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# Economic Development Through Biomass System Integration: Volume 1

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## Project Team

The Center for Alternative Plant and Animal Products (CAPAP) within the College of Agriculture, University of Minnesota is coordinating the work related to alfalfa production as part of the dedicated feedstock supply system (DFSS) and will help evaluate the sustainability of the proposed system. To accomplish these tasks, CAPAP is working closely with farmers, business persons and local government agencies in the region, and with the Minnesota Extension Service (MES), the Minnesota Institute for Sustainable Agriculture (MISA), the United States Department of Agriculture - Agricultural Research Service (USDA-ARS), the Soil Conservation Service (SCS), the Minnesota Department of Agriculture (MDA), and the Minnesota Department of Natural Resources (MNDNR).

We welcome your comments, concerns, and suggestions. Project meetings and information gathering sessions will continue throughout the development and implementation of this project. Contact the University of Minnesota for more information.


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# CHAPTER 1. INTRODUCTION

## A Study To Determine The Feasibility of Producing Electricity and Leaf Meal Protein From Alfalfa

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[1]Center for Alternative Plant and Animal Products, [2]Minnesota Institute for Sustainable Agriculture, and the [3]Centre for Agricultural Education, University of Minnesota

The U.S. Department of Energy (DOE) predicts that renewable biomass energy crops will provide a significant portion of future fuel needs in America. This is good news for farmers. Crops grown specifically for energy production provide a major new market for agriculture.

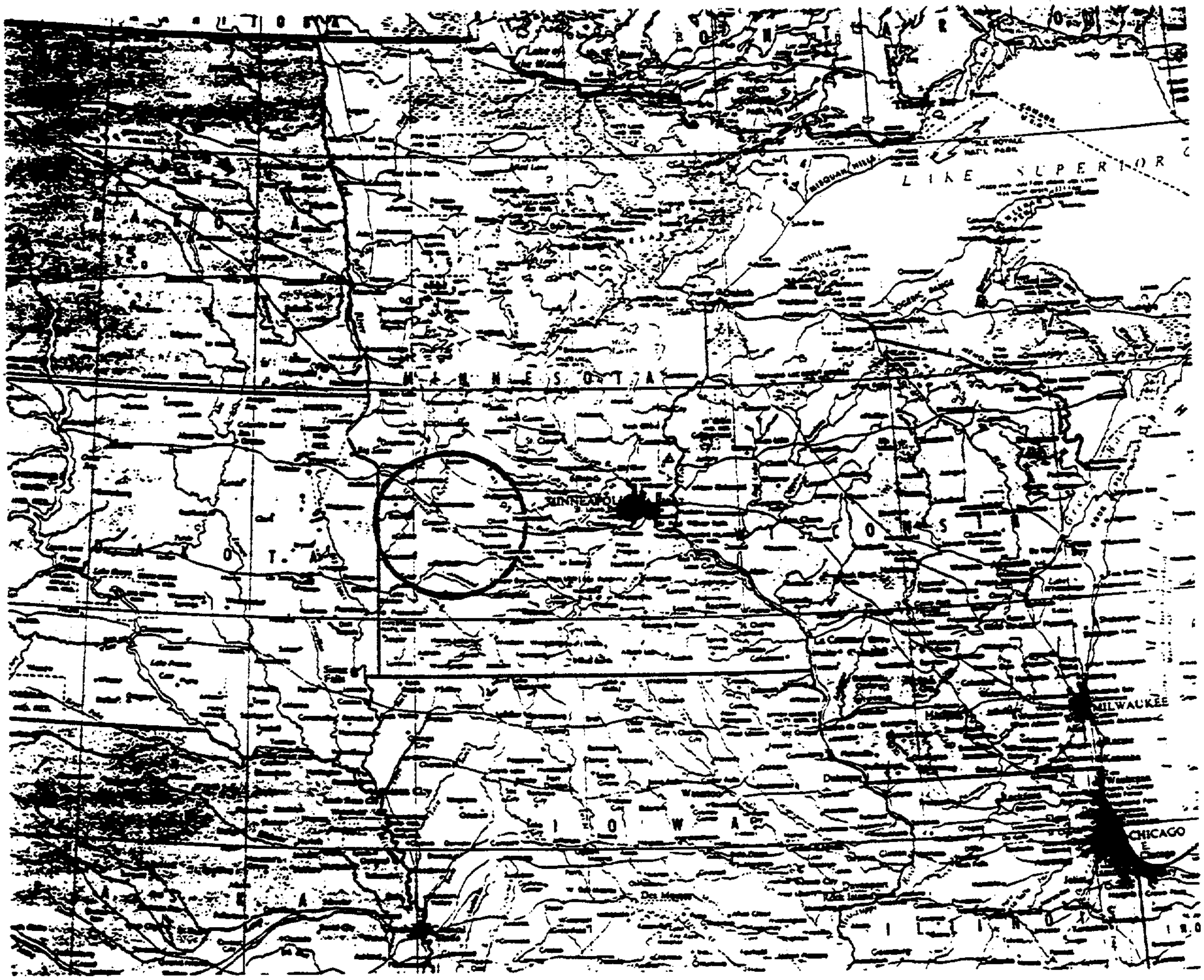
To make electricity from biomass (plant matter) you could burn it, making steam that would drive a steam turbine which in turn produces electricity. Most of the electricity produced in America today is made by burning fossil fuels (coal and natural gas).

