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MINNESOTA AGRI-POWER PROJECT

Quarterly Report for the Period:
January - March 1998

Minnesota Valley Alfalfa Producers

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PREPARED FOR THE UNITED STATES DEPARTMENT OF ENERGY

Under Cooperative Agreement
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MINNESOTA AGRI-POWER PROJECT

Instrument No.: DE-FC36-96GO10147

PROGRAM STATUS AND ACCOMPLISHMENTS

FIRST QUARTER-1998 REPORT

FOR PERIOD
01 JANUARY 1998 THROUGH 31 MARCH 1998

Task 1 Design Package

1.1 FEEDSTOCK TESTING

1.1.1 Alfalfa Separation Pilot Plant Testing - Completed May 1997

1.1.1A FEEDSTOCK PROCESSING, DENSIFICATION ANALYSES AND DESIGN-

Feedstock processing and system improvements continue, densification analysis is underway, and a preliminary design and cost estimate for the first new process plant is being developed.

As part tour of other processing facilities on the US West coast was completed. Various new hay grinding technologies and densification systems were looked at. Information collected on this tour will be useful in finalizing plant design.

Monitoring of the leaf stem separation equipment performance has continued. The first stage separator, which separates out the stem material, is operated continuously, whenever the plant is operating. The stem and leaf material are, under most operating conditions, blended back into the pellet production stream. Stem quality has averaged 11.5% Protein (DMB) with a standard deviation of 2.0%, while the leaf material from this circuit has averaged 22.0% (DMB) Protein, with a standard deviation of 2.7%.

The continuous in-line production of leaf meal, using the two stage separation system, has been operated as allowed by production and market conditions. Output from the line has averaged 26.2% Protein (DMB), with a standard deviation of 0.8%, on the leaf meal circuit. Stem quality under these conditions remains unchanged.

As mentioned under section 1.1.6A, an ash equation has been developed and ash analysis are now available. It has been observed that there is potential problem with the ash content of all the materials received at the plant, which with the present equipment is being concentrated in the ALM portion. Typical alfalfa, in other areas, will average about 8% ash and feed industry standards accept materials with up to about 12% ash. Initial results indicate that the ash content of leaf meal averages 16.1%, with a standard deviation of 0.5%. Further investigation of the analysis and of the overall ash content of hay delivered and particularly the concentration of ash in the ALM is underway.

1.1.2 Gasification Test Plan and Testing – Completed December 1997.

1.1.2A ALTERNATIVE DESIGN AND TECHNOLOGY OPTIONS

Stone & Webster Engineering Corporation completed a "Summary Report on Evaluation of Alternative Technologies" on November 17, 1997. United Power Association continues to assess alternative technology options, and prospective developers are considering alternative technologies that could be utilized if the original project technologies are determined to be not feasible.

No funding for this task has been authorized under Phase IA.

1.1.3 Design of Gasification Plant –**UPA**

Carbona and Kvaerner continued to develop gasification plant design and cost estimate.

1.1.3A ADDITIONAL GASIFICATION PLANT DESIGN

This task has not been authorized

1.1.4 Combustion Testing – Delayed to Phase IA

1.1.4A REVISED COMBUSTION TESTING BUDGET

Testing completed December 1997, Final Report in progress.

1.1.5 Alfalfa Leaf Meal Product Tests

Phase I feeding trials and product analysis to determine the value of ALM in dairy, beef, and turkey rations have been completed and the results of this work were presented in a University of Minnesota Technical Report issued November, 1997.

1.1.5A ADDITIONAL ALFALFA LEAF MEAL PRODUCT TESTS

Dairy Research

Dairy Research is completed and a final report is being prepared.

Beef Research

Beef Receiving Study St. Paul--Cattle completed 60 days on test. Rates of gain have not been calculated. Final weights appeared to be similar for both ALM and soybean meal treatment groups. Also, no health problems were observed.

Beef Finishing Study Crookston--Cattle have been on feed for over 120 days. Rates of gain are about 4 lb. or better. There does not seem to be a particular advantage for any treatment. Cattle will be fed through early June.

See Attachment (University of Minnesota Quarterly Technical Report).

<u>Turkey Research</u>

Samples of leaf meal (ALM) were obtained with the cooperation of AURI (Rose Patzer) that varied in proportion of leaf(L) and stem (S). The samples were designated as 25L:75S; 50L:50S, 75L:25S, and 100L. Preliminary analyses provided by AURI showed that respective protein contents(%) were 14.2, 17.9, 21.1, and 26; respective crude fiber contents (%) were 37.5, 31, 25.4, and 18.5.

To determine available energy content, the true metabolizable energy assay as developed by Sibbald (1983) was used. Young turkeys (6-8 weeks of age) were used in two assays. The turkeys were placed in individual cages and allowed to acclimate for 5 days. The turkeys were fasted for 36 hrs and precision fed 35g of the test ALM samples. Control turkeys were fed a small amount of glucose. Excreta was collected for 60 hrs after feeding. After the collection period ended, the excreta was quantitatively collected and all material was freeze dried. Each sample was allowed to reach equilibrium with atmospheric conditions and then weighed. The excreta was finely ground and analyzed for moisture, protein and gross energy. Samples of the fed ALM were treated in similar manner.

The true metabolizable energy content (nitrogen corrected) of the ALM appeared correlated to the portion of leaf present in the sample. PRELIMINARY TME contents (kcal/kg as fed) were 1100, 1534, 1592 and 2150 for the samples containing the 25, 50, 75 and 100% leaf, respectively. Results should be considered preliminary as some variation does exist and the assay needs to be rerun.

However, it does appear that the proportion of leaf in the meal has a significant effect on energy content of the material for turkeys. Once assay values are established, regression equations will be determined so the TME content can be predicted based on the protein and/or fiber content of the meal.

Attachment (University of Minnesota Quarterly Technical Report)

<u>Sheep Research</u>

The sheep feeding trial is completed. Data is still under analysis and a final report is being prepared.

1.1.6A ALFALFA FEEDSTOCK VARIABILITY ANALYSES

Work on this task is continuing. An ash equation for leaf and stem material has been developed and work on an equation for ALM is underway. Performed diagnostic tests to flag irregularities in data sets. Conducted a more sophisticated statistical analysis on season total yield and season average forage quality. Developed statistical models for analysis of within-season changes in alfalfa yield and forage quality. Conducted preliminary economic analysis of harvest regimes using three different methods of calculating dollar returns.

Turned a portion of the Biomass stem samples in for mineral analysis. Used the results to create mineral equations for phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), aluminum (Al), iron (Fe), sodium (Na), zinc (Zn), copper (Cu), boron (B), lead (Pb), nickel (Ni), chromium (Cr), and cadmium (Cd). Nine samples were also analyzed for sulfur (S). They had a range of 0.08 to 0.15% sulfur. These were then used to analyze all the Biomass 97 stem samples. Statistical analysis is in process. See University of Minnesota Quarterly Technical Report: Alfalfa Variability Analysis attachment 1: Mineral Equation Statistics.

Analyzed leaf/stem separated at MnVAP using their new apparatus (scalper) and discovered that dirt may be concentrated in the leaves. This gives very high ash values and therefore the current quality equations gave incorrect fiber values. Developed new equations to use on leaf, stem and whole plant samples suspected of being contaminated. Put the equations along with a new output form on MnVAP's computer. These equations will be updated as more samples are received. See attachment 2: Dirt Contaminated Sample Equation Statistics. We feel that as MnVAP's separating process evolves this problem will be reduced or eliminated.

Summarized MnVAP hays from 2/97-10/97, 10/97-2/98 and 7/96-2/98. Attachments 3, 4 and 5 show the same information over different periods. In the period since MnVAP began using their NIR (7/96-2/98), 2431 hay samples have been analyzed (Attachment 5). The following table gives the minimum, maximum, and average relative feed value (RFV) and percentage crude protein (CP) for that period. From the chart in attachment 5 you can see within the same range of CP the RFV can vary tremendously. This means that hay with the same CP value, when fed to livestock, could cause a large difference in animal performance. We are using this data to evaluate paying on more than just CP values.

Max	Min	Average
% CP	% CP	% CP
27.55	5.80	19.15
RFV	RFV	RFV
222	62	114

An Interim Report on Alfalfa Stem Variability is included in the UofM Report. This task is scheduled for completion October 1998.

1.1.7A ADVANCED PRODUCT RESEARCH

This recent section of work is analysis of the water floatation-sedimentation products, from the ALM grind received from the MAP project.

In water floatation (rough diagram in the previous report), if the grind is given a short exposure to water, floated for about 0.5 to 1 minute, the stem particles tend to float and be removed off the top. The more dense leaf particles sink, to be removed at the bottom. Floating particles are the cellulose-rich particles, and do not wet very well. Sinking (sedimenting, bottoming) particles are more dense, protein-rich particles.

In this section of work, the protein rich (bottom) particles were extracted in the cold by acetone, and also by warm solvent, again acetone, to get a perspective on tocopherol (vitamin E, α-tocopherol), presence of nitrogenous (alkaloid related) compounds. This was done with 3 samples by mass spectrometry (our central instrument facility, Tom Krick, supervisor for NMR and mass spectrometry). There is some evidence for presence of antioxidant (vitamin E) related compounds in the cold acetone interaction, but not in the hot. This contrast was expected because under warm conditions, with any air in the extraction system, oxidation-sensitive compounds like vitamin E and related compounds are destroyed by oxidation.

These extracts contain phenolics, giving back a lot of signal by the Folin test, which detects tannin-related compounds. The phenolics (tannin related materials) tend to act as anti-nutritional compounds towards animals. Therefore inexpensive ways to get them out are of some priority. One extraction for them was carried out, using mild alkali, about 0.01 N alkali, to make them water-soluble. It is relatively easy to analyze for phenolic compounds with several kinds of assays, including ferric ion, and the traditional Folin method. Roughly, the bottom sedimenting material is 1 to 2% phenolic compounds in the rapidly extracting (by alkali) fraction. However, it is necessary to carry out more of these, to reach a conclusion. One of the future tasks should be to see if ruminant digestion can either withstand these sorts of compounds in ruminant anaerobic and micro-aerobic conditions or where, at some level, they inhibit any of the enzymes necessary for ruminant digestions.

The nitrogen containing (alkaloid related) fractions come out of the bottom-sedimenting (crude protein) material, in many extraction conditions. However they are more susceptible to lower pH leaching, as in silage making, than to high pH extraction. We are preparing to get perspectives on these kinds of compounds, by spectroscopic analysis. Because of some work on another project, we are set up for human red cell assays to scan for bio-activity of such compounds. The human red cell changes shape (seen in microscopy) in response to nitrogenous compounds, and to phenolic and lipid compounds that bind to it. These are relatively easy assays to carry out. That is, to gauge response to alfalfa-derived compounds based on the one, readily accessible human cell, the red cell.

In the previous report, it was noted that about 3% of alfalfa leaf (protein fraction) weight appear to be proteases. The proteases should be value-added products, if they can be readily removed, and if they are stable. It appears that the alfalfa proteases are stable (for several days) in acid. However, they quickly autolyze, destroy themselves, in alkaline (above pH7) exposure.

Subtask 1.2 Integrated Plant Design and Cost Estimate -

SWEC will provide plant design and cost estimate status at the DOE Project Meeting scheduled for June 1998.

Task 2 Feedstock Supply System

Subtask 2.1A SCALE-UP OF FEEDSTOCK SUPPLY SYSTEM -MNVAP

All documents necessary for the sale of shares in both Minnesota and South Dakota have been completed and the Pool 4 share drive was started in early March 1998. Copies of the Disclosure Statements, and information packets used for both states are attached.

A total of 31 meetings have been held throughout, and slightly beyond, the Focus Area. Producer interest in the MAP project has been very high, with a total attendance at these meetings of about 1,200 area farmers.

A partial measure of the success of the current share offering will be available in early June, as the price of equity increases effective June 1, 1998. This share pricing mechanism was established, in part, to provide some milestones during the Offering. Share sales to date are well ahead of sales made during last year's Offering.

Subtask 2.2A DEVELOPMENT OF BIOMASS -TYPE ALFALFA VARIETIES

Crossing schemes for the alfalfa biomass populations are nearly completed. Non-lodging large stemmed types have been crossed to disease resistant populations as well as populations with increased leaf yield. Crosses have been repeated to increase seed availability for demonstration plots to be planted at Lamberton and Morris, MN in the spring of 1998. The first of two populations have been selected for resistance to Phytophthora root rot and crosses will be made among the resistant plants this spring. As soon as seed is available a second population will be selected for Phytophthora root rot resistance.

Preliminary analyses from a management study examining the effects of plant population density and cutting frequency on leaf and stem yield of a diverse group of alfalfa genetic sources has been completed. The preliminary results from one location in one year suggest that different combinations of population density and cutting frequency has a major influence on both leaf and stem yield in alfalfa. A combination of 16 plants per ft^2 and a two-harvest management system had the highest leaf and stem yields on a land area unit basis. This study will be repeated again at two locations in 1998.

Subtask 2.3A PREPARATION of the MAP PRODUCER'S GUIDE -

Publication of the MAP Producers Guide(hardcopy and video) has been pushed back to make the Guide available for farm planning (winter 1998/99) for the Spring 1999. UofM Best Management Practices research is scheduled for completion Fall 1998.

MnVAP will request a no-cost extension for this task to February 1999 as part of its Phase IB proposal and cooperative agreement amendments request.

Best Management Practices-Planning is underway for Spring planting of management trials.

Subtask 2.4A EVALUATION OF ALTERNATIVE BIOMASS RESOURCES

A Draft Report on Alternative/Supplement Biomass Resources available in the region has been reviewed. The Final Report is attached to the UofM Report.

Task 3 Performance Guarantees -

No progress toward accomplishment of this task occurred during this quarter.

Subtask 3.1A EPC CONTRACT DEVELOPMENT -

United Power Association and MnVAP staff continue to consider alternative EPC contract forms, and Prudential Capital Group (PCG) has been asked to provide model EPC contracts that PCG views as suitable from a financing perspective. In addition, prospective developers are considering how they would organize the project team under an EPC contract or other instruments.

Task 4 Sales Contracts -

Subtask 4.1A POWER PURCHASE AGREEMENT

NSP submitted the Power Purchase Agreement to the Minnesota Public Utilities Commission for review and approval. The Department of Public Service began reviewing the Power Purchase Agreement in February, 1998 for the purpose of making a recommendation for approval or disapproval to the Public Utilities Commission. To date, MnVAP, UPA, and NSP have responded to 19 information requests made by the Department of Public Service. A Department recommendation is expected in April.

The Minnesota Legislature approved two items relevant to the Power Purchase Agreement in March of the 1998 Session. The first item explicitly authorizes the use of natural gas or non-qualifying biomass in the event of a fuel force majuere without such use counting against a project's total allowance of non-qualifying fuel. The second item provides NSP the ability to recover 100 percent of its costs under the power purchase agreement irrespective of regulatory changes. The Power Purchase Agreement will be amended to reflect these legislative measures.

Subtask 4.2A BIOMASS FUEL SUPPLY AGREEMENT -

MnVAP continues to discuss the desired form and content of the fuel supply agreement with prospective equity partners and developers.

Subtask 4.3A SUPPLEMENTAL FUEL SUPPLY SYSTEM -

The primary fuel for this project will be Alfagas. The secondary fuel will be un-interruptible or firm natural gas, rather than fuel oil, because firm natural gas is less expensive than oil and the Westinghouse multi-annular swirl burner (MASB) has been designed and tested for use with these fuels. The Mid-Continent Area Power Pool (MAPP) requires a **firm** fuel supply for pool accredited generation. A firm natural gas contract would meet both the Westinghouse technical requirements and MAPP requirements. Also, natural gas is a suitable fuel for start-up of the gasifier.

The application for high pressure natural gas service has been submitted to the local pipeline company. Negotiations are scheduled for the second and third quarters of 1998.

Subtask 4.4A ALFALFA PRODUCT SALES -

MnVAP has demonstrated market acceptance for a limited quantity of ALM products based on University feeding trials using first generation leaf meal product (23% C.P). Further product testing is required to evaluate livestock performance using the improved ALM (26% C.P.) product that is currently being produced.

4.4.1A DOMESTIC MARKETING OF ALFALFA PRODUCTS

First quarter sales of traditional alfalfa products (15-17% pellets) are below expectation. Generally, the alfalfa feed market is at its weakest point in the last 20 months.

The current domestic market clearly reinforces the project's need to develop new higher value products that are able to effectively compete in the global supplemental protein market.

4.4.2A INTERNATIONAL MARKETING OF ALFALFA PRODUCTS

MnVAP has engaged an international trading company and is working with the Minnesota Department of Agriculture to develop international markets for alfalfa leaf meal (ALM) products.

Subtask 4.5A INERT GAS SUPPLY SYSTEM -

No activity to report at this time. The preliminary design details have not been released by SWEC. This task is scheduled to begin June 1998.

Task 5 Environmental Permits -

Subtask 5.1A PREPARE CRITICAL PATH PERMIT APPLICATIONS

UPA met with the MEQB staff on February 19, 1998. This meeting brought the MEQB staff up to date on the biomass project. Many telephone calls and e-mails have been exchanged on the details of the applications. As part of the permitting process, letters were sent to all the affected government entities during the last week in February 1998.

UPA is preparing the site selection application which will be submitted to the State of Minnesota and reviewed by both the DOE and the State of Minnesota, under their pending joint coordination agreement.

The air permit application is being prepared by Wenck and Associates. The emissions calculations from Westinghouse are needed to complete this task.

A meeting was held with NSP on March 31, 1998, to begin work on the 115 Kv transmission line routes to both sites.

Subtask 5.2A ALTERNATIVE POWER PLANT SITING STUDY

Costs for siting at the alternate location (Yellow Medicine County) are being assembled. Environmental review of the alternate site is proceeding as required by Minnesota siting regulations.

Subtask 5.3A ALFALFA PROCESSING FACILITIES SITING STUDY

This activity is being coordinated with Subtask 2.1A.

5.4.1A COOLING/PROCESS WATER SUPPLY SYSTEM

A study of the Minnesota River flows and area well drilling records is being conducted by B.A. Liesch Associates. This firm will assist in preparing applications for the necessary water permits after the results of their studies are reviewed

5.4.2A ALTERNATIVE ASH DISPOSAL METHOD

A search of area landfill capacity and capability is underway. The activities for this task are scheduled for the second quarter. The activities include meeting with the Minnesota Pollution Control Agency (MPCA) to review plans for short-term ash storage.

Effect of Ash Application on Plant Biomass and Elemental Composition:
Statistical analysis of the data indicated a significant treatment effect for dry weight of corn plants grown in the Hubbard soil but not in the Barnes soil. The mean dry weight (per two plants) for Hubbard and Barnes soil is presented is presented in Figures 1 and 2. Ash application at the rate equivalent to 12,800 lb/acre negatively impacted dry weight of corn plants. It should be noted that in the Hubbard soil the dry weight response was not consistent across all treatments. The coefficient of variation for the dry weight means was 8-21%.

The trends in plant fresh weight were similar to that of the dry weight (Tables 3-4).

Ash or fertilizer application did not have a significant effect on the concentration of P in plant grown in either soil (Figure 3). However, a significant treatment effect was observed in concentration of K in plants grown in both soils. Regression analysis indicated a significant positive linear correlation existed between the ash application rate and plant K concentration (Figure 4). Ash application did not have a significant effect on Ca content of corn grown in Barnes soil, but significantly depressed Ca in plants grown in the Hubbard soil (Figure 5). There was a significant negative correlation between ash application rate and plant Mg in both soils (Figure 6).

Effect of Ash Application on Selected Soil Chemical Properties:
Ash application significantly increased pH in the Hubbard soil but not in the Barnes soil and the increase in pH of the Hubbard soil was significantly correlated with ash application rate (Figure 7). Ash application rate significantly increased the the electrical conductivity (EC) of the water saturated paste prepared from both soils. At ash application rate of 12,800 lb/acre electrical conductivity of the extract from Hubbard and Barnes soil was 2.8 and 1.7 mmohs/cm respectively. The electrical conductivity was 0.9 and 1 mmoh/cm for untreated Barnes and Hubbard soils respectively indicating that Barnes soil was more highly buffered (Figure 8). The high EC value is perhaps one of the causes of reduced plant dry mass in plants grown in Hubbard soil and treated with the highest rate of ash.

Available P in soil as measured by Bray or Olsen method was significantly increased by ash application in both soils. It should be noted that due to the nature of the reagent used in each method, Bray method removes more P from an acid soil (e.g Hubbard) while Olsen removes more P from an alkaline soil (e.g. Barnes) (Figure 9-10). The general consensus among the soil scientists is that Bray is a better predictor of plant available P in soil in acid soils while Olsen is a better one for alkaline soils.

Exchangeable K in both soils significantly increased as a result of ash application and in both soils there was a significantly positive correlation between the ash application rate and exchangeable K (Figure 11). These soil data and the associated plant data indicates that the ash is an excellent source of K for plants.

Statistical evaluation of the data continues.

5.4.3A IMPACTS OF SUPPLEMENTAL FUELS - UPA

No activity at this time pending finalization of supplemental fuels report. It is noteworthy that an initial comment letter from the Minnesota DNR includes a recommendation that the impacts and benefits of other biomass resources available in the region be addressed.

Task 6 Education, Environment, Economy

Subtask 6.1A ENHANCED COMMUNITY EDUCATION PROGRAM

Education Initiative – "Energy for Life"

This educational initiative expands our thinking about energy to include renewable energy and how our use of energy impacts our environment. "Energy for Life" is being introduced into schools and communities in the Minnesota River Basin and around the world as the result of a collaboration with Hamline University, the Minnesota Department of Agriculture, the Minnesota Extension Service, the 4-H program, and a wide range of business and civic leaders from the region. Students include farmers, ag professionals, teachers, and children of all ages.

An Ag Professional Training Seminar was held February 10th and 11th and four alfalfa informational meetings were held on February 17th and 18th. About 25 people attended each informational meeting. Speakers included Neal Martin, Professor, Department of Agronomy and Plant Genetics and Extension Forage Specialist, Craig Sheaffer, Professor, Department of Agronomy and Plant Genetics, Greg Cuomo, Forage Specialist, West Central Experiment Station, Bruce Potter, IPM Specialist, Southwest Experiment Station, and Rich Kvols, Extension Educator. Rich Kvols has received several requests for follow-up education from producers who attended the meetings.

Rich Kvols, Yellow Medicine County Extension Educator, is continuing to contact other agricultural organizations to form producer education partnerships, is working to educate new alfalfa growers and is working with implement dealers to hold a Hay Days demonstration in June. He is also working with growers to establish demonstrations on their farms.

Used public forums to, teach proper hay sampling technique, forage quality test interpretation and to provide free analysis of hay for producers in Southwestern Minnesota.

The Energy Odyssey on-line educational program began March 9^{th}. A study guide was developed and distributed to the educators participating in Hamline University's Rivers of Life: Mississippi Adventure. The WWW address for the Rivers of Life: Mississippi Adventure site, which is hosting Energy Odyssey, is http://cgee.hamline.edu/rivers98/index.html.

Rivers of Life: Mississippi River Adventure is an online distance-learning program that runs for 10 weeks from mid-March to mid-May. For 1998, the dates are March 9 to May 15. Currently, the program is in its sixth week and has a total of 236 educators subscribed to the program. Rivers of Life has four program areas: "Energy Odyssey", "Steamer Trunk", "Chasing the Flood", and "Rivers of Time".

Rivers of Life provides conference centers on-line where students and teachers can post comments and questions for each of the program areas. Each of the four conference centers have been active with questions from teachers and students. In addition, the online experts have addressed wide-ranging questions from students and teachers in the U.S. and Russia. [Note: there are 17 classrooms in Russia that have been active on the website and some of those classrooms are participating in Energy Odyssey.]

Subtask 6.2A ENVIRONMENT: LAND USE DEMONSTRATIONS

Minnesota River Basin Initiative – (MRBI)

Land use in the Minnesota River Basin has a major impact on water quality in the Minnesota River. Plantings of resource conserving crops like alfalfa, hybrid poplar, willow, and native grasses will be used to demonstrate their economic and environmental benefits. The Minnesota River Basin Joint Powers Board (an organization of County Commissioners from the 37 Minnesota Counties in the Basin together with all the key state agencies with responsibilities for improving water quality in the basin and USDOE and USDA are proposed participants in this effort.

Subtask 6.3A ECONOMIC BENEFITS FOR RURAL COMMUNITIES

State and Local Policy Initiative – (SLPI)

The development and support for state and local policies that encourage the development and implementation of biomass production and processing systems has been initiated with the Hubert H. Humphrey Institute for Public Affairs and with the State Department of Trade and Economic Development (DTED). This task has been suspended pending review and planning meetings with DTED.

Task 7 Final Report – Phase II Application

Scheduled for submittal December 1998.

Task 8 Project Coordination and Control - MnVAP

The completion of the Phase 1 preliminary design and capital cost estimate tasks continue to be delayed as the result of project delays for tasks that provide input into the design and cost estimate tasks. Stone and Webster Engineering expects the preliminary design basis and capital cost estimate to be available by the end of May 1998 and a Draft Final Report for Phase 1 tasks by June 1, 1998. Completion of these Phase I tasks was previously scheduled to occur by February 28, 1998.

MnVAP continued discussions with prospective equity partners and developers. On March 20, 1998, MnVAP sent requests for proposals to Enron, Black & Veatch, Stone & Webster Development Corporation, Fagen Engineering, and Hartford Steam and Boiler. Proposals are due in April, and concurrent negotiations will be conducted in April and May.

Project Vendors continued to work on design and cost estimation, and MnVAP expects to receive a construction cost estimate in May, 1998.

Reporting, Invoicing, and Disbursement – MnVAP and C&A
MnVAP is transitioning the administration of accounting (fiscal agency) from Stone and Webster Engineering Corporation to Christianson and Associates (MnVAP's local CPA firm). This transition will be complete prior to authorization of Phase IB funding.

Technical and Financial Services – UPA
UPA continues to provide technical and financial analysis services to MnVAP for the MAP project.

Research Coordination – CAPAP, UofM
Three major project initiatives (as detailed in Task 6 above) have been developed to expand the base of support for the MAP project. Each of these initiatives are designed to continue without USDOE support following completion of Phase I of the MAP project.

The Research Coordinator and staff continue to provide overall coordination for MAP research and provide accounting and administrative services for the UofM research tasks.

The Research Coordinator participates in a wide variety of meetings and forums to promote the benefits and opportunities presented by the MAP project and organizes and develops additional project support in the form of partnerships, grants, or other appropriate means.

Minnesota Agri-Power Phase I
University of Minnesota Report to MnVAP
Quarterly Report (January through March 1998)

Task I Feeding Trials and Analysis

Work on this task is completed. A final technical report was submitted in October.

Task II Alfalfa Supply System

Task II was completed in February and final reports are being prepared.

Task III Biomass Energy Production Effects on Environment

Ash

Effect of Ash Application on Plant Biomass and Elemental Composition:
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P from an alkaline soil (e.g. Barnes). The general consensus among the soil scientists is that Bray is a better predictor of plant available P in soil in acid soils while Olsen is a better one for alkaline soils.

Exchangeable K in both soils significantly increased as a result of ash application and in both soils there was a significantly positive correlation between the ash application rate and exchangeable K. These soil data and the associated plant data indicates that the ash is an excellent source of K for plants.

We will continue our statistical evaluation of the data and report the outcome in future reports. This task should be completed in May 1998. A quarterly technical report " Effect of Ash from Alfalfa Stem Gasification on Plant Biomass, Mineral Content, and Selected Soil Chemical Properties" is attached (Attachment 1).

Water Quality

Water Quality activities are continuing under a grant from the Legislative Commission on Minnesota Resources. A report "Biomass Energy Production Effects on Environment: Surface and Ground Water Quality" is attached summarizing the University's continuing research (Attachment 2).

Wildlife

Demonstration projects on cooperating farms in the biomass production region will be used to evaluate impact on wildlife abundance and diversity.

Task IV Economic Analysis

Work is completed on this task and a final report is being prepared.

Task V Community Education

The community and producer education program is continued under Phase IA. A full-color summary, which highlights the MAP project, the benefits of alfalfa production, and research results, is in review.

