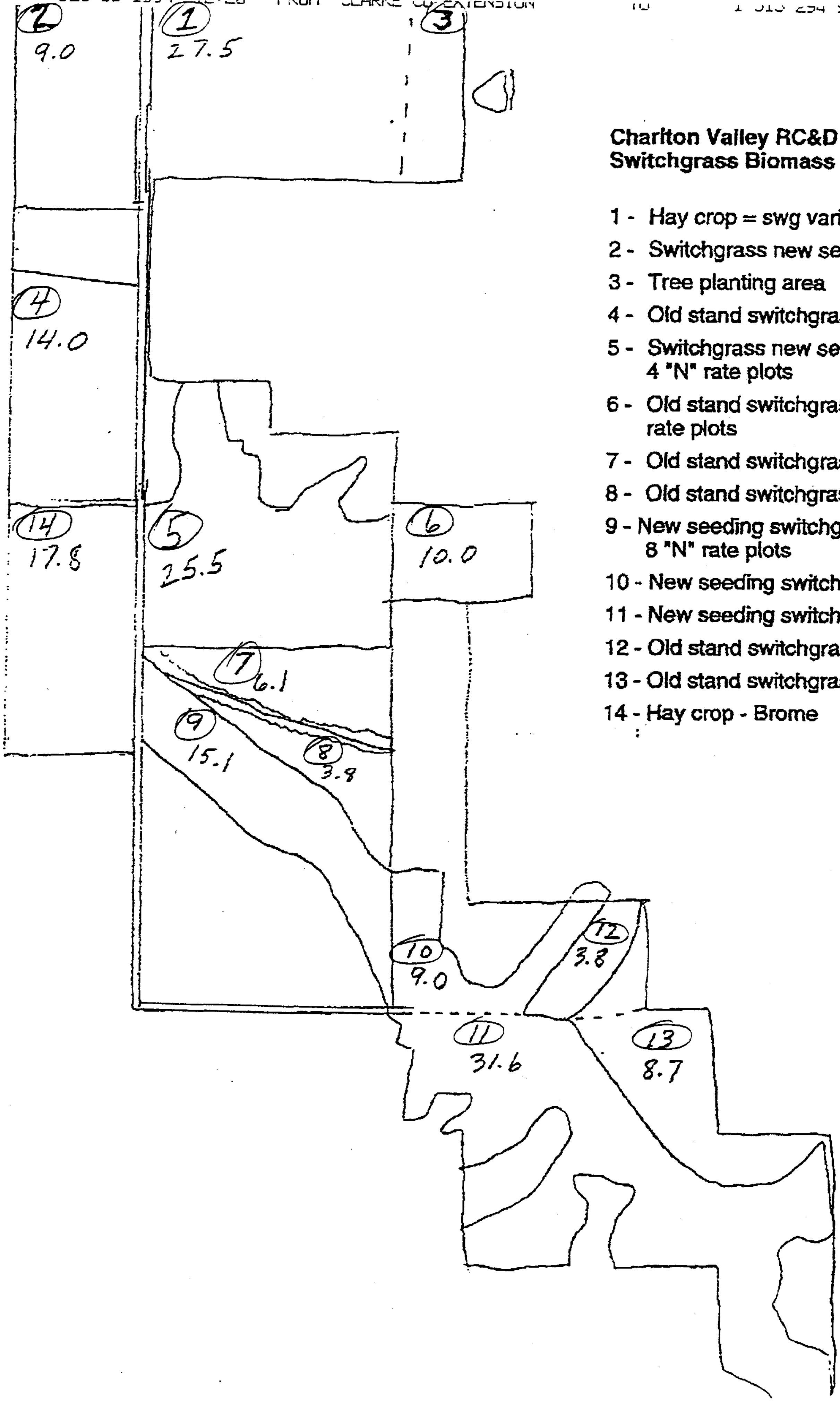
4.3 Total Acres Grass

4.5 Total Acres Shrubs

[illegible]3.2 Total Acres Trees, Shrubs, and/or Grass

Charlton Valley RC&D
Switchgrass Biomass

1 - Hay crop = swg variety plots
2 - Switchgrass new seeding
3 - Tree planting area
4 - Old stand switchgrass
5 - Switchgrass new seeding - 1993
4 "N" rate plots
6 - Old stand switchgrass - 16 "N" rate plots
7 - Old stand switchgrass
8 - Old stand switchgrass
9 - New seeding switchgrass - 1993
8 "N" rate plots
10 - New seeding switchgrass - 1993
11 - New seeding switchgrass - 1995
12 - Old stand switchgrass
13 - Old stand switchgrass
14 - Hay crop - Brome