A more efficient process to convert mass to electricity is gasification. Plant matter placed in a chamber under pressure and at high temperature (over 1500°F) is converted to gases (over 95% conversion). Biomass gasification produces a low Btu gas which may then be ignited in a combustion turbine for the production of electricity. Biomass electricity generation by a combustion turbine is more efficient and may be done on a much smaller scale than is typical for steam-turbine power plants.

Biomass fueled power plants distributed on the transmission system reduce grid and capacity upgrade requirements and also distribute cooperative business opportunities between biomass producers and power companies.

Northern States Power Company (NSP), Minnesota's largest electric utility, submitted a proposal to DOE and the Electric Power Research Institute (EPRI) to evaluate a proposed biomass energy production system. The following report analyses the feasibility of an alfalfa biomass fueled electric power generation system at an existing NSP power plant in Granite Falls, Minnesota (**Illustration 1.0-1**).

**Illustration 1.0-1** Map of the Upper Midwest. The alfalfa biomass production area is identified as the area within a 50 mile radius of Granite Falls in southwestern Minnesota.



NSP contracted with the University of Minnesota to determine the technical and economic feasibility of the biomass feedstock supply system. Power plants must have reliable, dedicated fuel supplies and biomass energy cropping systems must be sustainable. To be sustainable biomass energy production systems must provide viable economic returns for farmers and produce electrical power at a price that is competitive with new fossil fuel systems. Because all biomass fuels are less energy dense than coal, biomass crops must provide other sources of revenue for producers and utilities.

Alfalfa may be processed, much like we process corn and soybeans, to produce a wide variety of renewable products including electricity. Alfalfa grown in rotation with corn, soybeans, and other crops in the region, has the potential to provide a stable biomass fuel supply, improve profitability for farmers, and fuel electric power generation at a cost that is competitive with 'new generation' power production systems.

Alfalfa yields in southwestern Minnesota around the Granite Falls plant site are sufficient for sustainable biomass energy production. Additionally, current alfalfa breeding programs such as a joint effort by researchers at the University of Minnesota, United States Department of Agriculture-Agricultural Research Service (USDA-ARS), Pioneer Hi-Bred International and Forage Genetics are expected to provide alfalfa varieties specifically adapted for energy production. Selection for elevated lignin concentrations in alfalfa stems to increase energy density is one aspect of this plant breeding effort. Although improvements in per acre yield and energy yield (Chapter 2) are expected, we believe that current yields are adequate to establish alfalfa as a base crop for biomass energy production.

Benefits from including alfalfa in the rotation include: increased yield from other crops in the rotation, reduced external inputs of nitrogen, lower overall production costs (fossil fuels inputs), and distinct environmental benefits (Chapter 10). Environmental benefits include reduced soil erosion, improved soil tilth, increased soil organic matter levels, reduced potential for nitrate leaching, and a reduction in diffuse source pollutants.

The integration of energy production systems into rural communities has great potential to stimulate economic development by creating new opportunities for small businesses and diversifying our rural economic base. The integration of alfalfa biomass energy crops into traditional agricultural cropping systems provides a dedicated energy fuel supply capability that is here, today.