Task VI Project Coordinator

Project Coordinator tasks are reported under Phase IA.

Task VII Research Coordination

Performed monthly accounting, reporting, and research coordinating tasks under MnVAP's Cooperative Research Agreement with the University of Minnesota. Coordinated team meetings; prepared and submitted monthly and quarterly expense and progress reports through February 1998; reconciled research accounts and verified University expenses.

Attachment 1.

Effect of Ash from Alfalfa Stem Gasification on Plant Biomass, Mineral Content, and Selected Soil Chemical Properties.

Effect of Ash from Alfalfa Stem Gasificationon on Plant Biomass, Mineral Content, and Selected Soil Chemical Properties

Morteza Mozaffari, Carl Rosen, Michael Russelle, and Edward Nater

Department of Soil, Water, and Climate and USDA-ARS
University of Minnesota

INTRODUCTION AND METHODOLOGY

The major emphasize of our research effort during this reporting period was on a greenhouse experiment to evaluate the potential use of ash as a fertilizer or a soil amendment. Corn was used as a test crop since it is one of the major agronomic crops in Minnesota. Two soils representing a range of chemical and physical properties found in agricultural soils of Minnesota were used. One was a Barnes clay loam with high pH and the other was a Hubbard sand with low pH. The basic physical and chemical properties of the two soils are presented in table 1. The experimental design consisted of ten treatments for each soil as summarized in table 2. Each treatment was replicated four times in a randomized complete block design.

Eight corn seeds (Pioneer hybrid 3730) were planted in each plastic pot on November 7,1997. The seedlings were thinned to two per pot one week after germination. The greenhouse temperature was maintained at 85 degrees Fahrenheit during the day and 75 degrees during the night. Artificial light was provided by sodium and metal halogen light bulbs. The plants were watered to maintain the moisture content of the pots at 'Field Capacity'.

The total above soil level portion of plants was harvested on December 29 and plant fresh weight was measured. Plants were dried in a forced air oven and then plant dry weights were measured. Dried plants were ground in a Wiley Mill and a representative sub-sample was collected for subsequent chemical analysis. The following chemical analyses were performed on the plant samples. 1) total N by semi-micro Kjeldahl digestion followed by colorimetric flow injection analysis; 2) total Cl by the mercuric thiocyanate-ferric nitrate procedure in which ferric thiocyanate is formed proportionally to the original Cl concentration; and 3) other elements (P, K, Ca, Mg, Na, Al, Fe, Mn, Zn, Cu, B, Pb, Ni, Cr, Cd, Si, and S) by ICP-AES after wet digestion.

Following the plant harvest, soil samples were collected from each pot by taking six soil cores from each pot and compositing the cores from each pot. The following chemical analysis were performed on the soil samples:

1) 1 *M* HNO_3-extractable metals (Fe, Al, Mn, Cu, Zn, Cd, Ni, Pb, and Cr);
2) DTPA-extractable metals (Cu, Zn, Fe, Mn, Cr, Cd, Ni, and Pb);
3) extractable P by Bray and Kurtz P-1 (suitable for acid soil) or Olsen and Sommer $NaHCO_3$ (suitable for alkaline soil);
4) SO_4-S by extraction with 0.008 *M* $Ca(HPO_4)_2$;
5) exchangeable K, Na, Ca, and Mg by 1 *M* ammonium acetate;
6) inorganic N as NH_4+ and NO_3- by 2 *M* KCl extraction and colorimetric flow injection analysis;
7) hot water soluble B;
8) pH (1:1 soil:water); and
9) soluble salts.

All of the above chemical analysis have been completed recently. Currently we are summarizing and analyzing the data. Effect of ash application on plant yield is reported here. The effect of ash application on selected mineral constituents of the plants and selected soil chemical characteristics are also reported here. We will continue with the statistical evaluation of the data and present the outcome in future reports.

RESULTS

Effect of Ash Application on Plant Biomass and Elemental Composition:
Statistical analysis of the data indicated a significant treatment effect for dry weight of corn plants grown in the Hubbard soil but not in the Barnes soil. The mean dry weight (per two plants) for Hubbard and Barnes soil is presented is presented in Figures 1 and 2. Ash application at the rate equivalent to 12,800 lb/acre negatively impacted dry weight of corn plants. It should be noted that in the Hubbard soil the

dry weight response was not consistent across all treatments. The coefficient of variation for the dry weight means was 8-21%.

The trends in plant fresh weight were similar to that of the dry weight (Tables 3-4).

Ash or fertilizer application did not have a significant effect on the concentration of P in plant grown in either soil (Figure 3). However, a significant treatment effect was observed in concentration of K in plants grown in both soils. Regression analysis indicated a significant positive linear correlation existed between the ash application rate and plant K concentration (Figure 4). Ash application did not have a significant effect on Ca content of corn grown in Barnes soil, but significantly depressed Ca in plants grown in the Hubbard soil (Figure 5). There was a significant negative correlation between ash application rate and plant Mg in both soils (Figure 6).

Effect of Ash Application on Selected Soil Chemical Properties:

Ash application significantly increased pH in the Hubbard soil but not in the Barnes soil and the increase in pH of the Hubbard soil was significantly correlated with ash application rate (Figure 7). Ash application rate significantly increased the the electrical conductivity (EC) of the water saturated paste prepared from both soils. At ash application rate of 12,800 lb/acre electrical conductivity of the extract from Hubbard and Barnes soil was 2.8 and 1.7 mmohs/cm respectively. The electrical conductivity was 0.9 and 1 mmoh/cm for untreated Barnes and Hubbard soils respectively indicating that Barnes soil was more highly buffered (Figure 8). The high EC value is perhaps one of the causes of reduced plant dry mass in plants grown in Hubbard soil and treated with the highest rate of ash.

Available P in soil as measured by Bray or Olsen method was significantly increased by ash application in both soils. It should be noted that due to the nature of the reagent used in each method, Bray method removes more P from an acid soils (e.g Hubbard) while Olsen removes more P from an alkaline soil (e.g. Barnes) (Figure 9-10). The general consensus among the soil scientists is that Bray is a better predictor of plant available P in soil in acid soils while Olsen is a better one for alkaline soils.

Exchangeable K in both soils significantly increased as a result of ash application and in both soils there was a significantly positive correlation between the ash application rate and exchangeable K (Figure 11). These soil data and the associated plant data indicates that the ash is an excellent source of K for plants.

We will continue our statistical evaluation of the data and report the outcome in future reports.

Table 1. Description of treatments used for the evaluation of ash in the greenhouse study with corn.

Treatment		K_2O Rate (lb/acre)	P_2O_5 Rate (lb/acre)
1	Control	None	None
2	K	200	0
3	P	0	29.5
4	K+P	200	29.5
5	Ash 400 lb/acre	50	7.38
6	Ash 800 lb/acre	100	14.77
7	Ash 1,600lb/acre	200	29.50
8	Ash 3,200lb/acre	400	59
9	Ash 6,400 lb/acre	800	118
10	Ash 13,200 lb/acre	1600	236

Table 2. Selected physical and chemical properties of the Hubbard and Barnes soils.

Soil	Sand	Silt	Clay	Texture	pH	Elec. Cond.	Exch. K*	Bray P**	Olsen P***
		%				mmohs/cm		mg/kg	
Hubbard	88	8	4	Sand	5.0	1.0	54.6	91	40
Barnes	27	45	28	clay loam	7.5	1.2	230	12	11

* K extracted by 1 N ammonium acetate.

** P extracted by Bray solution.

*** P extracted by Olsen solution.

Table 3. Fresh weight of corn plants grown in the greenhouse in Hubbard soil treated with ash or synthetic fertilizer.

Treatment	K_2O Rate (lb/acre)	P_2O_5 Rate (lb/acre)	Ave. FW * (gr)	Std. Dev (gr)
Control	None	None	353	55.0
K	200	0	404.5	39.0
P	0	29.5	335.5	54.4
K+P	200	29.5	385	29.4
Ash	50	7.38	349	19.3
Ash	100	14.77	381.8	36.1
Ash	200	29.55	375.0	49.2
Ash	400	59	389.5	34.2
Ash	800	118.2	431.5	35.5
Ash	1600	236.4	373.5	37.3

* Fresh weight of 2 plants grown in the same pot.

Table 4. Fresh weight of corn plants grown in the greenhouse in Barnes soil treated with ash or synthetic fertilizer.

Treatment	K_2O Rate (lb/acre)	P_2O_5 Rate (lb/acre)	Ave. FW (gr)	Std. Dev. (gr)
Control	None	None	423.0	37.9
K	200	0	372.5	49.7
P	0	29.5	353.5	68.3
K+P	200	29.5	396.5	57.6
Ash	50	7.38	390	41.0
Ash	100	14.77	355.5	51.6
Ash	200	29.55	390.5	37.3
Ash	400	59	373.5	41.7
Ash	800	118.2	435.0	35.7
Ash	1600	236.4	395.8	50.1

* Fresh weight of 2 plants grown in the same pot.

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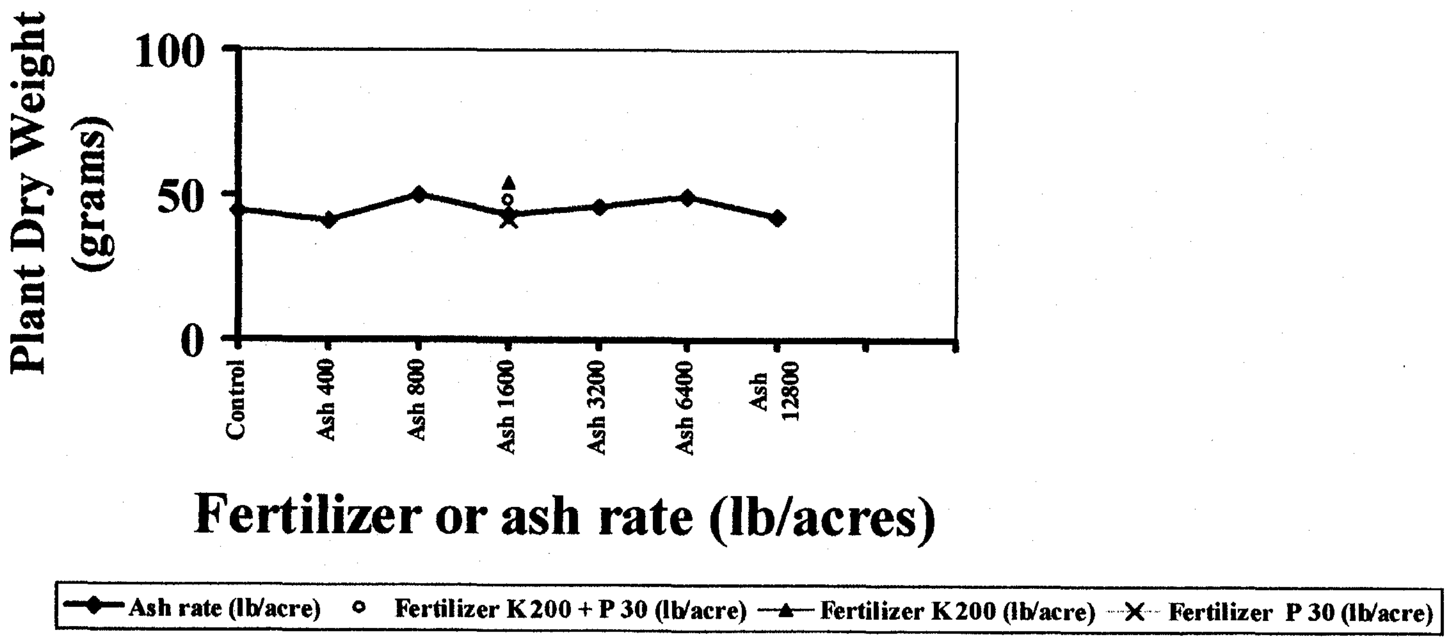
Hubbard Soil

Figure 1. Effect of fertilizer or ash application rate on corn dry weight



Barnes Soil

Figure 2. Effect of fertilizer or ash application rate on corn dry weight

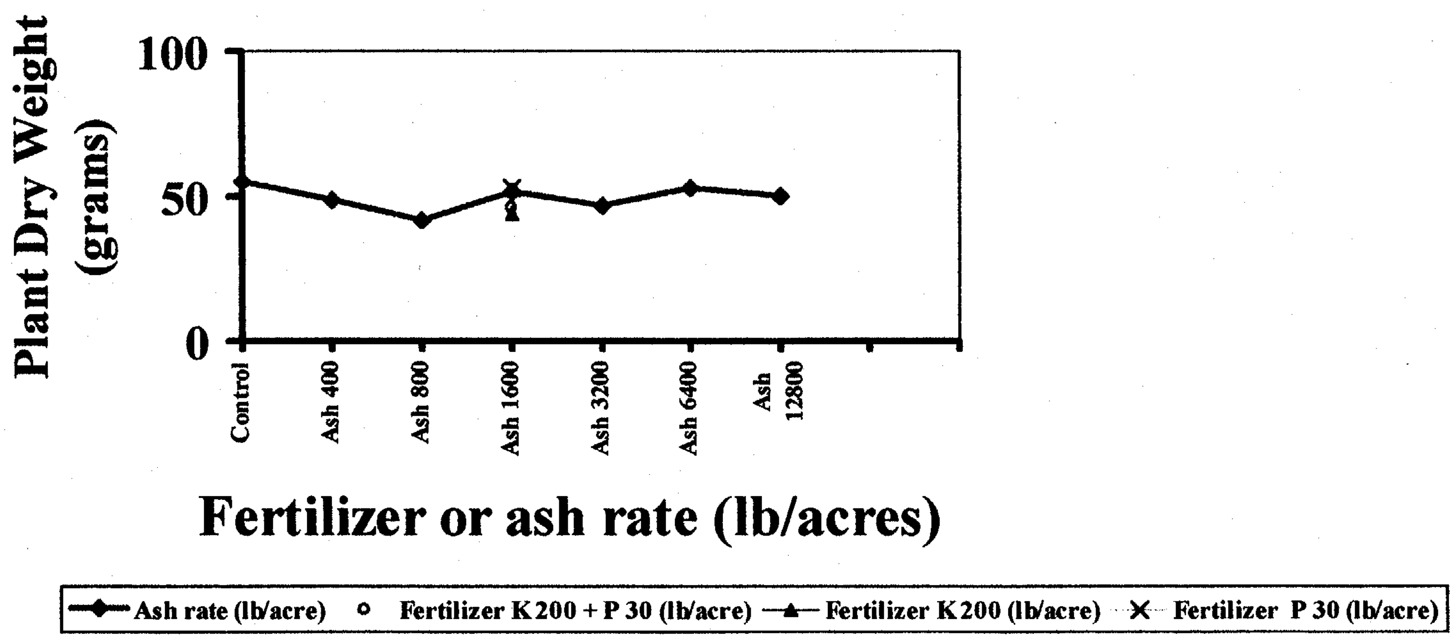
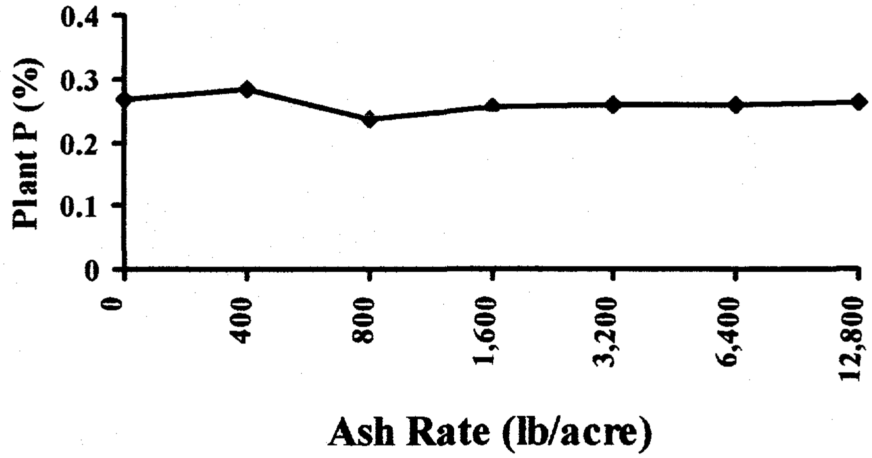
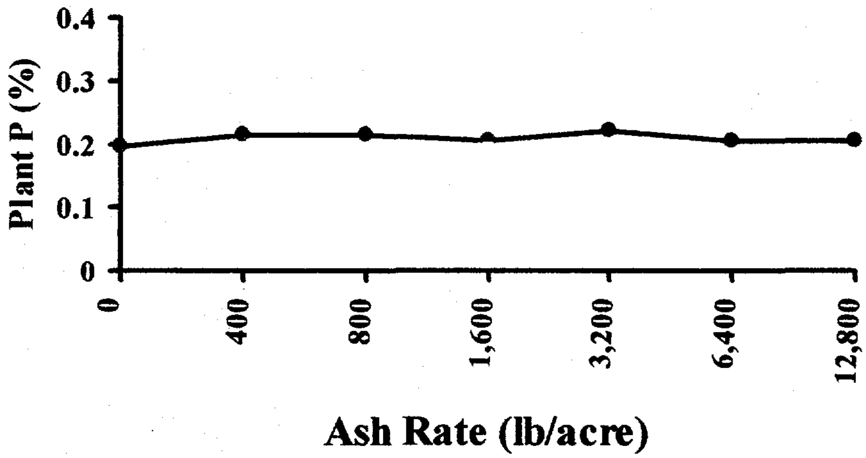


Figure 3. Effect of ash and fertilizer application on corn P.

Hubbard Soil

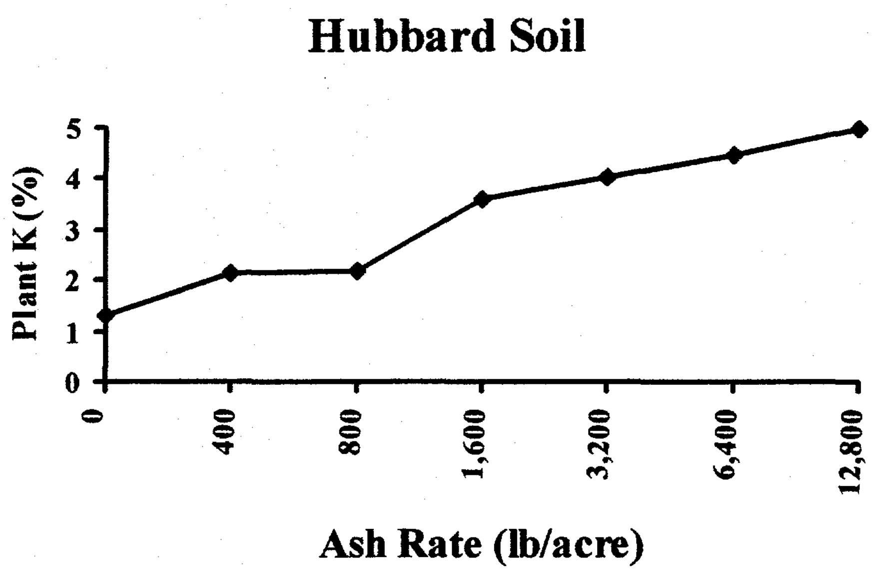


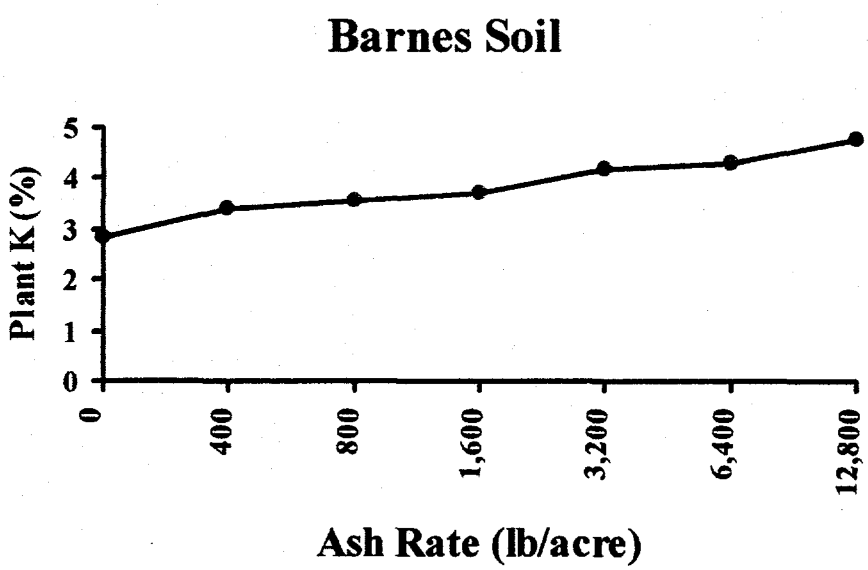
Barnes Soil



Note: the small square denotes the concentration of P in plants that received inorganic fertilizer equivalent to that ash rate

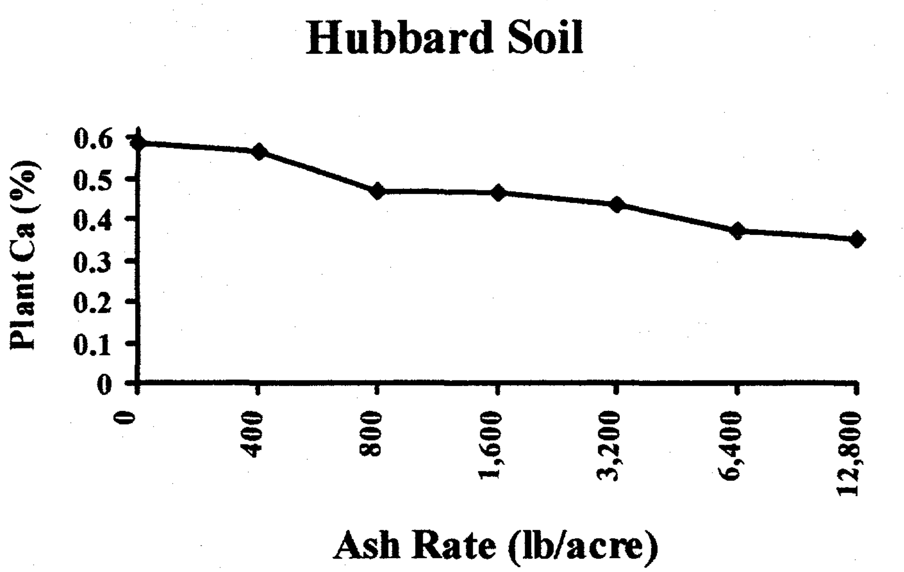
Figure 4. Effect of ash and fertilizer application on corn K.





Note: the small square denotes the concentration of K in plant that received inorganic fertilizer equivalent to that ash rate.

Figure 5. Effect of ash and fertilizer application on corn Ca.



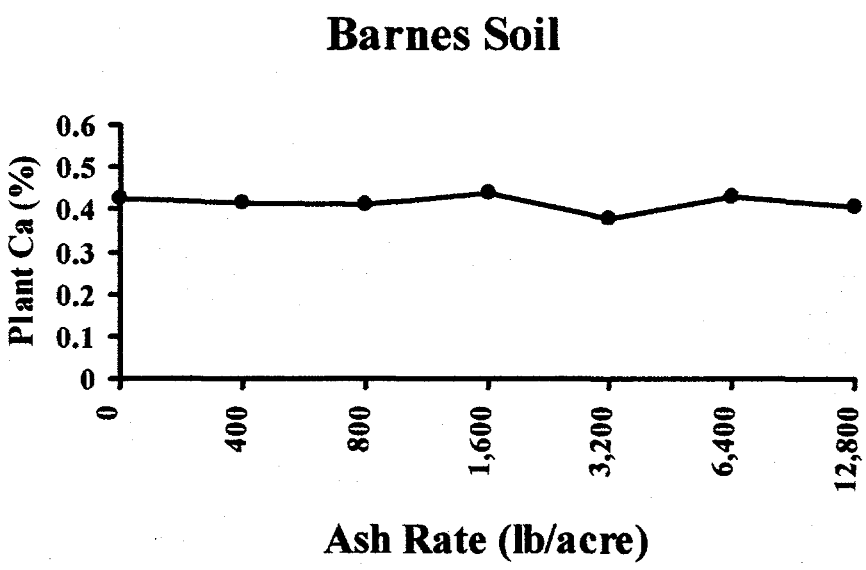
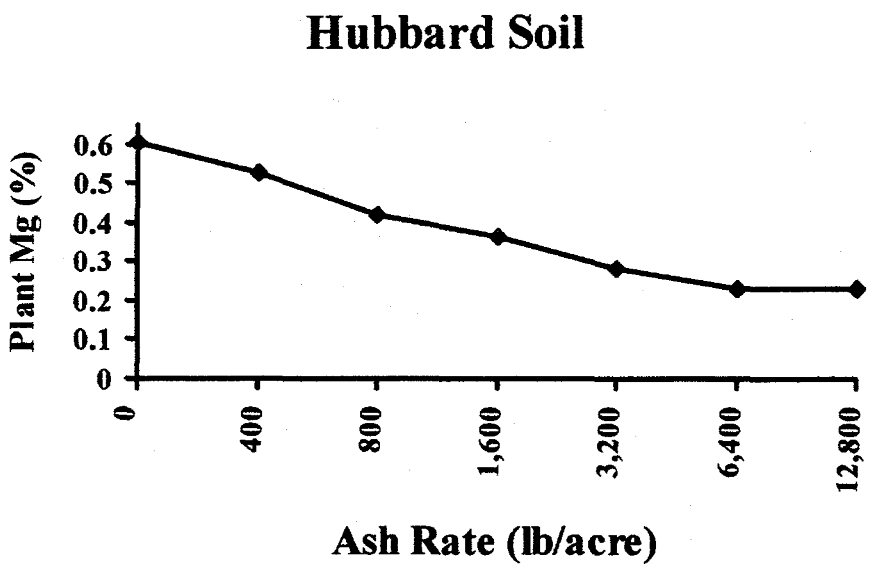


Figure 6. Effect of ash and fertilizer application on corn Mg.



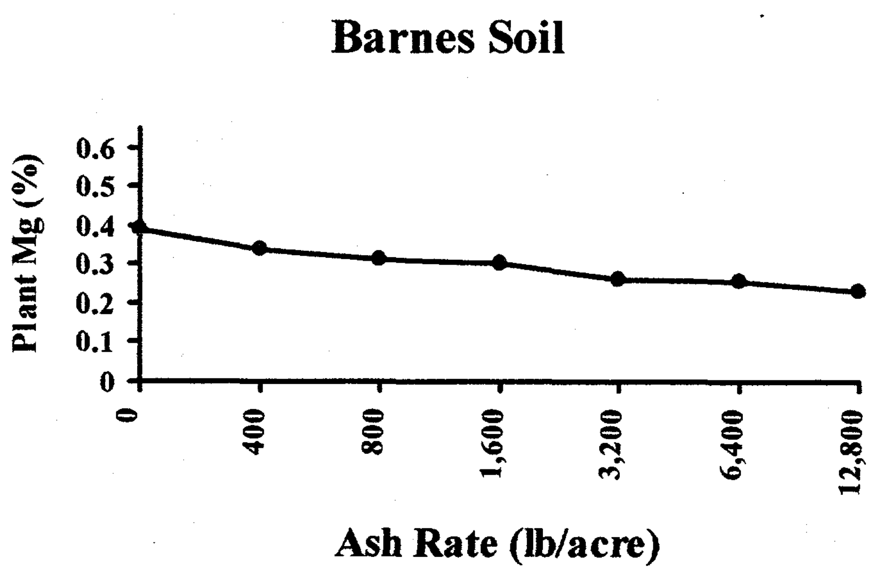
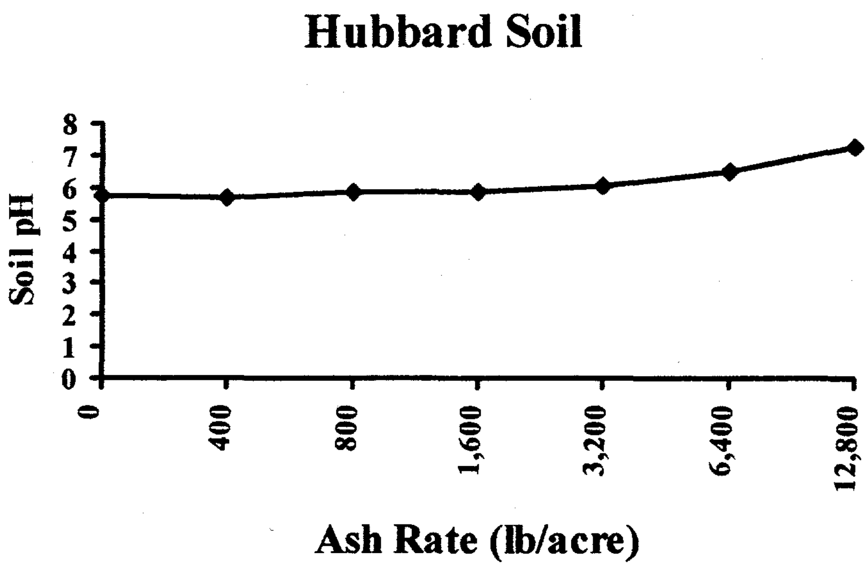


Figure 7. Effect of ash on soil pH.