Cost of Production Estimate for Switchgrass Biomass Production
Chariton Valley RC&D Bioenergy Project

Input assumptions

Land	$70.00/A	Hauling	$2.10/loaded mile
Fertilizer	36.77/A	Stack	1.00/bale
Estab. prorated	9.97/A	Storage	1.60/bale
Mow & Cond.	8.00/A	Labor	4.00/acre
Rake	3.50/A	Truck load =30-800# bales=12 ton	
Bale	9.00/bale	Storage cost--5 bales high in roof only shed at a cost of $5.00/sgft.	
Load bales	1.00/bale		
		Bale size=3'X4'X8' 800#	

Cost of production per Acre by Tons of Production per Acre

INPUTS	4 TON	4.5 Ton	5 Ton
Land	$70.00	$70.00	$70.00
Fertilizer	36.77	36.77	36.77
Establishment	9.97	9.97	9.97
Mow &Condition	8.00	8.00	8.00
Rake	3.50	3.50	3.50
Bale	90.00	101.25	112.50
Load	10.00	11.25	12.50
Hauling	42.00	47.25	52.50
Stack in field	10.00	11.25	12.50
Storage	16.00	18.00	20.00
Labor	4.00	4.00	4.00
Total	300.24	321.24	342.24
Cost per ton	75.06	71.39	68.45
Harvest-stack	131.50	146.00	160.50
per ton	32.87	32.44	32.10
Load & haul	52.00	58.50	65.00
per ton	13.00	13.00	13.00
Land-fert-estab.	116.74	116.74	116.74
per ton	29.18	25.94	23.35

Cost of production on 300 A of DNR land using:

land cost	0
fertilizer	$36.77
Estab.	0
Prod.	4.5 ton/A
Harvest & Storage	$128.00/A
load & haul	$58.50 /A

Total Cost per Acre-----$186.50

Total Cost for 300 Acres-- $55,950

If baling in-kind: total cost per acre=11,075 and total cost for 300 A =33,225

Cost of production on CRP already in switchgrass--4,5 ton /A

Land & estab.	0
Fertilizer	$ 36.77
Harv. stack-stor	136.00
Load & haul	58.00
Total Cost per A	240.77
Total Cost per ton	53.50

Appendix 3.

Summary of the Agronomic, Economic, Energy, and Environmental Considerations for Establishment and Use of Switchgrass as a Biomass Fuel

Irvin C. Anderson, Professor of Agronomy
Iowa State University

The U.S. Department of Energy has chosen switchgrass as a herbaceous energy crop to develop for combustion (Turhollow, 1988; Cushman et al., 1989). On average, fiber (cellulose, hemicellulose, and lignin) makes up 75% of the dry matter of switchgrass. In a five year study we obtained values varying from 65 to 79%. The lower fiber values were for slightly immature crops or crops with a large percentage of leaves. The greater values were for mature crops allowed to remain in the field for a time before baling. The high concentration of fiber along with very low protein content makes switchgrass an ideal herbaceous crop for combustion. A standing crop at maturity contains about 6% protein and after maturity and baling the value is about 3% or about 50 kg ha^{-1} of nitrogen in a yield of 10 metric tons. The amount of potassium removed from the land is similar to that of nitrogen.

As noted by Sanderson and Wolf (1995), low N, K and ash concentrations increase hydrocarbon yields during thermochemical conversions. The combustion value of switchgrass averages about 18,000 B.T.U. per kilogram; compared with average coal that has a value of 24,000 B.T.U. (Helsel and Wedin, 1983). Biomass from herbaceous crops is generally a cleaner source of energy than fossil fuels. It is lower in sulfur than coal, thus decreasing the polluting potential from electrical generating plants (EPRI, 1993).

Crop growth rates and seasonal yields of warm-season, perennial grasses, such as switchgrass, have excellent biomass yielding capacity with a single harvest per year. Because they have the C_4 photosynthetic pathway, they are less sensitive to drought and are productive during warm, dry summer months (Moser and Vogel, 1995; Nelson, 1995). Because switchgrass has unusually low N requirements and is drought and heat tolerant, it is well adapted to thinner and lower productive soils. It also withstands acid soils to below pH 5.0. Once established switchgrass has excellent year-round ground cover that reduces soil erosion. If properly managed, switchgrass can be harvested for many years; actually indefinitely as it did in the tall grass prairies of the midwest. Switchgrass is a sod forming grass grown from seed, that produces 1 to 2 meter columns from rhizomes. This is in contrast to big bluestem, another C_4 native grass, that is mainly a bunchgrass, but may produce some rhizomes.