## 1.1 THE PRODUCTION SYSTEM

Minnesota farmers currently produce over 6.9 million tons of alfalfa hay per year, the fourth largest production level of alfalfa in the country. However, alfalfa acreage covers less than 6% of Minnesota's total cropland (Minnesota Agricultural Statistics 1992). The production of alfalfa for energy is a major new market that allows producers to benefit from including alfalfa in traditional rotations. Alfalfa production for multiple use, as in the proposed biomass energy production system, will be significantly different from alfalfa produced strictly as feed.

The proposed production area for alfalfa (biomass shed) is defined for this study as an area within a 50 mile radius of Granite Falls, Minnesota. This region of southwestern Minnesota depends primarily on cash crop production agriculture. The farmland within the counties included in the shed currently produce 2.8, 2.6, and 0.34 million acres of corn, soybean, and alfalfa, respectively. The size of the average farm in the shed is 580 acres.

Based on focus group interviews (Appendix 1.1), we anticipate that biomass producers will be experienced farmers operating farms in the biomass shed. These farmers will be motivated to start producing or increase their production of alfalfa to increase profitability, reduce risk through diversification, and enhance environmental quality on their farms.

Economic evaluation of a dedicated feedstock supply system (DFSS) for the production of energy from alfalfa indicates that the breakeven price for alfalfa in this system (compared to a conventional corn-soybean rotation) is about $67/ton (Chapter 4). The example 7-year biomass rotation (DFSS rotation) evaluated in this study was four years of alfalfa followed by two years of corn and then one year of soybeans. Economic advantages of the DFSS rotation may be directly attributed to the inclusion of a perennial legume in the rotation. Reduced input costs, compared to conventional rotations and increased yields for other crops in the rotation result in increased profits for producers.

The benefits of including alfalfa in a rotation are well documented. However, alfalfa production has been limited due to the problems associated with shipping alfalfa long distances (hundreds of miles in some cases) to reach markets and a declining market for average quality hay (Chapter 8). **High regional demand for alfalfa, such as that provided by a biomass power plant, will stimulate production, allow for value-added processing, and allow producers to achieve the economic and environmental benefits of a perennial legume in agricultural production systems.**

Overview of Biomass Energy Production

About 2000 farmers in southwestern Minnesota invest in a biomass energy cooperative and sign contracts to produce about 680,000 tons of alfalfa annually for their grower-owned cooperative (contract price offered is competitive with other crops in the region). Grower-owners are paid on the basis of tonnage and quality.

Biomass-type alfalfa varieties are developed specifically for biomass energy production. Biomass-type alfalfa varieties have greater standability than current varieties and allow producers to opt for a two-harvest production system (Chapter 2).

Alfalfa is baled into large-round bales and transported by the grower to one of the regional storage sites that surround the alfalfa processing plant in Granite Falls, MN. The transportation and storage system has been designed so that most producers have less than 5 miles to travel to a remote storage site. Alfalfa is weighed and tested for quality at the remote storage site. During the growing season about 40% of the crop is direct-hauled from remote storage, by the cooperative, to the processing plant. About 60% of the crop is placed in storage at the remote site (under plastic cover and/or in steel pole buildings, see Chapter 5).

A fleet of twenty tractor-trailer rigs work two shifts per day, 6 days per week for about 300 days per year delivering alfalfa to the plant. A small stockpile, two or three days worth, of alfalfa is held at the plant for processing during times when delivery is interrupted by bad weather or other supply system problems.

At the plant, alfalfa is separated into stem and leaf fractions. The stem fraction is fed under pressure to a gasifier, converted to a low Btu fuel gas, and combusted in a turbine to produce electricity. The leaf fraction is processed into various alfalfa leaf meal products.

Farmer members of the cooperative produce alfalfa and deliver their crop to remote storage where ownership of feedstock changes hands. Growers are paid based on tonnage and quality. The alfalfa cooperative now collectively owns the crop. Storage losses, transportation, and processing become the responsibility of the cooperative or potentially a joint-venture between a cooperative and NSP.