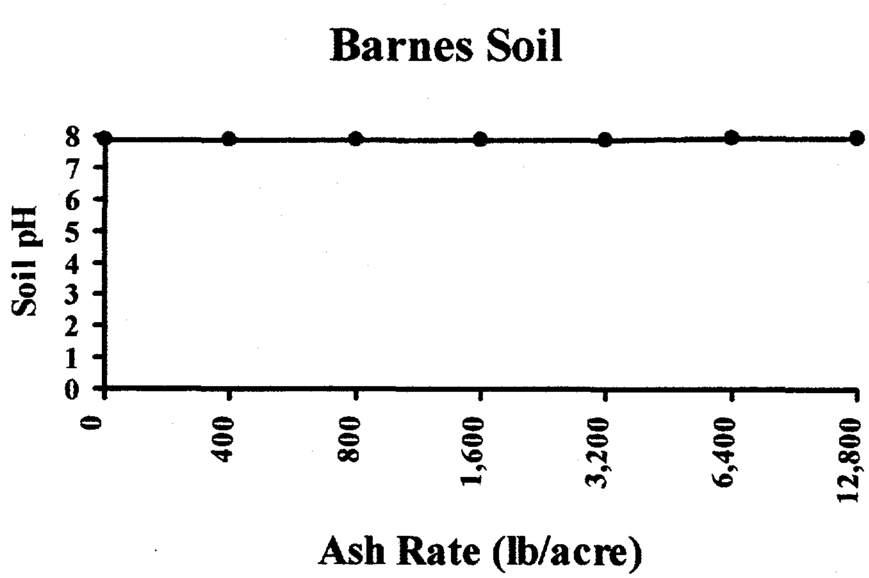
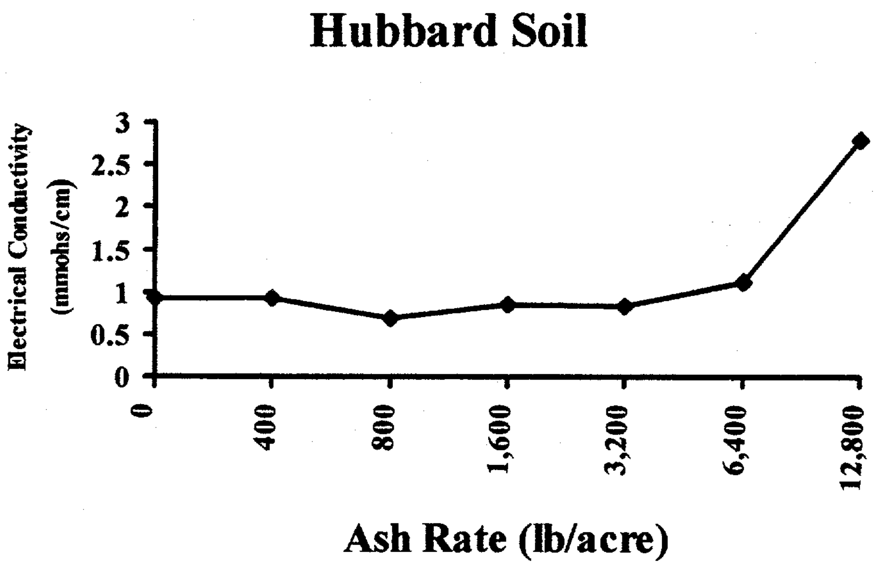


Figure 8. Effect of ash on electrical conductivity of the saturated paste prepared from the soil.



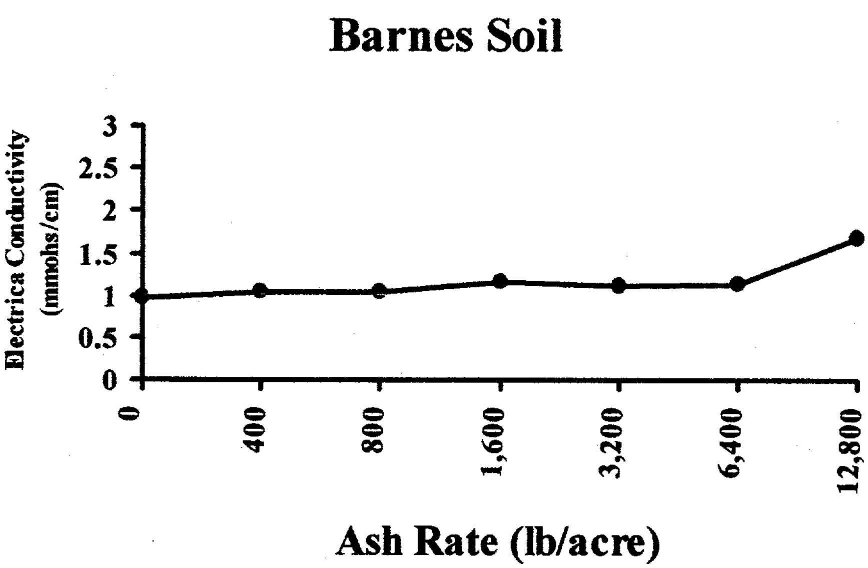
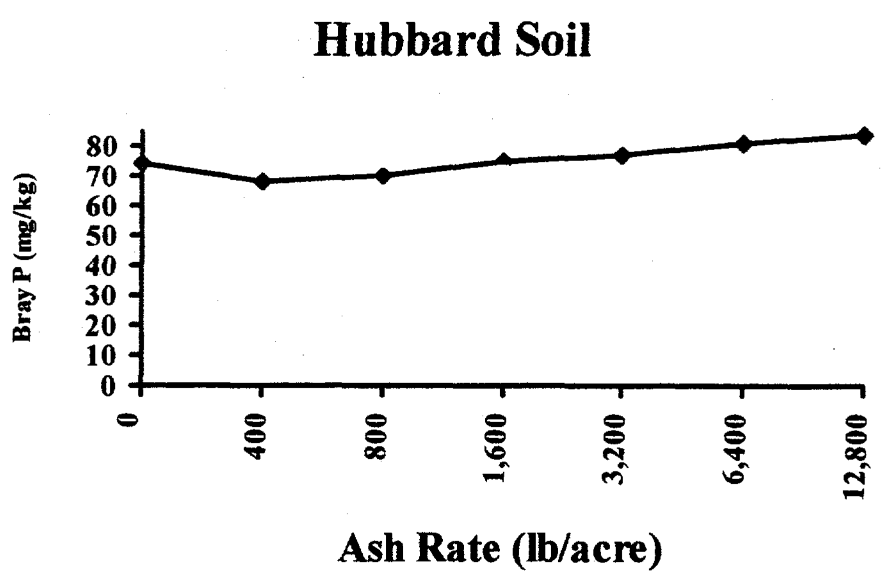
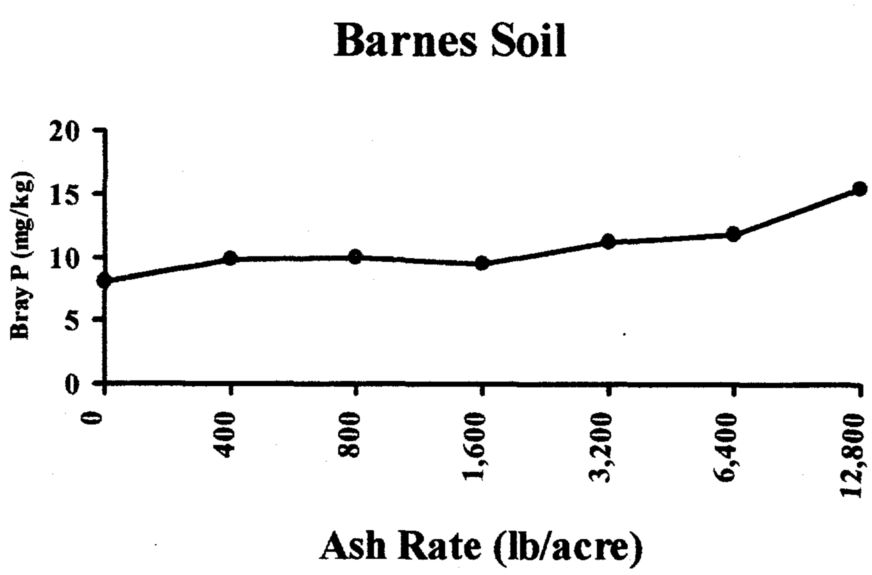


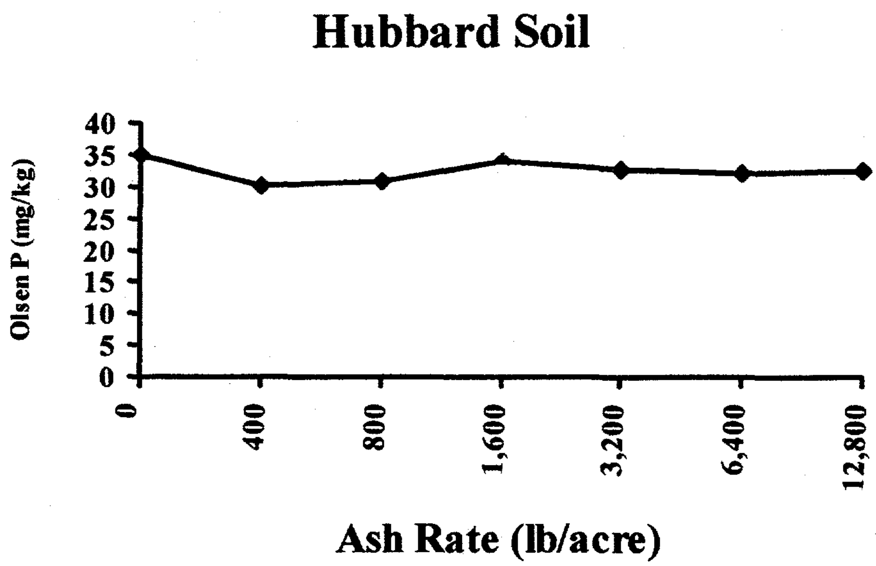
Figure 9. Effect of ash on P extracted by Bray method from soil.

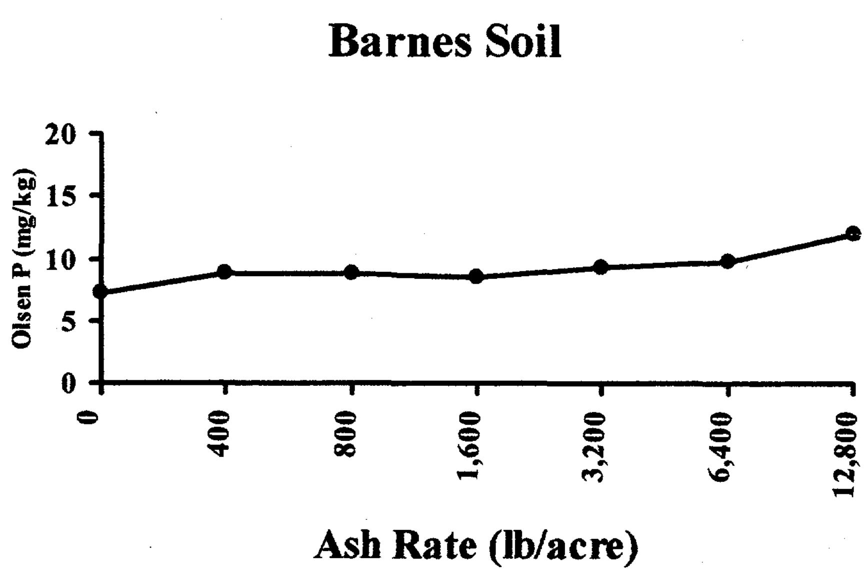




Note: The small square denotes the level of Bray P in soil that received inorganic P at the rate equivalent to the amount of P supplied by the respective ash treatment.

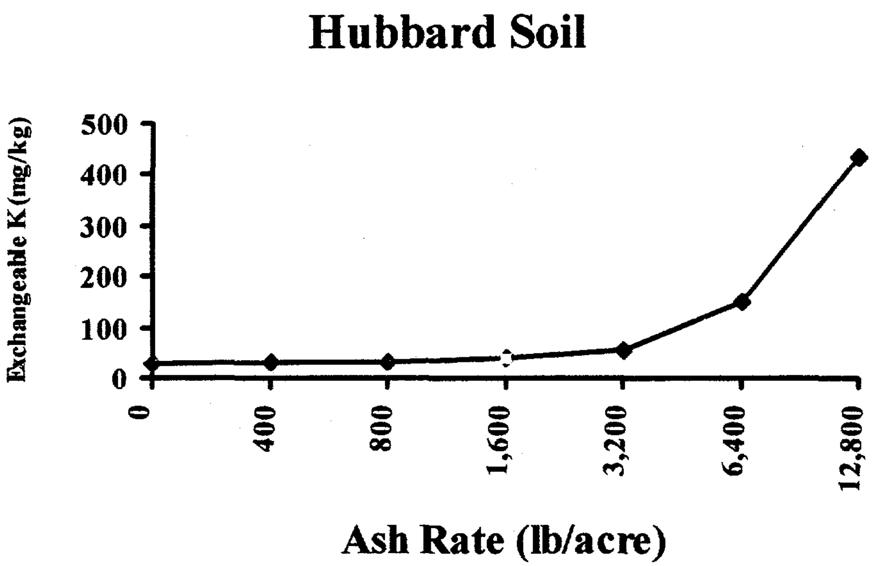
Figure 10. Effect of ash on P extracted by Olsen method from soil.

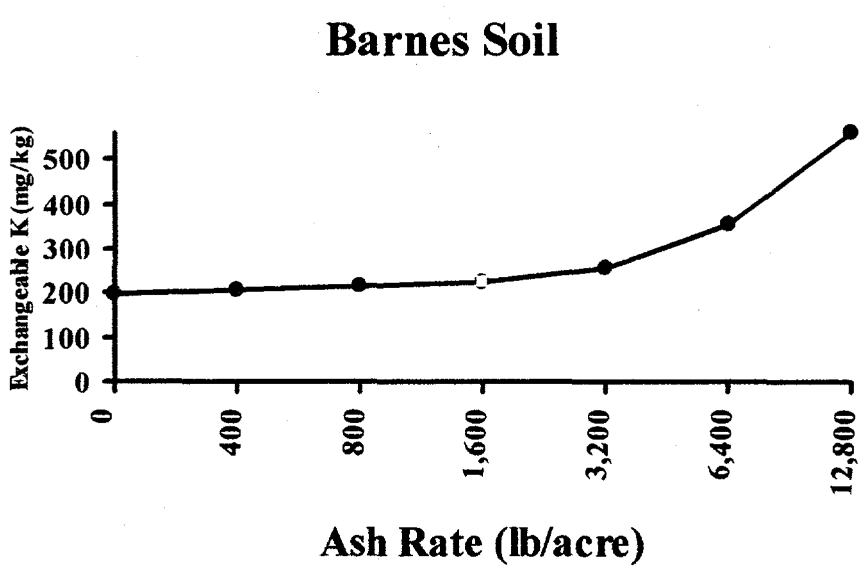




Note: The small square denotes the level of Bray P in soil that received inorganic P at the rate equivalent to the amount of P supplied by the respective ash treatment.

Figure 11. Effect of ash on exchangeable K.





Note: the small square denotes the concentration of K in soil that received inorganic fertilizer equivalent to that ash rate.

Attachment 2.

Biomass Energy Production Effects on Environment: Surface and Ground Water Quality

Project Report for Task III
Biomass Energy Production Effects on Environment
Sub Task: Surface and Ground Water Quality

Principal Investigator(s) and support staff

Dept. of Soil Water and Climate: John Moncrief, Satish Gupta, Padam Sharma, Ed Dorsey, Juanjuan Xia

West Central Experiment Station: George Nelson, Dave Luethard, Carlos Bright

Scope of Work and Progress:

Watershed Study at West Central Experiment Station (WCES) at Morris

Four field size watersheds established in 1996 at West Central Experiment Station field E-5 in Morris are continuously monitored to measure runoff and water quality from alfalfa and corn-soybean fields. Figure 1 shows the general layout of the study area. Two corner fields has been cropped with alfalfa since 1996, and the central two fields were planted with corn in 1996 and soybean in 1997. Earthen berms at the lower boundaries of each field guide runoff water towards a pair of specially constructed fiberglass flumes. We use a pair of 6-inch Parshall and a 4-inch Palmer-Bowlus flumes to accommodate both large and small runoff expected to occur during snow-melt and summer rainfall events.

Along the side of the two flumes at each field, a specially constructed instrument shelter houses a data logger and a water sampler. A pressure sensor at the flume measures the height of water in the flumes. A recording raingage and thermocouples are also connected to the data-logger to measure rainfall and temperature. A computer program written for the data-logger sends signal to instruments every minute and measures the height of water in each flume. Whenever a minimum depth of flow is recorded, the program also triggers a water quality sampler to periodically grab runoff samples for water quality.

The collected runoff water samples are brought to Department of Soil, Water and Climate water quality laboratory in St. Paul and analyzed for biochemical oxygen demand (BOD), sediment load, chemical oxygen demand (COD), dissolved molybdate reactive phosphorus (DMRP), bioavailable phosphorus, total phosphorus, ammonium, and nitrate nitrogen.

Figure 2 shows the comparison of temperature and cumulative runoff from snow-melt during March-April 1997 and during February 1998. During both years, the alfalfa stubble retained more snow on the surface than either corn or soybean residue. There was about 8 times more snow on alfalfa ground last year due to snow drifts occurring from adjoining fields. Combined with rainfall during the snow-melt periods, on both alfalfa and corn-soybean fields, there was about five times more water available for runoff and infiltration last year.

The average spring-melt runoff from the two alfalfa fields were higher than either corn or soybean fields during both the years. While about half of total water on the surface was recorded as runoff during last year's snow-melt period, almost all of the water available on the surface was measured as runoff from the alfalfa fields this year. While alfalfa fields show negligible infiltration, about 57% of total water infiltrated from fields following a soybean crop in 1997. Two factors may have contributed to this result. First, alfalfa fields were still frozen during the February snow-melt period this year. The alfalfa roots are still alive and occupy the macropores, and the remaining water filled pore space is frozen. Second, the soybean fields may contain more open macropores due to decay of roots since soybean harvest. Contour application of anhydrous ammonia during Fall of 1997 also disturbed the soil in soybean fields. The low residue cover on soybean fields may have also facilitated an early thawing of soil.

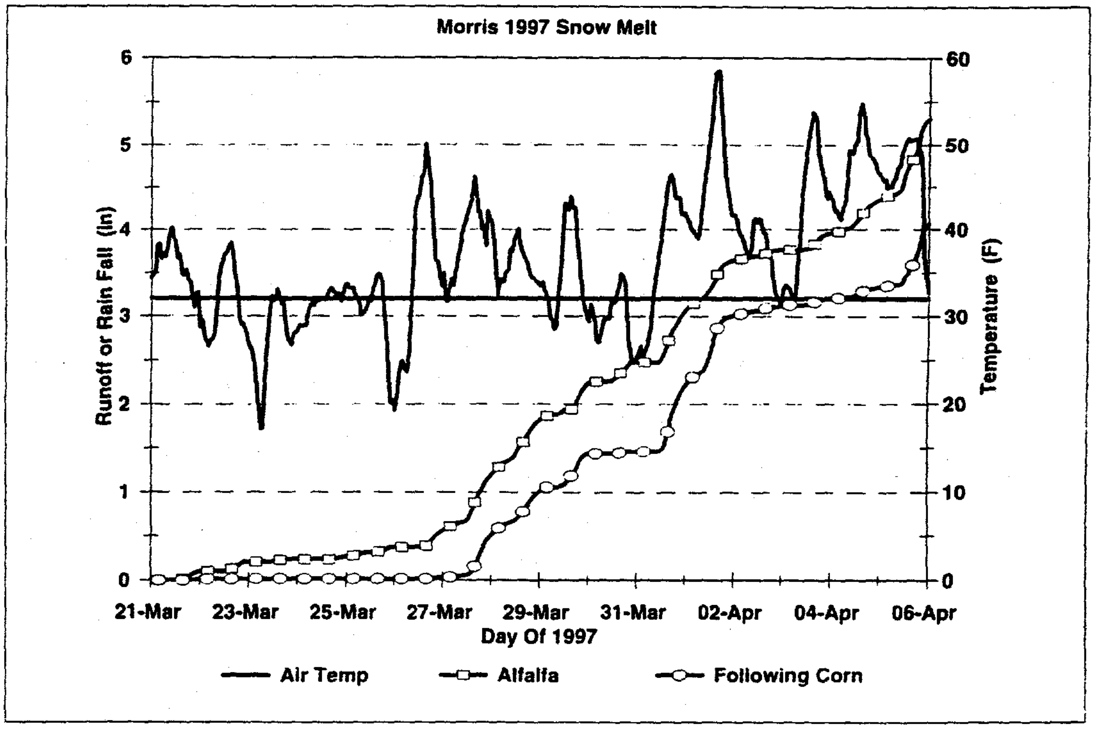
The product of the watershed study is an updated continuous weather, runoff and pollutant loading database that would be needed to evaluate the (a) environmental effects of alfalfa vs. corn-soybean cropping systems, and (b) validate simulation model(s) to be used to evaluate long term effects of such cropping systems.

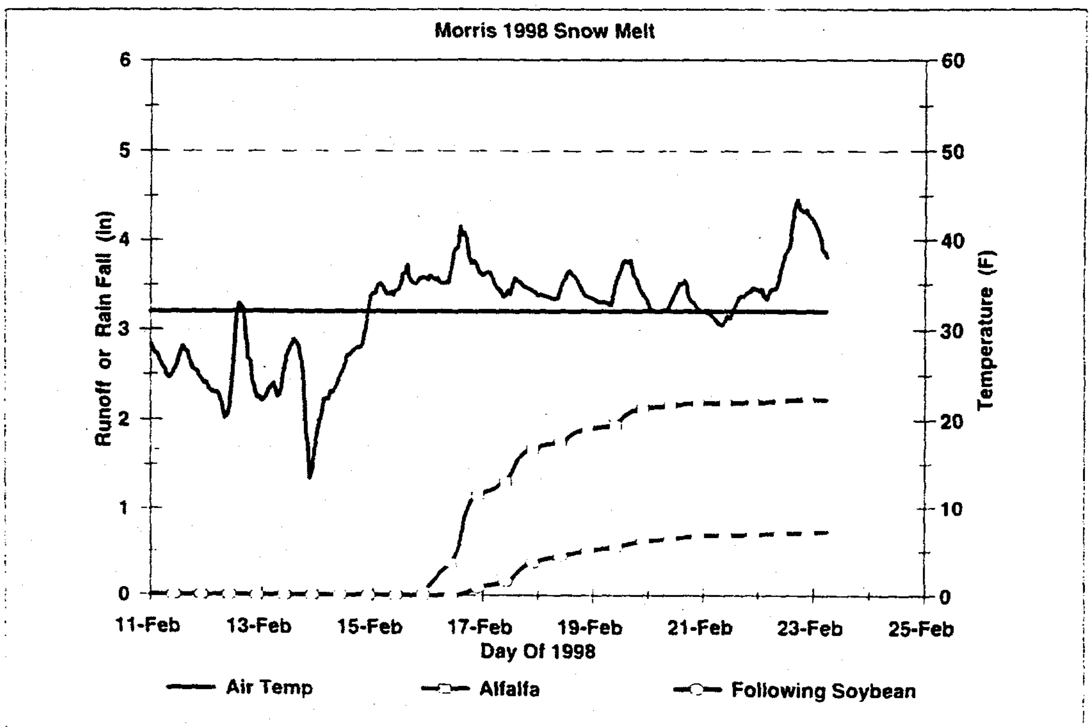
Simulation Study:

To evaluate long term effects of corn-soybean vs. alfalfa cropping system, we have selected to use EPIC (Erosion Productivity Impact Calculator) model. EPIC is a continuous simulation model that uses similar algorithm to determine the effect of management strategies on agricultural production and environment from small areas.

The EPIC program code and model documentation has been acquisitioned with technical support from model developers at USDA-ARS, Temple, Texas. The model is being tested for typical weather and soil parameters from Morris, MN. A generic management scenario for corn-soybean and alfalfa-corn rotations is being developed to use in simulation of long term production and environmental effects of the two cropping systems. The database developed from the watershed study will also be used to validate the model for short term predictions.

Fig. 2: Snowmelt runoff hydrographs for 1997 and 1998.





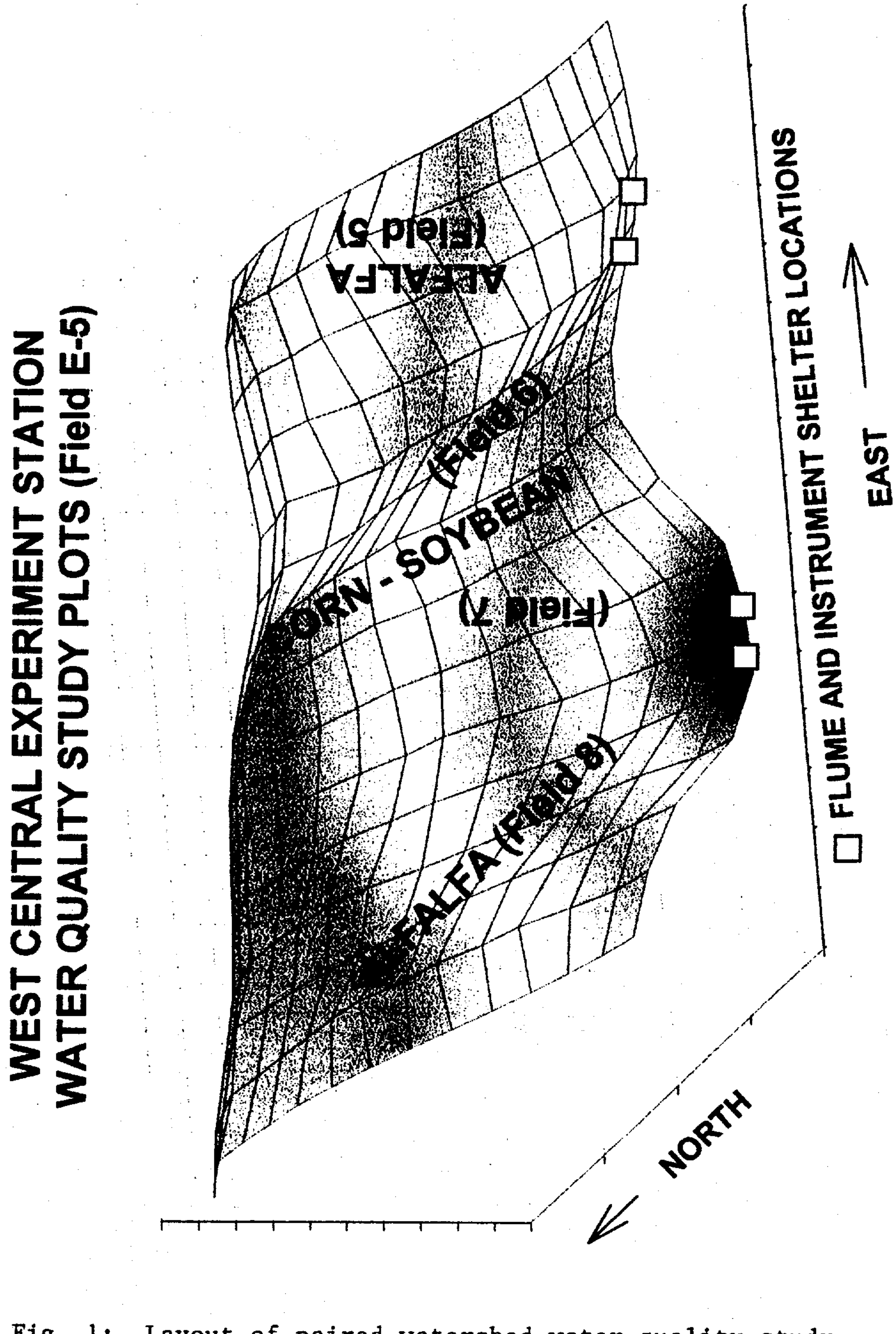


Fig. 1: Layout of paired watershed water quality study site at Morris

Minnesota Agri-Power Phase IA
University of Minnesota Report to MnVAP
Quarterly Report (January through March 1998)

Task 1. Feeding Trials and Analysis

Dairy Research

Dairy research has been completed and a final report is being prepared.

