BIOMASS POWER FOR RURAL DEVELOPMENT

**Quarterly Report for the Period
October 1, 1999 - December 31, 1999**

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**CHARITON VALLEY
RESOURCE CONSERVATION & DEVELOPMENT, INC.**

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Project Progress Report for the Period 10/1/99 to 12/31/99

Cooperative Agreement: DE-FC36-96GO10148

Program/Project Title: Biomass Power for Rural Development/
Chariton Valley Biomass Project

Recipient: Chariton Valley Resource Conservation & Development, Inc.

Task 2.9.3 Harvest, load, transport, unload, and store switchgrass

- Prairie Lands Bio-Products, Inc. is coordinating the harvest of approximately 2,800 tons of switchgrass from 1,100 acres provided by cooperating producers. The estimated average yield from established stands of switchgrass has been 3 tons per acre and the estimated average yield from recently established stands of switchgrass has been 1.75 tons per acre. The switchgrass is being stored in a number of temporary locations, e.g., under tarps in fields, until its transport to the Ottumwa Generating Station for its use in the planned co-fire test campaign in 2000. Harvest activities have been conducted in conjunction with and support of related project tasks including Task 5.40 Evaluate harvest and handling equipment, 5.4.1 Biomass procurement system design, and Task 8.40 Wildlife impacts.

Cooperating producers and contracted crews harvested switchgrass biomass for planned co-fire test campaign.

- Task 2.9.4 Assign Alliant technical staff to the project
- Task 2.9.5 Secure the services of engineer, purchase, and construct contractor(s)
- Task 2.9.6 Equipment acquisition, site preparation, and facility modifications

- Alliant assigned additional technical personnel to assist the project during this period. Alliant personnel Mr. Steve Hoch and Mr. Bill Morton, Project Engineers, have joined current Alliant personnel working with the project. In addition, Ms. Cynthia Lord has joined Alliant personnel working on the project in her position as Associate General Manager at OGS.
- Alliant conducted a series of meetings and discussions with Foster Wheeler Development Corporation during the reporting period that has led to an agreement between the two parties for collaboration on the project. Foster Wheeler will serve in the capacity Alliant's engineer, purchase, and construct (EPC) contractor for the project. Alliant personnel and representatives of Foster Wheeler, Mr. David Tillman and Mr. Byron Roth have initiated activities required for the planned co-fire test campaign in 2000, e.g., final engineering design, fabrication of the burner-insert. In addition, communication is underway between Alliant, Foster Wheeler, and other technical resources including Elsam and Midtkraft in Denmark and Technical Consultants, Inc. in order to incorporate and coordinate a broad range of expertise into project activities. Alliant, Foster Wheeler, and project staff will also begin a review of the current project schedule of activities and budget.

Task 3.90 Design, develop, and test gas clean up systems

- Activities included the fabrication and installation of a moving granular bed filter (MGBF) and reconstruction of the fluidized bed gasifier at a new location. A vendor was chosen to fabricate the MGBF. Fabrication is complete and installation initiated at the Biomass Energy Conversion Facility (BECON). The fluidized bed gasifier formerly located at ISU has been relocated to BECON. Procurement and installation of the gasifier system continues. The system should be operational by February.
- The role of gasification technology in the Chariton Valley Biomass Project has been reviewed in terms of its potential contribution to co-firing at OGS. Biomass gasification can offer an "insurance policy" in co-firing efforts if direct firing encounters technical hurdles, e.g., if co-firing jeopardizes markets for fly ash, gasification may be attractive as ash streams are segregated. Other advantages of gasification are flexibility in fuel handling; opportunities for higher co-firing ratios; and reduced NO_x emissions by using the producer gas and reburning fuel. Project partners propose to direct gasification activities toward exploring producer gas as a co-firing/reburning fuel in pulverized coal boilers. Issues to be investigated include the effects on ash quality, carbon burnout, and NO_x emissions. During FY 2001 the project proposes to integrate an existing pilot-scale gasifier with a laboratory furnace that simulates the performance of a pc boiler. Most of the instrumentation required for analysis of both producer gas and flue gas is also available.

- Task 5.20 Assess the genetic variability for biofuel traits
Task 5.30 Determine the effect of timing of harvest on burning qualities
Task 5.3.1 Fuel quality analysis

- Fall biomass harvest of switchgrass variety trials was completed as planned in mid-October. Yields were excellent. Lowland varieties yielded more than upland varieties, however, long-term survival and productivity of this germplasm is still subject to a good winter test. Biomass samples collected have been prepared for lab analysis to be performed this winter.
- Reed canarygrass variety/management trials in Ames and Chariton IA, Lexington, KY, and Arlington, WI all look excellent. Fall harvests were completed at Ames, and Arlington. The Lexington trial survived well despite an extreme drought after planting this year. The Chariton trial has good stands. That being the case, all trials should produce good data in 2000. Samples collected have been prepared for lab analysis to be performed this winter.
- The second harvest was completed of the reed canarygrass plant introduction trials in Ames, IA and Arlington, WI. Excellent regrowth at both locations. Samples collected have been prepared for lab analysis to be performed this winter.
- Samples have been collected from natural stands of reed canarygrass located in proximity to the switchgrass fertility trials. Analysis of these samples to assess biofuel characteristics of unmanaged reed canarygrass will be completed this winter.
- Laboratory analysis and interpretation of results continues at ISU and the Federal Energy Technology Center for unharvested and harvested switchgrass samples collected during the 1998/1999.
- Mention should be made that the graduate student at ISU who is conducting much of the research related to Task 5.20 is in the process of preparing his MS thesis. It is anticipated that their theses will be completed in early 2000.
- Researchers at ISU in cooperation with other project partners have prepared a draft scope of work that addresses the need for continued investigation related to these tasks. The draft scope *Switchgrass and Reed Canarygrass as Biomass Crops in Iowa: Agronomy, Germplasm Evaluation and Development, and Soil Suitability* is enclosed with this report. The scope of work has been presented to Oak Ridge National Laboratory (ORNL) for review and consideration. The RC&D and project partners would also like to request that the DOE review and consider this proposed research for inclusion in the project statement of work.

Task 5.40 Evaluate harvest and handling equipment

Task 5.4.1 Biomass procurement system design

- Prairie Lands, cooperating switchgrass producers, contracted operators, and project staff worked with technical personnel from John Deere to conduct and evaluate trials of the company's prototype forage harvesting equipment including self-propelled mower-conditioners and experimental large square balers.

John Deere, Prairie Lands, and cooperating producers evaluated prototype forage equipment during the harvest of switchgrass biomass.

- At the request of project partners, researchers at ISU prepared a draft scope of work that addresses the need for improved understanding of the effects of exposure to weather conditions in southern Iowa on fuel characteristics of baled switchgrass and the associated storage requirements. The draft scope *Biomass Storage and Preservation* is enclosed with this report. The scope of work has been presented to ORNL for review and consideration. The RC&D and project partners would also like to request that the DOE review and consider this proposed research for inclusion in the project statement of work.

Task 5.50 Economic analysis of energy crop production

- An analysis of the regional economic impacts of switchgrass biomass production has been completed. The results of this analysis are being reviewed, evaluated, and interpreted. At the request project partners, the regional analysis focused on assessing the overall impact of additional economic activity generated by the use of land for biomass production relative to its enrollment in the Conservation Reserve Program (CRP). This analysis will be of particular relevance and value given the project's objectives of (1) developing biomass production as a viable post-CRP alternative land use and (2) promoting biomass production as a land use compatible with CRP, that is permitting the production of biomass on land enrolled in CRP.
- Researchers at ISU have prepared a draft scope of work that addresses the need for continued investigation related to this task. The draft scope *Adoption of Biomass Production and Other Alternative Land Uses by Farmers in the Chariton Valley Area of South Central Iowa* is enclosed with this report. The scope of work has been presented to ORNL for review and consideration. The RC&D and project partners would also like to request that the DOE review and consider this proposed research for inclusion in the project statement of work.

Task 5.60 Obtain commitments on 4,000 acres

Task 5.6.1 Field coordination and stand maintenance

- Field coordination and stand maintenance activities during the reporting period have consisted primarily of conducting field visits with cooperating producers to assess the condition of switchgrass stands and the effectiveness of, and need for, management practices including fertilizer application, weed control, and re-seeding. Plans and arrangements were made during this period in preparation for the re-seeding and initial seeding of switchgrass stands to be completed in late winter-early spring, i.e., frost seeding, and post-harvest fertilizer application and weed control.
- Activities continued that were part of the preliminary study of switchgrass diseases being conducted by ISU researchers in cooperation with local producers. A progress report for the study that was submitted by Dr. Gary Munkvold with ISU accompanies this report. Due to available project funding, the scope of the switchgrass disease study was limited. At project partners' request, Dr. Munkvold has included on page 9 of the progress report a list of additional research needs. Should these needs be consistent with the interests of the DOE, the RC&D and project partners would also like to request that the DOE review and consider this research for inclusion in the project statement of work.
- As previously reported, field coordination also consists of providing assistance and support to field related activities that are conducted as part of Tasks 2.9.2 to 2.9.6, 5.1.0 to 5.50, 5.70, 6.10, 8.10 to 8.50, and 9.0.

Task 5.70 Biomass cropping systems

- The harvest of switchgrass from the biomass cropping system research plots has been completed. The analysis of samples collected from research plots is scheduled to be completed this winter. The results of these analyses and field data collected from research plots will be interpreted by researchers at ISU. ISU researchers have met with project staff and cooperating producers to review and discuss the second year management of biomass cropping system plots. Preparations have been completed for the establishment of additional cropping system research plots that will feature legumes and corn in combination with switchgrass. A description of the biomass cropping system research plots follows:

Switchgrass Grazing-Biomass System: Two research plots were established to determine the compatibility between spring grazing and fall biomass production. Paddocks were developed at the Loren Eddy and John Sellers farms. Treatments were applied at the Sellers farm but not at the Eddy farm due to difficulties in managing the cattle.

Switchgrass Haying-Biomass System: Two research plots were established to determine the effect of timing of haying on subsequent biomass production. These plots were established in conjunction with the grazing-biomass systems above.

Legume-Switchgrass Biomass System: Two research plots were established to determine the effects of interseeding legumes (red clover, birdsfoot trefoil, and sweetclover) into switchgrass on yield and quality of first-cutting hay and subsequent switchgrass biomass production. Plots were established at the John Osenbaugh and Chariton Valley RC&Ds demonstration farms. Excellent legume stands were achieved at both locations and first year treatments have been applied.

Small Grains-Switchgrass Biomass System: The research objective for this system has been modified due to lack of adequate moisture for establishing the small grains this fall. Given the positive results of legume trials to date, researchers and project staff decided to establish these plots to two legumes, crimson clover and annual sweet clover, to expand the legume haying-switchgrass biomass system research.

Corn or Forage Sorghum-Switchgrass Biomass: Planned establishment of research plots was postponed until 2000 due to poor weather for planting in spring 1999.

- Project staff have assisted cooperating producers with the harvest of biomass cropping system demonstration fields that combined switchgrass with corn production. These fields are being evaluated for corn yield as well as establishment success of switchgrass. Project staff continue to work with producers to evaluate the results of other biomass cropping system field-scale demonstrations that included legumes with switchgrass biomass and timothy with switchgrass biomass.

Task 6.10 Sales contracts and biofuel market development

- Project partners including the Iowa Department of Natural Resources (DNR), Pheasants Forever, Iowa Farm Bureau, and Prairie Lands cooperated in efforts that resulted in the amendment of the 1985 Food Security Act (H.R. 1906). This amendment allows the establishment of up to six pilot projects under which land enrolled in the CRP may be harvested and marketed for biomass used in energy generation. Project partners are currently providing input regarding the administrative and technical guidelines for implementation of the pilot projects.
- Project partners including the Iowa Farm Bureau and Prairie Lands cooperated in efforts that resulted in a two and one half year extension of the Renewable Resources Electricity Credit (H.R. 1180). The extension provides for qualified facilities to receive a tax credit for electricity produced from wind and closed-loop biomass. Changes to the Renewable Resources Electricity Credit that would improve opportunities for existing facilities modified to co-fire closed-loop biomass with coal to be eligible for the credit were not made.
- Representatives of Alliant Energy and Prairie Lands have continued their cooperative efforts to develop model contractual agreement(s) for the generation and marketing of electricity from co-firing switchgrass biomass with coal.

Task 8.10 GIS Analysis

- As in previous reporting periods, assistance with GIS and related technologies has been provided with activities that are part of Tasks 5.4.1, 5.5, 5.60, 5.6.1, 8.20, 8.30, 8.40, 8.50, and 9.00. This assistance continues to consist primarily of field data collection, assembling, developing, and providing coverages and databases, creation and maintenance of project related databases, model application, data analysis, and the development of map products.

Task 8.20 Soil quality

- The fall harvest of biomass from the fertility plots in Lucas (Derby) and Wayne (Millerton) Counties was completed in mid-October as planned. Samples from plots were collected in October and prepared for analysis. Field notes were completed for all plots and the data is being organized and interpreted. All fieldwork has been completed to prepare the fertility plots for continued research.
- Switchgrass yield data has been collected during the fall 1999 harvest from 11 biomass production fields. This yield data, together with soils and field management information, is being interpreted by ISU researchers and project staff.
- Mention should be made that the graduate student at ISU who is conducting much of the research related to Task 8.20 is in the process of preparing his MS thesis. It is anticipated that their theses will be completed in early 2000.

Researchers collected biomass yield data during harvest.

Task 8.30 Water quality

- ISU Researchers and project staff continued to acquire the working knowledge needed to apply the soil and water assessment tool to model the potential impacts on water quality of switchgrass production for biomass. Technical assistance and training continued to be provided by the USDA Agricultural Research Service at the Grassland, Soil, and Water Research Laboratory in Texas.
- Efforts to develop other GIS-based approaches that may also be used to evaluate the water quality impacts of switchgrass production and identify land on which planting switchgrass for biomass may protect water quality have continued during the reporting period. These approaches combine available information about soil characteristics related to leaching and surface runoff potentials and land use data.
- A methodology has been developed and initiated for the collection, processing, and analysis of data that will be used to assess the impact on water quality of land use and practices in the Rathbun Lake watershed. This data will be used as input for SWAT and other watershed assessment approaches. Over 180 field data collection areas have been distributed across the 61 hydrologic units in the watershed. Collection areas consist of the land within 160-acre quarter sections as well as selected reaches of streams in these areas. Additional information required as input for the watershed assessment approaches, e.g., management practices, will be obtained through a series of interviews and meetings with producers and resource professionals.
- ISU researchers, project staff, and cooperating producers have completed the evaluation and selection of fields for the rainfall simulations. Plans and arrangements are being made in preparation for the series of rainfall simulations to be completed in 2000. The rainfall simulations will provide field data to help evaluate and compare the potential water quality impacts of producing switchgrass for biomass with row crop production.

Task 8.40 Wildlife impacts

- The application of harvest treatments for the wildlife research is being completed in 24 biomass production fields during the 1999-2000 harvest. Data collected from spring and summer field surveys to evaluate the wildlife impacts of switchgrass biomass production continues to be analyzed. Field survey reports are being prepared for distribution to cooperating landowners. Preparations are being made, e.g., recruitment of field technicians, to conduct winter field surveys once harvest activities have been completed.
- Additional work was completed on development of the GIS-based model that will be used to assess the impacts on wildlife of changes in land use to switchgrass biomass production. ISU researchers and project staff have determined the need to improve the existing GIS land use coverage available for the region by identifying the location of fields and other areas planted to warm season grasses. This information will enhance the application of the wildlife model by allowing the analysis to differentiate between cool season and warm season grass habitat. Local Soil and Water Conservation Districts and Iowa DNR field staff will assist with the collection of this information.