## 1.2 THE CONVERSION TECHNOLOGY

NSP has also contracted with the Institute of Gas Technology (IGT), Tampella Power Company, and Westinghouse Electric Corporation. IGT is a private non-profit research organization with ten years of development work on the process of pressurized biomass gasification. Tampella is a Finnish company with subsidiaries in the U.S. and has the capability to design and construct power plants. Westinghouse manufactures combustion turbines and has developed the hot gas cleanup system proposed for this project.

IGT developed the RENUGAS™ biomass gasification process, a pressurized, air-blown, single-stage fluidized bed gasifier. The RENUGAS™ process has been designed to operate at pressure, uses single-screened feedstock, uses no catalyst, and is mechanically simple to operate. Gasification tests in a 10 ton-per-day process development unit have been conducted at IGT in Chicago with a variety of biomass sources, including alfalfa. These tests have demonstrated high carbon conversions and high thermal efficiencies with a low production of condensible products. The RENUGAS™ process will handle a wide range of biomass materials from whole-tree-chips to finely chopped sugarcane bagasse.

Westinghouse has developed a hot-gas cleaning system that is critical for the successful integration of a biomass gasifier with a combustion turbine for high-efficiency power generation. Fuel gases derived from alfalfa biomass will contain contaminants which could lead to corrosion, erosion, and deposition in the combustion turbine. Therefore, a gas cleanup system, including particulate removal, and possibly alkali removal, is necessary.

A commercially available Westinghouse combustion turbine is specified in this design. Combustion turbines used for electricity production are similar, in design, to turbine engines on commercial jet aircraft. Westinghouse has developed a low $NO_x$ combustor (multi-annualar swirl burner) that reduces the conversion of fuel bound nitrogen to $NO_x$. Alfalfa stems are higher in fuel bound nitrogen than many other biomass feedstocks therefore $NO_x$ emissions have been a concern. Westinghouse test results confirm and warrantees and /or guarantees will assure that $NO_x$ levels do not exceed EPA clean air standards.

Tampella Power Company together with NSP determined capital cost of the power plant and the cost of electricity from the proposed system. Tampella has constructed and operates a biomass gasification plant in Finland that uses wood chips. The final report on the conversion technology is in Volume 2.

## 1.3 SUSTAINABILITY

Sustainable biomass energy production systems must be productive (positive energy balance), must provide viable economic and environmental returns for farmers and rural communities, and must provide society at large with low cost environmentally friendly energy.

Energy balance:

Chapter 10 of this volume offers a detailed analysis of the energy balance for the proposed project. Energy input:output analysis indicates the conversion of alfalfa to electricity results in a highly positive energy balance (1:3). The ratio of energy in to energy out is critical in determining the overall system efficiency for biomass energy production. Energy balances for the two different crop rotations studied (DFSS and corn-soybean) indicate that the DFSS rotation generates more gross energy and more crude protein per acre with lower energy inputs than a traditional corn-soybean rotation.

Economic and Environmental Benefits:

Will farmers and rural communities benefit from alfalfa biomass energy production?

**Economic Impact**

The economics for alfalfa biomass energy production are calculated to provide equal or higher returns to growers for the production of biomass in the proposed DFSS rotation compared to traditional corn-soybean rotations. Diversification of the agricultural base in the region is expected to stimulate small business development and provide economic stability in the region (Chapter 5.6).

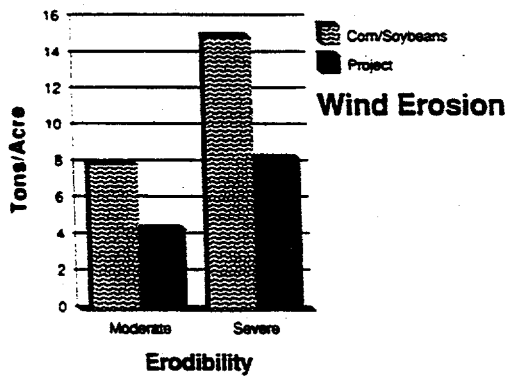
Feedstock production, in state, replaces imported coal from the western U.S. and contributes to Minnesota's energy self-sufficiency. A 75 MWe coal fired power plant would consume over $10 million dollars of coal annually.