Beef Research

Objectives

Alfalfa leaf meal is a byproduct of the separation of stems and leaves of alfalfa hay. Stems will be used for power generation. Leaves can be processed as a pellet or meal to be fed to livestock. Previous studies with alfalfa leaf meal (ALM) indicated that it could substitute more commonly used protein sources, namely soybean meal (SBM), in diets of growing feedlot cattle. The current studies are being conducted to evaluate effects of substituting all of SBM with ALM in receiving rations, and substituting some or all of SBM with ALM in finishing.

Receiving Study

One-hundred-forty steers were trucked to the St. Paul Campus from Fort Pierre, SD. Cattle lost approximately 6% of their original body weight. Cattle were fed a common ration containing corn silage and corn. Their supplemental protein source was either ALM or SBM. Diets contained sufficient energy and protein to achieve gains of 2.5 lb/head/day. Cattle were weighed, bled and processed (vaccination, dewormer and ear tag) at the start of the trial. Seven pens were allocated to each of the two treatments (100% SBM vs 10% ALM). Cattle were weighed every 7 d. On day 56, cattle were taken off trial. Currently, data from this study are being evaluated.

Finishing Study

One-hundred-twelve steers that had been received at Crookston were allocated to one of four treatments. Treatments consist of varying the amount of ALM that substituted SBM in supplements to corn-barley finishing diets. Alfalfa leaf meal comprises 0, 33, 66 or 100% of the supplemental protein; the balance was SBM. Steers are fed diets for maximum gain and feed efficiency. Cattle have been on trial for over 120 days. Gains appear to be over 4 lb./head/day regardless of treatment. Additional data are to be collected until cattle are processed around June.

Turkey Research

Samples of leaf meal (ALM) were obtained with the cooperation of AURI (Rose Patzer) that varied in proportion of leaf(L) and stem (S). The samples were designated as 25L:75S; 50L:50S, 75L:25S, and 100L. Preliminary analyses provided by AURI showed that respective protein contents(%) were 14.2, 17.9, 21.1, and 26; respective crude fiber contents (%) were 37.5, 31, 25.4, and 18.5.

To determine available energy content, the true metabolizable energy assay as developed by Sibbald

(1983) was used. Young turkeys (6-8 weeks of age) were used in two assays. The turkeys were placed in individual cages and allowed to acclimate for 5 days. The turkeys were fasted for 36 hrs and precision fed 35g of the test ALM samples. Control turkeys were fed a small amount of glucose. Excreta was collected for 60 hrs after feeding. After the collection period ended, the excreta was quantitatively collected and all material was freeze dried. Each sample was allowed to reach equilibrium with atmospheric conditions and then weighed. The excreta was finely ground and analyzed for moisture, protein and gross energy. Samples of the fed ALM were treated in similar manner.

The true metabolizable energy content (nitrogen corrected) of the ALM appeared correlated to the portion of leaf present in the sample. PRELIMINARY TME contents (kcal/kg as fed) were 1100, 1534, 1592 and 2150 for the samples containing the 25, 50, 75 and 100% leaf, respectively. Results should be considered preliminary as some variation does exist and the assay needs to be rerun.

However, it does appear that the proportion of leaf in the meal has a significant effect on energy content of the material for turkeys.

Once assay values are established, regression equations will be determined so the TME content can be predicted based on the protein and/or fiber content of the meal.

<u>Sheep Research</u>

The sheep feeding trial is completed. Data is still under analysis and a final report will be prepared.

Task 2. Alfalfa Feedstock Variability Analysis

Work on this task is continuing. An ash equation for leaf and stem material has been developed and work on an equation for ALM is underway. Performed diagnostic tests to flag irregularities in data sets. Conducted a more sophisticated statistical analysis on season total yield and season average forage quality. Developed statistical models for analysis of within-season changes in alfalfa yield and forage quality. Conducted preliminary economic analysis of harvest regimes using three different methods of calculating dollar returns.

Turned a portion of the Biomass stem samples in for mineral analysis. Used the results to create mineral equations for phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), aluminum (Al), iron (Fe), sodium (Na), zinc (Zn), copper (Cu), boron (B), lead (Pb), nickel (Ni), chromium (Cr), and cadmium (Cd). Nine samples were also analyzed for sulfur (S). They had a range of 0.08 to 0.15% sulfur. These were then used to analyze all the Biomass 97 stem samples. Statistical analysis is in process.

Analyzed leaf/stem separated at MnVAP using their new apparatus (scalper) and discovered that dirt is being concentrated in the leaves. This gives very high ash values and therefore the current quality equations gave incorrect fiber values. Developed new equations to use on leaf, stem and whole plant samples suspected of being contaminated. Put the equations along with a new output form on MnVAP's computer. These equations will be updated as more samples are received. We feel that as

MnVAP's separating process evolves this problem will be reduced or eliminated.

Summarized MnVAP hays from 2/97-10/97, 10/97-2/98 and 7/96-2/98 In the period since MnVAP began using their NIR (7/96-2/98), 2431 hay samples have been analyzed. The following table gives the minimum, maximum, and average relative feed value (RFV) and percentage crude protein (CP) for that period. Within the same range of CP the RFV can vary tremendously. This means that hay with the same CP value, when fed to livestock, could cause a large difference in animal performance. We are using this data to help MnVAP understand the importance of paying on more than just CP values.

Max	Min	Average
% CP	% CP	% CP
27.55	5.80	19.15
RFV	RFV	RFV
222	62	114

A technical report "Alfalfa Stem Variability" is attached (Attachment 1).

Task 3. Advanced Product Research

This recent section of work is analysis of the water floatation-sedimentation products, from the ALM grind received from the MAP project.

In water floatation (rough diagram in the previous report), if the grind is given a short exposure to water, floated for about 0.5 to 1 minute, the stem particles tend to float and be removed off the top. The more dense leaf particles sink, to be removed at the bottom. Floating particles are the cellulose-rich particles, and do not wet very well. Sinking (sedimenting, bottoming) particles are more dense, protein-rich particles.

In this section of work, the protein rich (bottom) particles were extracted in the cold by acetone, and also by warm solvent, again acetone, to get a perspective on tocopherol (vitamin E, α-tocopherol), presence of nitrogenous (alkaloid related) compounds. This was done with 3 samples by mass spectrometry (our central instrument facility, Tom Krick, supervisor for NMR and mass spectrometry). There is some evidence for presence of antioxidant (vitamin E) related compounds in the cold acetone interaction, but not in the hot. This contrast was expected because under warm conditions, with any air in the extraction system, oxidation-sensitive compounds like vitamin E and related compounds are destroyed by oxidation.

These extracts contain phenolics, giving back a lot of signal by the Folin test, which detects tannin-related compounds. The phenolics (tannin related materials) tend to act as anti-nutritional compounds towards animals. Therefore inexpensive ways to get them out are of some priority. One extraction for them was carried out, using mild alkali, about 0.01 N alkali, to make them water-soluble. It is relatively easy to analyze for phenolic compounds with several kinds of assays, including ferric ion, and the traditional Folin method. Roughly, the bottom sedimenting material is 1 to 2% phenolic compounds in the rapidly extracting (by alkali) fraction. However, it is necessary to carry out more of these, to reach a conclusion. One of the future tasks should be to see if ruminant digestion can either withstand these sorts of compounds in ruminant anaerobic and micro-aerobic conditions or where, at some level, they inhibit any of the enzymes necessary for ruminant digestions.

The nitrogen containing (alkaloid related) fractions come out of the bottom-sedimenting (crude protein) material, in many extraction conditions. However they are more susceptible to lower pH leaching, as in silage making, than to high pH extraction. We are preparing to get perspectives on these kinds of compounds, by spectroscopic analysis. Because of some work on another project, we are set up for human red cell assays to scan for bioactivity of such compounds. The human red cell changes shape (seen in microscopy) in response to nitrogenous compounds, and to phenolic and lipid compounds that bind to it. These are relatively easy assays to carry out. That is, to gauge response to alfalfa-derived compounds based on the one, readily accessible human cell, the red cell.

In the previous report, it was noted that about 3% of alfalfa leaf (protein fraction) weight appear to be proteases. The proteases should be value-added products, if they can be readily removed, and if they are stable. It appears that the alfalfa proteases are stable (for several days) in acid. However, they quickly autolyze, destroy themselves, in alkaline (above pH7) exposure.

Task 4. Development of Biomass-type Alfalfa Varieties

Crossing schemes for the alfalfa biomass populations are nearly completed. Non-lodging large stemmed types have been crossed to disease resistant populations as well as populations with increased leaf yield. Crosses have been repeated to increase seed availability for demonstration plots to be planted at Lamberton and Morris, MN in the spring of 1998. The first of two populations has been selected for resistance to Phytophthora root rot and crosses will be made among the resistant plants this spring. As soon as seed is available a second population will be selected for Phytophthora root rot resistance.

Preliminary analyses from a management study examining the effects of plant population density and cutting frequency on leaf and stem yield of a diverse group of alfalfa genetic sources has been completed. The preliminary results from one location in one year suggest that different combinations of population density and cutting frequency has a major influence on both leaf and stem yield in alfalfa. A combination of 16 plants per ft^2 and a two-harvest management system had the highest leaf and stem yields on a land area unit basis. This study will be repeated again at two locations in 1998.

Task 5. Best Management Practices

Best Management Practices-Planning is underway for Spring planting of management trials.

Analysis of the 1997 alfalfa variety trial material continues and results are reported under Alfalfa Feedstock Variability Analysis.

Task 6. Alternative Biomass Resources

A draft report "Alternative Biomass Resources" is attached (Attachment 2).

Task 7. Community Education

Education Initiative – "Energy for Life"

This educational initiative expands our thinking about energy to include renewable energy and how our use of energy impacts our environment. "Energy for Life" is being introduced into schools and communities in the Minnesota River Basin and around the world as the result of a collaboration with Hamline University, the Minnesota Department of Agriculture, the Minnesota Extension Service, the 4-H program, and a wide range of business and civic leaders from the region. Students include farmers, ag professionals, teachers, and children of all ages.

An Ag Professional Training Seminar was held February 10th and 11th and four alfalfa informational meetings were held on February 17th and 18th. About 25 people attended each informational meeting. Speakers included Neal Martin, Professor, Department of Agronomy and Plant Genetics and Extension Forage Specialist, Craig Sheaffer, Professor, Department of Agronomy and Plant Genetics, Greg Cuomo, Forage Specialist, West Central Experiment Station, Bruce Potter, IPM Specialist, Southwest Experiment Station, and Rich Kvols, Extension Educator, Yellow Medicine County. Rich Kvols has received several requests for follow-up education from producers who attended the meetings.

Rich Kvols is also continuing to contact other agricultural organizations to form producer education partnerships, is working to educate new alfalfa growers and is working with implement dealers to hold a Hay Days demonstration in June. He is also working with growers to establish demonstrations on their farms.

Used public forums to teach proper hay sampling technique, to teach forage quality test interpretation and to provide free analysis of hay for producers in Southwestern Minnesota.

The Energy Odyssey on-line educational program began March 9th. A study guide was developed and distributed to the educators participating in Hamline University's Rivers of Life: Mississippi Adventure. The WWW address for the Rivers of Life: Mississippi Adventure site, which is hosting Energy Odyssey, is http://cgee.hamline.edu/rivers98/index.html.

Rivers of Life: Mississippi River Adventure is an online distance-learning program that runs for 10 weeks from mid-March to mid-May. For 1998, the dates are March 9 to May 15. Currently, the program is in its sixth week and has a total of 236 educators subscribed to the program. Rivers of Life has four program areas: "Energy Odyssey", "Steamer Trunk", "Chasing the Flood", and "Rivers of Time".

Rivers of Life provides conference centers on-line where students and teachers can post comments and questions for each of the program areas. Each of the four conference centers have been active with questions from teachers and students. In addition, the online experts have addressed wide-ranging questions from students and teachers in the U.S. and Russia.

The "Rivers of Life: Mississippi Adventure Study Guide" is attached (Attachment 3).

Task 8. Environmental Modeling

Cost-sharing partnerships have been developed to accomplish Task 8 objectives as required under the cooperative agreement. A comprehensive work plan and letters of commitment are in final review.

Task 9. Economic Benefits for Rural Communities

The development and support for state and local policies that encourage the development and implementation of biomass production and processing systems has been initiated with the Hubert H. Humphrey Institute for Public Affairs and with the State Department of Trade and Economic Development. This task has been suspended.

Task 10. Research Coordination

Performed monthly accounting, reporting, and research coordinating tasks under MnVAP's Cooperative Research Agreement with the University of Minnesota. Coordinated team meetings; prepared and submitted monthly expense and progress reports for the University through February 1998; submitted University and MnVAP October-December 1997 Quarterly Reports; reconciled research accounts and verified University expenses.

Attachment 1.

Alfalfa Stem Variability

Alfalfa Stem Variability **Summary Status Report 3/31/1998**

Analysis of alfalfa stem variability is being conducted to determine the extent of variation in alfalfa stem material relative to its as the primary fuel for pressurized gasification. Initial results and a review of existing information on the compositional variability in alfalfa are included in this brief summary report.

Crude Protein (CP), Acid Detergent Fiber (ADF), and Neutral Detergent Fiber (NDF), were determined using near infrared reflectance spectroscopy (NIRS) analysis of leaf, stem, and whole plant samples from three locations over two seasons (1996 and 1997).

CP, ADF, and NDF are compositional criteria that were developed to assess the variability of alfalfa as a livestock feed, however, these characteristics are also indicative of alfalfa variability for use as fuel.

> Crude Protein (CP) is predicted based on total nitrogen content of the sample. Total plant nitrogen times 6.25 estimates total crude protein.
>
> Acid Detergent Fiber (ADF) is a measure of the poorly digested portion of the plant cell wall (primarily lignin and cellulose).
>
> Neutral Detergent Fiber (NDF) is an indicator of total cell wall (lignin, cellulose, and hemicellulose) and may correlate better with the heating value of the material. Correlation of NIRS analysis to specific fuel characteristics is ongoing.

Alfalfa stem variability based on harvest regime was determined at three locations in Minnesota. Alfalfa was harvested at the mid-bud stage, at early flower, and at late flower. Results indicate that as alfalfa matures (mid-bud > early flower > late flower), crude protein of stems declines, ADF and NDF increase.

Results (Tables 1 and 2) indicate that as alfalfa matures, crude protein of the stem declined from 12.7 to 11.2 to 9.0 (1996) and from 14.9 to 11.5 to 10.4 (1997). Dividing crude protein by 6.25 yields total nitrogen content which declined from 2.03 to 1.79 to 1.44 (1996) and from 2.38 to 1.84 to 1.66 (1997).

NDF (as an indicator of heating value) increased from 58.1 to 61.8 to 67.3 (1996) and from 56.9 to 61.3 to 65.6 (1997).

Figure 1 (page 3) is a scatter plot showing the relationship between nitrogen content and lignin content for alfalfa. As nitrogen content declines, lignin content tends to increase.

Alfalfa fuel composition may be expected to vary significantly based on both the degree of separation of leaf material from the stem fuel and by stage of alfalfa maturity at harvest.

Table 3 introduces additional variability resulting from the inclusion of grasses and other weeds in the alfalfa feedstock and from the effects of rain during harvest. Calcium, phosphorus, and potassium levels in whole alfalfa and the percent leaf material from these samples are also reported.

Pages 5 to 7 are excerpts from the 1994 Feasibility Study. Data collected during the winter of 1993/94 reports on a broader range of nutrients and nutritional characteristics (Table 4) as well as the elemental composition of alfalfa leaves and stems (Table 5). collected from on-farm storage.

Alfalfa Stem Analysis: Project Design Basis (page 8) reported by Dan King, SWEC on September 10, 1997, currently serves as the preliminary fuel design basis for the project

Alfalfa Properties (page 9) reported by Carbona presents a more detailed list of fuel characteristics for the "Loose Alfalfa Stem –February 1997" and "Pelletized Alfalfa Stem – April 1997" as the preliminary design basis fuel quality range.

Tables 6, 7, and 8 report the mineral composition of alfalfa stems harvested at three different levels of maturity (mid-bud, early flower, and late flower).

Tom Vivenzio, SWEC, provided the enclosed list of specific fuel characteristics of concern and the recommended method of analysis to evaluate fuel supply variability (page 11). Further stem evaluation is being conducted by C. Sheaffer and N. Martin, UofM, in cooperation with NREL and FETC.

Table 1. Seasonal means (1996) of selected varieties for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) in leaves, stems, and whole plants of alfalfa.

Entry	Leaf			Stem			Whole Plant		
	CP	ADF	NDF	**CP**	**ADF**	**NDF**	CP	ADF	NDF
	%								
Mid-Bud Harvest Regime†									
Rosemount, MN	32.1	16.2	20.1	**12.7**	**49.5**	**58.1**	22.9	31.7	37.2
Early Flower Harvest Regime									
Rosemount, MN	30.2	17.5	21.6	11.6	53.8	62.6	21.0	36.3	42.9
Morris, MN	31.1	16.0	19.5	10.8	52.7	61.9	21.1	34.0	39.3
Lamberton, MN	30.1	17.5	21.4	11.2	52.0	60.9	20.7	33.8	40.1
Mean				**11.2**	**52.8**	**61.8**			
Late Flower Harvest Regime									
Rosemount, MN	29.3	18.7	23.1	9.8	56.5	65.5	18.7	39.3	46.6
Morris, MN	27.5	18.5	22.3	8.7	59.1	69.0	16.7	41.2	48.3
Lamberton, MN	28.2	19.1	23.1	8.6	58.1	67.5	17.3	40.4	47.9
Mean				**9.0**	**57.9**	**67.3**			

† The mid-bud harvest regime was used at Rosemount only. The mid-bud means are included in this table for comparison

Table 2. Seasonal means (1997) of selected varieties for crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) in leaves, stems, and whole plants of alfalfa.

Entry	Leaf			Stem			Whole Plant		
	CP	ADF	NDF	**CP**	**ADF**	**NDF**	CP	ADF	NDF
	%								
				Mid-Bud Harvest Regime†					
Rosemount, MN	30.0	17.7	21.1	**14.9**	**47.5**	**56.9**	23.0	31.5	37.7
				Early Flower Harvest Regime					
Rosemount, MN	30.3	17.0	20.5	11.2	52.2	62.1	20.3	35.5	42.4
Morris, MN	29.8	16.4	19.5	11.8	51.3	61.1	21.0	33.5	39.8
Lamberton, MN	26.6	18.0	21.8	11.6	50.3	60.6	19.3	33.8	40.8
Mean				**11.5**	**51.4**	**61.3**			
				Late Flower Harvest Regime					
Rosemount, MN	26.3	20.0	24.8	10.4	56.7	67.2	16.2	43.5	51.9
Morris, MN	25.2	18.5	22.2	10.4	55.5	65.6	17.3	38.2	45.3
Lamberton, MN	25.4	19.1	22.9	10.5	54.0	64.0	16.8	39.4	46.8
Mean				**10.4**	**55.4**	**65.6**			

† The mid-bud harvest regime was used at Rosemount only. The mid-bud means are included in this table for comparison

FIGURE 1.

Variation in Alfalfa Composition

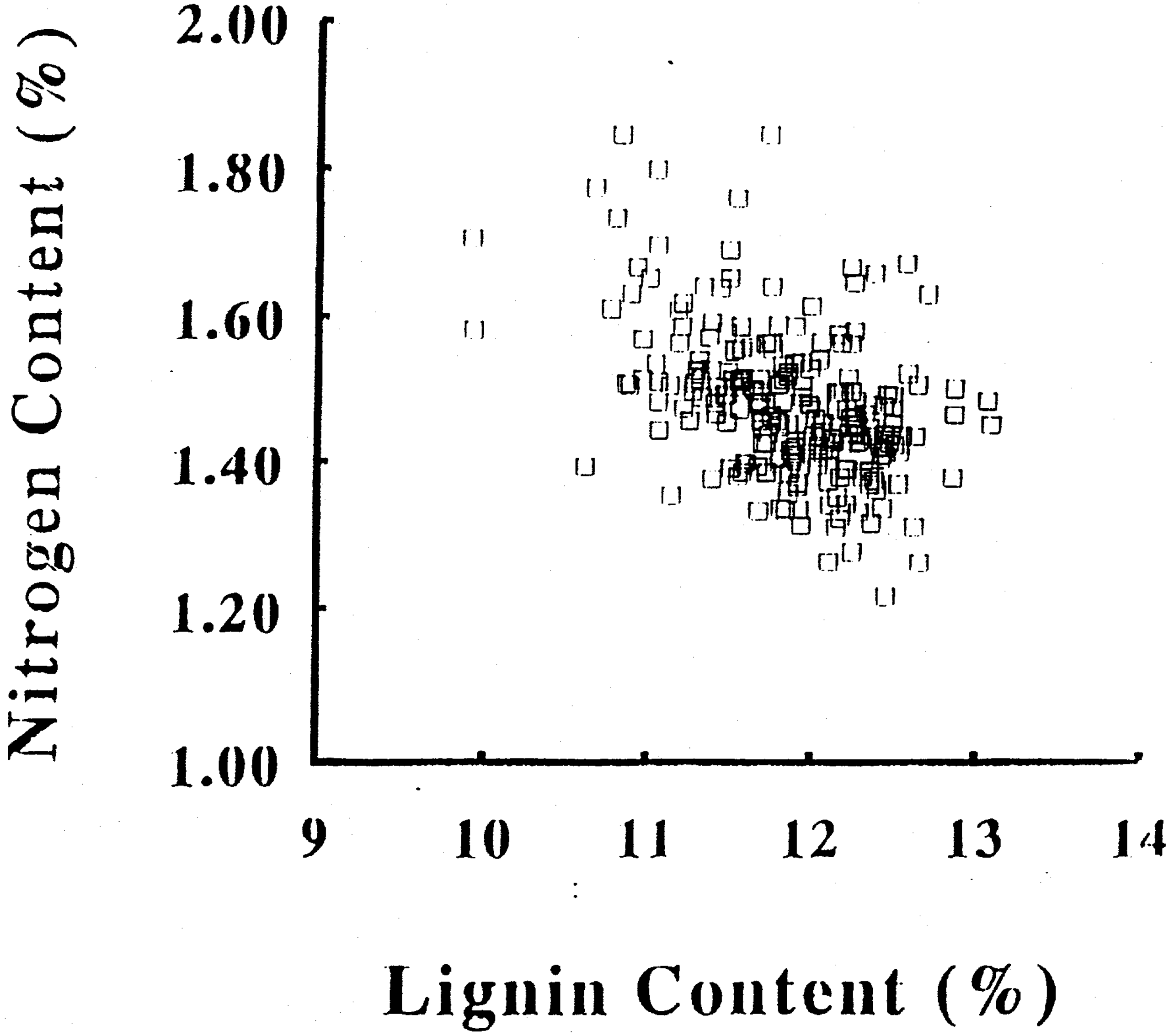


Table 3. Forage quality tests were conducted on hay samples from on-farm storage in the proposed biomass shed. Samples were collected from December 1993 to February of 1994. Results are given for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), percentage of leaf (% Leaf), calcium (Ca), phosphorus (P), and potassium (K).

Sample	CP	ADF	NDF	RFV	% Leaf	Ca	P	K
	------- % of dwt		--------	index	---------- % of dwt		----------	
Alfalfa & alfalfa grass mixtures (n=67)								
average	18.6	38.5	53.6	106	39.5	1.35	.30	2.56
max.	24.0	57.6	77.5	157	54.5	1.61	.41	3.34
min.	8.2	28.2	39.7	53	7.7	.67	.07	.33
Alfalfa (n=29)								
average	19.8	36.4	50.1	115	42.5	1.42	.31	2.73
Alfalfa-grass mixture (n=27)								
average	17.6	39.4	55.7	101	37.0	1.27	.30	2.48
1st cut (n=7)								
average	19.5	38.8	52.1	110	42.9	1.47	.30	2.60
LR (2)	18.0	42.6	57.3	93	40.2	1.41	.29	2.42
SQ (5)	20.0	37.3	50.0	116	44.0	1.50	.31	2.68
2nd cut (n=11)								
average	20.2	37.4	52.8	107	39.5	1.37	.33	2.77
LR(4)	20.0	36.68	52.4	107	38.7	1.36	.32	2.75
SQ (7)	20.2	37.7	52.2	107	40.0	1.38	.33	2.78
3rd cut (n=11)								
average	19.6	34.0	46.6	128	45.3	1.42	.30	2.76
LR (2)	16.6	40.8	54.0	105	36.4	1.29	.28	2.55
SQ (9)	20.3	32.5	45.0	133	47.3	1.45	.31	2.81
Rain damaged (n=30)								
average	19.8	36.7	50.3	114	42.2	1.41	.31	2.74
dry storage (19)	20.2	34.7	47.4	123	45.4	1.44	.31	2.81
no cover (11)	19.1	40.0	55.4	99	36.8	1.35	.31	2.61

Protocol

Alfalfa samples were analyzed for the following nutrients and nutritonal characteristics:

Crude Protein (CP)	total plant nitrogen x 6.25
Acid Detergent Insoluble Nitrogen (ADIN)	a measure of the protein which is heat damaged and unavailable for digestion
Neutral Detergent Fiber (NDF)	a measure of the poorly digested portion of the plant cell wall, related to intake potential of hay
Acid Detergent Fiber (ADF)	another measure of the most poorly digested portion of the cell wall, related to total hay digestibility
Acid Detergent Lignin (ADL)	a measure of lignin, ~ 1/3 lower than Klason lignin concentration of legumes, related to digestibility
In Vitro Dry Matter Digestibility (IVDMD)	a test tube measurement of total digestibility using rumen microorganisms from a cow
Ether Extract (EE)	a measure of total plant lipid
Ash	the inorganic constituents of the biomass after combustion at 450°C

Minerals . . calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), sulfur (S), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), zinc (Zn), aluminum (Al), boron (B), cadmium (Cd), nickel (Ni), and Lead (Pb)

All analyses were done in duplicate on each bale's total leaf meal and stem sample. A sample of the pan leaf fraction from each bale was also analyzed to determine how much higher in quality this purer leaf material was. The data were analyzed by analysis of variance to compare the different hay quality grade groups. The least significant difference method was used to compare quality grade means for those traits having a significant F-test.

Table Nutrient composition and digestibility of alfalfa leaves and stems.

Component[1]	Leaves		Stems
	Total	Pan	
CP, % DM	25.2	28.1	12.1*
ADIN, % N	6.3*	6.4*	12.7*
NDF, % DM	36.0*	32.9*	63.1*
ADF, % DM	21.5*	17.6*	47.9*
ADL, % DM	5.3*	5.5*	10.7*
EE, % DM	2.9	3.0	1.4
Ash, % DM	11.3*	12.8	6.9
IVDMD, %	73.5*	73.5*	53.8*

[1] Abbreviations defined in text.

* Significant variation found among the hay quality grades (P<0.05).