Biomass harvest in strips as part of the wildlife research being conducted by ISU and cooperating producers.

Task 8.50 Carbon sequestration

- Researchers at ISU have continued the: (a) collection of soil cores from a variety of switchgrass stands as well as alternative land uses including row crops, pasture, and woodland and (b) description and analyses of soil cores collected during previous reporting periods.
- University of Iowa researchers with the Center for Global and Regional Environmental Research, Dr. Jerald Schnoor and Richard Ney, have completed a preliminary draft of their study *Comparison of Life Cycle Greenhouse Gas Emissions from Switchgrass and Coal for Electric Generation*. A copy accompanies this report. At the present time, this preliminary draft report is undergoing revision to include additional information that was not available at the time of its initial preparation.
- Researchers at ISU have prepared a draft scope of work that addresses the need for continued investigation related to this task. The draft scope *Soil Carbon Farming in the Chariton Valley, Iowa: Landscape Scale Changes in Soil Organic Carbon and Quality* is enclosed with this report. The scope of work has been presented to Oak Ridge National Laboratory for review and consideration. The RC&D and project partners would also like to request that representatives of DOE review and consider this proposed research for inclusion in the project statement of work.
- Representatives of the Iowa Farm Bureau, Prairie Lands, Iowa DNR, ISU, University of Iowa, Environmental Financial Products, and University of Colorado continued meetings and discussions with the purpose of developing market opportunities for carbon sequestration and avoidance associated with the production and use of biomass in Iowa.

Task 9.0 Information and education

- A display and materials on the project were developed and presented at the Iowa Forage and Grassland Council's Annual Conference in Pella, Iowa.
- Project partners continued to cooperate with preparations for the conference *Carbon: Exploring the Benefits to Farmers and Society* to be held in Des Moines in August, 2000.
- Developed and made available a PowerPoint presentation on the project to project partners and via the project web site www.cvr.cd.org
- Prepared and distributed articles to local, regional, and statewide media regarding the 1999-2000 harvest activities.

Task 5.20 Assess the genetic variability for biofuel traits

STATEMENT OF WORK (DRAFT)

IOWA STATE UNIVERSITY

Reed Canarygrass And Switchgrass as Biomass Crops in Iowa: Germplasm Evaluation and Development, Agronomy, and Soil Suitability

Principal Investigators - Charles Brummer and Lee Burras

1 January 2000 - 31 December 2002

INTRODUCTION

This research represents an extension of experiments currently in progress in support of the DOE Biomass Power for Rural Development Initiative project with the Chariton Valley Resource Conservation and Development District in southern Iowa. This project continues the reed canarygrass improvement, fertility, and harvest management work begun in 1998-9, completes the initial switchgrass evaluation phase, and proposes three new phases.

OBJECTIVES

- I. Evaluate and develop reed canarygrass and switchgrass germplasm for bioenergy production and adaptation to Iowa,
- II. Determine appropriate agronomic practices (fertilization, harvest management) for optimum biomass production of reed canarygrass and switchgrass,
- III. Relate yield and quality parameters of biomass crops to soil and landscape characteristics.

JUSTIFICATION, METHODS, AND DELIVERABLES FOR EACH OBJECTIVE

- I. **Evaluate and develop reed canarygrass and switchgrass germplasm for bioenergy production and adaptation to Iowa and surrounding states.**

Objective 1.1—Reed canarygrass variety and harvest treatment evaluation

Reed canarygrass has potential as a biomass crop, but evaluation of the available varieties and the best harvest management scheme to optimize productivity is needed. A pilot experiment was planted in 1997 at Ames, IA to compare seven cultivars and three harvest treatments. This experiment was subsequently expanded to three additional sites evaluating five harvest managements: Arlington, WI (planted in 1998), Chariton, IA (1999), and Lexington, KY (1999). This task will evaluate biomass production under a 3, 2, or 1 cut per year, and include an evaluation of overwintering in the field as a potential option. The plots are being evaluated under one fertility regime of 100 lb N/acre applied in early April each year. Yield and quality will be determined on all plots at each harvest time from all locations.

Objective 1.2—Reed canarygrass germplasm evaluation

The small amount of breeding done on reed canarygrass in the United States has focused exclusively on "low-alkaloid" genotypes, which produce better pasture and hay than native/naturalized populations. However, this focus has probably discounted much extant germplasm that may have high yields. Experiments were planted at Ames, IA (121 accessions) and Arlington, WI (100 accessions) in 1998 and data collected for the first year in 1999. Twenty plants of each accession were planted in each of two replications. This task will add a second year of data collection in 2000, after which the most desirable accessions will be evaluated further (see below). Yield and quality data are being collected at two harvest dates in late May-early June and in late September-October on all entries.

Objective 1.3—Development of improved populations of reed canarygrass

Following the second year of evaluation of objective 1.2, we plan to select 5-10 desirable accessions to test more extensively for potential release as cultivars and to use as sources for further selection. Seed of the most desirable accessions will be produced in 2001 for variety trial tests in Chariton, IA, Ames, IA, and Arlington, WI. Additionally, 2000 plants from the best accessions will be transplanted to selection nurseries in 2002 in Chariton, Ames, and Arlington for selection in 2004. Thus, germplasm with desirable biomass yield and quality will be available immediately after the initial evaluation from the accessions *per se* (1.2) and after several years from the selected material.

Objective 1.4—Evaluation of native and/or naturalized North American reed canarygrass populations.

Little evaluation has been conducted of naturalized or native populations of reed canarygrass. We have coordinated a minor collection of reed canarygrass samples from a number of states including VT, NY, PA, WI, MN, IA, MT, OR, Quebec, and Prince Edward Island. We plan to evaluate this germplasm in a trial similar to that in Objective 1.2 to be planted in 2000, with data collected in 2001 and 2002. We plan to expand the scope of this evaluation through further collecting across North America; we are planning to submit a germplasm collection grant proposal to the National Plant Germplasm System in 2000, for funding a collection trip in 2001.

Objective 1.5—Switchgrass variety evaluation

(a) The ongoing trial at the McNay Farm in southern Iowa will be continued for at least one additional year. We have collected data from 1998 and 1999, but the stands were not fully productive in 1998. These trials will also be maintained for a number of years after active data collection to determine long-term persistence.

(b) Based on the results of the initial trial, strip trials of 2-5 of the best cultivars will be planted at several locations in southern Iowa. These plots will be planted, managed, and harvested with farm equipment rather than plot equipment to determine which cultivar or germplasm is the most widely adapted.

II. Determine appropriate agronomic practices (fertilization, harvest management) for optimum biomass production of reed canarygrass and switchgrass

Objective 2.1—Harvest management of reed canarygrass

This has been covered in objective 1.1—the reed canarygrass variety trial.

Objective 2.2—Reed canarygrass fertility plots

Two large fields of reed canarygrass will be used for fertility research. Four replications of five fertility regimes will be evaluated at each location, with individual plots roughly $\frac{1}{4}$ acre in size. Fertility will be assessed under a two harvest management system. Treatments will include 0, 100, and 200 lb/N per acre, with the 100 and 200 treatments being applied either as a single spring application or as a split spring/summer after first harvest management.

Objective 2.3—Switchgrass fertility plots

The current fertility plots will be maintained for an additional year to begin to understand the effects of repeated fertilization on stand vigor, thickness, and yield. However, based on the results from this initial fertility plots, other plots need to be established for two reasons: (1) to sample more soils and landscapes, and (2) to study fertility effects in stands that have been well managed for biomass production. Part of the problem with the first fertility plots is that the fields had not been previously well managed, and the stands were thin. Thus, continuing work with those fields will show the longer-term effects of fertilization on stand improvement, and the new work can show the effects in well-managed, highly productive stands. Finally, experiments to evaluate the effect of pH will be started, since preliminary results suggest pH to be a important variable to consider for yield in southern Iowa.

III. Relate yield and quality parameters of biomass crops to soil and landscape characteristics.

Objective 1.1—Monitor soil type, pH, bulk density, and organic matter and mineral content on sites where variety tests or fertility research is ongoing

In all the research that we conduct in large plots, we would like to regularly sample soils to correlate yield and quality of biomass with the underlying soil properties. These studies are critical to understanding the dynamics of biomass crop production in southern Iowa. Particular attention will be paid to sampling the various soil types, slopes, aspects, and landscape positions present in our plots.

Objective 1.2—Relating soil characters to germplasm collections

We have begun to extensively collect reed canarygrass germplasm (*Objective 1.4*). In an effort to more fully characterize the genetic potential of our collections, and to attempt to guide future efforts, we will sample soils at the exact site of seed collection for a number of reed canarygrass collections in central and southern Iowa. These collections will be evaluated in common nurseries to determine true productive capacities under similar conditions. Relating performance to particular qualities of the environment in which the plants were collected will help make collection more scientifically based, and may show some interesting reasons for the productivity and/or quality of certain collected populations.

BUDGET (2000-2002) BY YEAR:

Technician for field and lab analysis	
Salary	\$28,000
Benefits	\$ 9,000
Hourly labor	\$ 7,000
Supplies, lab expenses	\$20,000
Transportation	\$ 5,000
<u>Travel to meetings</u>	<u>\$ 1,000</u>
Total	\$70,000

The technician would conduct the day-to-day research as described, working in some cases with farmers or other personnel in the Chariton Valley project for field scale harvesting. This person could also conduct many of the laboratory analyses. Hourly labor is needed for sampling, grinding, weeding, and other field and lab tasks. The supplies cover a range of needs, including laboratory costs for fiber, proximate, ultimate, BTU, and ash analyses. Transportation costs cover a pick-up rental, and travel monies are for the PIs to report results at national/international meetings.

STATEMENT OF WORK (DRAFT)
IOWA STATE UNIVERSITY

**Switchgrass and Reed Canarygrass as Biomass Crops in Iowa:
Agronomy, Germplasm Evaluation and Development, and Soil Suitability**

Principal Investigators - Charles Brummer, Lee Burras, and Mike Duffy
1 January 2000 - 31 December 2002

INTRODUCTION

This research represents an extension of experiments currently in progress in support of the DOE Biomass Power for Rural Development Initiative project with the Chariton Valley Resource Conservation and Development District in southern Iowa. This project continues the reed canarygrass improvement, fertility, and harvest management work begun in 1998-9, completes the initial switchgrass evaluation phase, and proposes three new phases.

OBJECTIVES

- I. Determine appropriate agronomic practices (fertilization, harvest management) for optimum biomass production of reed canarygrass and switchgrass,
- II. Evaluate and develop switchgrass and reed canarygrass germplasm for bioenergy production and adaptation to Iowa,
- III. Relate yield and quality parameters of biomass crops to soil and landscape characteristics.
- IV. Conduct an economic analysis of switchgrass and reed canarygrass based on the results of I-III.

JUSTIFICATION, METHODS, AND DELIVERABLES FOR EACH OBJECTIVE

- I. **Determine appropriate agronomic practices (fertilization, harvest management) for optimum biomass production of reed canarygrass and switchgrass**

Objective 1.1: Switchgrass fertility plots (continuing project)

The current fertility plots will be maintained for an additional year to begin to understand the effects of repeated fertilization on stand vigor, thickness, and yield. However, based on the results from this initial fertility plots, other plots need to be established for two reasons: (1) to sample more soils and landscapes, and (2) to study fertility effects in stands that have been well managed for biomass production. Part of the problem with the initial fertility plots was that the fields had not been well managed previously, and the stands were thin. Thus, continuing work with those fields will show the longer-term effects of fertilization on stand improvement, and the new work can show the effects in well-managed, highly productive stands. Finally, experiments to evaluate the effect of pH will be started, since preliminary results suggest pH to be an important variable to consider for yield in southern Iowa.

Objective 1.2: Harvest management of reed canarygrass (continuing project)

Reed canarygrass has potential as a biomass crop, but evaluation of the available varieties and the best harvest management scheme to optimize productivity is needed. A pilot experiment was planted in 1997 at Ames, IA to compare seven cultivars and three harvest treatments. This experiment was expanded to three additional sites evaluating five harvest managements: Arlington, WI (planted in 1998), Chariton, IA (1999), and Lexington, KY (1999). This task will evaluate biomass production under 3, 2, or 1 cut per year, and include an evaluation of overwintering in the field as a potential harvest option. The plots are being evaluated under one fertility regime of 100 lb N/acre applied either in a single application for the one harvest treatments or in split applications of 50 lb/N in early April and 50 lb/N after first harvest each year for the 2 and 3 cut systems. Yield and quality will be determined on all plots at each harvest time from all locations.

Objective 1.3: Reed canarygrass fertility plots (new project)

Two large fields of reed canarygrass will be used for fertility research. Four replications of four fertility regimes will be evaluated at each location, with individual plots roughly $\frac{1}{4}$ acre in size. Fertility will be assessed under a two harvest management system. Treatments will include 0, 50, 100, and 200 lb/N per acre, with the 100 and 200 treatments being a split application in spring and in summer after first harvest. Each of these sites will be limed to slightly acid to neutral conditions (pH between 6.5 and 6.9) prior to the initiation of the study.

Objective 1.4: Side-by-side evaluation of switchgrass and reed canarygrass (new project)

The first set of experiments developed under the previous agreement considered switchgrass and reed canarygrass alone. However, in order to make recommendations of the crops to producers, side-by-side evaluations are needed. For this task, we will evaluate 'Cave-in-rock' switchgrass and 'Palaton' reed canarygrass in a common experiment at three locations in the Chariton Valley. The first location, to be planted in 2000, will be the McNay Research Farm, in an area adjacent to the current switchgrass and reed canarygrass trials, making it accessible for field days. The other two locations will be on-farm and will be planted in 2001. At each of these two locations, the experiment will be planted as a split-block design, with three landscape positions (upland, side-slope, and bottomland) representing the blocks. Plots will be large enough to be harvested with field equipments. Two nitrogen treatments will be included at each location—50 and 100 lb/A. These are subject to change based on the other ongoing fertility studies, but our preliminary evidence suggests they are viable alternatives. Subsamples at the time of harvest will be made to assess the biomass quality—cell-wall components and ash analysis. Soils in each plot will be sampled as described below in III.

II. Evaluate and develop reed canarygrass and switchgrass germplasm for bioenergy production and adaptation to Iowa and surrounding states.

Objective 2.1: Small plot switchgrass variety evaluation

The ongoing variety trial at the McNay Farm in southern Iowa will be continued for at least one additional year. We have collected data from 1998 and 1999, but the stands were not fully productive in 1998. These trials will also be maintained for a number of years after active data collection to determine long-term persistence, particularly important for some of the potentially higher yielding lowland germplasms.

Objective 2.2: Field scale switchgrass variety evaluation

Based on the results of the initial trial, strip trials (20' x 200') of 2 to 5 of the best cultivars will be planted at three locations in southern Iowa to evaluate adaptation and stability over multiple landscapes. These plots will be planted, managed, and harvested with farm equipment rather than plot equipment. All plots will be fertilized annually with 100 lb/A of nitrogen.