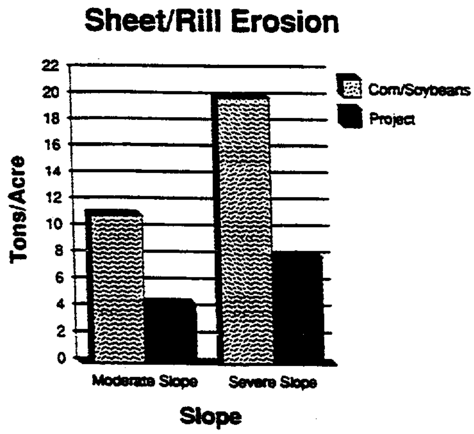
The processing plant will employ over 50 persons (full-time) to produce both electricity and leaf meal products. Over 50 (full-time) transportation related jobs and 60 - 80 (part-time) jobs will be created for storage and handling of the feedstock. Distribution, sales, and marketing of leaf meal products will provide additional economic opportunities.

## Soil and Water Resource Impacts

Chapter 10 outlines the potential impacts on the soil and water resources in the proposed biomass shed. An evaluation was made by looking at present land use and soil erosion levels compared with projected soil erosion levels when those same acres are placed in an alfalfa-based rotation. The analysis shows that the alfalfa-based rotation would reduce sheet and rill water erosion by 60% and wind erosion by 45% (**Figure 1.1-1**). Targeting fields with high erosion rates as well as on eroding fields with high sediment delivery rates to surface waters for biomass production would maximize environmental benefits.

**Figure 1.1-1** Changes in different types and levels of erosion as measured in tons/acre for project rotations that include alfalfa as a biomass energy crop compared to traditional corn-soybean rotations in the area.




## Wildlife Benefits

Establishing alfalfa in the area surrounding Granite Falls to produce a high-protein livestock feed and stems to fuel the power plant will have a significant impact on the abundance and diversity of wildlife in the area. The magnitude and direction (positive or negative) of these impacts will depend on the following factors: mowing schedule; amount of residual cover over the winter; previous field use (CRP land, corn and soybeans, etc.); size and shape of the fields; distribution of the fields; and mowing patterns. Chapter 10 includes a detailed analysis of the impact of the proposed DFSS on wildlife.

A proposed alfalfa harvest schedule (two-cuttings per year (late June and late August) would have very significant positive impacts on both wildlife abundance and diversity. Mowing schedules similar to those used in conventional forage production have significant negative impacts on wildlife.

Perceptions and Attitudes

What are the impacts on communities and rural residents in the proposed biomass shed should a demonstration project be approved for the Granite Falls power plant?

**Farmers Concerns and Willingness to Participate**

Farmers participating in focus group interviews generally expressed the belief that the plan could benefit them and the community at large. However, farmers indicate they would require a clear, concise plan before making a decision about including alfalfa in their crop rotation. The complete report of the focus group study is found in Appendix 1.

In all five of the focus groups conducted for this project, the idea that alfalfa is a "good" crop to grow was unanimous; participants clearly understood the benefits of including a perennial legume in their crop rotations. Yet, this perception of "good" was continually tempered with the farmers' perception of financial risk.

Given the perception that change is risky, farmers must have assurances that the rewards for changing their crop rotations to include alfalfa as a biomass energy crop will be substantially greater than they presently receive with their current cropping system. Farmers indicated that if they perceive the rewards to be less than, equal to, or even slightly more than they currently receive, they would not participate.

**Community Impacts**

Regular community meetings were held during the course of the nine-month study. Meetings were held with area farmers, county Commissioners, county Extension Educators, the Granite Falls Chamber of Commerce, as open public forums, and with employees at NSP's existing Minnesota Valley power generation facility. A complete list of meeting is included in Appendix 1.3.

During these meetings community members expressed:

* concerns about this being "just another project touted to be good for the region with no positive impacts realized" (they cited problems in the past with Jerusalem artichokes and wind energy proposals);

* that farmers need a long-term commitment from NSP regarding purchase of the alfalfa stems for biogasification;

* concern about marketing the high-protein by-product and competition with other sources of animal feed supplements produced regionally;

* various opinions on storage issues;

* and, about the benefits of increasing jobs at the power plant and in the production, transportation and handling sectors in the region.