Establishment success is variable (Voight and MacLauchlan, 1985). Switchgrass can be seeded with a grain drill or with more standard forage seeding equipment. Seed may be broadcast and soil firmed with a corrugated roller, but better results can be obtained by drilling seeds 0.5 inches deep into soil, with subsequent packing. Seed drilled in mulched seedbeds helps control soil erosion and conserve soil water for seed germination. The seeding rate should provide about 500 live seed per 10 square feet or 6 pounds per acre.

In our five year study with switchgrass grown at Ames and Chariton, we averaged about 3.5 tons per acre with no N fertilization. With 70 pounds of N per acre the yields were 5 tons, and with higher rates of N, 6-7 tons were obtained during years with adequate moisture. In an Iowa study by Barnhart and Hintz (1989) they obtained about 3 tons per acre without fertilizer N and up to 6 tons with high rates of N.

Bulkiness of switchgrass biomass is a disadvantage that increases transportation costs when compared with wood or coal. The density of baled switchgrass is about 0.4, which limits its use to the local area where it is produced. The environmental advantages of switchgrass as a combustion fuel are great. It is a renewable source of energy. Combustion produces only traces of sulfur and, at common furnace temperatures, little nitrogen oxides are produced. On a combustible energy basis, switchgrass biomass would need to cost $25-30 per ton to be competitive with Wyoming coal. This does not include the extrinsic cost of the recent mandate for improvement of smoke stacks to reduce emmissions which was passed onto the electrical consumers. Nor, does it include the environmental cost of acid rain or many extrinsic cost of using nonrenewable combustion fuel material.

BIBLIOGRAPHY

Barnhart, S. and E. Hintz. 1989. Warm-season grasses for hay and pasture. Iowa State Univ. Ext. Pub. Pm-569. Iowa State University, Ames, IA.

Cushman, J. H., A. F. Turhollow, and J. W. Johnston. 1989. Herbaceous energy crops program: Annual progress report for FY 1987. ORNL, Environmental Sciences Division, pub. #3191.

EPRI. 1993. A "how-to" primer for biomass resource development. Electric Power Research Institute, Palo Alto, CA.

Helsel, Z. R. and W. F. Wedin. 1981. Harvested dry matter from single and double-cropping systems. Agron. J. 73:895-900.

Moser, L. E. and K. P. Vogel. 1995. Switchgrass, big bluestem, and indiangrass. p. 409-420. In R. F Barnes, D. A. Miller, and C. J. Nelson (ed.) Forages (vol. I) An Introduction to Grassland Agriculture (5th ed.). Iowa State University Press, Ames, IA.

Nelson, C. J. 1995. Photosynthesis and carbon metabolism. p. 31-43. In R. F Barnes, D. A. Miller, and C. J. Nelson (ed.) Forages (vol. I) An Introduction to Grassland Agriculture (5th ed.). Iowa State University Press, Ames, IA.

Sanderson, M. A. and D. D. Wolf. 1995. Switchgrass biomass composition during morphological development in diverse environments. Crop. Sci. 35:1432-1438.

Turholoow, A. F. 1988. Second year growth and productivity for potential herbaceous energy crops in the southeast and midwest/lake states. Oak Ridge National Laboraotry. Pub. #3016.

Voight, P. W. and R. S. MacLauchlan. 1985. Native and other western grasses. p. 177-187. In: Heath, Barnes, and Metclafe (ed.), Forages: The Science of Grassland Culture. Iowa State University Press. Ames, IA.

Agri-News Sept. 30, 93

Gustafson liked the machines so much he bought five Gravelys, three of which run and two which may turn their wheels again some day. He also has a shed full of attach- ... the average person changes the oil, they'd last 30 years."I think he was the kind of guy who wanted to build the best garden ... machines in 1920. The company ... now owned by Ariens Co., and the tractors are still built in Brillion, Wis. ... toy?" Gustafson asked, ... wheel.

Grassroots support grows for biomass

By PAUL ADAMS
Agri News Staff Writer

WINONA, Minn. — Electric power plants powered by plants?

It makes sense to Allen Teel, an Iowa State University extension agronomist in Osceola, Iowa.

Teel is working on a biomass project that he believes could provide inexpensive electricity for rural areas, develop rural economies, provide farmers with a decent return on their investment, prevent soil erosion and clean up the atmosphere.

All farmers have to do is make the switch — to switchgrass, that is.

Teel is studying the viability of using switchgrass as a biomass fuel that would be burned to create electricity.

He discussed the project at a recent meeting on renewable energy organized by the Clean Water Action Alliance at the Winona Technical College. The idea was a hit with participants.