Objective 2.3: Reed canarygrass germplasm evaluation

The small amount of breeding done on reed canarygrass in the United States has focused exclusively on "low-alkaloid" genotypes, which produce better pasture and hay than native/naturalized populations. However, this focus has probably overlooked much extant germplasm that may have high yields. Experiments were planted at Ames, IA (121 accessions) and Arlington, WI (100 accessions) in 1998 and data collected for the first year in 1999. Twenty plants of each accession were planted in each of two replications. This task will add a second year of data collection in 2000, after which the most desirable accessions will be evaluated further (see below). Yield and quality data are being collected at two harvest dates in late May-early June and in late September-October on all entries.

Objective 2.4: Development of improved populations of reed canarygrass

Following the second year of evaluation of objective 1.2, we plan to select 5-10 desirable accessions to test more extensively for potential release as cultivars and to use as sources for further selection. Seed of the most desirable accessions will be produced in 2001 for variety trial tests to be planted in Chariton, IA, Ames, IA, and Arlington, WI in fall 2001.

These accessions could be potential cultivars; if acceptable based on the variety trials, seed increase could begin in 2004.

III. Relate yield and quality parameters of biomass crops to soil and landscape characteristics.

Objective 1.1: Monitor soil type, pH, bulk density, and organic matter and mineral content on sites where variety tests or fertility research is ongoing

In all the research that we conduct in large plots, we will regularly sample soils to correlate yield and quality of biomass with the underlying soil properties. These studies are critical to understanding the dynamics of biomass crop production in southern Iowa.

Particular attention will be paid to sampling the various soil types, slopes, aspects, and landscape positions present in our plots.

Soil fertility analyses will consist of standard assessments (pH, buffer pH, available P & K) as well as complementary assessments of available Ca, Mg, Zn and Na. These analyses will be completed on soil samples collected at two depths: standard soil testing depth (0-15 cm) and "deep samples" (50 to 75 cm). The standard samples will permit conventional comparison of soil properties-yield relationships between our sites and other sites. The deep sampling will permit evaluation of the specific subsoil conditions in the Chariton Valley on yield. This component is included because reed canary grass and switchgrass growth and yield may be retarded by the highly root limiting properties of subsoil conditions in the Chariton Valley.

Other soil analyses to be completed are surface (0-15cm) and deep (50 to 75 cm) soil bulk density and total organic carbon to a depth of 1 m. Representative pedons will be described using standard NRCS methods across each plot in order to evaluate the which morphological features best predict switchgrass and reed canary grass growth. Current anecdotal observations suggest it will be B horizon color, with switchgrass competing best when the B horizon is 10YR 4/3 or brighter, while reed canary grass "prefers" 10YR 4/2 or grayier colors.

IV. Economic analysis of switchgrass and reed canarygrass productivity.

Objective 4.1: Analysis of cost of production and expected returns for switchgrass and reed canarygrass.

In order to make producer recommendations, we will conduct an economic analysis based on the fertility and variety trials in I., accounting for the particular soil characteristics as described in III. The results will be summarized as an extension bulletin for distribution to potential growers.

BUDGET (2000-2002) BY YEAR:

Technician for field and lab analysis

Salary	\$28,000
Benefits	\$ 9,000
Hourly labor	\$ 7,000
Supplies, lab expenses	\$20,000
Economic analysis	\$ 5,000
Transportation	\$ 5,000
<u>Travel to meetings</u>	<u>\$ 1,000</u>
Total	\$75,000 per year

The technician would conduct the day-to-day research as described, working in some cases with farmers or other personnel in the Chariton Valley project for field scale harvesting. This person could also conduct many of the laboratory analyses. Hourly labor is needed for sampling, grinding, weeding, and other field and lab tasks. The supplies cover a range of needs, including laboratory costs for fiber, proximate, ultimate, BTU, and ash analyses. Transportation costs cover a pick-up rental, and travel monies are for the PIs to report results at national/international meetings.

Attachment for

Task 5.40 Evaluate harvest and handling equipment

PROJECT PROPOSAL (DRAFT)

Title: Biomass Storage and Preservation

Investigators: K. J. Moore, Iowa State University
R. L. Hintz, Iowa State University

Rationale:

Seasonal production of biomass crops such as switchgrass will require substantial storage to sustain operation of electrical generation plants throughout the year. There are a number of options available for storage of switchgrass grown for biomass. Since the crop is generally harvested following frost, it could potentially be stored *in situ* and harvested just prior to delivery to the electric plant. However, switchgrass stored in this way may be subject to severe weathering and field conditions during winter may preclude timely harvest. There are several types of hay packages that would be amenable to storage and transport of biomass. These include large round bales, and conventional and large rectangular bales. Rectangular bales have the advantages of ease of stacking and transport. Large bales, both rectangular and round, are easier to handle and therefore require less labor to stack and load. However, large round bales are generally hauled as wide loads and safety may be an issue when transporting the tonnage required to supply an electric plant. For these reasons, large rectangular bales are probably the best option for storing and transporting biomass.

Storage of biomass crops could be either centralized (stored near the point of use), or decentralized (stored near the point of production), or some intermediate option where the crop is stored at regional accumulation sites. Regardless, biomass crops will need to be preserved for a period of time between harvest and their end use. The storability of switchgrass produced for biomass and packaged as large rectangular bales under various storage conditions has not been studied. Several studies have been conducted looking at grass crops preserved as hay for livestock consumption. However, the chemical composition of these materials differs in ways that make them more subject to deterioration during storage than biomass. Also, the effects of heating and molding which have a large detrimental effect on feed quality of hay would presumably have little or no impact on the suitability of biomass for combustion.

Objectives:

The overall goal of this project is to determine the influence of storage conditions on the preservation of switchgrass produced for biomass. Specific objectives are:

- 1) determine the effects of cover and lot surface on dry matter losses and composition changes.
- 2) determine rate of weathering loss with respect to season on bales stored outside (exposed to the elements).

Based upon this research it should be possible to develop strategies for storing switchgrass biomass that minimize storage losses and costs.

Approach:

Objective 1. The effects of cover (plastic or inside storage) and lot surface (soil or rock) during storage on biomass preserved as hay will be determined. Treatments will consist of: 1) stack exposed on soil 2) stack exposed on raised rock surface, 3) stack covered with plastic on raised rock surface, and 4) stack stored inside a building. Treatments will be replicated three times in a completely random design. Stacks will consist of 27 large rectangular bales stacked in three rows three bales high. The storage period will be six months. Each bale will be weighed and sampled before and after storage. Samples will be collected at the exposed surface (outer 10 cm) and from the interior of bales using a hay probe. Dry matter and ash concentration will be determined to ascertain the effects of weathering and/or storage on organic matter preservation. Physical and handling characteristics of the bales will also be evaluated. Data analysis will include the overall effects of the four treatments on preservation of the stacks and spatial analysis to determine the effect of bale position within a stack on deterioration during storage.

Objective 2. Rates of weathering loss will be determined for individual bales stored outside without cover for a 12-month period following storage. Bales of switchgrass harvested following frost will be placed in storage for periods of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 months. Each storage period will be replicated four times in a randomized complete block design. Bales will be stored on soil and completely exposed to weather to determine weathering losses under the most extreme circumstances. Each bale will be weighed and sampled before and after storage. Samples will be collected at the exposed surface (outer 10 cm) and from the interior of bales using a hay probe. Dry matter and ash concentration will be determined to ascertain the effects of weathering and/or storage on organic matter preservation. Physical and handling characteristics of the bales will also be evaluated.

Budget:

The estimated cost of this project is \$65,613. In addition, producers cooperating with the project will contribute an estimated 136 hours of labor and equipment valued at \$3,264.

Item	Total
Salaries and Wages	
Graduate Student, (.25)	\$6,750
Hourly Labor	<u>3,000</u>
Total Salaries	9,750
Nonexpendable Equipment	2,000
Materials and Supplies	21,300
Travel	4,000
Laboratory Analyses	<u>15,440</u>
Total Direct Costs	52,490
Indirect Costs (25%) ^a	<u>13,123</u>
Total Costs	<u>\$65,613</u>

^a Contributed by Iowa State University.

Attachment for
Task 5.50 Economic analysis of energy crop production

PROJECT PROPOSAL (DRAFT)

Title: Adoption of Biomass Production and Other Alternative Land Uses by Farmers in the Chariton Valley Area of South Central Iowa

Principal Investigator: Dr. Michael Duffy, Department of Agricultural Economics, Iowa State University

Rationale:

The participation and support of potential biomass producers are essential to the successful development of the energy crop industry in Iowa. Currently, more than 60 farmers cooperate with the Chariton Valley Biomass Project. These producers have made the decision to dedicate close to 6,000 acres of land that they own and manage to switchgrass production for biomass. In addition to this land use decision, a majority of these producers have invested significant time and financial resources to assist with the planning and completion of project activities during the initial three years of the project's development. These decisions have been made and this level of effort has been put forth by cooperating producers in spite of the fact that no market currently exists for switchgrass biomass as an energy crop. Accomplishment of the long-term project goal of producing and using 200,000 tons annually of biomass to generate electricity will likely require the participation of as many as 500 agricultural producers.

An improved understanding of the economic and non-economic factors that farmers in southern Iowa take into consideration when evaluating alternative land uses and making decisions regarding the use of their other resources will help the development and implementation of guidelines for long-term producer participation in the Chariton Valley Biomass Project.

Objectives:

Key questions and issues specific to agricultural producers in the Chariton Valley area that will be addressed through this proposed study will include, but not be limited to, the following:

- What motivates the adoption and non-adoption of energy crops, other alternative crops, and new agricultural production practices?
- What are the incentives and disincentives to adoption, including profit, risk, uncertainty, reputation, inputs and equipment availability, financial status, financial guarantees, program subsidies, support networks, learning curves, community attitudes, and family attitudes?
- What crop and product attributes, infrastructure and markets, financial and community support programs facilitate or impede adoption?

Study Methods:

Methods that will be employed in completing the proposed study will include a combination of the following:

- Ethnographic Fieldwork
- Interviews
- Participant Observation
- Focus Groups
- Informal Discussion Groups
- Archival Review
- Facility and Farmer Tours

It is anticipated that 12 months will be required to complete all study activities including the final report.

Budget:

The estimated cost of this project is \$58,405. In addition, farmers cooperating with the project will contribute an estimated 180 hours of time valued at \$4,320.

Item	Costs
Salaries and Wages	
Research Assistants (2)	\$31,240
Travel	14,428
Supplies	1,056
Total Direct Costs	46,724
Indirect Costs (25%) ^a	11,681
Total Costs	\$58,405

^a Contributed by Iowa State University

Attachment for
Task 5.6.1 Field coordination and stand maintenance

Switchgrass Diseases in the Chariton Valley

Progress Report, 10/30/99

G.P. Munkvold and C.E. Gravert, Department of Plant Pathology,
C.E. Brummer and S.K. Barnhart, Department of Agronomy,
W.M. Carlton, Monroe Co. Extension,
Iowa State University

Introduction

In 1998 the Chariton Valley project coordinators became aware that biomass and seed yields were declining in some fields. Expected yields are approximately 4.0 t/a (9.0 mt/ha), but in some fields there has been a decline of approximately 2.5 t/a (5.6 mt/ha) in the past two years. Diseases were suspected of contributing to the declining yields, but it was unclear which diseases may be involved or to what extent they affected biomass production.

The objectives of this project are to: investigate problem fields for possible disease-related causes of declining yields, assess switchgrass diseases in biomass production areas, develop a database on switchgrass diseases in Southern Iowa, and develop disease control strategies if necessary.

Procedures

A literature search was conducted to gather information on potential diseases of switchgrass in the area. We identified numerous reports of individual diseases or fungi on switchgrass and a few references with detailed information on specific diseases.

Preliminary sampling was conducted on May 27 and June 24 in fields previously identified as problem areas, and at the cultivar trial at ISU McNay Research Farm near Chariton. Symptomatic stem, leaf, and root samples were collected from cooperator fields near Derby, Millerton, Iconium, and Lucas. Photographs of diseases found were taken in the field and in the laboratory for future reference. During the preliminary sampling, a seed smut, caused by the fungus *Tilletia maclaganii*, was identified as a major problem in a few fields.

A more intensive survey was conducted in late August. We used a weighted random sampling procedure to select 20 switchgrass fields from approximately 60 fields identified by Chariton Valley RC&D. The sampling procedure was designed so that the probability of each field being chosen was proportional to its acreage. This resulted in samples being taken from 17 fields representing approximately 50% of the total acreage in the 60 fields. A few selected fields were not suitable for sampling due to low switchgrass densities. In each field, five samples were taken from arbitrary locations. Each sample consisted of one square meter in which all vegetation was clipped approximately 6 inches above the soil and brought to the laboratory. Samples were stored in a cold room until they were assessed for disease. The total number of tillers and the number of tillers with smut were counted. The incidence of smut (% of tillers with smut) was calculated for each sample. Other disease symptoms were recorded and sub-samples were retained for disease identification. Presence of known diseases was recorded for each sample.

Leaf and stem samples were placed into moist chambers and allowed to develop for four to seven days. Fungi developing on symptomatic tissue were microscopically examined and identified. If the disease could not be identified from the lesions, Fungi were isolated from the lesions onto potato dextrose agar with antibiotics (PDA) or carnation leaf agar (CLA). Fungal identifications were based on published descriptions.

Several samples with symptoms resembling Barley Yellow Dwarf Virus (BYDV) were tested for the virus by Agdia, Inc.. No strains of BYDV were present in the leaf tissue tested.

Seeds collected from a commercial seed producer in Lucas County were cultured for seedborne pathogens.

Root samples were cultured on PDA. The samples were put in a dark room for 7 days for isolation of the fungi. Fungal colonies were examined microscopically for identification, or transferred to CLA, and then examined.

Root inoculations were conducted in the greenhouse to determine whether *Fusarium oxysporum* and *F. solani* isolates from root lesions were pathogenic.

Results

The literature search resulted in a list of 41 fungi that infect switchgrass, but only eight have been reported in Iowa. It is likely that many of the other 33 fungi are common in Iowa but have not been reported. Table 1 is a list of fungi that infect switchgrass in Iowa and other states, according to the literature.

Table 1. List of fungi reported to infect switchgrass in Iowa and other areas of the United States .

Fungi reported to infect switchgrass	Found in Iowa (+)	Fungi reported to infect switchgrass	Found in Iowa (+)
Oomycetes		Basidiomycotina- Others	
<i>Pythium arrhenomanes</i>		<i>Thanatephorus cucumeris</i>	
<i>Pythium debaryanum</i>		Deuteromycotina-	
		Hyphomycetes	
<i>Pythium graminicola</i>		<i>Alternaria sp.</i>	
<i>Sclerophthora macrospora</i>		<i>Beniowskia sphaeroidea</i>	
Ascomycotina		<i>Bipolaris sorokiniana</i>	
<i>Balansia epichloe</i>		<i>Cerebella andropogonis</i>	
<i>Balansia henningsiana</i>		<i>Curvularia geniculata</i>	
<i>Claviceps sp.</i>		<i>Fusarium acuminatum</i>	
<i>Elsinoe panici</i>	+	<i>Fusarium equiseti</i>	
<i>Exarmidium fusariisporum</i>		<i>Microdochium bolleyi</i>	
<i>Graphyllum hysterioides</i>		<i>Phaeoramularia fusimaculans</i>	
<i>Metasphaeria subseriata</i>		Deuteromycotina-	
		Coelomycetes	
<i>Phyllachora graminis</i>	+	<i>Ascochyta missouriensis</i>	
Basidiomycotina-		<i>Ascochyta sp.</i>	
Uredinales			
<i>Puccinia emaculata</i>	+	<i>Colletotrichum graminicola</i>	
<i>Puccinia graminis</i>		<i>Hendersonia panicicola</i>	
<i>Uromyces graminicola</i>	+	<i>Phoma sorghina</i>	
Basidiomycotina-		<i>Phoma terrestris</i>	
Ustilaginales			
<i>Sporisorium cenchri</i>		<i>Phyllosticta panici</i>	
<i>Tilletia barclayana</i>	+	<i>Pseudoseptoria donacis</i>	
<i>Tilletia maclaganii</i>	+	<i>Septoria sigmoidea</i>	+
<i>Ustilago heterogena</i>	+	<i>Wojnowicia hirta</i>	
<i>Ustilago trebouxii</i>		Deuteromycotina- Other	
		<i>Rhizoctinia solani</i>	

The results of the identifications show a wide variety of diseases in switchgrass fields. We have not completed identification of some of the fungi

isolated from diseased plants. Below is a list of the fungi identified and their associated symptoms when found in field situations.