Interestingly, there was some, but very limited, concern about increased traffic around the power plant facility and on roads in the counties. Appendix 1.3 provides an overview of questions and comments made during some of these meetings.

It is important to note that in spite of concerns expressed and questions asked about the plan by people attending the community meetings, overall support for the plan was very high. Should a demonstration project be implemented in Granite Falls, additional meetings (potentially using the focus group format) should be held to solicit further community input into the development of sustainable biomass energy production.

An Agricultural Advisory Council was formed early during the course of the nine month study. The Ag Advisory Council is made up of persons from southwestern Minnesota that are interested in this project. A complete listing of the Ag Advisory Council is included in Appendix 1.3. At the conclusion of this study a subset of the council (all active farmers) decided to form a producers cooperative to further their ability to continue to evaluate and potentially to implement sustainable biomass energy production in Minnesota. The list of the Board of Directors of the newly formed **Minnesota Valley Alfalfa Producers** follows.

# 1.4 Minnesota Valley Alfalfa Producers

**Board of Directors**

Mr. Dick Jepson, Chairman
Rt 3, Box 98, Granite Falls MN 56241
(612) 564-4068

Mr. Dennis Goehring, Vice-chair
1952 County Rd 4 NE, Atwater MN 56209
(612) 974-8846

Mr. Tim Dale, Treasurer
R2, Box 50, Hanley Falls MN 56245
(612) 669-4666

Mr. Leon Doom, Secretary
RR1, Box 123, Cottonwood MN 56229
(507) 423-6459

Mr. Rollie Ammerman, member
4035 140th Ave S.E., Clara City MN 56222
(612) 847-2519

Mr. Jason Boike, member
5060 40th St. SE, Maynard, MN 56260
(612) 367-2972

Mr. Marvin Boike, member
2050 40th Ave SE, Maynard, MN 56260
(612) 367-2767

Mr. Dennis Gibson, member
2030 10th Ave NE, Montevideo MN 56265
(612) 269-8103

Mr. Marshall Herfindahl, member
RR1, Box 171, Boyd, MN 56218
(612) 855-2542

Mr. Wayne Karels, member
5028 Hwy 212 SW Montevideo, MN 56265
(612) 269-8321

Mr. Kim Larson, member
7911 Co #5 NW, Willmar MN 56201
(612) 235-3575

Mr. John Moon, member
RR4, Box 129, Montevideo, MN 56265
(612) 269-5957

Administrator:

Mr. L. David Velde, member
RR2, Box 53A, Granite Falls, MN 56241
(612) 564-4187

### 1.5 Time Frame for Full Production of the DFSS

Maximum yield of alfalfa is reached in the second year after seeding. The establishment year yield is typically 40 - 60% of full production. Because success in alfalfa establishment is influenced by weather, growers participating in the production of alfalfa biomass for energy should consider planting a portion of their total acreage commitment over a number of years thereby achieving diversity of stand age and minimizing establishment year risk.

## Biomass Project Team

**Minnesota farmers**
**University of Minnesota**
**Minnesota Extension Service**
**Minnesota Department of Agriculture**
**Minnesota Department of Natural Resources**
**Minnesota Institute for Sustainable Agriculture**
**Agricultural Research Service, USDA**
**Soil Conservation Service, USDA**
**Local community leaders**
**and others**

# CHAPTER 2. ALFALFA BASICS

## 2.1 Diversity and Adaptability

Donald K. Barnes, Research Leader, Plant Science Research Unit,
ARS, USDA

**Introduction**
Alfalfa is the primary forage legume in the United States. In Minnesota alone, there are about 2,000,000 acres. It is grown for livestock feed and is harvested and stored as hay or silage. A smaller amount is harvested as greenchop or grazed by cattle. Hay, silage, and greenchop differ in the moisture content at harvest. Greenchop is cut directly from the field at a moisture content often >80% and is fed immediately to animals. In hay and silage production, moisture loss must occur for effective long-term storage. Hay is stored aerobically at moisture content of <20%, while silage is stored anaerobically at between 40 and 75% moisture.