Minnesota Sen. Steve Morse, DFL-Dakota, expressed interest in the idea. Morse has proposed legislation that would provide incentives to producers of renewable, biomass energy.

Allen Teel

The switchgrass project was initiated after the biomass buzzword caught on at the federal level.

"We have received nothing but green lights so far all the way to Washington. If I were a betting person, I'd say the odds are heavy in our favor that this thing will get approved."
— Allen Teel

The U.S. Department of Energy expressed interest in a new kind of biomass energy alternative, and the idea took root, so to speak, in Iowa. Since then, a consortium of state and federal organizations has taken up the cause.

The Shariton Valley Resource Conservation Development leads the pack, with the Soil Conservation Service, ISU extension service, Department of Natural Resources, Iowa Southern Electric Co-op and the U.S. Geological Survey all joining in the project.

The concept of renewable biomass energy is nothing new to many in the industry. Afterall, ethanol produced from corn is a form of biomass energy. But the switchgrass project is the first of its kind in the United States.

If a federal grant is approved, the group plans to build a 20 megawatt electric power plant in southern Iowa, probably near Centerville. The plant would generate enough electricity to serve one county and would come on line in 1997. The cost of the project, including payments to farmers who grow switchgrass, is estimated at about $20 million.

Teel has been conducting field tests on switchgrass since last spring. He is confident the grant, despite its size, will be approved. The department of energy is currently considering the proposal.

"We have received nothing but green

See BIOMASS C2

Historic Preservation to place the ... There are a lot of people who agree that there are certain barns ... unique, said Mary Humstone, Barn Again director.

★ BIOMASS: Bill could bolster ethanol industry, too

Continued from C1

lights so far all the way to Washington," Teel said. "If I were a betting person, I'd say the odds are heavy in our favor that this thing will get approved."

But why switchgrass?

"It was here long before we started plowing," Teel said. And the plant adapts well to a variety of soil types — especially soils that typically can't support corn and soybeans.

But there are many other benefits to switchgrass. Since it is a perennial plant, switchgrass is relatively maintenance free once a stand is established. That means there is no need for annual planting, tillage, herbicides or insecticides.

Some even question whether fertilizer is necessary to grow a healthy crop. Switchgrass is also a sod-producing plant, meaning it will prevent soil erosion.

But perhaps most importantly, Teel says projects such as this could be an economic boon to rural areas.

"Our original thought was that we'd like to put one of these (electric power) plants in every county across the southern tier of Iowa," Teel said.

The project would be profitable for farmers within a 15-mile radius of the proposed power plant. About 30,000 acres producing an average of 3.5 tons of switchgrass per acre would be needed to meet the fuel needs of the electric plant, Teel estimates.

Farmers would be paid about $50 per ton, providing them with roughly $175 per acre of income, Teel said. Considering the lack of inputs and field work required, that's a sizable profit for farmers who are used to much smaller profits growing corn and soybeans.

In addition to providing farmers with a substantial income, switchgrass could give rural communities increased income and job creation, Teel said.

The other pleasant side effect of the proposal is that it brings environmentalists, the government and farmers together while helping the economy at the same time.

The environmental benefits alone might be enough to generate more support for the proposal.

"We worry about carbon balance," Teel said. "Because when you're burning hydrocarbons, you're putting carbon into the atmosphere."

Burning switchgrass will release carbon to the atmosphere, he said. But because plants remove carbon as they grow, some of that carbon will be consumed by the switchgrass before it is burned.

"And so we end up with a balance," Teel said. "In other words, we're not putting in more than we're taking out."

If Sen. Morse has his way, renewable energy — including biomass — will take hold in Minnesota.

He said the switchgrass proposal has promise.

"Those are the types of solutions we need to look at. I'm convinced that it can be done," he said.

Morse has helped forward a bill in the Senate that would provide more incentives for renewable energy, particularly ethanol and wind.

The Sustainable Energy Transition Act would provide a 2 cents per kilowatt hour production credit for power plants generating energy with renewable fuels in any form, including wind and biomass fuels. The act would also increase the ethanol production credit to 3 cents per gallon, and fund the credit several years into the future. The current production credit is 2 cents per gallon.

"The idea is to nurture an industry for our agriculture and our economies in rural Minnesota," he said. Without the funding, Morse said Minnesota could lose its ethanol industry.

The act will have a tough time in the Senate, Morse admits. That's because metropolitan senators and representatives are reluctant to spend money in outstate Minnesota, he said.

"We've got some real resistance there," he said.

Morse is also a big proponent of wind power. The Buffalo Ridge area in western Minnesota is home to some of the most powerful, consistent winds in the United States.