***Alternaria alternata*:** This fungus was isolated from fresh leaf material and can be parasitic or saprophytic on plant material.

***Bipolaris* sp.:** This fungus was isolated from fresh leaf material. The leaf lesions were elliptical, approximately 1 to 3 mm, and had yellowish halos. The halo was surrounded by tissue that had a reddish-purple tint. *B. sorikiniana* has been reported previously on switchgrass. This fungus was isolated from seeds and from dark lesions at the base of seedling leaves in the greenhouse.

***Colletotrichum graminicola*:** This fungus was isolated from a 3 to 5 mm, elliptical tan lesion with a yellow halo. Within the lesion were black dots that were identified as protruding acervuli.

***Fusarium* sp.:** These fungi were isolated from root tissue and seed. There were three species isolated: *F. acuminatum*, *F. oxysporum* and *F. solani*. The necrotic lesions on the roots were brown to dark brown in color and covered 1 to 3 mm of tissue.

***Penicillium* sp.:** This fungus was isolated from root tissue and seed. The root lesions covered 2 to 5 mm on the roots and were brown to dark brown.

***Phoma* sp.:** This fungus was isolated from fresh leaf tissue. The lesions were elliptical, 3 to 5 mm, and yellow to tan with dark spots in the middle of the lesion. The dark spots were identified as pycnidium under the epidermis.

***Pseudoseptoria* sp.:** This fungus was isolated from fresh leaf tissue. The lesions were elliptical, 2 to 5 mm, and tan with black spots in the middle of the

lesion. The black spots were identified as asci under the epidermis.

Pseudoseptoria donacis has been reported previously on switchgrass.

***Puccinia* sp.:** This fungus was isolated from year old stem samples. The lesions were 1 to 2 mm long, black, linear, and contained between veins on the stems. *Puccinia emaculata* has been reported previously on switchgrass.

***Tilletia maclaganii*:** This fungus was isolated from the seed heads on new growth. The disease is characterized by a purpling of the panicles, early heading, stunted plants, and seeds replaced by orange-brown teliospore masses.

***Trichoderma* sp.:** This fungus was isolated from root material. The lesions were 2 to 5 mm and brown to black in color.

The diseases were distributed throughout the sampling area on several different varieties of switchgrass. Table 2 shows the different fungi isolated, variety, locations, and infected tissues of switchgrass. The area sampled was not representative of the four-county area, as much of this information was generated from preliminary samples. The survey data will provide more quantitative estimates of disease prevalence in the Chariton Valley.

Table 2. Fungi isolated from switchgrass in the Chartion Valley in 1999; varieties, locations, and infected tissue.

Fungi	Variety	Field	Symptomatic Tissue
<i>Alternaria alternata</i>	Blackwell	Derby McNay Millerton	Leaf
<i>Bipolaris sp.</i>	Blackwell	Millerton	Leaf , seed
<i>Colletotrichum graminicola</i>	Blackwell	Derby	Leaf
	Carthage/Shawnee	McNay	
	Cave In Rock	Millerton	
	Forestburg	RC&D1	
	IALM	RC&D2	
	NU94-2CH	Sellers1	
	Sunburst	Sellers 2	
<i>Fusarium acuminatum</i>	Cave in Rock	McNay RC&D1	Root, seed
<i>F. oxysporum</i>	Cave in Rock	McNay	Root
<i>F. solani</i>	Cave in Rock	McNay	Root
<i>Penicillium sp.</i>	Cave In Rock	RC&D1	Root
<i>Phoma sp.</i>	Cave In Rock	RC&D1	Leaf
<i>Pseudoseptoria donacis</i>	Blackwell	RC&D2	Leaf
<i>Puccinia sp.</i>	Cave In Rock	RC&D1	Year-old
		Sellers1	leaf/stem
<i>Tilletia maclaganii</i>	Cave In Rock	Derby McNay Millerton RC&D1 RC&D2 Sellers1 Sellers 2	Head
<i>Trichoderma sp.</i>	Blackwell	RC&D1	Root

The results of the root inoculations were inconclusive due poor growing conditions in the greenhouse. Cultivar reactions to disease could not be assessed due to low incidence in the cultivar trial plots.

Survey data for *Tilletia maclaganii* have been completed and are presented in Table 3. This disease was widespread in the Chariton Valley switchgrass plantings. Incidence ranged from 0 to 70% of tillers in individual

fields, with a mean of 10% (the Lodge land was not included in this calculation since it was not one of the randomly selected fields). The percentage of the sampled acreage affected by smut was in the range of 50-82%. A more precise estimate is not possible without a more intensive sampling procedure.

Discussion

Of the 12 fungi identified so far, only two (*Puccinia* and *Tilletia*) have been reported from Iowa switchgrass previously. Six have been reported previously from switchgrass, but not in Iowa. Four (*Fusarium oxysporum*, *Fusarium solani*, *Trichoderma* sp., and *Penicillium* sp.) have not been reported previously from switchgrass. The data indicate that there is a wide distribution of two pathogenic fungi, *Tilletia maclaganii* and *Colletotrichum graminicola*. Both are well-known pathogens: *Tilletia maclaganii* is the causal agent of smut and *Colletotrichum graminicola* causes anthracnose. Both fungi were found in the majority of samples, however only *T. maclaganii* seems to have a significant impact on plant growth, which will affect the production of biomass.

Tilletia maclaganii is a Basidiomycete seed smut pathogen that infects the heads of switchgrass and causes a systemic infection that colonizes the crown of the plant. This pathogen is contributing to some of the reduction in seed and biomass production in the fields. The disease cycle of *T. maclaganii* is not fully understood so effective control practices will be difficult to ascertain.

It has been postulated that *T. maclaganii* overwinters in the soil and infects plants through the roots (D. Stuteville, personal communication). Covered smut of wheat, *Tilletia caries* and *T. foetida*, which are in the same genus

as *T. maclaganii*, have been found to survive up to three years in the soil in the teliospore stage. These fungi usually infect plants through the inflorescence and are seedborne.

Control of other smut diseases is accomplished by using disease free or heat-treated seed, fungicide-treated seeds, and resistant cultivars.

Current Recommendations:

1. Fields currently infested with *T. maclaganii* should be rotated to another crop or forage grass for at least three years. Switchgrass is the only host reported for *T. maclaganii*.
2. A variety trial should be established at an infested location. The Lodge land is a good candidate because it has the highest disease incidence.

Research Needs:

1. The role of seeds in the disease cycle needs to be determined. If the disease is being spread on or in seed, this aspect of the disease can be controlled through seed treatment or production of seed in disease-free areas.
2. A greenhouse method for evaluating varieties would facilitate evaluation of varieties. Experiments need to be conducted to determine effective greenhouse screening methods.
3. An investigation is needed to clarify other aspects of the disease cycle for this fungus, including mode of primary infection, importance of secondary spread, host range, and duration of survival. Control recommendations may be developed based on this information.

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Table 3. Incidence of head smut in cultivated switchgrass stands sampled in the Chariton Valley.

Field	Cooperator	County	Hectares	Acres	Tillers/m ²	Incidence (%) ^a
1	Mitchell, Robert	Appanoose	41.3	102	81	46.5
2	RC&D Lodgeland	Appanoose	53.4	132	252	70.5
3	Adams, Doyle	Lucas	5.7	14	128	9.4
4	Chandler, Gary	Lucas	13.0	32	61	0.0
4-1	Chandler, Gary	Lucas	13.8	34	86	1.2
5	D'Attilio, Gerald B.	Lucas	2.8	7	97	1.4
7	Petersen, Jeanne M.	Lucas	57.5	142	95	3.2
8	Petersen, Troy D.	Lucas	16.2	40	122	15.0
9	Schultz, James W.	Lucas	48.2	119	121	6.6
12	Van Pattern, Rich	Lucas	80.9	200	127	11.8
13	Lawless, John	Monroe	6.9	17	152	1.7
14	Cross, Joe	Wayne	8.1	20	176	0.8
15	Klinkhammer, Donald	Wayne	40.9	101	96	0.2
16	Martin, Larry	Wayne	68.9	170	112	0.0
18	Sellers, John Jr.	Wayne	30.8	76	171	21.4
19	Wayne Co.Conserv.Bd	Wayne	6.5	16	147	13.2
20	Wehrheim, Eugene	Wayne	12.1	30	126	8.8
Total			506.7	1,252		
Weighted mean ^b					114	10.1

^a % of tillers

^b Does not include Lodge land

**Task 8.50 Attachments for
Carbon sequestration**

**A Comparison of Life Cycle Greenhouse Gas
Emissions from Switchgrass and Coal
for Electric Generation**

A Report to the Chariton Valley RC & D

October 1, 1999

**Center for Global and Regional Environmental Research
Richard A. Ney
Jerald L. Schnoor**

EXECUTIVE SUMMARY

The Chariton Valley Biomass Project has been initiated in an attempt to develop the infrastructure necessary to create a market for switchgrass-fired electric generation in south central Iowa. The Center for Global and Regional Environmental Research has completed a study of the life cycle greenhouse gas (GHG) emission impacts of switchgrass production and combustion as electric generation fuel. The proposed displacement of up to five percent of the coal fired generation at the Ottumwa Generating station appears to provide very positive results for the environment. Switchgrass sequesters carbon dioxide from the atmosphere prior to combustion offering a net advantage over coal. Greenhouse gas emissions due to switchgrass seeding, fertilizing, weed control, transport, and disposal of ash were all included in the analysis. The current analysis indicates that co-firing five percent switchgrass with coal may reduce emissions of carbon dioxide equivalent cases ($\text{CO}_2\text{-eq}$) by nearly 177,000 tons per year. However, emissions of nitrous oxide (N_2O) from switchgrass combustion, a powerful greenhouse gas with a large global warming potential, are yet to be calculated, pending results of a test burn of switchgrass in the power plant. The results of this test, while not expected to completely remove the emission benefits of switchgrass co-firing, may create a reduction in these benefits on the order of ten percent.

The cultivation of perennial grassy crops such as switchgrass provide many additional environmental benefits in the highly erodible soils of south central Iowa. Among the benefits are reductions in soil erosion, water contamination with agricultural chemicals, and improvement in wildlife habitat. In addition, emissions of sulfur dioxide (SO_2) a precursor to acid rain, are also reduced by as much as 113 tons per year. Using the current values of tradable emission credits that could potentially be derived from a shift to switchgrass cofiring, the reductions in greenhouse gases and sulfur dioxide emissions are worth an estimated \$420,000 annually. These credits may create a significant, secondary revenue stream that will make alternative fuels such as switchgrass, more economically viable under today's market conditions and in a future deregulated electric utility market.

In life cycle assessments, the assumption on prior land use makes a difference in the "bottom line" for net greenhouse gas emissions. Fallow land currently enrolled in the Conservation Reserve Program (CRP) sequesters a significant amount of carbon dioxide from the atmosphere and stores it as organic carbon in the soil. If land use changes from the CRP program to switchgrass for energy, it is less favorable than if land was previously in row crops prior to switchgrass. But the largest savings in greenhouse gas emissions is due to avoiding the combustion of 5% of the coal at the power plant, and the total balance is favorable. For a mature crop of switchgrass, GHG emissions are reduced by 338 lbs of $\text{CO}_2\text{-eq}$ per million BTUs of thermal energy produced (338 lbs $\text{CO}_2\text{-eq/MMBTU}$) for use of land that was previously in corn, and 259 lbs $\text{CO}_2\text{-eq/MMBTU}$ for land that was previously in the CRP program. In either case, it is a significant net benefit for the environment, and it creates a new market for biomass energy in Iowa.

INTRODUCTION

The Chariton Valley RC&D operates the Chariton Valley Biomass Project, funded by several agencies. In the project, large tracts of southern Iowa farmland and Conservation Reserve Program (CRP) set-aside have been replanted, or are planned for replanting to switchgrass, which will be harvested and burned in the Ottumwa Generating Station (OGS) operated by Alliant utility. The Center for Global and Regional Environmental Research (CGRER) has estimated the potential for reducing OGS greenhouse gas emissions by switching from 100 percent coal-fired generation to a mix of five percent switchgrass/95 percent coal. The pollutants investigated are carbon dioxide equivalent ($\text{CO}_2\text{-eq}$), sulfur dioxide (SO_2) and nitrogen oxides (NO_x). SO_2 and NO_x emissions are estimated at the point of combustion within the utility boiler at OGS in order to estimate potential compliance costs or benefits of switchgrass-fired generation with Acid Rain Program requirements under Title IV of the Clean Air Act. A modified Life Cycle Analysis (LCA) is conducted on $\text{CO}_2\text{-eq}$ emission balances, where $\text{CO}_2\text{-eq}$ includes emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), related to $\text{CO}_2\text{-eq}$ through use of global warming potentials proscribed by the Intergovernmental Panel on Climate Change (IPCC). The modified life cycles of coal and switchgrass are compared to determine a truer picture of potential net emission reductions from implementation of a switchgrass co-firing scheme at OGS.

Table 1. Global Warming Potentials (GWP)

Pollutant	GWP relative to CO_2
CO_2	1
CH_4	21
N_2O	310

JUSTIFICATION OF A MODIFIED LIFE CYCLE ANALYSIS

Both coal and switchgrass must undergo several preparatory steps to become viable as boiler fuel for electric generation. Each step in the process leads to an energy expenditure, which in turn leads to emission of pollutants including the greenhouse gases. As a review of the modified life cycles of these fuels will indicate, a full life cycle calculation of energy expenditure and resulting pollutant emissions will become extremely complex. In the case of coal preparation, working backwards, combusted coal must be prepared at the facility for insertion into the boiler. This normally requires some level of grinding the coal to uniform size, pneumatic or mechanical transport of the coal from storage bin to boiler feed mechanism, pneumatic or mechanical transport of coal from truck or rail to storage bin, rail or truck transport from the mine to the facility, washing and preparation of the coal, and physical mining of the coal at the mine site. A full LCA would include the energy expended in each of these steps, but then goes further, to investigate the energy inputs into manufacturing the equipment utilized in the mining, transportation and preparation functions. While inclusion of these outer stages of the LCA may indeed capture more energy expenditure and emissions within the full life cycle, such an undertaking becomes rapidly complex and ultimately must depend upon simplifying assumptions, which increase the uncertainty of the resulting estimates. Thus, in order to simplify the overall analysis of the switchgrass project, and to avoid over-parameterization in an attempt to calculate ever-decreasing increments of life cycle impact, we are performing a modified LCA for this analysis. The stages of the analysis are described below and are outlined in tables 2 and 4. Though some parameterization still must occur, the modified LCA represents a limited approach to LCA whereby the

analysis focuses on only the first few layers of the life cycle, which are most readily quantified and present a lesser amount of uncertainty in energy expenditure and emission estimation. It is believed that such an analysis will capture a significant portion of the true life cycle emissions.