Results

Table 4. lists the mean nutrient composition, across quality grades for the alfalfa leaf meal, the pan fraction of leaf, and stem material. Mineral composition is shown in **Table** 5. As expected, the pan leaf fraction, which contained less stem material, was higher in quality (more protein, less fiber, higher digestibility) than the total leaf meal. For all alfalfa fractions, the significant hay quality grade differences observed resulted from declining quality (less protein, more fiber, lower digestibility) as the alfalfa samples went from prime to standard five quality grade. **However, the CP content of the alfalfa leaf meal did not change significantly (26.0 to 22.7 %, P>0.05) among hay quality grades, suggesting that all alfalfa leaves will have similar protein content. The increase in fiber content (26.1 to 48.4%, P<0.05) and decline in digestibility (78.5 to 61.0%, P<0.05) indicate that energy content of the leaf meal will be lower from poorer quality hay. These results indicate that leaf meal from hay is more variable than the quality of alfalfa leaves on the plant prior to harvest.**

Table 5 Elemental composition of alfalfa leaves and stems.

Element	Leaves		Stems
	Total	Pan	
Ca, % DM	1.88	2.29	0.70
P, % DM	0.33	0.34	0.24
Mg, % DM	0.37	0.40	0.20*
K, % DM	2.31*	2.04*	2.18
Na, % DM	0.04	0.04	0.05
S, % DM	0.32*	0.36*	0.12
Fe, ppm	184.18	288.92	56.13
Mn, ppm	63.44	88.35	19.78
Cu, ppm	8.01	9.11	6.62
Cr, ppm	0.81	0.94	0.47
Zn, ppm	24.94	28.23	16.46*
Al, ppm	141.05	241.54	37.04
B, ppm	42.91*	51.86*	18.67*
Cd, ppm	0.17	0.20	0.11
Ni, ppm	2.28	2.56	1.34
Pb, ppm	1.22	2.39	0.51

* Significant variation found among the hay quality grades ($P<0.05$).

Data from the Joint US - Canadian Feed Composition Tables for alfalfa leaf meal indicate a CP content of 30%, NDF of 20%, ADF of 15%, Ca of 2.5%, and P of 0.27%. The quality of the total leaf meal and the pan leaf fraction from our study was lower than these published data. Other data in the scientific literature indicate that the 30% CP and 20% NDF values for pure leaf meal are correct (Albrecht et al., 1987; Hatfield et al., 1994). The fact that our values are lower, plus the visual observations made during the separation process, indicate that the separation method we used was inadequate to achieve a pure leaf meal. **This lack of complete elimination of stems from the leaf meal will negatively impact the feeding value of this product. As for leaf yield, the industrial separation technology utilized will have a major impact on the economic value of the leaf meal by-product from this biomass energy system.**

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ALFALFA STEM ANALYSIS
PROJECT DESIGN BASIS

Carbona is initiating the preliminary design of the gasification plant and has asked us for project design basis information including the variation in the alfalfa stem composition. Obtaining data on the variability in composition is one of the subtasks in the Phase I extension proposal. To our knowledge the only analyses available at present are those performed by VTT as part of the gasification test program. VTT analyzed both the loose stem material and the pelletized stem material and determined the analyses to be as follows:

Constituent, Dry Basis Weight %	Loose Alfalfa Stem	Pelletized Alfalfa Stem
Carbon	45.8	45.3
Hydrogen	5.4	5.55
Nitrogen	2.2	2.8
Sulfur	0.1	0.22
Ash	5.0	9.2

As has been previously discussed at the project meeting in June, the analysis of the loose material is consistent with the alfalfa composition data presented in the LOI report. The stem analysis showed significantly higher concentrations of nitrogen, sulfur and ash.

We have instructed Carbona to use the above values as the expected range in composition. If MnVAP has any additional analytical data to establish an alfalfa stem specification, please let us know as soon as possible. Since the gasification test program established the gasifier operating temperature, the only real critical parameter affecting Carbona's design work at this point is the maximum ash content. However, the sulfur and nitrogen contents will have a significant impact on the design of the power plant heat recovery steam generator and on the plant air emissions.

If you have any questions, please call.

Very truly yours,

Dan King

Daniel S. King
Project Manager

cc: J.Patel - Carbona
C.Hanson

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Alfalfa Properties / I

Fuel	loose alfalfa		pelletized	
	February 1997		April 1997	
Proximate analysis				
moisture when analyzed, %w	12.0	by TGA	11.6	DIN 51718
ash content @ 815 C/1500 F, %w (d.b.)	5.0	DIN 51719	9.2	DIN 51719
volatile matter, %w (d.b.)	75.8	DIN 51720	74.4	DIN 51720
Ultimate analysis				
carbon, %w (d.b.)	45.8	LECO CHN-600	45.3	ASTMD5373
hydrogen, %w (d.b.)	5.4	LECO CHN-600	5.55	ASTMD5373
nitrogen, %w (d.b.)	2.2	LECO CHN-600	2.8	ASTMD5373
sulfur, %w (d.b.)	0.1	ASTMD 4239	0.22	ASTMD4239
oxygen, %w (d.b.)	44.4	by difference	37.08	by difference
chlorine, mg/kg (d.b.)	3920	mg/kg dry fuel,		
potassium, mg/kg (d.b.)	15940	mg/kg=ppmw		
sodium, mg/kg (d.b.)	960			
Heating Value				
Higher Heating Value, kJ/kg (d.b.)	18400	DIN 51900	18200	DIN 51900
Lower Heating Value, kJ/kg (d.b.)	17200	DIN 51900	16995	DIN 51900
Higher Heating Value, Btu/lb(d.b.)	7910		7825	
Lower Heating Value, Btu/lb(d.b.)	7395		7307	

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CARBONA

MINERAL COMPOSITION OF ALFALFA STEMS

The tables below report the mineral composition of alfalfa stems harvested at three different maturity stages: mid-bud, early flower, and late flower. Most Minnesota alfalfa fields are currently harvested at the early flower stage. Determination of statistically valid compositional differences is currently underway.

Table 6. Mineral composition of alfalfa stems harvested at the mid-bud (vegetative) stage

Mineral	Mean	Minimum	Maximum	Range
P %	0.27	0.21	0.38	0.17
K %	2.48	2.02	3.23	1.21
Ca %	0.72	0.63	0.87	0.24
Mg %	0.24	0.15	0.33	0.18
Mn ppm	12	9	18	9
Al ppm	44	0	191	191
Fe ppm	46	36	65	29
Na ppm	433	0	998	998
Zn ppm	22	7	57	50
Cu ppm	24	0	157	157
B ppm	18	15	20	5
Pb ppm	1.7	1.7	1.7	0.0
Cr ppm	0.5	0.2	1.5	1.3
Cd ppm	0.1	0.1	0.2	0.1
Ni ppm	1.7	0.4	3.7	3.3

ppm = parts per million

Table 7. Mineral composition of alfalfa stems harvested at the early flower stage.

Mineral	Mean	Minimum	Maximum	Range
P %	0.21	0.14	0.29	0.15
K %	1.88	1.09	2.87	1.78
Ca %	0.72	0.58	0.85	0.27
Mg %	0.25	0.12	0.43	0.31
Mn ppm	13	7	23	16
Al ppm	66	0	304	304
Fe ppm	40	22	65	43
Na ppm	800	0	1,414	1,414
Zn ppm	21	3	60	57
Cu ppm	24	0	199	199
B ppm	19	15	25	10
Pb ppm	1.7	1.7	1.7	0.0
Cr ppm	0.5	0.1	1.8	1.7
Cd ppm	0.1	0.1	0.2	0.1
Ni ppm	1.8	0.0	4.9	4.9

ppm = parts per million

Table 8. Mineral composition of alfalfa stems harvested at the late flower stage.

Mineral	Mean	Minimum	Maximum	Range
P %	0.18	0.08	0.27	0.19
K %	1.81	0.55	2.85	2.30
Ca %	0.70	0.53	0.87	0.34
Mg %	0.19	0.07	0.33	0.26
Mn ppm	14	9	21	12
Al ppm	47	0	197	197
Fe ppm	44	23	30	57
Na ppm	730	0.0	1,443	1,443
Zn ppm	15	2	45	43
Cu ppm	15	0	142	142
B ppm	19	15	27	12
Pb ppm	1.7	1.7	1.7	0.0
Cr ppm	0.4	0.2	1.3	1.2
Cd ppm	0.1	0.1	0.2	0.1
Ni ppm	1.3	0.3	3.1	2.8

ppm = parts per million

ALFALFA STEM ANALYSES

	CARBONA
Proximate Analysis (ASTM Procedure D3172)	
•Weight % Moisture (ASTM Procedure D3302)	DIN-51718
•Weight % Volatile Matter (ASTM Procedure D3175)	DIN-51720
•Weight % Ash (ASTM Procedure D3174)	DIN-51719
•Weight % Fixed Carbon (by difference)	DIN-51900
Ultimate Analysis (ASTM Procedure D3176)	
•Weight % Total Carbon (ASTM Procedure D5373)	ASTM-D5373
•Weight % Hydrogen (ASTM Procedure D5373)	ASTM-D5373
•Weight % Nitrogen (ASTM Procedure D5373)	ASTM-D5373
•Weight % Sulfur (ASTM Procedures D4239, D2492 and D3177)	ASTM-D4239
•Weight % Oxygen (by difference)	
•Chlorine, ppmw - added by Carbona	ASTM-D4208
•Potassium, ppmw - added by Carbona	EPRI method J1
•Sodium, ppmw - added by Carbona	EPRI method J1
Higher Heating Value (HHV), BTU/lb (ASTM Procedure D2015)	DIN-51900
Ash Fusion Temperature (in reducing atmosphere) (ASTM Procedure D1857)	ASTM-D1875
Ash Analysis (ASTM Procedure D 3174)	ash preparation:
Weight %	DIN-51719
•SiO2	analysis:
•Al2O3	atomic emission
•Fe2O3	spectrometry
•CaO	
•MgO	
•Na2O	
•K2O	
•TiO2	
•P2O5	
•SO3	
•Carbonates (CO3) - added by Carbona	

Attachment 1: Mineral Equation Statistics

Biomass 97 Rosemount, Morris, Lamberton stem

Variable	N	Mean	SEC	RSQ	SECV	1-VR
N	87	0.220 %	0.020	.847	0.027	0.732
K	87	1.974 %	0.095	.963	0.125	0.936
Ca	85	0.705 %	0.047	.662	0.053	0.584
Mg	85	0.233 %	0.015	.960	0.023	0.901
Mn	85	12.641 PPM	1.522	.800	1.871	0.698
Al	83	40.502 PPM	18.058	.856	26.047	0.703
Fe	76	40.585 PPM	5.820	.763	6.453	0.712
Na	78	633.282 PPM	132.695	.879	168.396	0.807
Zn	77	18.432 PPM	3.197	.862	4.778	0.969
Cu	80	19.827 PPM	7.793	.937	11.365	0.869
B	82	18.229 PPM	0.837	.876	1.019	0.816
Pb	71	1.685 PPM	0.014	.262	0.15	0.080
Cr	80	0.449 PPM	0.070	.881	0.116	0.678
Cd	78	0.137 PPM	0.012	.797	0.018	0.548
Ni	83	1.574 PPM	0.338	.860	0.409	0.794

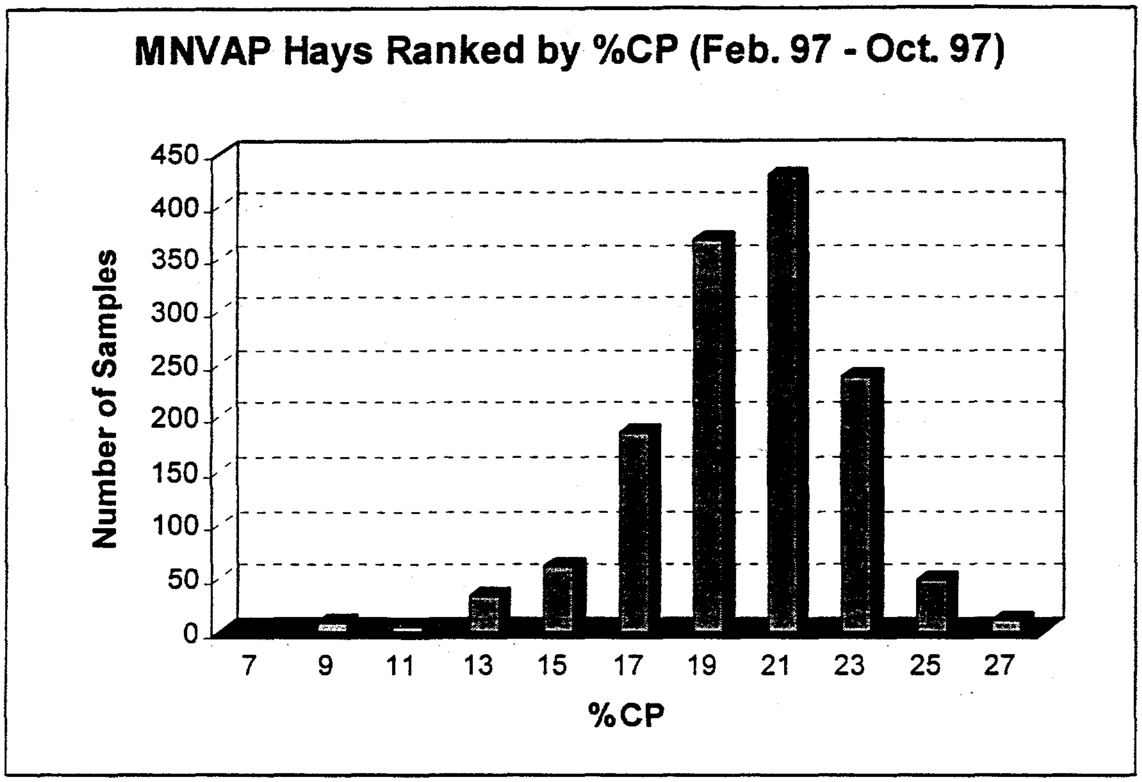
Attachment 2: Dirt Contaminated Sample Equation Statistics.

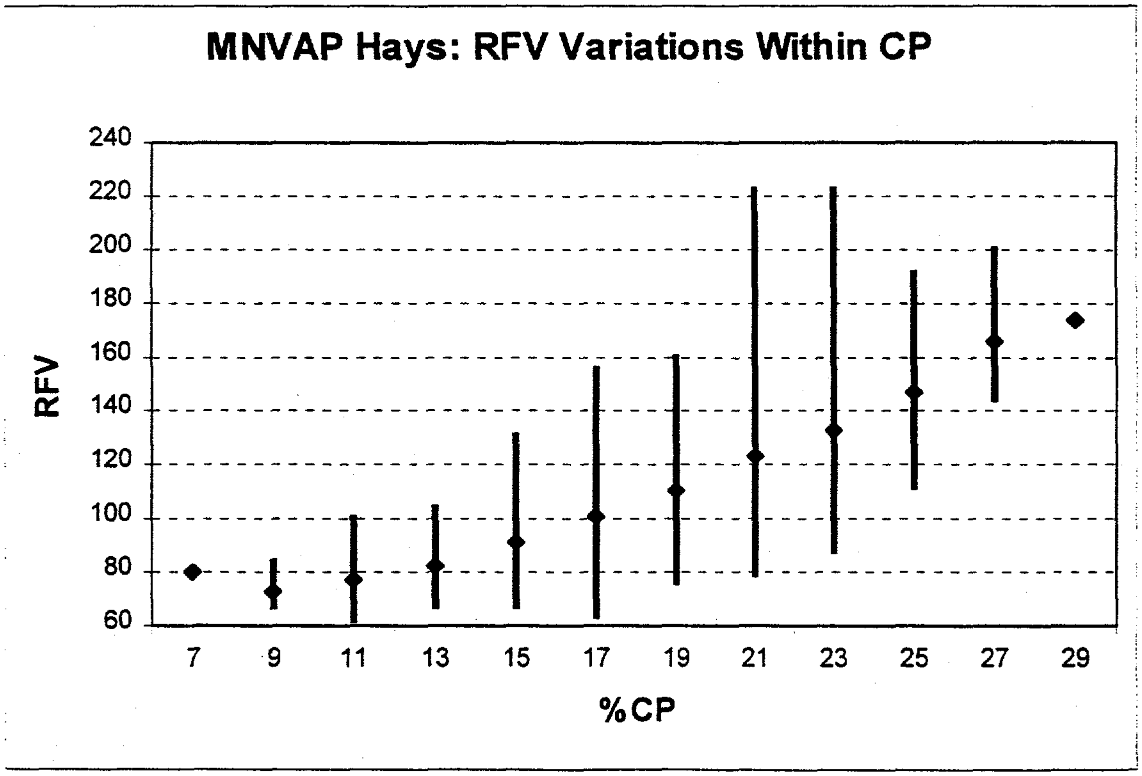
Variable	N	Mean	SEC	RSQ	SECV	1-VR
ADF	54	42.986	1.204	.979	1.588	0.964
NDF	55	54.549	1.220	.987	1.536	0.979
CP	54	18.501	0.665	.986	0.748	0.982
Total-Ash	55	13.712	0.787	.973	1.146	0.945
DM	526	92.882	0.365	.965	0.403	0.958

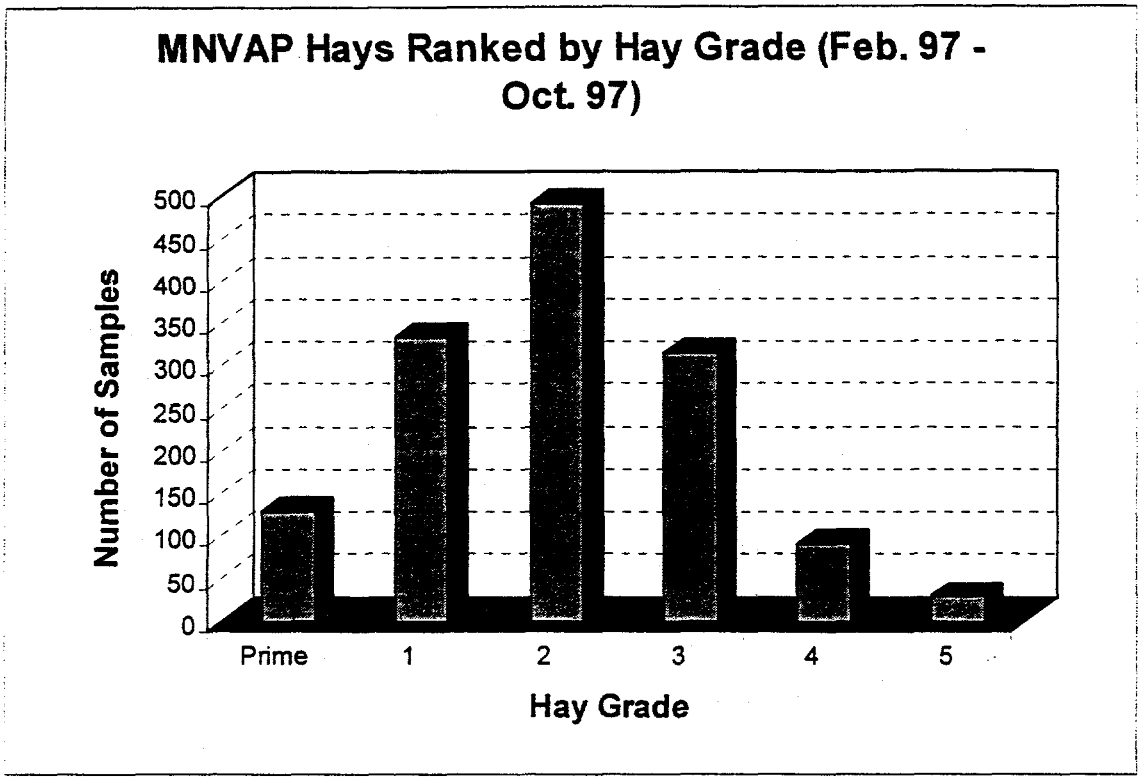
Calculated Equations:

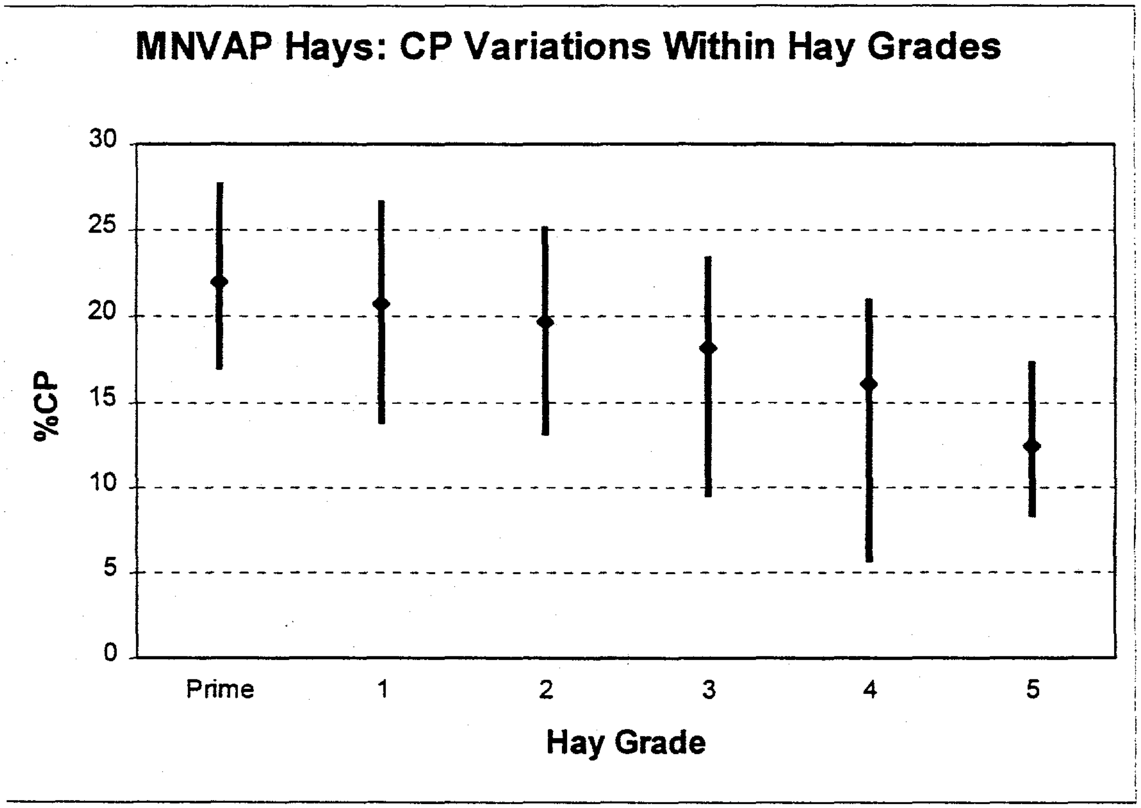
MOISTURE = 100.0 - DM
NEL = 1.044 - (.0119 * ADF)
TDN = 4.898 + (89.796 * NEL)
ENE = 82.6 * NEL
ME = .01642 * TDN
NEM = - .508 + (1.37 * ME) - (.3042 * ME * ME) + (.051 * ME * ME * ME)
NEG = - .7484 + (1.42 * ME) - (.3836 * ME * ME) + (.0593 * ME * ME * ME)
DDM = 88.90 - (.779 * ADF)
DRYMI = 120 / NDF
RFV = (DRYMI * DDM) / 1.29

Attachment 3: MNVAP Hays 2/97-10/97

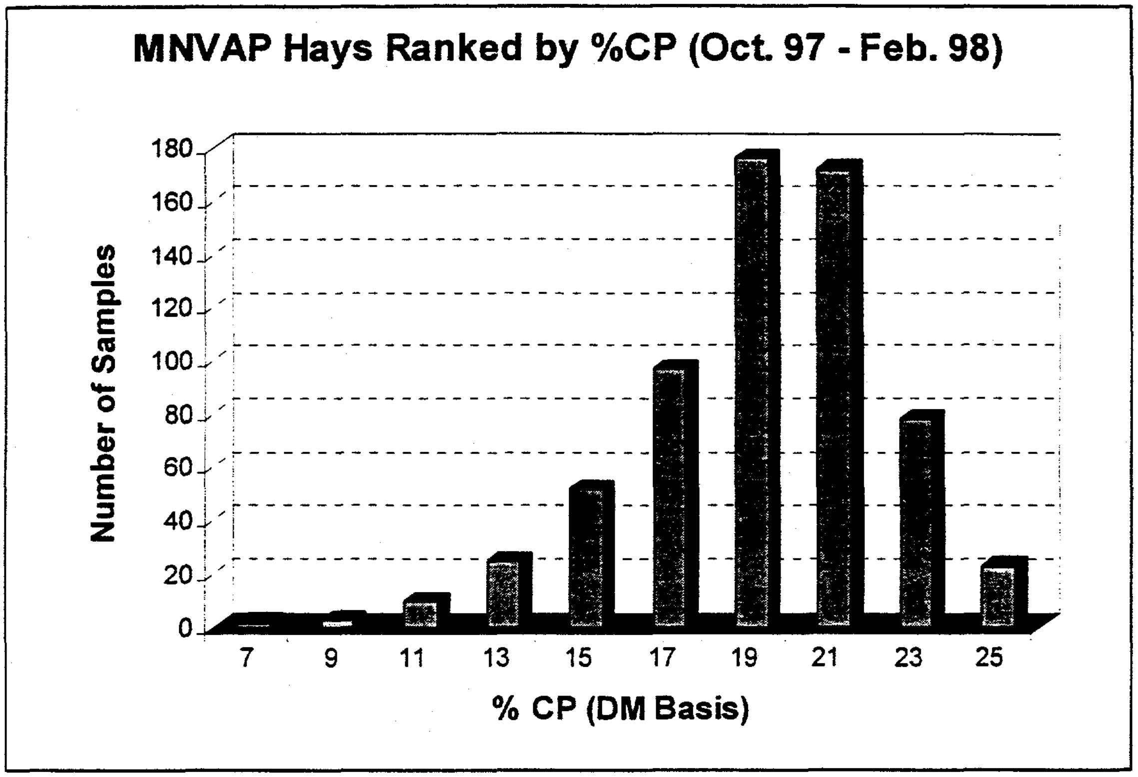


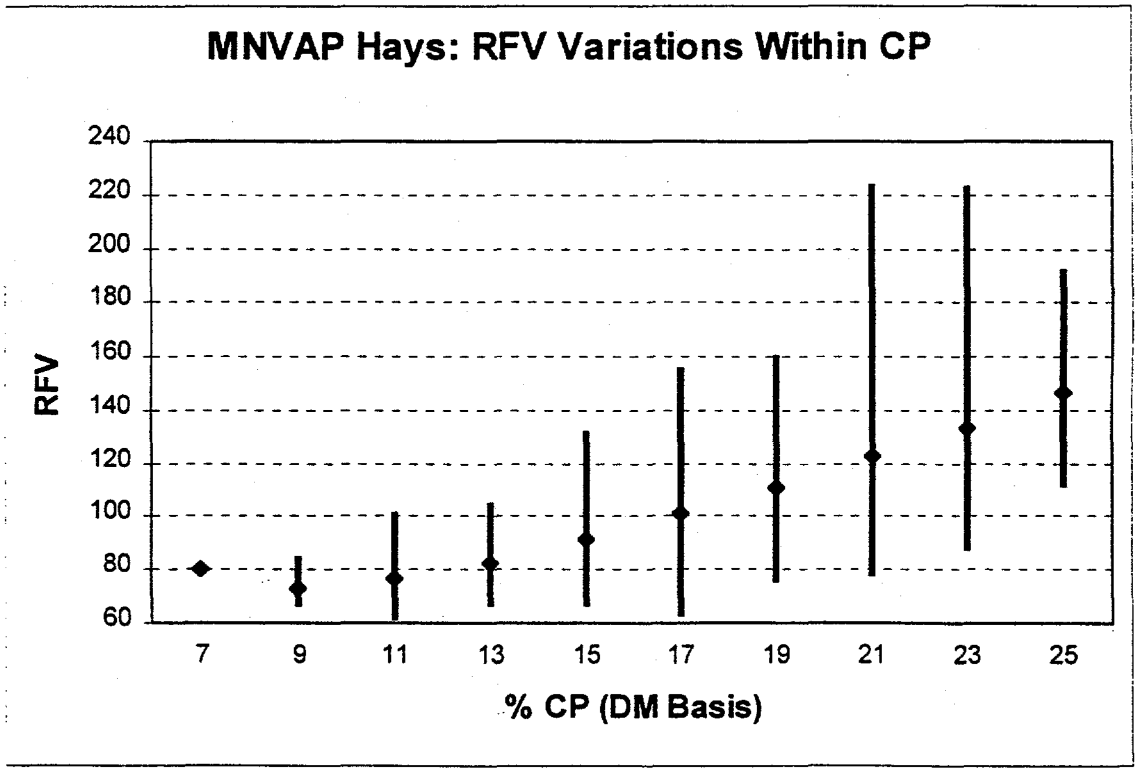


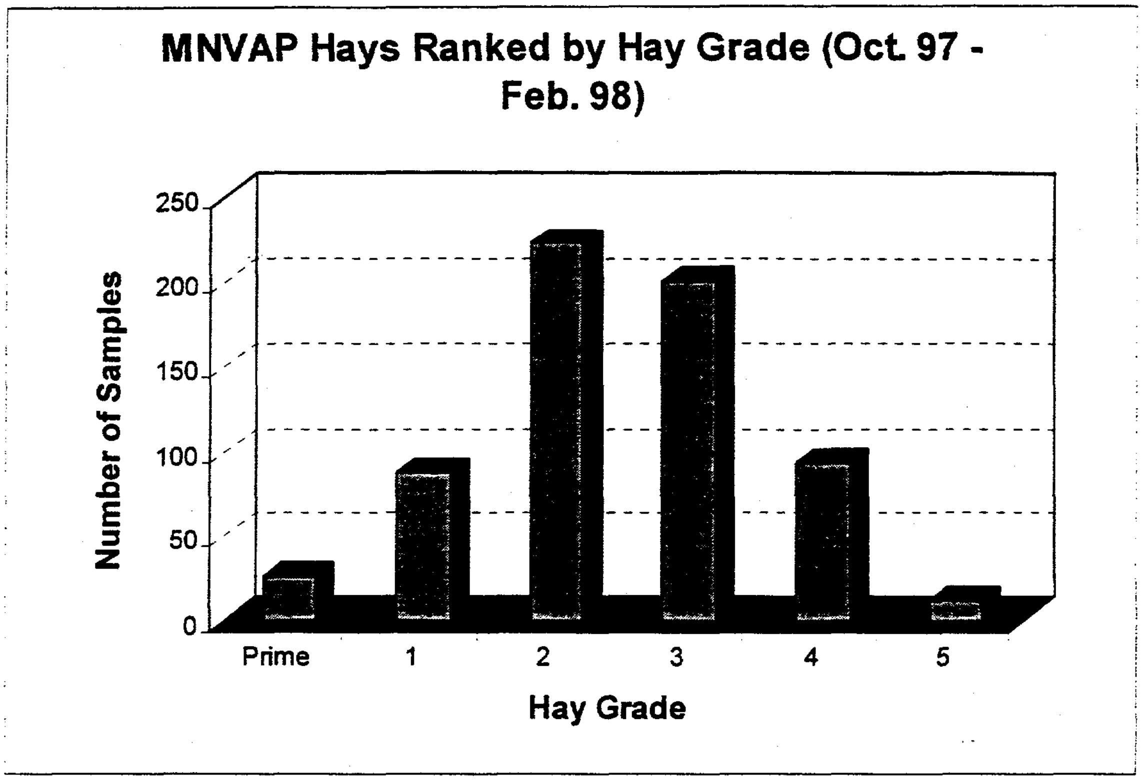

MNVAP Hays Ranked by Hay Grade (Feb. 97 - Oct. 97)
Number of Samples
500
450
400
350
300
250
200
150
100
50
0
Prime
1
2
3
4
5
Hay Grade