"Just in Buffalo Ridge alone, we have enough capacity to generate 15 times our annual electrical consumption within the state of Minnesota," he said. Farmers in that area could rent their land to power companies, who would construct wind generators.

That type of production could save the state billions, Morse contends. Currently, Minnesotans spend about $7 billion annually on energy. About $4 billion of that is spent on energy forms imported from other states.

The Sustainable Energy Transition Act is scheduled for hearings in the Senate, and will likely be considered by the full Senate sometime in the 1994 session, Morse said.

APPENDIX FIVE

SWITCHGRASS PRODUCTION INFORMATION FORM

by

Prof. Mike Duffy

Name:______________________________
Address:____________________________
____

SWITCHGRASS PRODUCTION

Field Description:

Legal Description: ____

Soil Classification: ____

Land Value ($/acre): ____

Previous Cropping History: Give crop and yield information (if available).

1996: ______________________ 1993: ______________________

1995: ______________________ 1992: ______________________

1994: ______________________

Equipment Used:

	Equipment	Make	Model	Year
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

Notes:

1. ____
2. ____
3. ____
4. ____
5. ____

Cost of Production Worksheet

Preharvest Machinery:

	Date	Operations	Variable Cost/Acre	Fixed Cost/Acre	Labor Hours/Acre
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Seed:

	Rate	Unit	$/Unit
Seed Estimate			

Chemicals:

	Date	Chemical Name	Rate	Unit	$/Unit
1.					
2.					
3.					
4.					
5.					

Fertilizers:

	Date	Fertilizer Element	Rate	Unit	$/Unit
1.					
2.					
3.					
4.					
5.					

Harvest Machinery:

	Date	Operations	Variable Cost/Acre	Fixed Cost/Acre	Labor Hours/Acre
1.					
2.					
3.					
4.					
5.					

Harvest One

Biomass Yields:

Bales per field: ______________________________

Yield per acre: (Number of bales x mean wt./bale)/acres): ______________________________

Wet and dry weights will be from 200-300 g. subsamples taken from cores form the middle of bale (boring into the side of the bale cylinder) to the center of the bale. Samples will be sent to Lincoln for final drying for dry matter weights. Same samples will be used for quality analyses.

List unit of measurement under column heading in all columns.

Bale	Dry Matter % and Dry Weight Yields				
Bale #	**Bale Weight**	**Wet Weight**	**Dry Weight**	**Dry Matter %**	**Bale Dry Weight**
1					
2					
3					
4					
5					
Means					

Biomass Shipped:

Bales #: ______________________________

Yield Shipped per Acre: (Number of bales x mean wt./bales)/acres: ______________________________

Wet and dry weights will be from 200-300 g. subsamples taken from cores from the middle of bale (boring into the side of the bale cylinder) to the center of the bale. Wet weights will be taken at the time of coring. Samples will be sent to Lincoln for final dying for dry matter weights. Same samples will be used for quality analyses.

List unit of measurement under column heading in all columns.

Bale	Dry Matter % and Dry Weight Yields				
Bale #	**Bale Weight**	**Wet Weight**	**Dry Weight**	**Dry Matter %**	**Bale Dry Weight**
1					
2					
3					
4					
5					
Means					

Harvest Two

Biomass Yields:

Bales per field: ______________________________

Yield per acre: (Number of bales x mean wt./bale)/acres): ______________________________

Wet and dry weights will be from 200-300 g. subsamples taken from cores form the middle of bale (boring into the side of the bale cylinder) to the center of the bale. Samples will be sent to Lincoln for final drying for dry matter weights. Same samples will be used for quality analyses.

List unit of measurement under column heading in all columns.

Bale	Dry Matter % and Dry Weight Yields				
Bale #	**Bale Weight**	**Wet Weight**	**Dry Weight**	**Dry Matter %**	**Bale Dry Weight**
1					
2					
3					
4					
5					
Means					

Biomass Shipped:

Bales #: ______________________________

Yield Shipped per Acre: (Number of bales x mean wt./bales)/acres: ______________________________

Wet and dry weights will be from 200-300 g. subsamples taken from cores from the middle of bale (boring into the side of the bale cylinder) to the center of the bale. Wet weights will be taken at the time of coring. Samples will be sent to Lincoln for final dying for dry matter weights. Same samples will be used for quality analyses.

List unit of measurement under column heading in all columns.

Bale	Dry Matter % and Dry Weight Yields				
Bale #	**Bale Weight**	**Wet Weight**	**Dry Weight**	**Dry Matter %**	**Bale Dry Weight**
1					
2					
3					
4					
5					
Means					