Description of the Switchgrass Life Cycle

We begin by examining a modified life cycle of greenhouse gas emissions from switchgrass cultivation and its use as a power plant fuel. The modified life cycle analysis is proposed in the belief that a calculation methodology relying upon only direct, point-of-use emission factors would fall short of capturing the larger benefit of utilizing a biomass crop for electric production. Yet completion of a full life cycle analysis is not desirable, from either an execution standpoint or for purposes of accuracy. Inclusion of the full life cycle analysis might lead to significant averaging and parameterization schemes that do not accurately reflect the greenhouse gas emission balances of the particular project being studied. Therefore, we have attempted to draw sensible boundaries around our analysis in an attempt to capture the majority of greenhouse gas emissions, while minimizing the need for averaging and parameterization. Point-of-use emission factors are utilized at each of the different levels of our analysis. Some life cycle-generated emission factors are also utilized to complete the picture of emissions from within our bounded system. The ultimate goal of the analysis is to represent the real life cycle balances of greenhouse gases within a reasonable and replicable framework, using a synthesis of best available emission calculation techniques.

Life Cycle Levels Defined

We have attempted to categorize the various levels of our analysis by using terminology to reflect the spatial and temporal characteristics of the emission-producing activity. It is also hoped that the terminology provides an instant indication of the importance and robustness of the emission estimate. We have largely confined the analysis to a two-level analysis, thus the terms primary and secondary are employed. In addition, the terms direct and indirect are specified to further describe the character of the emission.

- Primary, direct emissions are those which occur from the activities central to the switchgrass life cycle. This level includes emissions from the farming activities needed to produce the crop such as plowing of the soil or nitrous oxide emission from fertilizer application, or the energy expended during power plant on-site fuel preparation and combustion.
- Primary, indirect emissions are defined as those which are generated in support of primary direct activities. These primary indirect sources of emissions include the fuels combusted during performance of the primary activity. Thus emissions from fuels combusted in the agricultural machinery, or in transporting the fuel are classified as primary but indirect sources.
- Secondary emissions are defined as those which occur from processes that create a product for use within the primary level. The greenhouse gas emissions that arise from the production of a product, such as fertilizer or herbicide are considered secondary emissions. Emission of nitrous oxide from fertilizer production is considered a secondary direct emission. Emissions from the combustion of fuel sources to create the secondary product are secondary, indirect emissions.

A further life cycle analysis could be undertaken to examine the energy inputs that go into production and maintenance of basic equipment, such as the trucks transporting the fuel,

or the tractors working the fields. However, it is believed that pursuing the life cycle analysis further than the second level described above would greatly increase the amount of averaging and parameterization involved in producing those estimates.

Table 2. The Switchgrass Life Cycle

Process	Aspect Creating Emission	Pollutant
Primary Direct Emissions		
Plant growth	Carbon uptake	CO ₂
Fertilizer	Direct emissions from fertilizer	N ₂ O
Avoided Emissions- Impact of alternative land-use	Carbon uptake rate of alternative	CO ₂
Primary Indirect Emissions		
Soil preparation	Energy used	
CO ₂ ,CH ₄ ,N ₂ O		
Seeding	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Chemical application	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Fertilizer application	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Mechanical weed control	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Harvest	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Fuel preparation	Energy used to chip or shred	CO ₂ ,CH ₄ ,N ₂ O
Combustion	Fuel combustion	CO ₂ ,CH ₄ ,N ₂ O
Secondary Direct Emissions		
Transport to OGS	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Transport of chemicals to field	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Transport of combustion waste to landfill	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Secondary Indirect Emissions		
Fertilizer production	Energy used	CO ₂ ,CH ₄ ,N ₂ O
Herbicide production	Energy used	CO ₂ ,CH ₄ ,N ₂ O

Primary Emission Mechanisms

Soil preparation

During initial soil preparation for the first year of planting, the soil is disturbed. For conversion of corn or soybean acreage to switchgrass production tillage requirements indicate disking once or twice, harrow once, and culti-pack. A firm seed bed is needed for successful switchgrass seeding. Each trip over the field utilizes an 80 to 120 horsepower tractor. Seeding can also be accomplished in existing pasture or through no-till operations with use of herbicides for control of existing vegetation. Soil preparation for re-seeding, which is required in up to 25 percent of fields does not involve reopening of the soil.

Seeding

Recommended seeding rates of 5 pounds of live seed per acre are applied mixed with fertilizer using a 60 foot boom truck with flotation tires, or using drill or brillion seeder pulled by a 80 to 120 horsepower tractor. Re-seeding is required in up to 25 percent of fields using the same methods as in the establishment year.

Chemical application

During site preparation an initial application of atrazine is recommended at 2 pounds per acre. Application is accomplished using custom spray equipment "Row Gator" sprayer (Braster). During plant growth, an additional 2 pounds per acre of atrazine may be applied by Row Gator sprayer. For up to 25 percent of fields re-seeding is required with an additional 2 pounds of atrazine applied per acre.

Fertilizer application

During the establishment year fertilizer is applied during seeding. In subsequent years, if reseeding is not required, the fertilizer application is accomplished using a 60 foot boom truck on flotation tires.

Mechanical Weed Control

A sickle or rotary mower bush hog pulled by a 50 to 100 horsepower tractor is utilized in the establishment year, and then again in subsequent years for weed control.

Plant growth

During the first two years of establishment, yields are expected to be 2 tons dry matter per acre at the end of the second year. Current yields on establishment grounds have been 2 to 3 tons of harvestable dry mass per acre (Braster). These fields have not yet received the level of management expected for production fields, for which expected yields would be 4 tons harvestable dry matter per acre. Of the dry matter harvested, approximately 44 percent is carbon, per ultimate analysis. Thus if 4 tons of dry matter per acre are realized, this equates to 1.76 tons carbon per acre or 6.45 tons of CO₂ sequestered during crop growth.

Harvest

In the second establishment or first production year, yields of about 2 tons per acre have been realized. In out years the crop is expected to yield up to 4 tons per acre (Braster). The crop is mowed and conditioned, raked, and baled, each trip pulled by a 80 to 120 horsepower tractor. The bales are then staged at the side of the field using a 100 horsepower tractor with front end scoop or loader and stabber. Alternatively a tractor-pulled bale carrier wagon is employed for fields greater than 40 acres which would involve a 1/4 mile haul to roadside. Finally, a 100 horsepower tractor with front end scoop or loader is used to load the bales on a semi trailer for transport to OGS.

Transport to OGS

A typical load for a semi-trailer is expected to be 14 tons. Average distance traveled is assumed to be 50 miles (Braster).

Fuel preparation

Upon reaching the site, a 100 horsepower tractor with front-end scoop or loader pulls the bales from the trailer. Three to four lift trucks will then be required to feed the bales to the combustion system within the OGS facility (R.W. Beck). The fuel handling train at OGS, as proposed by designers R.W. Beck, include the following equipment for each of two 12.5 ton per hour (TPH) handling trains:

Table 3. Switchgrass Processing Equipment Energy Requirements

De-Baler	50 hp
Fluidizing Air Fan	40 hp
De-Stoner	25 hp
Vibrating Pan Feeder	25 hp
Materials Handling Blower (return from baghouse)	5 hp
Baghouse Blower	10 hp
Hammernill Shredder	300 hp
Main Materials Handling Blower	100 hp
Rotary Lobe compressor	125 hp
Rotary Solids Feeder	10 hp
Materials Handling Blower (return from baghouse)	30 hp
Total horsepower requirement for two trains (25 TPH)	1440 hp

Assumption: We will utilize the assumption that electric power for these motors will come directly from the OGS plant, minimizing line losses, and that the conversion efficiency of the plant is 67 percent. Thus it is assumed that a delivered kilowatt-hour at 3,413 Btu was created by input of nearly 5,100 Btu of coal.

Combustion

Combustion parameters for the switchgrass co-fired with coal will be determined through a stack test scheduled to occur in May of 2000. Ultimate analysis of the switchgrass is utilized to estimate emissions of carbon dioxide and sulfur dioxide from combustion. Nitrogen oxide, and nitrous oxide emissions will have to be determined from the stack testing. The level of N₂O emissions are of particular concern for overall CO₂-eq emission balances.

Avoided Emissions

Impact of alternative land-use on carbon storage

Land use is an important factor in determination of net CO₂-eq emissions. The emission of CO₂ from switchgrass combustion is offset by the annual uptake of carbon during plant growth. The conversion of annual row-crop agricultural land to perennial switchgrass production also has the potential to increase the amount of carbon retained in the soil storage reservoir. Studies are being conducted by Dr. Lee Burras of Iowa State University to quantify this impact on the southern Iowa soils involved in the Chariton Valley Biomass Project. As Dr. Burras' study results are not yet available, we have utilized soil carbon accumulation studies made by the Oak Ridge National Laboratory. Soil Conservation Service (now NRCS) studies indicate that perennial grasses add 1.1 Mg per hectare per year to the top 300 cm of Midwestern soils (McLaughlin, 1998). This value equates to 980 pounds of carbon per acre or 1.79 tons of carbon dioxide sequestered into the soil per acre. The studies indicate that perennial crops rapidly build carbon into the soil when introduced into carbon-depleted soils. It is hoped that the study of Dr. Burras will provide data related to a soil carbon accumulation in soils that moved from CRP into switchgrass production.

Secondary Emission Mechanisms

Fertilizer

Application of nitrogen fertilizer leads to the formation of nitrous oxide emissions from the soil. Typical fertilization rates for switchgrass is 30 pounds per acre for the

establishment year (Braster). During production years 50 to 100 pounds of nitrogen is applied per acre (Braster).

Transport of chemicals to field

Michael Wang of Argonne National Laboratory has provided quantification of emissions of greenhouse gases related to the transport of fertilizers for agricultural use. The figures are incorporated into the GREET Model which is a life cycle model designed to return life cycle emission values for comparison of various transportation fuels. The transportation of fertilizer from production to farm involves an interim stop at a bulk holding/mixing facility. Typical emission values used in the GREET model include:

Production site to Bulk Storage

$\text{CH}_4 = 0.000025 \text{ lb/lb fertilizer}$

$\text{CO}_2 = 0.030210 \text{ lb/lb}$

Bulk Storage to Mixing

$\text{CH}_4 = 0.000010 \text{ lb/lb}$

$\text{CO}_2 = 0.011040 \text{ lb/lb}$

Mixer to Farm

$\text{CH}_4 = 0.000020 \text{ lb/lb}$

$\text{CO}_2 = 0.022995 \text{ lb/lb}$

No appreciable quantities of nitrous oxide (N_2O) are emitted during the transportation process. The transport of herbicide is analogous to fertilizer transport with values duplicated per pound of herbicide.

Transport of Switchgrass Combustion Residue to Landfill

Unburned materials are collected and must be transported to off-site storage facilities. For switchgrass combustion, the waste stream is composed primarily of bottom-ash and captured fly-ash. For our computation of ash generation rates, it has been assumed that all of the ash identified in the ultimate analyses will be captured and removed as waste. The movement of this material results in the expenditure of energy in the form of fuel oil for the truck hauling the waste. Data are presented from the GREET model (Wang, 1997) and are coupled with fuel oil carbon dioxide emission values from USEPA.

Secondary Indirect Emission Mechanisms

Fertilizer production

The fertilizer production process involves the input of significant amounts of energy. The use of this energy leads to the release of greenhouse gas emissions. According to Michael Wang and the GREET model, CH_4 , N_2O and CO_2 are emitted during production of nitrogen fertilizers at the rates of:

$\text{CH}_4 = 0.0097 \text{ lb/lb fertilizer}$

$\text{CO}_2 = 3.7538 \text{ lb/lb}$

$\text{N}_2\text{O} = 0.0001 \text{ lb/lb}$

Herbicide production

The GREET model provides estimates of emissions from production of four major types of herbicide, Atrazine, Metolachlor, Acetochlor, and Cyanazine. Switchgrass production

utilizes atrazine in a pre and post-emergence application for weed control. The GREET model provides the following estimates of emissions from atrazine production.

CH₄ = 0.0302 lb/lb atrazine
 N₂O = 0.0024 lb/lb
 CO₂ = 18.9753 lb/lb

DESCRIPTION OF THE COAL LIFE CYCLE

The coal life cycle analysis is not a true life cycle analysis in that we do not attempt to account for the geological time frame of the coal life cycle. Rather, the coal life cycle is viewed somewhat analogous to the switchgrass life cycle, including the mining, preparatory stages, transport and combustion of the fuel. The time frame analyzed is thus similar temporally to the switchgrass life cycle.

Table 4. The Coal Life Cycle

Process	Aspect Creating Emission	
Primary Direct Emissions		
Coal mining and transport	Methane from exposed coal	CH4
Combustion	Fuel combustion	CO2,CH4,N2O
Primary Indirect Emissions		
Coal mining and refining	Energy used to clean/refine	CO2,CH4,N2O
Fuel preparation	Energy used to crush coal	CO2,CH4,N2O
Secondary Direct Emissions		
Transport mine to rail loading	Methane from exposed coal	CH4
Transport mine to rail loading	Energy used	CO2,CH4,N2O
Rail transport to powerplant	Energy used	CO2,CH4,N2O
Transport of combustion waste	Energy used	CO2,CH4,N2O

Primary Direct Emissions

Coal Mining - Methane Losses

Exposure of a coal seam to the atmosphere allows the escape of methane gas trapped within the porous structure of the coal. The emission of this potent greenhouse gas can become significant. In the Emission Inventory Improvement Program document, "Introduction to Estimating Greenhouse Gas Emissions," emission factors are provided to estimate the amount of methane lost from opening the coal seam to the atmosphere. The emission factors are specific to location of the coal mine, and the mining method. Coal burned at OGS is a western sub-bituminous coal that is typically surface-mined. Emission of methane is estimated to occur at the rate of 30.6 cubic feet per ton of coal mined.

Coal Transportation - Methane Losses

The USEPA methodology provides an estimation mechanism for methane lost from the coal as it is transported across the country. In the Emission Inventory Improvement Program document, "Introduction to Estimating Greenhouse Gas Emissions," emission factors are provided to estimate the amount of methane lost in this phase of coal production. During transport, the coal is estimated to emit 5.0 cubic feet per ton of coal.

Combustion

The combustion of coal, as with any fuel, releases several pollutants to the atmosphere. Of principal concern for this study are SO₂, NO_x and the greenhouse gases, CO₂, CH₄ and N₂O. USEPA, the Energy Information Administration, and IPCC provide emission factors for these pollutants. Sulfur emissions are calculated on a mass balance basis, with existing control equipment included.

CO₂ = 212.7 lbs/MMBtu (from EIA)
CH₄ = 0.0016 lbs/MMBtu (from EIIP document)
N₂O = 0.1474 lbs/MMBtu (from EIIP document)
NO_x = 21.7 lbs/ton (from USEPA, AP-42)
SO₂ = Sulfur = 0.33% by weight, thus uncontrolled SO₂ emissions are
 $0.33 / 100 * 2000 * 64 / 32 = 13.2 \text{ lb/ton coal}$

Primary Indirect Emissions

Coal Mining and Refining

It takes energy to mine and prepare coal for use as a combustion feedstock. Coal is dug from the earth, washed, crushed, screened and sorted prior to loading into transportation equipment. The GREET Model estimates the emissions from energy consumed in this process.