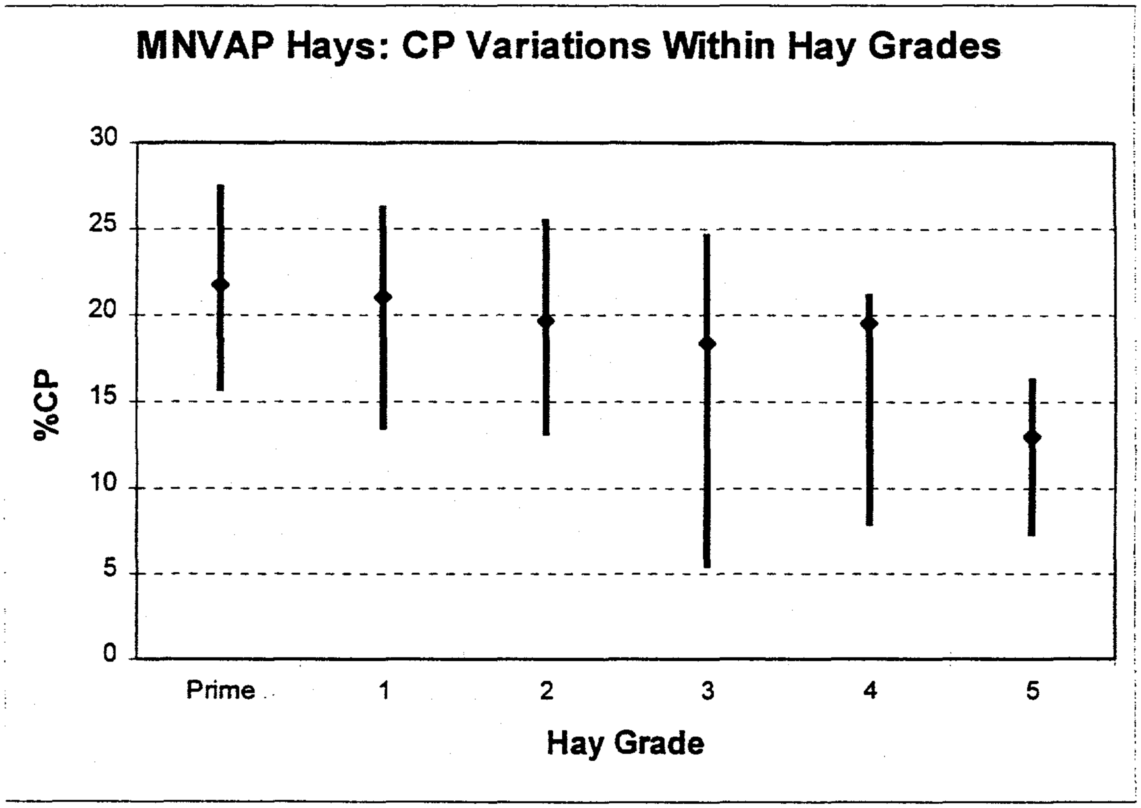

MNVAP Hays: CP Variations Within Hay Grades
%CP
30
25
20
15
10
5
0
Prime
1
2
3
4
5
Hay Grade

Attachment 4: MNVAP Hays 10/97-2/98

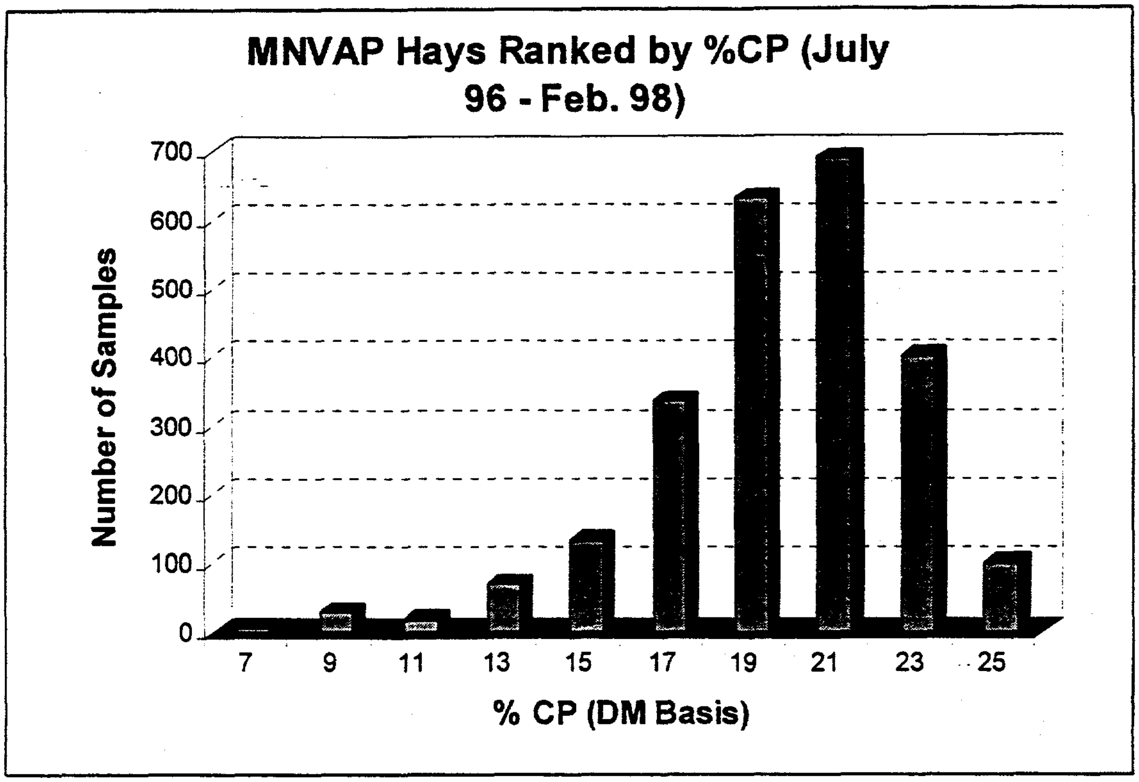


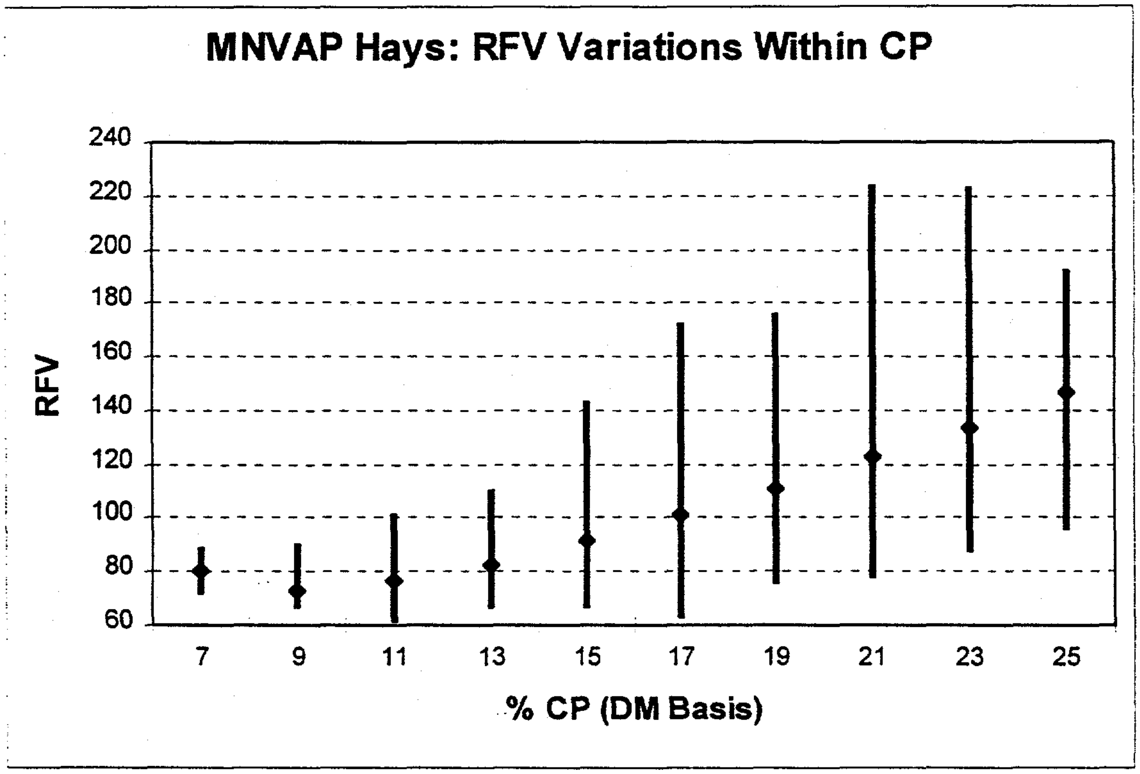


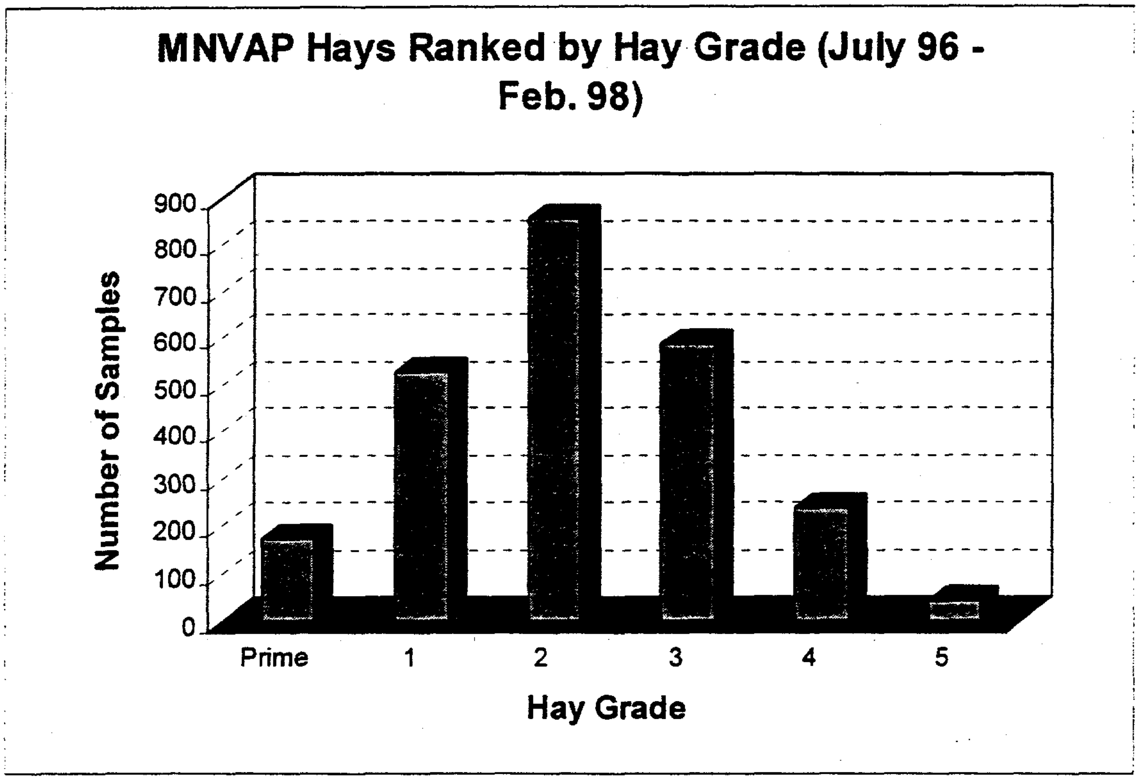

MNVAP Hays Ranked by Hay Grade (Oct. 97 - Feb. 98)
Number of Samples
250
200
150
100
50
0
Prime
1
2
3
4
5
Hay Grade


MNVAP Hays: CP Variations Within Hay Grades
%CP
30
25
20
15
10
5
0
Prime
1
2
3
4
5
Hay Grade

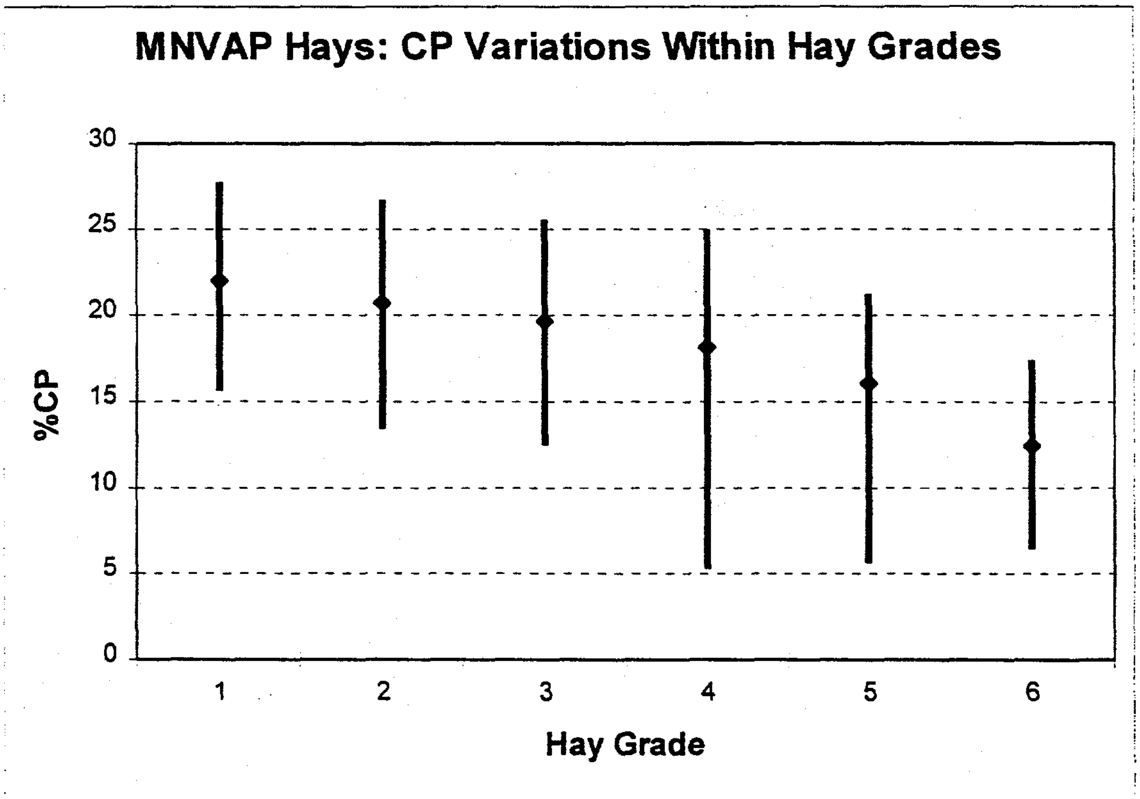
Attachment 5: MNVAP Hays 7/96-2/98







MNVAP Hays Ranked by Hay Grade (July 96 - Feb. 98)
Number of Samples
900
800
700
600
500
400
300
200
100
0
Prime
1
2
3
4
5
Hay Grade



MNVAP Hays: CP Variations Within Hay Grades
%CP
30
25
20
15
10
5
0
1
2
3
4
5
6
Hay Grade

Attachment 2.

Alternative Biomass Resources

DRAFT

ALTERNATIVE BIOMASS RESOURCES

MINNESOTA AGRIPOWER PROJECT PHASE IA
TASK 6 RESEARCH REPORT

J. Jewett

University of Minnesota
Center for Alternative Plant and Animal Products

March 30, 1998

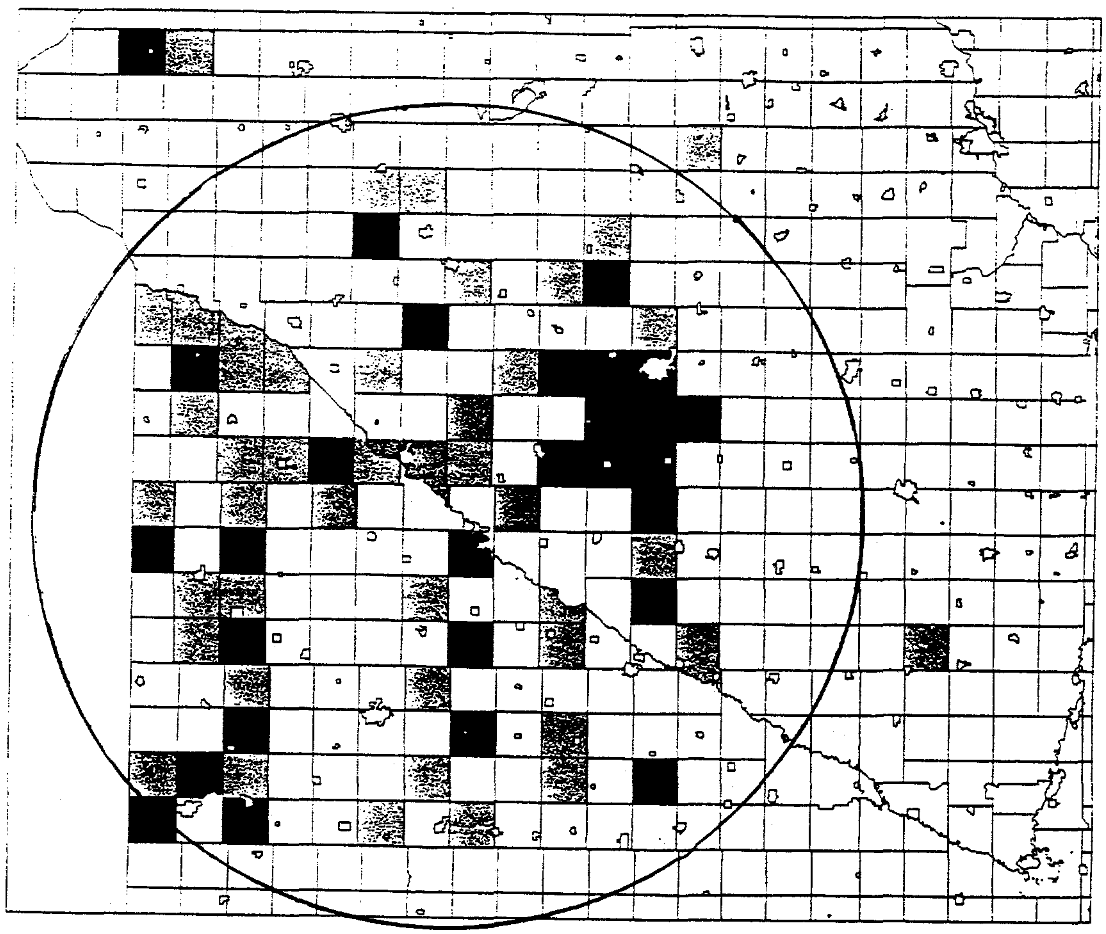
BIOMASS RESOURCES IN WEST CENTRAL AND SOUTHWESTERN MINNESOTA

INTRODUCTION

The proposed Minnesota Agri-Power (MAP) plant to be located in Granite Falls, Minnesota will convert alfalfa stems to a biomass fuel by gasification. Alternative farm-grown and non-farm sources of biomass may be needed to supplement the alfalfa stem fuel. The MAP plant may add alternative biomass fuels to alfalfa to lower the cost of biomass fuel, to improve the quality of the fuel for gasification, and/or to increase the reliability of the biomass fuel supply.

This report is a compilation of information about the quantity and type of existing biomass fuel resources in the Granite Falls area, predictions of potential for additional biomass production over the next decade, and existing cost and chemical composition data on alternative biomass fuels. This information will aid decision-makers in evaluating the potential for integration of alternative biomass fuels into the MAP gasification system.

The biomass production region (biomass shed) is defined in this report as the 21 counties partially or wholly within a 50-mile radius of Granite Falls, Minnesota. The 21 counties are divided into the 9 counties closest to Granite Falls (Inner Ring Counties) and the 12 more distant counties (Outer Ring Counties).



CURRENTLY AVAILABLE BIOMASS RESOURCES

Farm-grown biomass resources

Grasses and Legumes

As of December 1997 there were 272,000 CRP acres in the biomass shed. About 86%, or 234,000 acres, was in cool-season grasses and legumes. Another 6%, or 16,000 acres, was in native grasses such as switchgrass (U.S. Farm Service Agency, 1998). At an estimated yield of 0.5 dry tons/acre/year (Figure 1), CRP grassland in the biomass shed produces 125,000 tons of biomass per year (Table 1).

Non-alfalfa hay is produced on 79,900 acres of cropland in the biomass shed (Minnesota Agricultural Statistics Service, 1997). At an average yield of 2.4 dry tons/acre/year (Figure 1), these hay acres produce 196,000 tons of biomass per year (Table 2).

Production of 10% of the annual biomass requirement of the MAP plant would require 70,000 acres of CRP grassland, or 30% of current CRP grassland. Producing 10% of the MAP requirements would require 14,600 acres of grass and legume hay, or 18% of current non-alfalfa hay acreage (Table 3, Figure 2).

Table 1. Estimated grass production on 250,000 Conservation Reserve Program (CRP) grassland acres†.

County	Grass/legume	Native grass	Total grass CRP
	---------- dry tons/year ----------		
INNER RING			
Chippewa	2,250	150	2,400
Kandiyohi	12,700	900	13,600
Lac Qui Parle	9,650	700	10,350
Lincoln	14,450	1,000	15,450
Lyon	5,350	350	5,700
Redwood	3,450	250	3,700
Renville	1,300	100	1,350
Swift	9,500	650	10,150
Yellow Medicine	6,600	450	7,100
Subtotal	65,250	4,550	69,800
OUTER RING			
Big Stone	3,150	200	3,350
Brown	2,650	200	2,850
Cottonwood	3,150	200	3,350
McLeod	1,100	100	1,150
Meeker	5,300	350	5,650
Murray	5,200	350	5,550
Nicollet	900	50	950
Pipestone	3,750	250	4,000
Pope	11,200	800	12,000
Sibley	500	50	550
Stearns	10,300	700	11,000
Stevens	4,600	300	4,900
subtotal	51,750	3,550	55,350
21 County Total	117,000	8,160	125,150

Sources: U.S. Economic Research Service, 1995; U.S. Farm Service Agency, 1998.

† Yields were assumed to be 0.5 tons/acre/year on all CRP grassland; figures are rounded to the nearest 50.

Table 2. Non-alfalfa hay production in the 21-county biomass shed.

	Average of 1995 and 1996		
County	Acres harvested	Annual yield per acre	Total Annual Yield †
	---acres---	---------dry tons/year	--------
INNER RING COUNTIES			
Chippewa	1,400	2.1	3,000
Kandiyohi	1,600	2.2	3,500
Lac Qui Parle	2,050	2.7	5,500
Lincoln	5,650	2.3	13,000
Lyon	3,300	2.3	7,750
Redwood	2,100	2.8	5,950
Renville	5,300	2.4	12,700
Swift	1,850	2.2	4,150
Yellow Medicine	2,750	2.4	6,700
Subtotal	26,000	2.4	62,250
OUTER RING COUNTIES			
Big Stone	2,200	2.6	5,800
Brown	2,500	2.9	7,250
Cottonwood	1,750	2.3	3,950
McLeod	3,250	3.0	9,700
Meeker	6,750	2.3	15,800
Murray	1,850	2.1	3,850
Nicollet	1,850	2.6	4,900
Pipestone	1,700	2.2	3,750
Pope	10,300	2.0	20,550
Sibley	2,700	3.0	8,000
Stearns	16,200	2.7	44,450
Stevens	2,850	2.1	5,900
Subtotal	53,900	2.5	133,900
Total	79,900	2.4	196,150

Source: Minnesota Agricultural Statistics Service, 1997.

† Total annual yield = Acres x dry tons/acre/year; acres and total yields are rounded to the nearest 50.

Table 3. Acres required for grass and legume hay on CRP land and cropland to meet part of the Minnesota Agri-Power (MAP) plant annual requirement of 350,000 tons of biomass per year.

		Percentage of MAP plant annual requirement†		
Crop	Location	25%	10%	1%
		acres		
CRP hay ‡	9 Inner Ring Counties	97,650	39,050	3,905
	12 Outer Ring Counties	77,350	30,950	3,095
	Total 21 Counties	175,000	70,000	7,000
Cropland hay §	9 Inner Ring Counties	11,850	4,750	475
	12 Outer Ring Counties	24,600	9,850	985
	Total 21 Counties	36,450	14,600	1,460

† Figures in the 25% and 10% columns are rounded to the nearest 50.

‡ There were 250,000 acres of CRP grassland in the biomass shed as of December 1997 (U.S. Farm Service Agency).