CH₄ = 1.237 g/MMBtu coal produced
N₂O = 0.138 g/MMBtu
CO₂ = 843 g/MMBtu

Fuel preparation

Coal must be handling and prepared at the facility for combustion in the boiler. Typical operations include crushing, conveying and screening. The coal is conveying to large storage bins for later conveyance into the boiler. Alliant Utility has been contacted for more precise information regarding the size and energy demands of the coal handling equipment at OGS. Until that information is received we will assume that the energy consume is equivalent to the switchgrass production train.

Secondary Direct Emissions

Coal Transportation = Energy Consumption

The transportation of coal from mine mouth to power plant involves several steps, including transport from the mine to the rail loading point, rail transport to the power plant, (or in some cases rail transport to coal piles outside of the plant boundary), and truck transportation of coal within the facility (or from a remote storage area to the facility). The GREET model estimates energy consumption and resulting emissions from the transportation activities.

CH₄ = 0.494 g/MMBtu coal
N₂O = 0.021 g/MMBtu
CO₂ = 566 g/MMBtu

Transport of Coal Combustion Residue to Landfill

Unburned materials are collected and must be transported to off-site storage facilities. For coal combustion, the waste stream is composed primarily of bottom-ash and captured fly-ash. For our computation of ash generation rates, it has been assumed that all of the ash identified in the ultimate analyses will be captured and removed as waste. The

movement of this material results in the expenditure of energy in the form of fuel oil for the truck hauling the waste. Data are presented from the GREET model (Wang) and are coupled with fuel oil carbon dioxide emission values from USEPA.

ASSUMPTIONS AND LIMITATIONS OF THE ANALYSIS

Switchgrass Assumptions and Limitations

In order to calculate the emission balance of switchgrass we must look at two different timeframes in development of the switchgrass crop. We will perform an emission calculation for the first two year period of establishment, and we will estimate emission balances for successive years of crop maintenance. Due to the two-year sequence required to reach full production, and the additional inputs associated with establishment, separation of these cases will allow judgement of the operation at maturity. The following assumptions are also used in the analysis.

- In all cases where a range of engine sizes are given we will use the higher rated engine.
- Soil Preparation - we will assume that the vast majority of switchgrass to be burned at OGS will be planted on lands requiring initial tilling for seeding.
- Seeding - we will assume that 25 percent of the land will require re-seeding with no-till, and addition of 2 pounds per acre atrazine during the re-seeding effort.
- Chemical application - we will assume that 2 pounds per acre atrazine will be used at seeding and annually thereafter.
- Fertilizer application - we will assume that 30 pounds of N fertilizer is applied at establishment and 100 pounds N per acre annually thereafter.
- Mechanical weed control - we will assume that mowing will be accomplished in each year.
- Plant growth - following the guidance provided by Chariton Valley RC&D we will assume that 2 tons per acre are harvestable following the second year of establishment, and 4 tons per acre are harvestable per year thereafter.
- Harvest - we will assume the use of a bale hauler for all switchgrass harvested since at process maturity, we would anticipate a majority of the crop would be grown in fields greater than 40 acres.
- Transport to OGS - 14 ton loads will be assumed. The average distance each load must travel will be 50 miles as estimated by Chariton Valley RC & D.
- Fuel preparation - we will assume that all switchgrass passes through each step of the preparation process, and that the preparation train is utilized for all projected 7992 operating hours (estimated operation time by R.W. Beck).
- Fertilizer - we assume that fertilization requirements will come from application of commercial fertilizers and will not be supplemented by manure fertilization.

- Transport of chemicals to field - in the absence of information regarding sources, production centers, and distances of transport, the GREET model assumptions will be utilized. The GREET model reflects a national average value for transportation energy requirements and emissions.
- Fertilizer and herbicide production - in the absence of specific data relating fertilizer and herbicide production to specific facilities, and the energy consumed at those facilities, the GREET model figures will be utilized.

Coal Assumptions and Limitations

- Methane lost from coal mining - the western sub-bituminous coal is understood to be surface mined from the Utah-Wyoming border areas. Emission factors employed for methane loss correspond to this assumption.
- Coal mining and refining - the GREET model is employed to generate estimated emissions from energy expended during mining and refining activities.
- Transport mine to OGS - the GREET model is employed to generate estimated emissions from mining and refining activities.
- Coal fuel preparation - in the absence of this plant-specific information it is assumed that energy requirements are identical to switchgrass processing energy requirements.

COMPARISON OF SWITCHGRASS AND COAL LIFE CYCLE EMISSIONS

Establishment Case

Table 5 presents the summary of modified life cycle emissions for switchgrass, considering the two-year establishment period. The switchgrass life cycle during the establishment phase indicates a net emission reduction of carbon dioxide equivalents, of 30.1 pounds per million Btu of switchgrass combusted. This value incorporates the initially higher inputs of energy required for seeding and re-seeding operations, as well as addition of herbicide and fertilizer for a two-year period prior to a first, reduced harvest of two tons dry matter per acre.

Table 5. CO₂-Equivalent Emissions During Establishment Period

Activity		CO ₂ -eq Emission lb/mmmbtu	CO ₂ -eq Credit lb/mmmbtu
Soil preparation			
	Disking	0.277	
	Harrowing	0.203	
	Culti-pack	0.162	
Seeding		0.180	
Chemical application		0.155	
Fertilizer application		0.155	
Mechanical weed control		0.398	
Harvest			
	Mowing	0.210	
	Baling	0.173	
	Stacking	0.314	
Plant growth			-230.476
Soil carbon			-64.167
Fertilizer		17.631	
Fertilizer production		18.518	
Fertilizer transport to bulk storage		0.143	
Fertilizer transport - storage to mizer		0.052	
Fertilizer transport - mixer to farm		0.109	
Herbicide production		2.908	
Herbicide transport to bulk storage		0.004	
Herbicide transport - storage to mizer		0.002	
Herbicide transport - mixer to farm		0.003	
SWG Transport to OGS		0.000	
SWG Fuel preparation		4.015	
SWG Combustion		218.952	
Waste Transport to Landfil		0.001	
SUM (lbs/mmmbtu)		264.566	-294.643
NET (lbs/mmmbtu)		-30.077	

Table 6 presents the findings of the modified life cycle analysis of coal, as combusted in the OGS boilers. The vast majority of coal-derived CO₂ emissions comes from combustion of the coal, which represents nearly instantaneous liberation of long-stored carbon. Mining and transport of the coal contribute only 8.5 pounds per million Btu of coal combusted.

Table 6. CO₂-Equivalent Emissions of The Coal Life Cycle

Activity	CO ₂ -eq Emission	CO ₂ -eq Credit
	lb/mmBtu	lb/mmBtu
Coal mining (methane lost)	1.624	
Post-mining/during transport (methane lost)	0.265	
Coal mining and refining (energy)	2.010	
Transport of coal to powerplant (energy)	1.285	
Coal Fuel preparation	3.357	
Coal Combustion	258.444	
Waste Transport to Landfill	0.001	
SUM (lbs/mmBtu)	266.986	0.000
NET (lbs/mmBtu)	266.986	

Mature Case

Table 7 presents the modified life cycle emission balances for switchgrass in the years beyond the second year, when the switchgrass crop is firmly established and harvestable yields are expected to be near four tons of dry matter per acre. With reduced inputs and higher yields, the net emission balance for carbon dioxide equivalent is a reduction of 56.4 pounds per million Btu combusted.

Table 7. CO₂ Emissions Balance from Established Switchgrass

Activity		CO ₂ -eq Emission lb/mmmbtu	CO ₂ -eq Credit lb/mmmbtu
Soil preparation			
	Disking	0.000	
	Harrowing	0.000	
	Culti-pack	0.000	
Seeding		0.000	
Chemical application		0.039	
Fertilizer application		0.039	
Mechanical weed control		0.100	
Harvest			
	Mowing	0.105	
	Baling	0.087	
	Stacking	0.157	
Plant growth			-230.476
Soil carbon			-64.167
Fertilizer		6.781	
Fertilizer production		7.122	
Fertilizer transport to bulk storage		0.055	
Fertilizer transport - storage to mixer		0.020	
Fertilizer transport - mixer to farm		0.042	
Herbicide production		0.727	
Herbicide transport to bulk storage		0.001	
Herbicide transport - storage to mixer		0.000	
Herbicide transport - mixer to farm		0.001	
SWG Transport to OGS		0.000	
SWG Fuel preparation		4.015	
SWG Combustion		218.952	
Waste Transport to Landfill		0.001	
SUM (lbs/mmmbtu)		238.244	-294.643
NET (lbs/mmmbtu)		-66.399	

Impact of Alternative Land Uses on Switchgrass Balance

The switchgrass is planted upon land which has the potential for another type of land use. Study of the Chariton Valley project area indicates that lands planted into switchgrass have been, and are predicted to be converted from either annual row-crop (corn-soybean) production, or from Conservation Reserve Program set-aside lands. The alternative use of the lands has significant impact upon the overall life cycle benefit of switchgrass production, because it will partially offset the benefit derived from switchgrass uptake of carbon. The two cases are described below.

CRP Set-Aside (Fallow)

Lands that are set aside under the CRP program are generally undisturbed, and natural biomass cover is allowed to grow. Some mowing may take place during the ten-year contract period. An analysis of the mature switchgrass case can lead to an estimate of the impact of this alternative land use. We will assume that the land is not actively managed, therefore there would be no soil preparation and no energy expended in mowing or harvesting the materials from CRP, no fertilizers or herbicides applied, no energy expended for fuel preparation and combustion, and no transport of combustion waste to the landfill. This means that CRP lands have virtually no emission of greenhouse gases to the atmosphere. The remaining impact of this alternative land use lies in its ability to store carbon into the soil. Reliable data are not available regarding the soil carbon storage potential of unmanaged prairie grasses. However, the ORNL research by Garten, et. al. does indicate that soil carbon below fallow plots is roughly equivalent to that found under switchgrass plots. Soil carbon inventories below fallow plots range between 87 percent and 107 percent of switchgrass plots studied. If we assume that soil carbon accumulation rates are equivalent for this alternative land use, the net switchgrass balance becomes an emission of 7.77 pounds CO₂-eq per MMBtu combusted.

Row-Crop Agriculture

Annual row-crop agriculture, using today's standard farming practices neither stores nor decreases the soil's organic content. Row-crop agricultural practices are also more energy intensive than those of switchgrass production, with more frequent trips through the field, and more application of nitrogen fertilizers. Thus a conservative estimate of the emission side of the ledger (table 7) would be that row-crop inputs are equal to switchgrass. If we add the nitrous oxide emissions created through the standard application of 125 pounds of nitrogen per acre (Hallberg, 1996), we add emissions of 200 pounds CO₂-eq per acre. Thus if switchgrass were planted in lieu of row-crop agriculture, the net emission benefit of replacing coal with switchgrass would be even greater than the value shown in table 7, at 70.7 pounds CO₂-eq per MMBtu combusted.

Table 8. Summary of Switchgrass Greenhouse Gas Emission Balances With Alternative Land Use Considerations (lbs CO₂-eq/MMBtu)

	Establishment Case	Mature Case
No Alternative Land Use	-30.1	-56.4
Conversion of CRP to SWG	+33.1	+7.8
Conversion of Row-Crop to SWG	-44.4	-70.7

Next we must also consider the amount of coal-generated emission that is displaced by the combustion of five percent switchgrass.

Table 9. Summary of Switchgrass Greenhouse Gas Emission Balances With Alternative Land Use Considerations and Coal Displacement (lbs CO₂-eq/MMBtu)

	Establishment Case	Mature Case
No Alternative Land Use	-297.1	-323.4
Conversion of CRP to SWG	-233.9	-259.2
Conversion of Row-Crop to SWG	-311.4	-337.7

Thus, when considering the modified life cycle impact of switchgrass combustion upon greenhouse gas emissions from coal fired electric generation, the amount of benefit is affected by the alternative land use that switchgrass is replacing. If switchgrass is planted to replace CRP land use, the benefit of switchgrass is slightly lessened than when row crop agriculture is replaced by switchgrass production. Overall, regardless of the alternative land use, switchgrass substitution for coal appears to provide a significant net benefit in reducing greenhouse gas emissions.

Annual Impacts on Emission Balances

Examination of the annual emission balances of switchgrass provides an estimate of the potential reduction of carbon, sulfur and nitrogen emissions that occur as a result of supplanting coal-fired generation with switchgrass. Often, electric generating facilities do not operate up to their full potential, as defined under the Clean Air Act. Therefore investigation of actual coal consumption in 1996 is presented. In 1996, the Ottumwa Generating Station combusted 1.25 million tons of coal, yielding 2,708 tons of sulfur dioxide, and 8,956 tons of nitrogen oxides (Ney and Schnoor, 1998).

Carbon Dioxide

Application of the modified life cycle emission rates for coal determined by this analysis, 266.986 pounds per million Btu, and the heat content reported for the coal, 8,373 Btu per pound, results in an estimated release of 2.79 million tons of CO₂-eq in 1996. If five percent of the annual coal combustion, on a heat content basis, were replaced with switchgrass, reductions in carbon dioxide emissions are estimated in table 10.

Table 10. Change in Greenhouse Gas Emissions by Combusting 5% SWG with Coal (tons CO₂-eq/year)

	Establishment Case	Mature Case
No Alternative Land Use	-155,469	-169,232
Conversion of CRP to SWG	-122,395	-135,635
Conversion of Row-Crop to SWG	-162,952	-176,715

Sulfur Dioxide

At 0.3 percent sulfur, the Cordero Mine coal burned at OGS is a low sulfur coal. At 1.25 million tons in 1996, a mass balance estimate of uncontrolled sulfur dioxide emissions is equal to 7,500 tons (assuming full oxidation of fuel-bound sulfur to SO₂). With controlled

emissions reported as 2,708 tons SO₂ for 1996 (Ney and Schnoor, 1998) controls at the facility are estimated to remove approximately 64 percent of available sulfur. Thus, replacement of five percent coal (heat content basis) with 74,759 tons of switchgrass at 0.04 percent sulfur (ultimate analysis), yields a reduction of 315.2 tons of SO₂, uncontrolled, or 113.7 tons of controlled SO₂ emission. This value is independent of the establishment or mature case analyses.

Nitrogen Oxides

Determination of emission increases or reductions of nitrogen oxides will be made possible by measurement during the upcoming trial burns of the switchgrass/coal mixture. At this time, insufficient data exists to make prediction of the magnitude, or direction, of nitrogen oxide emissions from switchgrass. As a crude estimate, it is thought that nitrogen in the fuel is approximately one percent of dry matter, and it will be 50% converted to nitrogen oxides emitted from the stack. If 10% of the N-emissions are N₂O, the reduction in GHG emissions would be approximately 18 lbs CO₂-eq/MMBTU (less than 10% of the benefits). NO_x emissions would further reduce the net benefit of switchgrass substitution for coal.

Analysis of Potential Economic Impacts

Emissions of sulfur dioxide, nitrogen oxides and carbon dioxide have become tradable commodities in recent years. Sulfur dioxide emissions have been traded under the auspices of Title IV of the Clean Air Act Amendments of 1990. Current SO₂ allowance values are \$217 (Cantor-Fitzgerald website, 8/1/99). Nitrogen oxide emissions are traded in some areas of the United States for regional tropospheric ozone control strategies. NO_x values range widely, from \$1,000, to as much as \$5,000 dollars per ton (Cantor-Fitzgerald website). However, the state of Iowa is not a participant in NO_x emission trading at this time so no value is assigned in this study to potential changes in NO_x emissions from switchgrass co-firing. Carbon dioxide emissions are currently being traded upon speculation that a domestic or international CO₂ emission trading program will become reality in the near future, under the United Nations Framework Convention on Climate Change (UNFCCC) and the subsequent international agreement, the Kyoto Protocol. Current values for CO₂-eq emission reductions are variable, based upon the type of reduction and rigidity of proof, however, reductions brought about by fuel-switching or alternative fuel consumption are currently bringing as much as \$2.25 per ton CO₂-eq (Cantor-Fitzgerald website).