§ Non-alfalfa hay is grown on 79,900 acres in the biomass shed (Minnesota Agricultural Statistics Service, 1997).

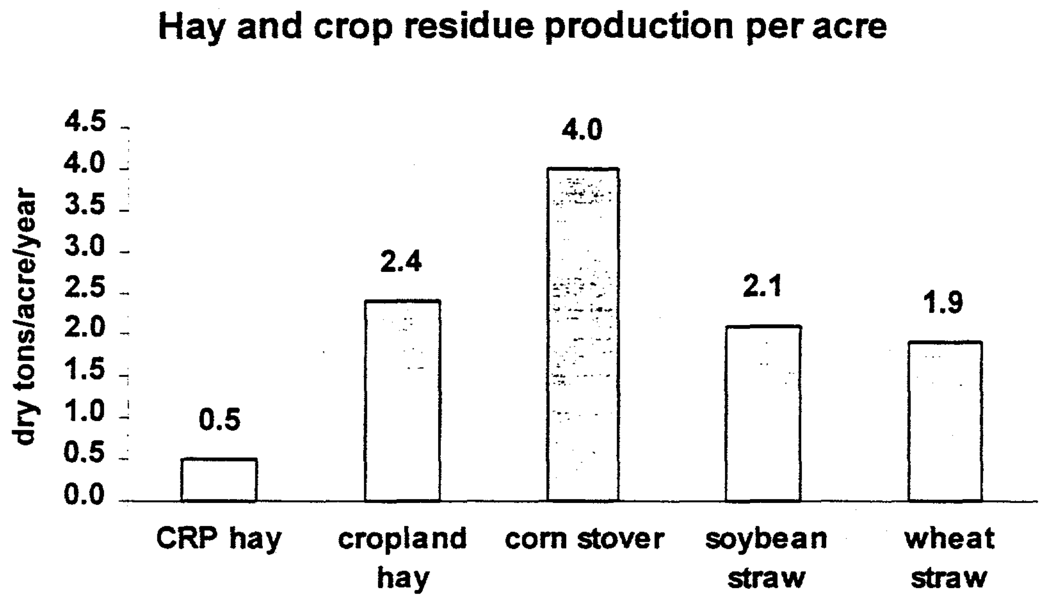


Figure 1. Average production per acre of hay on CRP land and cropland; corn, soybean, and wheat residue in the 21 county biomass shed. Sources: (CRP hay yield was estimated.) Minnesota Agricultural Statistics Service, 1997; Etkin et al., 1992. Corn stover, Cox et al., 1994. Soybean straw, Imsande, 1992; Ravuri and Hume, 1993. Wheat straw, McKendry, 1995.

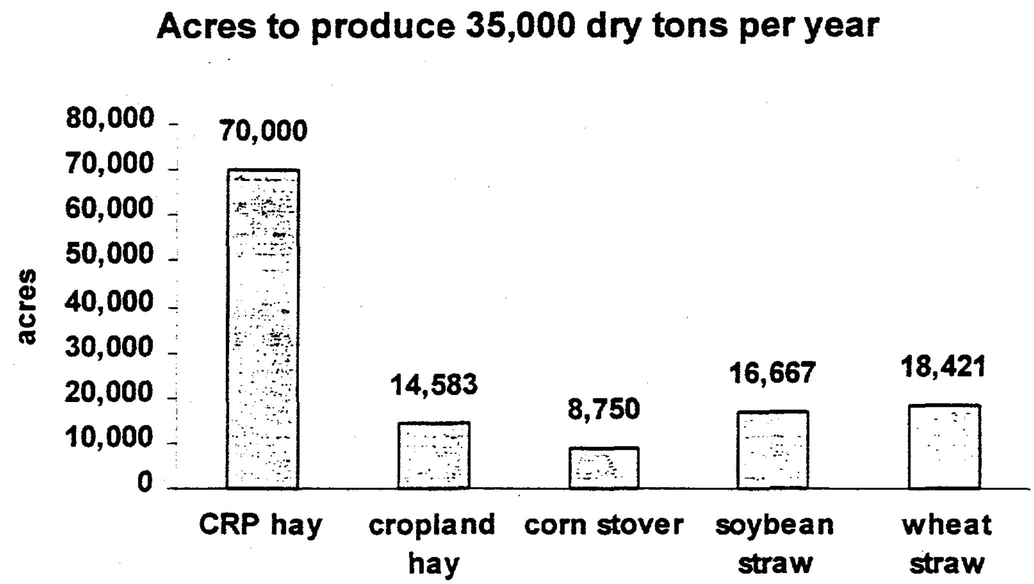


Figure 2. Acreage required for hay or crop residue production of 10% of the total Minnesota Agri-Power plant biomass requirement of 350,000 tons per year. Sources: U.S. Economic Research Service, 1995; Minnesota Agricultural Statistics Service, 1997; Etkin et al., 1992. Corn stover, Cox et al., 1994. Soybean straw, Imsande, 1992; Ravuri and Hume, 1993. Wheat straw, McKendry, 1995.

Agricultural Residues

Nearly 7,000,000 acres were planted to annual crops or alfalfa in the biomass shed in 1995 and 1996 (Minnesota Agricultural Statistics Service, 1997). Corn and soybeans were the most common crops, followed by alfalfa and then small grains. Corn stover, soybean straw, and grain straw are potential sources of farm-grown biomass fuel.

Grain yield information was taken from Minnesota Agricultural Statistics for the years 1995 and 1996. Tonnage of crop residue was calculated from grain yield figures as follows:

Total biomass yield = Grain yield/harvest index

Residue yield = Total biomass yield – Grain yield

One percent of the total crop residue in the 9 counties closest to Granite Falls could supply 87,000 tons of biomass to the MAP plant each year. One percent of total crop residue in all 21 counties could supply 174,000 tons of biomass per year (Table 4). Five percent of the total crop residue from the Inner Ring counties could supply 437,000 tons of biomass per year. Five percent of total agricultural residue from all 21 counties could supply 872,000 tons per year, which is 2.5 times the 350,000 ton annual biomass requirement of the MAP plant.

Corn stover production in the biomass shed averages 4.0 dry tons/acre/year. Soybean straw production averages 2.1 dry tons/acre/year, and wheat straw production averages 1.9 dry tons/acre/year (Figure 1). If agricultural residues were to supply 10% of the MAP plant requirement, the 35,000 tons could be produced by 8,750 acres of corn (Table 5, Figure 2). This represents 0.3% of the total corn acreage in the biomass shed. About 16,700 acres of soybean, or 0.6% of the total soybean acreage in the biomass shed, would be needed to produce 10% of the MAP requirements. Ten percent of MAP requirements could be supplied by 18,400 acres of wheat, which is 10% of total wheat acreage in the biomass shed.

Table 4. Crop residue produced per year in the 21-county biomass shed. †

Crop	Total Residue‡	1% capture§	5% capture¶
	----------------dry tons/year--------------		
INNER RING COUNTIES			
Corn	5,544,800	55,448	277,240
Soybean	2,972,300	29,723	148,620
Wheat	159,800	1,598	7,990
Oat	15,100	151	750
Barley	600	6	30
Sweet Corn	38,400	384	1,920
Subtotal	8,731,000	87,310	436,550
OUTER RING COUNTIES			
Corn	5,632,200	56,322	281,610
Soybean	2,775,200	27,752	138,760
Wheat	199,600	1,996	9,980
Oat	49,500	495	2,480
Barley	13,200	132	660
Sweet Corn	34,100	341	1,710
Subtotal	8,703,800	87,038	435,200
TOTAL 21 COUNTIES			
Corn	11,177,000	111,770	558,850
Soybean	5,747,500	57,475	287,380
Wheat	359,400	3,594	17,970
Oat	64,600	646	3,230
Barley	13,800	138	690
Sweet Corn	72,500	725	3630
Total	17,434,800	174,348	871,750

Source: 1997 Minnesota Agricultural Statistics.

† Calculated from average of 1995 and 1996 yields.

‡ Figures are rounded to the nearest 100.

§ 1% of the total annual crop residue captured for use by the MAP plant.

¶ 5% of the total annual crop residue captured for use by the MAP plant; figures are rounded to the nearest 10.

Table 5. Acres required for corn, soybean, and wheat to supply residue to meet part of the Minnesota Agri-Power (MAP) plant annual requirement of 350,000 tons of biomass per year.

Crop	Location	Percentage of MAP plant annual requirement†		
		25%	10%	1%
		acres		
Corn ‡	9 Inner Ring Counties	10,700	4,300	430
	12 Outer Ring Counties	11,150	4,450	445
	Total 21 Counties	21,850	8,750	875
Soybean §	9 Inner Ring Counties	21,900	8,750	875
	12 Outer Ring Counties	19,750	7,900	790
	Total 21 Counties	41,650	16,650	1,665
Wheat ¶	9 Inner Ring Counties	20,250	8,100	810
	12 Outer Ring Counties	25,800	10,300	1,030
	Total 21 Counties	46,050	18,400	1,840

† Figures in the 25% and 10% columns are rounded to the nearest 50.

‡ Corn is grown on 2,976,700 acres in the biomass shed (Minnesota Agricultural Statistics Service, 1997).

§ Soybeans are grown on 2,817,250 acres in the biomass shed.

¶ Wheat is grown on 186,150 acres in the biomass shed.

Non-Farm Biomass Resources

Roadside Vegetation

There are 116,617 miles of road in the 21-county biomass shed, not counting city streets (State Aid for Local Transportation, 1997). Units of government must maintain road rights-of-way within their jurisdiction. This maintenance usually includes controlling roadside vegetation by mechanical means (mowing or brush-hogging) or by herbicides. This vegetation control represents a cost to the governmental unit. Selling roadside biomass could benefit governments by reducing their costs of road maintenance, and could benefit the environment by reducing herbicide use.

We assumed a 0.5 dry tons/acre/year yield and a six-foot cutting swath for roadsides. The six-foot cutting swath represents what units of government would normally cut for roadside maintenance. Sloping terrain limits the accessibility of the remainder of road rights-of-way to harvest equipment. Vegetation in road rights-of-way is an important wildlife habitat in west central and southwestern Minnesota. Road rights-of-way are also an important preservation area for native prairie plant species (Albrecht, 1988). The Minnesota Department of Transportation would oppose harvest of biomass farther than six feet out from the roadbed (Leo Holm, Minnesota Office of Environmental Services, Minnesota Department of Transportation, personal communication, February 1998).

Harvestable roadside vegetation is likely to be mostly smooth bromegrass (*Bromus inermus* Leyss.). Assuming harvest from a six foot strip on each side of the road, roadsides in the nine counties closest to Granite Falls could produce about 9,000 dry tons of biomass per year (Table 6). All 21 counties could produce about 20,000 dry tons of roadside grass per year.

Table 6. Biomass production from the roadsides of four classes of roads in the 21 county biomass shed.

	Road Classes				
Parameter	Trunk Highways	County-State Aid Highways	County Roads	Township Roads	Total Roads
INNER RING					
Lane Miles†	2,393	6,227	2,764	14,168	25,552
Acres in 6-ft. strip	1,740	4,530	2,010	10,302	18,582
Dry tons/year in 6-ft. strip‡	870	2,264	1,005	5,152	9,292
OUTER RING					
Lane Miles†	2,982	7,287	2,949	15,705	28,923
Acres in 6-ft. strip	2,166	5,298	2,142	11,424	21,036
Dry tons/year in 6-ft. strip‡	1,084	2,650	1,072	5,711	10,517
TOTAL 21 COUNTIES					
Lane Miles†	5,375	13,514	5,713	29,873	54,475
Acres in 6-ft. strip	3,906	9,828	4,152	21,726	39,618
Dry tons/year in 6-ft. strip‡	1,954	4,914	2,077	10,863	19,809

Source: State Aid for Local Transportation; Mileages from MN/DOT, Transportation Information System.
† Lane miles = road miles x 2.
‡ Assuming yield of 0.5 dry tons/acre/year.

Waste Paper

The 1996 SCORE report (Minnesota Pollution Control Agency, *in press*) provided information about paper collected for recycling in the biomass shed (Table 7). We assumed that approximately an equal quantity of paper was currently entering landfills. Thus, about 82,000 tons of non-recycled waste paper would be available as a fuel source each year. The non-recycled paper available to the MAP plant would consist of different classes of paper than those collected for recycling, such as treated or glossy paper.

Table 7. Waste paper collected for recycling in the 21-county biomass shed.

County	Corrugated	Newsprint	Mixed Paper	Other Paper†	Total
	-------	-------	tons/year	-------	-------
INNER RING					
Chippewa	887	30	370	85	1,372
Kandiyohi	4,015	47	700	998	5,760
Lac Qui Parle	391	0	1,974	91	2,456
Lincoln	241	0	118	0	359
Lyon	3,780	383	671	34	4,868
Redwood	825	75	351	77	1,328
Renville	390	0	488	86	964
Swift	541	0	291	148	980
Yellow Medicine	300	0	179	37	516
Subtotal	11,370	535	5,142	1,556	18,603
OUTER RING					
Big Stone	178	0	108	53	339
Brown	3,954	2,849	0	0	6,803
Cottonwood	1,338	0	259	8	1,605
McLeod	1,571	944	1,083	24	3,622
Meeker	589	63	304	48	1,004
Murray	645	0	241	85	971
Nicollet	2,113	5,528	481	1	8,123
Pipestone	610	0	383	0	993
Pope	8,335	129	1,387	156	10,007
Sibley	2,105	165	350	1	2,621
Stearns	12,072	9,799	3,740	731	26,342
Stevens	425	30	192	32	679
Subtotal	33,935	19,507	8,528	1,139	63,109
TOTAL 21 COUNTIES	45,305	20,042	13,670	2,695	81,712

Source: 1996 SCORE report, Minnesota Pollution Control Agency.

† Other paper may include computer paper, magazines, office paper, and phone books.

Forest

As of 1990 the 21 counties in the Granite Falls area included 235,200 acres of forested land that were capable of producing a commercial tree crop (United States Forest Service, 1998; Hansen et al., 1998). These acres produce an estimated 212,200 tons per year of wood, based on Forest Service productivity indexes (Table 8). When mature timber stands are harvested, 15% to 20% of the biomass is considered slash; that is, branches and tops not suitable for most lumber or fiber uses. There would be 31,800 tons of wood biomass available to the MAP plant each year if 15% of the total wood production could be captured.

Table 8. Current wood resources in the Granite Falls area†.

Area	Timber acres‡	Annual production§	15% of annual production¶
	acres	Tons/year	
9 Inner Ring Counties	61,700	48,000	7,200
12 Outer Ring Counties	173,500	164,200	24,600
Total	235,200	212,200	31,800

Source: Eastwide Forest Inventory Data Base, United States Forest Service.
† Figures are rounded to the nearest 100.
‡ Forested acres capable of producing a commercial tree crop.
§ Estimated tonnage based on U.S. Forest Service site productivity indexes
¶ Represents the part of the tree crop not currently used for lumber or fiber.

Urban Wood and Yard Waste

The cities of Granite Falls, Marshall, Montevideo, Redwood Falls, Litchfield, and Hutchinson were contacted about their quantities of biomass waste: lawn clippings, tree trimmings, leaves, etc. Montevideo, Redwood Falls, Litchfield, and Hutchinson have composting programs that take all of their urban wastes. The city of Marshall chips and stockpiles all biomass waste; local residents and farmers take it for their own composting efforts or for animal bedding.

Granite Falls was the only city that did not report a composting or other use program for biomass wastes. Currently, Granite Falls residents haul their biomass waste to a burn site outside of town. Thus, the MAP plant could probably capture close to 100% of the Granite Falls biomass waste. The City of Granite Falls does not track the quantities of biomass wastes generated by Granite Falls residents. Based on reports from Redwood Falls (Wayne Hansen, Minnesota Extension Service, personal communication, February 1998), which has approximately 1.5 times the population of Granite Falls, we estimated that Granite Falls would generate about 375 tons of biomass waste per year.

Biomass Waste From Business

Businesses that may generate biomass wastes include sawmills, cabinet and woodworking shops, agricultural processing, and construction. Businesses in these categories in the Granite Falls area were contacted and asked about their biomass waste generation. All businesses that were contacted indicated that they had minimal production of wastes that would be suitable for the MAP plant.

POTENTIAL FUTURE BIOMASS RESOURCES

Farm crops with potential for biomass production for energy uses in west central Minnesota include short rotation woody crops (SRWC), grasses, and legumes. Many of these crops will grow on land that is marginal or unsuitable for alfalfa or other crops. Thus, they can add diversity to the farm ecosystem while providing income to the farmer. There has been a changeable political climate surrounding the issue of support payments to farmers for SRWC plantings, whether these payments are from the CRP or some other source. If financial assistance for SRWC plantings is not available to farmers, few may be willing to assume the burden of high per-acre establishment costs coupled with several years' delay in returns.

Potential Biomass Production from Woody Crops

Short rotation woody crops (SRWC) are fast-growing trees and shrubs that are planted at close spacing and fertilized for rapid production of biomass. Hybrid poplar (*Populus* spp.) silver maple (*Acer saccharinum* L.), and willow (*Salix* spp.) have been identified as candidate species for short rotation production in the northern United States (Easterly and Burnham, 1996; Kopp et al., 1993). Hybrid poplar and willow will be discussed in this report because these two genera have received the most research attention.

Big bluestem (*Andropogon gerardii* Vitman), indiangrass (*Sorghastrum nutans* (L.) Nash), switchgrass (*Panicum virgatum* L.), and other native perennial prairie grasses are potential biomass crops that fit in with the prairie ecosystem of west central and southwestern Minnesota. These warm-season grasses have most of their growth during the summer. Switchgrass will be used as the representative species in this report, although other native grasses could be substituted or included in a mixture.

Reed canarygrass (*Phalaris arundinacea* L.) is a productive grass commonly used for pasture or hay. It is a cool-season grass so most of its growth occurs in the spring. Reed canarygrass tolerates wet soil and temporary flooding and is therefore well adapted to certain low-lying lands.

Stand establishment and management

Hybrid Poplar

Good establishment of a hybrid poplar stand requires careful attention to site preparation and to weed control during the first three years. Site preparation should begin the summer before the planting year if the field is coming out of sod (Table 9). Glyphosate application, with or without mowing, is used to kill the vegetation. Moldboard plowing and disking follow the herbicide application. Plowed and disked fields are marked for accurate spacing of trees. An oat cover crop may be planted in the fall. A second herbicide treatment is applied in either the fall or the spring.

Planting of cuttings commences in the spring. Unrooted, ten-inch cuttings are planted at 8 ft. by 8 ft. spacing (Hansen, 1991). Experience with hybrid poplar establishment near Alexandria, MN has shown that hand-planting of the trees is only slightly more costly than machine-planting, and gives more accurate spacing and better survival of cuttings (Downing et al., 1996). Accurate spacing is important to allow cultivation, which is done three to four times during the first year. Additional herbicides may be used as needed to allow the trees to grow ahead of weeds. By about the third year the canopy closes and weed control measures are no longer necessary.

Harvest of hybrid poplar typically occurs by year seven if the stand is to be used entirely for energy purposes. Fiber uses require a longer rotation of 10 to 12 years. Branches and tops remaining after a harvest for fiber can be used as biomass fuel.

Table 9. Establishment costs for hybrid poplar.

Cost item	Cropland Low cost†	Cropland High cost	CRP land Low cost	CRP land High cost	Timing
	------------ $ / acre	--------------			
Fall Tillage					
Burndown herbicide	0	0	15	25	Summer of prior year
Plow	0	15	18	25	Summer of prior year
Disk/cultivate	0	12	8	12	Fall of prior year
Spring Tillage					
Disk/cultivate	0	10	8	18	April
Planting					
Tree stock	73	79	73	79	May
Planting	48	75	48	75	May to June 1
Herbicide	25	35	25	35	Pre- or post-planting
Year 1 weed control					
4 cultivations	40	40	40	40	As needed
mid-season herbicide	13	28	13	28	June to August
Fall herbicide	0	25	0	25	October to November
Year 2 weed control					
3 cultivations	30	30	30	30	As needed
mid-season herbicide	13	28	13	28	June to August
Fall herbicide	0	25	0	25	October to November
Year 3 weed control					
2 cultivations	20	20	20	20	As needed
Total Establishment Costs	262	422	311	465	

Source: WesMinn RC & D Council in consultation with the U.S. Forest Service, the Forestry division of the Minnesota Department of Natural Resources, and other partners. Data were generated in the course of work on the Minnesota Wood Energy Scale-Up Project.

† "Low cost" and "High cost" columns represent expected minimum and expected maximum establishment costs, respectively.

Hybrid Willow

Hybrid willow requires site preparation and herbicide treatment similar to the hybrid poplar requirements. Research at the State University of New York has shown that willow is most productive when planted at 1 ft. by 3 ft. spacing and harvested every three years (Kopp et al., 1997). In this harvest system, willow is coppiced (cut off) in the fall of the planting year, which promotes vigorous regrowth from many stems the following year.

A hybrid willow stand is expected to last for 22 years, through seven rotations (Graham et al., 1996). Both hybrid poplar and willow require fertilizer to achieve maximum production. The New York researchers applied P and K to willow at the start of the second growing season at 112 lbs./acre and 224 lbs./acre elemental rate, respectively (Kopp et al., 1997). Beginning in the second year, N was applied annually at 224 lbs./acre elemental rate.

Switchgrass

Native prairie grasses such as switchgrass are slow to establish and seedlings are non-competitive. Good weed control is needed for successful establishment. Existing stands of vegetation must be killed in the year prior to seeding by a combination of tillage and herbicide. A firm, smooth seedbed is required for good stand establishment. Moldboard or chisel plowing followed by disking, harrowing, and use of a cultipacker following seeding at ¼ in. to ½ in. depth are recommended practices. Switchgrass should be seeded at 5 to 8 lbs. of pure live seed per acre and seeding should be completed by June 1st (Sheaffer et al., 1995).

Periodic mowing at a 4 in. height during the first two years can help reduce weed competition. Native grass yields are increased by fertilizing with 75 to 100 lbs. N per acre per year after the seeding year. Switchgrass reaches its full potential yield in the third year and remains productive through approximately the tenth year (Sheaffer et al., 1995).

Reed Canarygrass

Reed canarygrass has a more vigorous seedling than the warm-season prairie grasses; it may be planted after conventional tillage or it may be planted using no-till techniques. The recommended seeding rate is 7 lbs. of pure live seed per acre (Etkin, 1992). A small grain nurse crop may be planted with reed canarygrass. Studies in Sweden found that spring harvest of the previous season's growth resulted in signficantly better fuel characteristics of reed canarygrass compared to harvest during the growing season (Burvall, 1997).

Production

Hybrid Poplar and Willow

Information about hybrid poplar and hybrid willow production presented in this section relies in part on the Oak Ridge Energy Crop County Level (ORECCL) Database (Graham et al., 1996). This database is available on the Internet at http://www.esd.ornl.gov/bfdp/papers/../oreccl/database.html.

A number of assumptions are built into the ORECCL Database:

1. There is no irrigation of hybrid poplar or willow production stands.
2. Annual expected poplar yields per acre are the mean annual increment of a seven year harvest rotation; all biomass is used for energy.
3. Annual expected willow yields per acre are the mean annual increment of a three year harvest rotation; all biomass is used for energy.
4. The SRWCs are planted on productive cropland using best management practices and best available genetic stock.

The situation in the biomass shed required some modification of these assumptions. In Minnesota the fiber industry is expected to out-compete the energy industry for the hybrid poplar supply (Greg Larson, WesMinn Resource Conservation & Development, personal communication, February, 1998). Therefore, we assumed a 12 year rotation in which 75% of the biomass (main stems) is sold to the fiber industry for uses such as paper or oriented-strand board production. The remaining 25% ("slash" including branches and tops) is sold as biomass fuel.

The assumption that hybrid poplar and willow will be planted on productive cropland may not be valid for the Granite Falls area, for economic as well as ecological reasons. Farmers may be unwilling to plant trees, which have high establishment costs and several years' delay in returns, on productive cropland. The Minnesota Department of Natural Resources prefers that tree plantings be limited to riparian areas in this prairie ecosystem (Kevin Lines, Minnesota Department of Natural Resources, personal communication, April, 1998). We assumed that woody crops are most likely to be planted on former CRP land or other land that is marginal for annual crops. The CRP acreages that we used were acres in CRP as of 1992 (Graham et al., 1996). About 40% of that land has since come out of CRP and moved into the cropland category, so CRP figures represent current and former CRP land. Yield figures for the cropland category are also shown because not all land that is marginal for a traditional crop was accepted into the CRP. At the 15th signup in March of 1997, nearly five times as much land was offered for CRP in the biomass shed as was accepted (Farm Service Agency, 1998). This suggests that a sizable portion of the land labeled as cropland is considered marginal by the landowners.

The expected annual yields of hybrid poplar and willow that are presented in this report are lower than those presented by the ORECCL Database due to flooding potential and lower soil fertility on marginal cropland or CRP land. On CRP land and cropland we used a 3.1 dry tons/acre/year total yield for hybrid poplar (Graham et al., 1995); 25% of this yield for energy purposes equals 0.8 dry tons/acre/year. Based on reports from the State University of New York, a 4.4 dry tons/acre/year yield was estimated for hybrid willow (Kopp et al., 1993) on cropland and CRP land. We assumed that 100% of the willow biomass would be used for energy because willow is not sought after by the Minnesota fiber industry. Pasture land was assumed to be less productive land; therefore the yield estimates were reduced 25% for pasture land to 0.6 dry tons/acre/year for hybrid poplar and 3.3 dry tons/acre/year for hybrid willow (Figure 3). Total agricultural land was defined as CRP land, cropland, and pasture land.
Based on these assumptions, in the 21 counties around Granite Falls, hybrid poplar could supply 54,700 tons of biomass per year to the MAP plant if it was planted on 1% of the total agricultural land and 25% of the total biomass was used for energy (Table 10; Figures 4,5,6). If breeding efforts improve production by 25%, the figure would increase to 68,400 tons of biomass per year. Hybrid poplar slash could supply 3,700 tons of biomass per year if planted on 1% of former CRP land in the 21 county biomass shed.

Hybrid willow is well suited to riparian areas that are prone to seasonal flooding. Willow planted on 1% of the total agricultural land could supply 301,000 tons of biomass per year at current yields, or 376,000 tons per year with a 25% increase in yields. On 1% of former CRP land, the biomass shed could produce 21,000 tons of willow biomass per year (Table 10; Figures 4,5,6).

Table 10. Annual biomass production potential of short rotation woody crops†.

Crop	Land Type	Inner Ring Counties	Outer Ring Counties	21 County Total	25% increase in productivity
		Annual Production Potential			
		dry tons/year †			
Hybrid Poplar‡	CRP	2,050	1,700	3,750	4,700
	Cropland	23,800	24,800	48,600	60,750
	Pasture land	850	1,500	2,350	2,950
	TOTAL	26,700	28,000	54,700	68,400
Hybrid Willow§	CRP	11,250	9,350	20,600	25,750
	Cropland	131,000	136,300	267,300	334,150
	Pasture land	4,750	8,350	13,100	16,300
	TOTAL	147,000	154,000	301,000	376,200

Sources: Oak Ridge Energy Crop County Level Database (Graham et al., 1996); Graham et al. 1995; Kopp et al., 1993.

† Tonnages were calculated assuming that 1% of each land type would be planted to the crop; figures are rounded to the nearest 50.

‡ Hybrid poplar yield for energy uses was 0.8 dry tons/acre/year on CRP and cropland; 0.6 dry tons/acre/year on pasture land. (Assuming that 25% of a total yield of 3.2 dry tons/acre/year would go for energy uses; the remaining 75% for fiber uses).

§ Hybrid willow yield was 4.4 dry tons/acre/year on CRP and cropland; 3.3 dry tons/acre/year on pasture land.

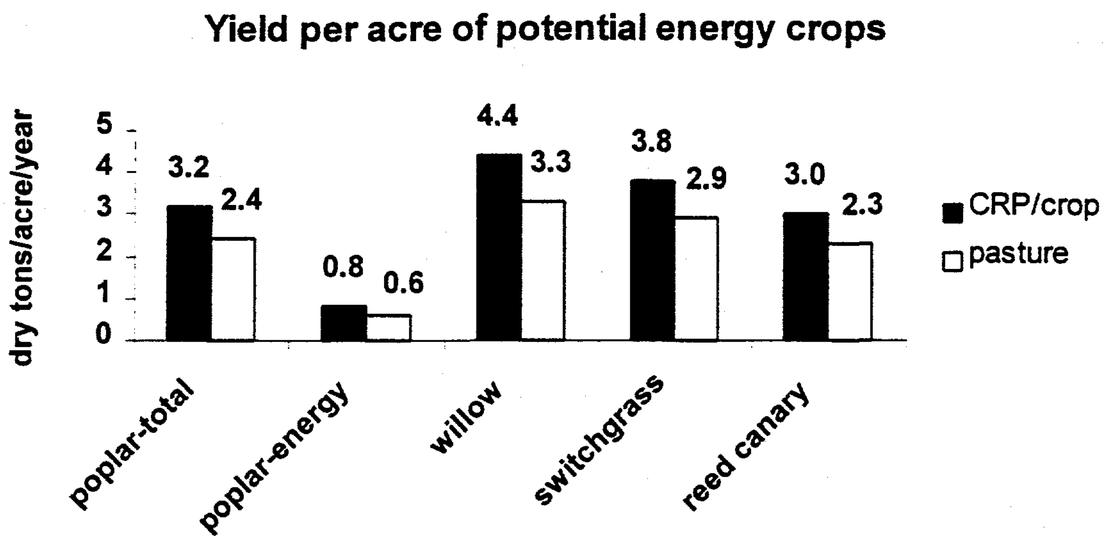


Figure 3. Expected yields per acre on Conservation Reserve Program (CRP) land, cropland, and pasture land in the 21 county biomass shed. Sources: Graham et al., 1996; Graham et al., 1995; Kopp et al., 1993; Sheaffer et al., 1995; Undersander et al., 1995.

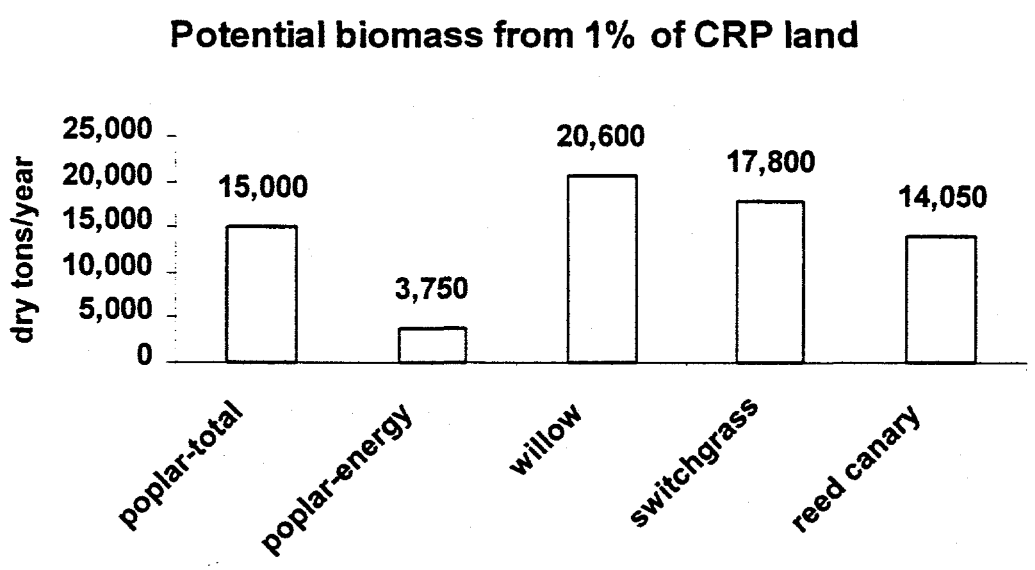


Figure 4. Annual biomass production from hybrid poplar, hybrid willow, switchgrass, and reed canarygrass on 1% of Conservation Reserve Program (CRP) land in the biomass shed.

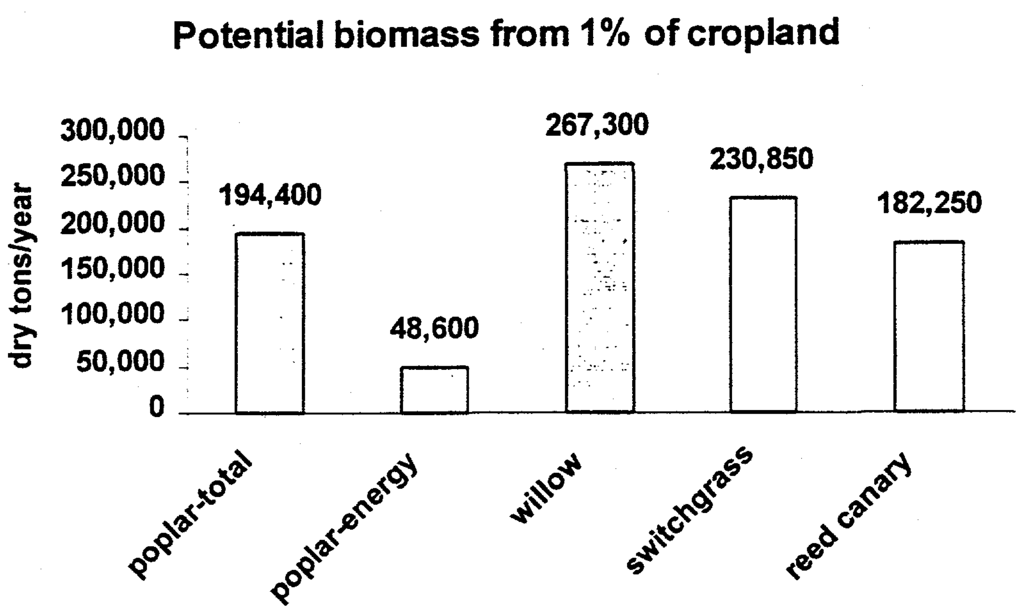


Figure 5. Annual biomass production from hybrid poplar, hybrid willow, switchgrass, and reed canarygrass on 1% of cropland in the biomass shed.

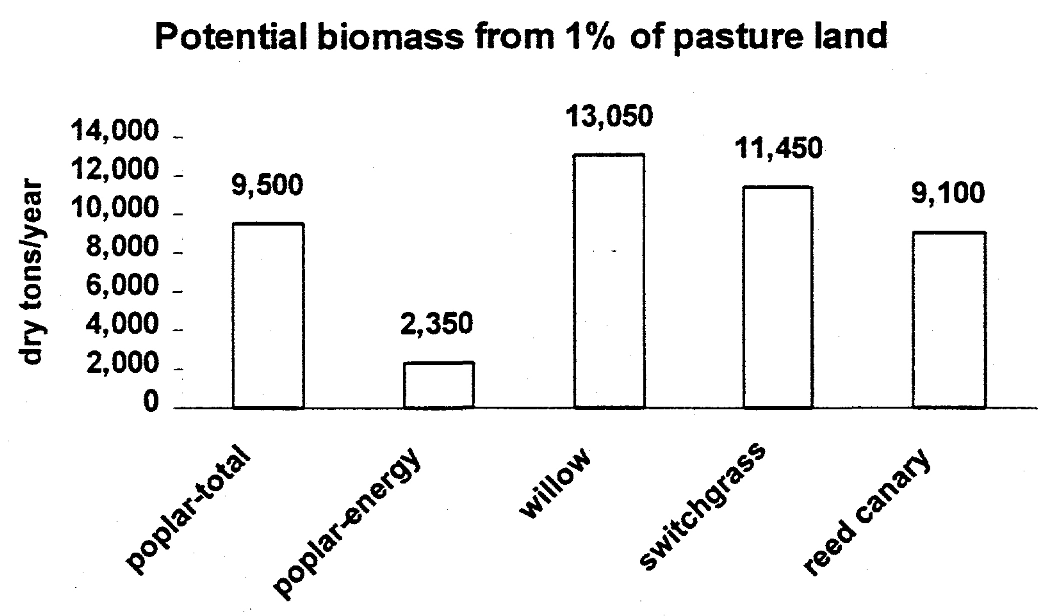


Figure 6. Annual biomass yield from hybrid poplar, hybrid willow, switchgrass, and reed canarygrass on 1% of pasture land in the biomass shed.

Switchgrass and Reed Canarygrass

Grasses offer farmers more flexibility than woody crops. They can be used either as an energy crop or as forage for animals, and have a shorter rotation than the woody crops. Land planted to grasses is easier to convert to annual crop production than land planted to trees. These features may facilitate grass biomass production on some productive land as well as on marginal land.

The ORECCL Database used switchgrass yields of 6.0 dry tons/acre/year in the 21 counties around Granite Falls. Research by the University of Minnesota supports a lower yield; about 3.8 dry tons/acre/year for a one-cut system (Sheaffer et al., 1995). Reed canarygrass produces about 3 dry tons/acre/year under a three-cut system in southern Minnesota (Undersander et al., 1995). We assumed that the grasses would be 25% less productive on pasture land than on CRP or cropland. Thus, pasture land yields were 2.9 dry tons/acre/year for switchgrass and 2.3 dry tons/acre/year for reed canarygrass (Figure 3).

Switchgrass could supply about 260,000 tons of biomass per year if planted on 1% of the total agricultural land in the 21 counties around Granite Falls (Table 11; Figures 4,5,6). Reed canarygrass could supply 205,000 tons of biomass per year if planted on 1% of total agricultural land. If breeding efforts increased productivity by 25%, these figures would rise to 325,000 tons/year and 257,000 tons/year, respectively.

Table 11. Annual biomass production potential of grasses.

Crop	Land Type	Inner Ring Counties	Outer Ring Counties	21 County Total	25% increase in productivity
		Annual Production Potential			
		dry tons/year†			
Switchgrass‡	CRP	9,700	8,100	17,800	22,250
	Cropland	113,150	117,700	230,850	288,600
	Pasture land	4,150	7,300	11,450	14,350
	TOTAL	127,000	133,100	260,100	325,200
Reed Canarygrass§	CRP	7,700	6,400	14,050	17,550
	Cropland	89,300	92,950	182,250	227,850
	Pasture land	3,300	5,800	9,100	11,350
	TOTAL	100,300	105,150	205,400	256,750

Sources: Oak Ridge Energy Crop County Level Database (Graham et al., 1996); Sheaffer et al., 1995; Undersander et al., 1995.

† Tonnages were calculated assuming that 1% of each land type would be planted to the crop; figures are rounded to the nearest 50.

‡ Switchgrass yield was 3.8 dry tons/acre/year for CRP and cropland; 2.9 dry tons/acre/year for pasture land.

§ Reed canarygrass yield was 3.0 dry tons/acre/year for CRP and cropland; 2.3 dry tons/acre/year for pasture land.

If alfalfa were to supply 90% of the MAP plant requirement, the remaining 10% could be supplied by 9,200 acres of switchgrass; or 7,950 acres of willow; or 11,650 acres of reed canarygrass; or 43,750 acres of hybrid poplar (Table 12, Figure 7). Supplying 10% of the MAP plant requirement with switchgrass or with willow would require 0.1% of the total agricultural land. Using reed canarygrass to supply 10% of the MAP plant requirement would require 0.2% of the total agricultural land. Supplying the 10% with the hybrid poplar slash remaining after harvest for fiber uses would require 0.6% of the total agricultural land.

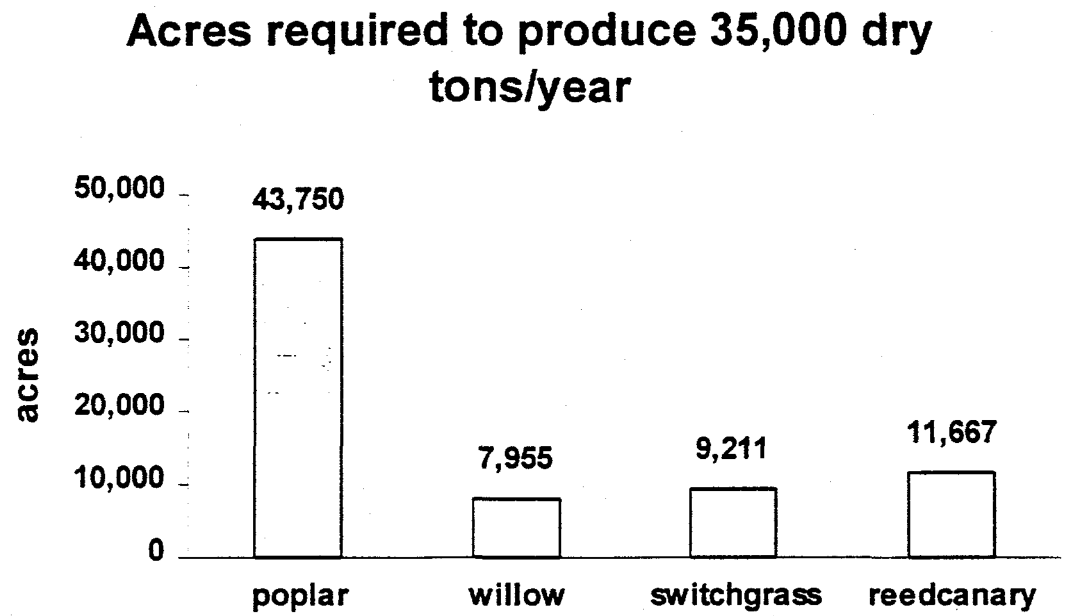


Figure 7. Number of acres needed for each crop to produce 10% of the Minnesota Agri-Power plant's annual biomass requirement of 350,000 tons. Sources: Graham et al., 1996; Graham et al., 1995; Kopp et al., 1993; Sheaffer et al., 1995; Undersander et al., 1995.

Table 12. Acres and percentage of total agricultural land in the biomass shed needed to produce energy crops to meet part of the Minnesota Agri-Power (MAP) plant requirement for 350,000 tons of biomass per year.

		Percentage of total MAP requirement†		
Crop	Yield‡	25%	10%	1%
	dry tons/acre/year	---------- Acres ----------		
Hybrid poplar	0.8	109,400	43,750	4,375
Hybrid willow	4.4	19,900	7,950	795
Switchgrass	3.8	23,050	9,200	920
Reed canarygrass	3.0	29,150	11,650	1,165
		----- Percentage of total agricultural land §-----		
Hybrid poplar	0.8	1.5	0.6	0.06
Hybrid willow	4.4	0.3	0.1	0.01
Switchgrass	3.8	0.3	0.1	0.01
Reed canarygrass	3.0	0.4	0.2	0.02

†Acreage figures in the 25% and 10% columns are rounded to the nearest 50.

‡ Yields are for CRP and cropland. Pasture land yields are 25% lower; thus, acres needed to meet MAP requirements are underestimated if pasture land will be used to produce the crops.

§ Total agricultural land; including CRP, cropland, and pasture land; in the biomass shed is 7,530,600 acres [Sources: U.S. Economic Research Service, 1995; Oak Ridge Energy Crop County Level Database (Graham et al., 1996); Minnesota Agricultural Statistics Service, 1997].

Projected Increases in Biomass Production from Woody Crops and Grasses

Hybrid poplar was assumed to require 12 years from planting to harvest. Willow would have a three-year establishment period followed by harvest every three years for 21 years before replanting. Switchgrass would have a two-year establishment period and annual harvest. Switchgrass stands would be expected to remain productive for ten years. Reed canarygrass would be harvested annually beginning the year after planting and stands would last four years.

Acreage planted to these biomass crops would increase over a period of years. For simplicity it was assumed that 1/12 of the hybrid poplar and hybrid willow acreage would be planted in each of 12 years, from 1998 to 2009. Reed canarygrass would be planted over a period of four years, one fourth of the total acreage each year. Reed canarygrass stands would be replanted after four years. Switchgrass would be planted over a period of ten years, one tenth of the total acreage each year. Switchgrass stands would be replanted after ten years.

If planting began in 1998 and 1% of the total agricultural land were evenly divided among hybrid willow, hybrid poplar, reed canarygrass, and switchgrass; the total biomass production would be almost 90,000 tons per year by the year 2002 (Table 13). By the year 2010, the total annual biomass production would be about 205,000 tons. Full production would be reached in 2010 under the assumptions listed above (Figure 8).

Table 13. Projected increases in biomass production† on 1% of total agricultural land (CRP, cropland, and pastureland) in the biomass shed; assuming the 1% is evenly split among reed canarygrass, switchgrass, hybrid willow, and hybrid poplar.

Year	Reed canarygrass‡	Switchgrass§	Hybrid willow¶	Hybrid poplar††	Total
	dry tons/year ‡‡				
1999	12,850				12,850
2000	25,700	6,500			32,200
2001	38,550	13,000	18,800		70,350
2002	51,400	19,500	18,800		89,700
2003	51,400	26,000	18,800		96,200
2004	51,400	32,500	37,600		121,500
2005	51,400	39,000	37,600		128,000
2006	51,400	45,500	37,600		134,500
2007	51,400	52,000	56,400		159,800
2008	51,400	58,500	56,400		166,300
2009	51,400	65,000	56,400		172,800
2010	51,400	65,000	75,200	13,700	205,300

† Biomass production for each crop = 0.25% of CRP, cropland, and pasture land acreage x crop yield/acre.
‡ Reed canarygrass yields were 3.0 tons/acre/year on CRP and cropland; 2.3 tons/acre/year on pasture land.
§ Switchgrass yields were 3.8 tons/acre/year on CRP and cropland; 2.9 tons/acre/year on pasture land.
¶ Hybrid willow yields were 4.4 tons/acre/year on CRP and cropland; 3.3 tons/acre/year on pasture land.
†† Hybrid poplar yields were 0.8 tons/acre/year on CRP and cropland; 0.6 tons/acre/year on pasture land. Poplar yields represented 25% of the total yield; the remaining 75% was assumed sold for fiber uses.
‡‡ Assuming that planting of all four crops begins in 1998; 1 year lag between planting and harvest for reed canarygrass, 2 year lag for switchgrass, 3 year lag for willow, and 12 year lag for poplar.

Hybrid Poplar Production Increases

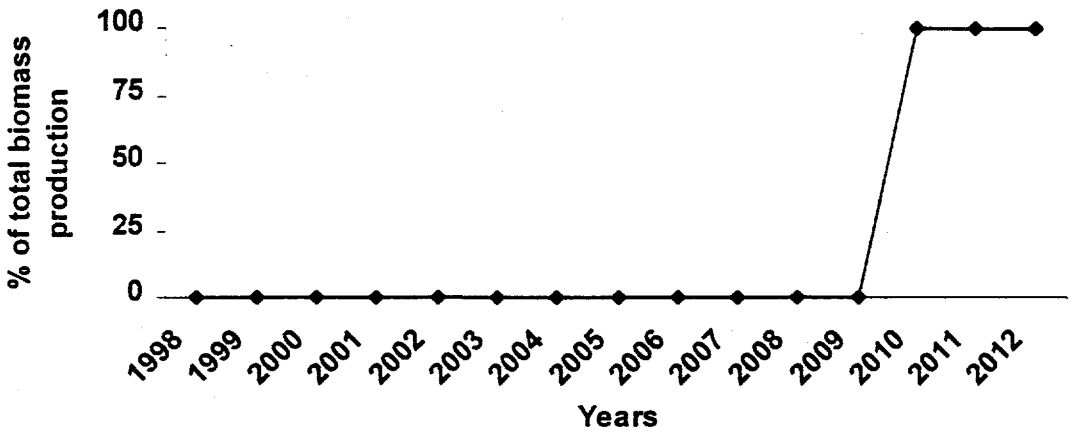


Figure 8A. Years to full production of hybrid poplar; assuming that 1/12 of the total acreage is planted each year from 1998 to 2009 and harvest occurs 12 years after planting.

Willow Production Increases

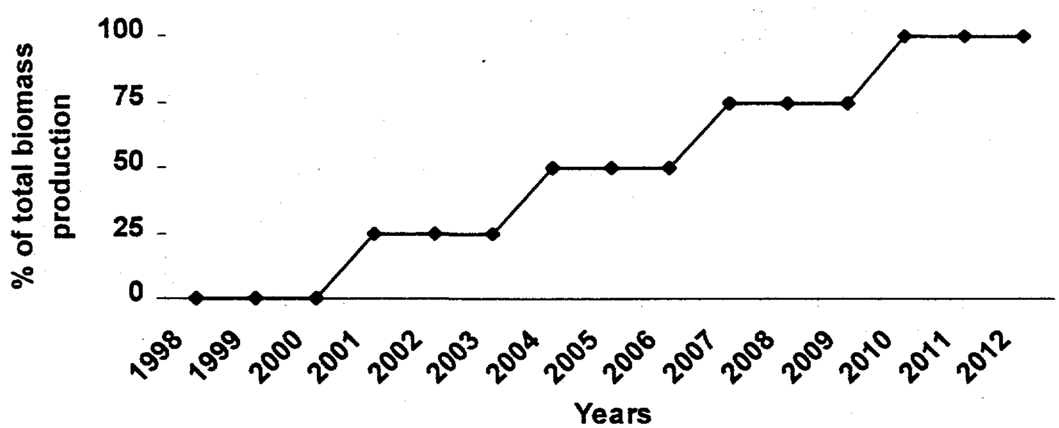


Figure 8B. Years to full production of hybrid willow; assuming that 1/12 of the total acreage is planted each year from 1998 to 2009, first harvest occurs three years after planting and every three years subsequently.

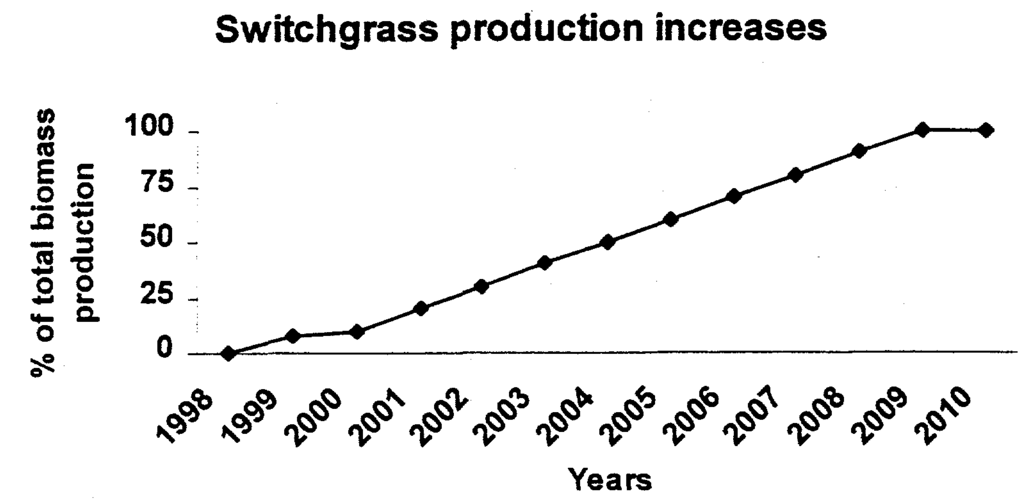


Figure 8C. Years to full production of switchgrass; assuming that 1/10 of the total acreage is planted each year, stands reach full production in the third year following planting, stands are harvested every year for ten years, and replanting occurs after ten years.

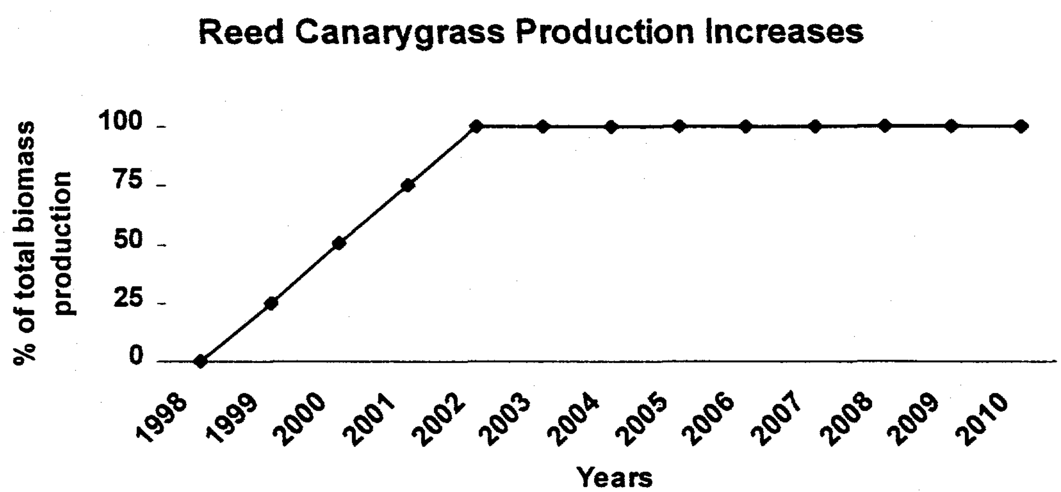


Figure 8D. Years to full production of reed canarygrass; assuming that one fourth of the total acreage is planted each year, harvest of the stand occurs every year for four years, and replanting is done after four years.

COST AND CHEMICAL COMPOSITION OF BIOMASS RESOURCES

Biomass fuel costs are competitive with fuel oil and natural gas in the current market (Table 14). Cost to acquire waste paper is expected to be zero or negative because in Minnesota there is currently a cost of about $40 to $50 per ton to landfill waste paper (Garrison Disposal Company, personal communication, March, 1998). There are processing and drying costs associated with biomass fuels. For waste paper, these costs are estimated to be $ 0.50 per MBtu (Carl Sulzer, United Power Associates, personal communication, May, 1998).

The chemical composition of biomass affects its suitability as a fuel. Low moisture is a desirable fuel trait because the drier the fuel, the less energy is required to dry it and thus more energy is available to produce electricity. Hay crops such as switchgrass can be sun-cured to a moisture content of about 15% before baling. Agricultural residues such as grain straw typically have low moisture content. (Table 15). Wood has a moisture content of around 50% at harvest.

Table 14. Comparative costs of fuel sources for electricity generation.

Fuel Source (point of purchase)	$ / Unit	$ / MBtu†	Reference
No.2 Fuel Oil ‡	$ 0.71 / gallon	$ 5.20	31
Coal §	$ 19.50 /ton	$ 1.12	29
Natural Gas ¶	$ 3.24 / 1000 ft^3	$ 3.40	30
Paper #	$ 0 / dry ton	$ 0	7,13
Poplar ††	$ 58.70 / dry ton	$ 3.94	8,18
Willow ††	$ 58.70 / dry ton	$ 3.51	8,19
Switchgrass ††	$ 40.79 / dry ton	$ 2.63	8,18
Alfalfa stems ‡‡	$ 40 / dry ton	$ 2.56	
Alfalfa stems	$ 50 / dry ton	$ 3.21	
Alfalfa stems	$ 60 / dry ton	$ 3.85	

† MBtu = Million British thermal units.
‡ 1997 average price to industrial consumers in the United States.
§ 1997 average price to electric plants in Minnesota.
¶ 1997 average price to industrial consumers in Minnesota.
# Cost to acquire waste paper is expected to be zero or negative.
†† Farmgate price; assuming no subsidy from the Conservation Reserve Program.
‡‡ Estimated range of alfalfa stem prices per ton; and assuming a higher heating value of 7800 Btu/lb. dry weight.

Table 15. Typical ultimate and proximate analysis of biomass products.

Parameter	Yard Waste	Construction /Demolition wood	Alfalfa Stems	Wheat Straw	Urban Waste Paper	Switch-grass	Hybrid Poplar
Heating Value †	2,472	6,997	7,108	6,992	8,892	7,015	4,498
Moisture %	41.61	16.27	10.48	8.39	6.73	13.68	45.00
Ash %	17.0	5.0	5.9	7.4	8.0	5.6	1.5
Nitrogen %	0.58	0.68	1.83	0.56	0.42	0.48	0.33
Sulfur %	0.06	0.17	0.09	0.17	0.07	0.05	0.01
Chlorine %	0.13	0.07	0.13	0.22	0.00	0.08	0.01

Sources: Generating Power with Wood Waste, Power Engineering, February 1995; EPRI Alternative Fuels Database, Electric Power Research Institute, Palo Alto, CA, December 1996 report TR-107602.

† Btu/lb. (British thermal units per pound).

Attachment 3.

Rivers of Life: Mississippi Adventure Study Guide