Placing an economic value on emission reductions through pollutant trading programs provides additional economic incentive to foster development of alternative fuel industries, such as the switchgrass co-firing proposed by Chariton Valley RC & D. Using the actual 1996 OGS data presented above, and the assumption that the goal of five percent co-firing can be reached, emission credits totaling as much as \$420,000 dollars can be generated annually by the project. This value is derived from reduction of 113.7 tons per year SO₂ at \$217 per ton, and reduction of up to 176,715 tons of CO₂-eq at \$2.25 per ton.

SUMMARY

Analysis of emissions generated during the production life cycles of coal and switchgrass, indicates that switchgrass can provide significantly lower life cycle emissions of carbon dioxide equivalent (greenhouse gases) than coal when combusted for electric generation, especially if the switchgrass crop is grown in lieu of row-crop agriculture. In this study of the Chariton Valley Biomass Project, and combustion at the Ottumwa Generating Station, reduction of nearly 177,000 tons of CO₂-eq can be accomplished per year, if full five percent of coal is replaced by switchgrass (on a heating value basis). While the reductions in greenhouse gas emissions are less when CRP set-aside lands are converted to switchgrass, the savings are still substantial, at 122,000 tons CO₂-eq per year. Emissions of sulfur dioxide can also be reduced, as confirmed by use of a mass balance analysis technique for emissions from the point of combustion. The emission-reducing potential of switchgrass as a coal substitute appears to be substantial. Placing an economic value on pollutant emission reductions through emission trading programs will lend an additional financial boost to make switchgrass a more economically competitive fuel for electric generation.

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APPENDIX A
CALCULATIONS FOR ESTABLISHMENT CASE

MODIFIED LIFE CYCLE ANALYSIS - EMISSION BALANCE CALCULATIONS FOR ESTABLISHMENT PERIOD

Table A-1. Greenhouse Gas Emissions from Agricultural Activities.

	passes per acre	gallons per acre per pass	energy content MJ/gal	CH4 lb/MJ	CO2-eq lb/acre	N2O lb/MJ	CO2-eq lb/acre	CO2 lb/acre	Total CO2-eq lb/acre	SWG harvest ton/acre	SWG Energy Btu/lb	Total CO2-eq lb/mmmbtu
Soil preparation												
Disking	1	0.75	147560	0.000024	2.684	0.000004	0.488	4.574	7.746	2	7000	0.277
Harrowing	1	0.55	147560	0.000024	1.968	0.000004	0.358	3.354	5.680	2	7000	0.203
Culti-pack	1	0.44	147560	0.000024	1.575	0.000004	0.286	2.683	4.544	2	7000	0.162
Seeding	1.25	0.39	147560	0.000024	1.745	0.000004	0.317	2.973	5.035	2	7000	0.180
Chemical application	2	0.21	147560	0.000024	1.503	0.000004	0.273	2.561	4.338	2	7000	0.155
Fertilizer application	2	0.21	147560	0.000024	1.503	0.000004	0.273	2.561	4.338	2	7000	0.155
Mechanical weed control	2	0.54	147560	0.000024	3.865	0.000004	0.703	6.586	11.154	2	7000	0.398
Harvest												
Mowing	1	0.57	147560	0.000024	2.040	0.000004	0.371	3.476	5.887	2	7000	0.210
Baling	1	0.47	147560	0.000024	1.682	0.000004	0.306	2.866	4.854	2	7000	0.173
Stacking	1	0.85	147560	0.000024	3.042	0.000004	0.553	5.184	8.778	2	7000	0.314

Energy use statistics from the University of Nebraska - NebGuide.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table A-2. Carbon Reduction Credit for Switchgrass Growth and Soil Carbon Accumulation

	no acres	harvestable dry matter ton	carbon content %	Net carbon ton/acre	Net CO2 ton/acre	soil carbon accumulation lbs/acre	CO2 for accumulation ton/acre	CO2 credit lbs/mmbtu
Plant growth	1	2	44	0.88	3.227			230.476
Soil carbon	1					490	0.8983	64.167

Plant carbon data from ultimate analysis on SWG.

Soil carbon data from ORNL - awaiting field study results.

Table A-3. Emissions of Nitrous Oxide from Fertilizer Application

	acres	lbs N/acre	ton SWG	fraction N volatile	fraction N non-volatile	lbs N ₂ O/ lb volatile	lbs N ₂ O/lb non-volatile	Total N ₂ O/acre (lbs N ₂ O)	CO ₂ -eq lbs/acre	CO ₂ -eq lbs/ton SWG	Total CO ₂ -eq lbs/MMBtu
Fertilizer	1	130	2	0.1	0.9	0.01	0.0125	1.5925	493.675	246.8375	17.63125

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table A-4. Emissions from the Production and Transport of Fertilizer and Herbicide

	Pounds fert/herb applied/ac	tons SWG per acre	Pounds fert/herb ton SWG	CH4 lb/lb f/h	CO2-eq lb/lb	N2O lb/lb f/h	CO2-eq lb/lb	CO2 lb/lb f/h	Total CO2-eq lb/lb f/h	CO2-eq lbs/ton SWG	Total CO2-eq lbs/MMBtu
Fertilizer production	130	2	65	0.0097	0.2037	0.0001	0.031	3.754	3.989	259.253	18.5180
Fertilizer transport to bulk storage	130	2	65	0.0000	0.0005	0	0	0.030	0.031	1.998	0.1427
Fertilizer transport - storage to mixer	130	2	65	0.0000	0.0002	0	0	0.011	0.011	0.731	0.0522
Fertilizer transport - mixer to farm	130	2	65	0.0000	0.0004	0	0	0.023	0.023	1.522	0.1087
Herbicide production	4	2	2	0.0302	0.6342	0.0024	0.744	18.975	20.354	40.707	2.9076
Herbicide transport to bulk storage	4	2	2	0.0000	0.0005	0	0	0.030	0.031	0.061	0.0044
Herbicide transport - storage to mixer	4	2	2	0.0000	0.0002	0	0	0.011	0.011	0.023	0.0016
Herbicide transport - mixer to farm	4	2	2	0.0000	0.0004	0	0	0.023	0.023	0.047	0.0033

Emission estimates made using the GREET Transportation Fuel Cycle Analysis Model, Argonne National Laboratory.

Table A-5. Emissions from the Transport of Switchgrass to OGS

	fuel tons	energy content btu/lb	energy content mmbtu/ton	transport fuel use Btu/ton/mi	average distance miles	CH4 lb/mmbtu	CO2-eq lb/mmbtu	N2O lb/mmbtu	CO2-eq lb/mmbtu	CO2 lb/mmbtu	Total CO2-eq lb/mmbtu oil	Total CO2-eq lb/mmbtu SWG
Transport of SWG to OGS	1	7000	14	1,056.240	50.000		0.0000		0.0000	159.720	159.720	0.00030

Assumed fuel for hauler is distillate oil.

Transport fuel use taken from Wang, et al., 1997.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table A-6. Emissions from Energy Spent in On-Site Preparation of Switchgrass for Combustion

	Processing energy				input required mmbtu/ ton swg	Emission rates assuming coal combustion for generation						Total CO2-eq per ton swg lb/ton	Total CO2-eq per mmbtu swg lb/mmbtu
	energy required total hp	energy required hp/ton	energy required mmbtu/ton	Plant eff %		CH4 lb/ mmbtu	CO2-eq lb/ mmbtu	N2O lb/ mmbtu	CO2-eq lb/ mmbtu	CO2 lb/ mmbtu	Total CO2-eq lb/mmbtu		
SWG Fuel preparation	1440	57.6	0.146	67	0.218	0.0016	0.0336	0.1474	45.694	212.7	258.428	56.214	4.015

Emission factors computed for coal combustion calculation, from EIIP Guidance document.

Energy requirement from R.W. Beck final design.

OGS conversion efficiency assumed from experience, neglecting line losses.

Table A-7. Emissions from the Combustion of Switchgrass

	tons	Energy content btu/lb	Energy content mmbtu/ton	Carbon content %	Fraction C oxidized %	CH4 lb/ton	CO2-eq lb/mmbtu	N2O lb/ton	CO2-eq lb/mmbtu	CO2 lb/ton	CO2 lb/mmbtu	Total CO2-eq lb/mmbtu	Total CO2-eq lbs/ton
SWG Combustion	1	7000	14	44	95		0		0	3065.33333	218.952381	218.952381	3065.333

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Note: CH4 and N2O emission factors are not published. Test data will supply these values.

Table A-8. Emissions from the Combustion of Coal

	tons	Energy content btu/lb	Energy content mmbtu/ton	Energy content tJ/ton	CH4 kg/tJ	CH4 lb/MMBtu	CO2-eq lb/MMBtu	N2O kg/tJ	N2O lb/MMBtu	CO2-eq lb/MMBtu	CO2 lb/MMBtu	Total CO2-eq lb/MMBtu	Total CO2-eq lbs/ton
Coal Combustion	1	8373	16.746	0.017668	0.7	0.0016	0.034	1.6	0.1474	45.709	212.7	258.444	4327.896

Emission estimates made using the state-specific CO2 emission factors from the Energy Information Administration.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table A-9. Methane Emissions from Coal Degassing During Mining and Transport

	tons	emission factor cf/ton	Energy content btu/lb	Energy content mmbtu/ton	methane lb/cf	emission factor lb/ton	CH4 lb/MMBtu	CO2-eq lb/MMBtu
Coal mining (methane lost)	1	30.6	8373	16.746	0.0423	1.295	0.077	1.624
Post-mining/during transport (methane lost)	1	5	8373	16.746	0.0423	0.212	0.013	0.265

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table A-10. Emissions from Energy Spent During Coal Mining and Transport

	coal tons	energy content btu/lb	energy content mmbtu/ton	CH4 lb/mmbtu	CO2-eq lb/mmbtu	N2O lb/mmbtu	CO2-eq lb/mmbtu	CO2 lb/mmbtu	Total CO2-eq lb/mmbtu
Coal mining and refining (energy)	1	8373	16.746	0.0027	0.0573	0.00030	0.0943	1.859	2.010
Transport of coal to powerplant (energy)	1	8373	16.746	0.0011	0.0229	0.00005	0.0144	1.248	1.285

Emission estimates made using the GREET Transportation Fuel Cycle Analysis Model, Argonne National Laboratory.

Table A-11. Emissions from Energy Spent Transporting Waste

	fuel tons	energy content btu/lb	energy content mmbtu/ton	fraction ash %	ash generated lb/MMBtu	transport fuel use Btu/ton/mi	CH4 lb/ mmbtu	CO2-eq lb/ mmbtu	N2O lb/ mmbtu	CO2-eq lb/ mmbtu	CO2 lb/ mmbtu	Total CO2-eq lb/mmbtu oil	Total CO2-eq lb/mmbtu SWG or coal
Transport of SWG Waste	1	7000	14	6.51	9.300	1,056.240		0.0000		0.0000	159.720	159.720	0.001
Transport of Coal Waste	1	8373	16.746	5.83	6.963	1,056.240		0.0000		0.0000	159.720	159.720	0.001

Assumed fuel for hauler is distillate oil.

Transport fuel use taken from Wang, et al., 1997.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table A-12. Emissions from Energy Spent in On-Site Preparation of Coal for Combustion

	Processing energy				input required mmbtu per ton coal	Emission rates assuming coal combustion for generation						Total CO2-eq per ton coal lb/ton	Total CO2-eq per mmbtu coal lb/mmbtu
	energy required total hp	energy required hp/ton	energy required mmbtu/ton	Plant eff %		CH4 lb/ mmbtu	CO2-eq lb/ mmbtu	N2O lb/ mmbtu	CO2-eq lb/ mmbtu	CO2 lb/ mmbtu	Total CO2-eq lb/mmbtu		
Coal Fuel preparation	1440	57.6	0.146	67	0.218	0.0016	0.0336	0.1474	45.694	212.7	258.428	56.214	3.357

Emission factors computed for coal combustion calculation, from EHIP Guidance document.

Energy requirement from R.W. Beck final design.

OGS conversion efficiency assumed from experience, neglecting line losses.

APPENDIX B
CALCULATIONS FOR MATURE CASE

MODIFIED LIFE CYCLE ANALYSIS - EMISSION BALANCE CALCULATIONS FOR MATURE SWITCHGRASS

Table B-1. Greenhouse Gas Emissions from Agricultural Activities.

	passes per acre	gallons per acre per pass	energy content MJ/gal	CH4 lb/MJ	CO2-eq lb/acre	N2O lb/MJ	CO2-eq lb/acre	CO2 lb/acre	Total CO2-eq lb/acre	SWG harvest ton/acre	SWG Energy Btu/lb	Total CO2-eq lb/mmmbtu
Soil preparation												
Disking	0	0.75	147560	0.000024	0.000	0.000004	0.000	0.000	0.000	4	7000	0.000
Harrowing	0	0.55	147560	0.000024	0.000	0.000004	0.000	0.000	0.000	4	7000	0.000
Culti-pack	0	0.44	147560	0.000024	0.000	0.000004	0.000	0.000	0.000	4	7000	0.000
Seeding	0	0.39	147560	0.000024	0.000	0.000004	0.000	0.000	0.000	4	7000	0.000
Chemical application	1	0.21	147560	0.000024	0.751	0.000004	0.137	1.281	2.169	4	7000	0.039
Fertilizer application	1	0.21	147560	0.000024	0.751	0.000004	0.137	1.281	2.169	4	7000	0.039
Mechanical weed control	1	0.54	147560	0.000024	1.932	0.000004	0.351	3.293	5.577	4	7000	0.100
Harvest												
Mowing	1	0.57	147560	0.000024	2.040	0.000004	0.371	3.476	5.887	4	7000	0.105
Baling	1	0.47	147560	0.000024	1.682	0.000004	0.306	2.866	4.854	4	7000	0.087
Stacking	1	0.85	147560	0.000024	3.042	0.000004	0.553	5.184	8.778	4	7000	0.157

Energy use statistics from the University of Nebraska - NebGuide.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table B-2. Carbon Reduction Credit for Switchgrass Growth and Soil Carbon Accumulation

	no acres	harvestable dry matter ton	carbon content %	Net carbon ton/acre	Net CO2 ton/acre	soil carbon accumulation lbs/acre	CO2 for accumulation ton/acre	CO2 credit lbs/mmbtu
Plant growth	1	4	44	1.76	6.453			230.476
Soil carbon	1					980	1.7967	64.167

Plant carbon data from ultimate analysis on SWG.

Soil carbon data from ORNL - awaiting field study results.

Table B-3. Emissions of Nitrous Oxide from Fertilizer Application

	acres	lbs N/acre	ton SWG	fraction N volatile	fraction N non-volatile	lbs N ₂ O/ lb volatile	lbs N ₂ O/lb non-volatile	Total N ₂ O/acre (lbs N ₂ O)	CO ₂ -eq lbs/acre	CO ₂ -eq lbs/ton SWG	Total CO ₂ -eq lbs/MMBtu
Fertilizer	1	100	4	0.1	0.9	0.01	0.0125	1.225	379.75	94.9375	6.78125

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table B-4. Emissions from the Production and Transport of Fertilizer and Herbicide

	Pounds fert/herb applied/ac	tons SWG per acre	Pounds fert/herb ton SWG	CH4 lb/lb f/h	CO2-eq lb/lb	N2O lb/lb f/h	CO2-eq lb/lb	CO2 lb/lb f/h	Total CO2-eq lb/lb f/h	CO2-eq lbs/ton SWG	Total CO2-eq lbs/MMBtu
Fertilizer production	100	4	25	0.0097	0.2037	0.0001	0.031	3.754	3.989	99.713	7.1223
Fertilizer transport to bulk storage	100	4	25	0.0000	0.0005	0	0	0.030	0.031	0.768	0.0549
Fertilizer transport - storage to mixer	100	4	25	0.0000	0.0002	0	0	0.011	0.011	0.281	0.0201
Fertilizer transport - mixer to farm	100	4	25	0.0000	0.0004	0	0	0.023	0.023	0.585	0.0418
Herbicide production	2	4	0.5	0.0302	0.6342	0.0024	0.744	18.975	20.354	10.177	0.7269
Herbicide transport to bulk storage	2	4	0.5	0.0000	0.0005	0	0	0.030	0.031	0.015	0.0011
Herbicide transport - storage to mixer	2	4	0.5	0.0000	0.0002	0	0	0.011	0.011	0.006	0.0004
Herbicide transport - mixer to farm	2	4	0.5	0.0000	0.0004	0	0	0.023	0.023	0.012	0.0008

Emission estimates made using the GREET Transportation Fuel Cycle Analysis Model, Argonne National Laboratory.

Table B-5. Emissions from the Transport of Switchgrass to OGS

	fuel tons	energy content btu/lb	energy content mmbtu/ton	transport fuel use Btu/ton/mi	average distance miles	CH4 lb/mmbtu	CO2-eq lb/mmbtu	N2O lb/mmbtu	CO2-eq lb/mmbtu	CO2 lb/mmbtu	Total CO2-eq lb/mmbtu oil	Total CO2-eq lb/mmbtu SWG
Transport of SWG to OGS	1	7000	14	1,056.240	50.000		0.0000		0.0000	159.720	159.720	0.00030

Assumed fuel for hauler is distillate oil.

Transport fuel use taken from Wang, et al., 1997.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table B-6. Emissions from Energy Spent in On-Site Preparation of Switchgrass for Combustion

	Processing energy				Input required mmbtu per ton swg	Emission rates assuming coal combustion for generation						Total CO2-eq per ton swg lb/ton	Total CO2-eq per mmbtu swg lb/mmbtu
	energy required total hp	energy required hp/ton	energy required mmbtu/ton	Plant eff %		CH4 lb/ mmbtu	CO2-eq lb/ mmbtu	N2O lb/ mmbtu	CO2-eq lb/ mmbtu	CO2 lb/ mmbtu	Total CO2-eq lb/mmbtu		
SWG Fuel preparation	1440	57.6	0.146	67	0.218	0.0016	0.0336	0.1474	45.694	212.7	258.428	56.214	4.015

Emission factors computed for coal combustion calculation, from EIIP Guidance document.

Energy requirement from R.W. Beck final design.

OGS conversion efficiency assumed from experience, neglecting line losses.

Table B-7. Emissions from the Combustion of Switchgrass

	tons	Energy content btu/lb	Energy content mmbtu/ton	Carbon content %	Fraction C oxidized %	CH4 lb/ton	CO2-eq lb/mmbtu	N2O lb/ton	CO2-eq lb/mmbtu	CO2 lb/ton	CO2 lb/mmbtu	Total CO2-eq lb/mmbtu	Total CO2-eq lbs/ton
SWG Combustion	1	7000	14	44	95		0		0	3065.33333	218.952381	218.952381	3065.333

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Note: CH4 and N2O emission factors are not published. Test data will supply these values.

Table B-8. Emissions from the Combustion of Coal

	tons	Energy content btu/lb	Energy content mmbtu/ton	Energy content tJ/ton	CH4 kg/tJ	CH4 lb/MMBtu	CO2-eq lb/MMBtu	N2O kg/tJ	N2O lb/MMBtu	CO2-eq lb/MMBtu	CO2 lb/MMBtu	Total CO2-eq lb/MMBtu	Total CO2-eq lbs/ton
Coal Combustion	1	8373	16.746	0.017668	0.7	0.0016	0.034	1.6	0.1474	45.709	212.7	258.444	4327.896

Emission estimates made using the state-specific CO2 emission factors from the Energy Information Administration.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table B-9. Methane Emissions from Coal Degassing During Mining and Transport

	tons	emission factor cf/ton	Energy content btu/lb	Energy content mmbtu/ton	methane lb/cf	emission factor lb/ton	CH4 lb/MMBtu	CO2-eq lb/MMBtu
Coal mining (methane lost)	1	30.6	8373	16.746	0.0423	1.295	0.077	1.624
Post-mining/during transport (methane lost)	1	5	8373	16.746	0.0423	0.212	0.013	0.265

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table B-10. Emissions from Energy Spent During Coal Mining and Transport

	coal tons	energy content btu/lb	energy content mmbtu/ton	CH4 lb/mmbtu	CO2-eq lb/mmbtu	N2O lb/mmbtu	CO2-eq lb/mmbtu	CO2 lb/mmbtu	Total CO2-eq lb/mmbtu
Coal mining and refining (energy)	1	8373	16.746	0.0027	0.0573	0.00030	0.0943	1.859	2.010
Transport of coal to powerplant (energy)	1	8373	16.746	0.0011	0.0229	0.00005	0.0144	1.248	1.285

Emission estimates made using the GREET Transportation Fuel Cycle Analysis Model, Argonne National Laboratory.

Table B-11. Emissions from Energy Spent Transporting Waste

	fuel tons	energy content btu/lb	energy content mmbtu/ton	fraction ash %	ash generated lb/MMBtu	transport fuel use Btu/ton/ml	CH4 lb/ mmbtu	CO2-eq lb/ mmbtu	N2O lb/ mmbtu	CO2-eq lb/ mmbtu	CO2 lb/ mmbtu	Total CO2-eq lb/mmbtu oil	Total CO2-eq lb/mmbtu SWG or coal
Transport of SWG Waste	1	7000	14	6.51	9.300	1,056.240		0.0000		0.0000	159.720	159.720	0.001
Transport of Coal Waste	1	8373	16.746	5.83	6.963	1,056.240		0.0000		0.0000	159.720	159.720	0.001

Assumed fuel for hauler is distillate oil.

Transport fuel use taken from Wang, et al., 1997.

Emission estimates made using the "Introduction to Estimating Greenhouse Gas Emissions" Draft, December 1998. USEPA Emission Inventory Improvement Program.

Table B-12. Emissions from Energy Spent in On-Site Preparation of Coal for Combustion

	Processing energy				input required mmbtu per ton coal	Emission rates assuming coal combustion for generation						Total CO2-eq per ton coal lb/ton	Total CO2-eq per mmbtu coal lb/mmbtu
	energy required total hp	energy required hp/ton	energy required mmbtu/ton	Plant eff %		CH4 lb/ mmbtu	CO2-eq lb/ mmbtu	N2O lb/ mmbtu	CO2-eq lb/ mmbtu	CO2 lb/ mmbtu	Total CO2-eq lb/mmbtu		
Coal Fuel preparation	1440	57.6	0.146	67	0.218	0.0016	0.0336	0.1474	45.694	212.7	258.428	56.214	3.357

Emission factors computed for coal combustion calculation, from EIIP Guidance document.

Energy requirement from R.W. Beck final design.

OGS conversion efficiency assumed from experience, neglecting line losses.

Soil Carbon Farming in the Chariton Valley, Iowa
Landscape Scale Changes in Soil Organic Carbon and Quality

Project Scope of Work – version 1.1

Lee Burras & Julie McLaughlin
Iowa State University
December 29, 1999

Introduction

Numerous farming practices conserve or even “build” soil organic carbon (SOC). Likewise, numerous ones degrade and/or consume soil organic matter. No-till is a commonly cited practice that can increase SOC content, at least relative to conventional tillage. For example, Havlin et al. (1990) found organic carbon content of the surface 2.5 cm of soil increased by as much as 49% after 12 years of no-till with sorghum-soybean rotation in eastern Kansas. Other studies that found increases in SOC content and/or carbon forms due to no- and/or other conservation-tillage practices include Lamb et al, 1985; Bauer and Black, 1981; Blevins et al., 1983; Hussain et al., 1999; and Six et al., 1999.

Use of forages in rotation with row-crop is another practice that can increase soil organic carbon contents – again, at least relative to continuous row crop. For example, Patton (1999) found the SOC content of the upper 50 cm increased from 5.3 kg/m² to 7.4 kg/m² when she compared soils collected on Minnesota Amish and conventional farms, respectively. These differences developed within 15 years following introduction of long-term rotations on fields formerly extensively row-cropped. These results indicate a 40% relative increase of SOC content over 15 years, or a mean annual increase of 2.6%, which reasonably compares with Havlin et al.’s (1990) mean annual increase of 4.1%. Perhaps more importantly, Patton’s (1999) data show SOC increases occurred to a significantly greater depth than Havlin et al. (1990), i.e., throughout 50 cm versus the surface 2.5 cm. This finding is thought to be especially important as management schemes are designed to promote stable sequestered soil carbon because it is speculated that depth of organic carbon storage in soil will be proportional to its long-term stability.

The two preceding paragraphs discuss soil organic carbon contents in terms of cropland management. Yet only about 40% of the six counties included in Iowa’s portion of the Chariton River Valley are typically devoted to cropland although about 90% is considered farmland (see pages 28 and 30 of Miller, 1999). Other land uses include CRP, pasture, woodlots, and farmyards with pasture and woodlots being thought to comprise about one-half of the total Chariton Valley. Thus, to fully understand the soil carbon balance of the Chariton Valley one must take into account soil dynamics in both cropped and noncropped systems.

Generally, less SOC data is available under noncropped land uses in Iowa although it is commonly speculated that a well managed woodlot or intensively grazed pasture will have more total SOC than for any other land use. Perhaps more importantly, even less data is available on the impact of converting fields away from SOC building practices – i.e., data is available to predict SOC increases due to a farmer switching from conventional to no tillage; however, very little data is available on what occurs to SOC if a farmer who no tilled for 10 years then switched back to moldboard plowing for two years.

Finally, it is important to realize natural soil variability resulting from geomorphic and pedological factors tremendously affects both the natural stable soil organic carbon content as well as the effects of human management on soil carbon contents. This is illustrated by returning to Patton's (1999) study comparing soils managed under Amish and conventional systems. As reported above, Patton (1999) did find the soils in Amish fields to have more soil organic carbon – at least in Minnesota. The same experiment in Ohio resulted in no significant differences when soil carbon contents were compared between Amish and conventional fields. Likewise, Havlin et al. (1990) did not find consistent increases in SOC contents with reduced tillage. Needleman et al. (1999) go further and conclude that no till can result in increased surface SOC yet due to stratification there may be no net increase in a profile SOC content. In other words, the literature is replete with examples that show there is considerable variability in soil carbon dynamics, even in small plots. It is expected this variability will be even greater when one considers whole fields that extend across rolling landscapes. Thus any study that does not consider the whole range of land uses and soils of a given watershed will likely provide results that are limited in the spatial and temporal scale to which they can be extrapolated.

Objectives and Approach

The two objectives of this proposed project are:

- (1) Quantify SOC distribution across landscapes resulting from the long-term farm adoption of non-SOC building practices in the Chariton Valley, and,
- (2) Quantify soil quality distribution across landscapes and land uses in the Chariton Valley.

These objectives build on the existing project "Spatial and temporal dynamics of carbon sequestration in the Chariton Valley, Iowa" by expanding the number and type of sites wherein we quantify SOC distribution across landscapes. With the first objective we seek to extend to applicability of our ongoing project via inclusion of landscape-scale SOC dynamics resulting from adoption of non-SOC building farming practices. With the second objective we seek to better analyze the impact on soil quality, as evidenced by erosional channels and aggregate stability, of various land use practices currently being promoted as carbon building.

The approach will focus on three new types of sites. The first will be former old fields of well-managed switchgrass that have been converted into row crops. The second will be "old" row cropped fields representing a suite of tillage practices. The third set of sites will be selected to quantify SOC variability due to various pasture and woodlot management schemes (e.g., rotational grazing versus unmanaged grazing).

Our proposed field design remains a cluster-based transect sampling scheme meant to capture the soil variability across representative landscapes and land uses of the Chariton Valley. A "cluster" is defined as a group of fields in proximity to one another that share landscape features but differ in terms of land use. We will build on the four established clusters (Iconium, Clio, Corydon, and Norwood) and add three new ones. Transects refer to a more or less linear sampling scheme across the range in soil properties at a given site. Each transect will average about 12 soil cores.

Land uses to be sampled are (a) switchgrass fields ≥ 9 years old; (b) switchgrass fields ≥ 9 years old converted to row crop in the past 2 to 4 years; (c) switchgrass fields ≥ 9 years old converted to row crop more than 6 years ago; (d) row crop fields under at least 10 years of no-till; (e) row crop fields under a combination of reduce tillage and conventional tillage over the past 10+ years, (f) row crop fields under long-term conventional tillage, (g) intensely managed pastures, (h) unmanaged pastures, (i) intensely managed woodlots, and (j) unmanaged woodlots. Please note, not all clusters will have all of these land uses because it is unlikely that comparable sites will be consistently in close proximity.

Each transect will consist of multiple cores spaced more-or-less equally from one another. Each transect point will be uniquely identified and have its exact location recorded. Locations will be GPS referenced as well as given in standard legal descriptions. All soil cores will be collected to a depth of 1.2 meters. Analysis of each soil core will include abbreviated profile description as well as horizon-by-horizon measurement of bulk density, organic carbon content, and pH. Aggregate stability will be measured on all horizons from the upper 50 cm of each soil core. A selected subset of cores will be further analyzed for POM, aggregate stability, CEC, and particle size.

The cluster and transect approach described and planned above will result in about 25 new sites and 250 new soil cores. These will be in addition to the 20 existing sites and 200 soil cores already being analyzed in the current study.

Long-term information about cultural practices and land use history will be obtained about each site.

Calendar

Time	Component
Year One	Identify sites that meet the landscape and land use criteria discussed previously. During this step, detailed records of erosional channels found in all field types will be maintained.
	Conduct field sampling using the above scheme.
	Begin laboratory analyses for bulk density, carbon content, aggregate stability, and pH.
Year Two	Finish field sampling.
	Finish laboratory analyses.
	Write final report as a series of manuscripts consistent with the objective. Present paper at national and international research conferences. Present findings at Chariton Valley extension-like meetings.

Budget

Category	Total 2-Year Estimate	Project Cost Year 1	Project Cost Year 2	Total 2-Year ISU Match
Personnel				
Lee Burras	12,000	0	0	12,000
Julie McLaughlin	62,400	31,200	31,200	0
Hourly help (\$7.50/hour)	22,500	11,250	11,250	0
Fringe Benefits	18,000	7,800	7,800	2,400
Travel	10,000	5,000	4,000	1,000
Supplies & Analyses Costs	27,000	9,000	18,000	0
Equipment	8,000	4,000	4,000	0
Total Direct Charges	159,900	68,250	76,250	15,400
Indirect Charges (25% TDC)	39,975	0	0	39,975
Total Costs	199,875	68,250	76,250	55,375

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