**Genetic Diversity and Adaptability of Alfalfa**
Alfalfa is grown in many areas of the world. It is a highly adaptable plant with aspects of genetic diversity that are exploited in various climates. Alfalfa originated near Iran, Turkey, and southwest Russia, although forms of it and related species are found as wild plants over central Asia and Siberia. Alfalfa may have first been cultivated in Iran. Romans record the introduction of the plant into Greece around 500 B.C. Alfalfa spread around the world, as fuel for horses of invading armies. Spanish explorers brought the crop to Central and South America.

Alfalfa was unsuccessfully tried in the colony of Georgia in 1736, and by George Washington and Thomas Jefferson in the 1790's. It was successfully introduced in California by gold seekers and missionaries who obtained seed from Chile (1850's). From California the crop spread east to Kansas, the Midwest, and later to the Eastern U.S.

In 1857 seed from Baden, Germany was introduced in Carver County, Minnesota by Wendelian Grimm. After many years of selecting seed from plants surviving Minnesota winters the variety "Grimm" was produced. Grimm proved winterhardy for north central states and Canada. The most rapid expansion of alfalfa acreage in this part of the country took place in the 1950's when varieties combining winterhardiness and resistance to bacterial wilt were developed.

Alfalfa grows under many diverse environmental conditions. It is noted for its tolerance of extremes in temperatures as well as its ability to survive moisture deficits. Adapted varieties have survived temperatures below -35°C (-31°F) and above 50°C (120°F). Alfalfa becomes dormant during periods of drought and resumes growth when moisture conditions become favorable. In Minnesota, adapted disease resistant varieties usually maintain productive stands for four years following the seeding year. However, management and cultural practices can affect stand longevity. Variation of temperature and moisture during the growing season influence yields. Highest growth rates usually occur in the spring with lower growth rates in mid-through late summer.

Alfalfa is best adapted to deep loam soils with porous subsoils which are well drained. Alfalfa grows best when soil pH levels are between 6.0 and 7.0 and when there are adequate levels of phosphorous, potassium, and micronutrients.

Over sixty years of intense breeding activity by public institutions and private companies has resulted in persistent varieties with high yields, disease resistance, and winterhardiness. Varieties are available that can be grown in most areas of the United States. Advances have been made in breeding alfalfas with improved forage quality, a characteristic that allows greater intake and nutritional benefits for most livestock. Alfalfas of this type require frequent harvests to prevent lodging with maturity. Breeding for resistance to plant diseases and insects has proven to be very beneficial. All varieties are now rated for resistance to various wilts, root rots, and particular insects. Nonhardy varieties have been released with abilities to fix large amounts of nitrogen for the succeeding crop in a plow-down situation.

**Alfalfa Breeding Goals and Challenges**

This review of the genetic variability found in alfalfa allows one to appreciate its broad range of adaptability and the special characteristics of the plant that can be exploited in a directed breeding program. Many recently developed alfalfa varieties currently are being sold in the proposed biomass shed. Most of these varieties have been bred for improved pest resistance and improved forage quality for the dairy animal. The current varieties have also been selected under either three or four harvest management systems.

Current varieties vary in potential to fit into a two-harvest co-product (leaves and stems), biomass system. Within the next several years the best available varieties will be used in the scale up of the biomass production system. Newly developed biomass-type varieties will increase the efficiency of the proposed system.

A proposed prototype variety would include the following traits: winterhardy; resistant to bacterial wilt, Phytophthora root rot, and Fusarium wilt; large diameter, solid stems with high lignin; late flowering; tall; non-lodging; resistant to common leafspot; and leafy with leaves that are retained during harvest. Development of this prototype will require that plant breeders go back to some old germplasm sources that will provide the needed stem morphology and quality traits. Breeding varieties with a combination of late maturing, common leafspot resistant, with high leaf retention will not be easy. This is because all current varieties were selected under frequent harvest systems that favored early maturity, and common leafspot was controlled by frequent harvest.

A program to select for tall, large diameter, and solid stems has been under way for several years in the USDA-ARS alfalfa breeding program at St. Paul. A population of plants with the desired stem traits was selected in 1993, intercrossed in the greenhouse during the 1993-94 winter, and that seed sent to Prosser, WA, in April 1994 for a seed increase. This seed will be available for planting in May 1995 and should provide a basis for comparing current varieties with prototype populations under several biomass harvest systems. Plantings of various selected populations also were planted in 1994 in order that further selections could be made in 1995.

It is our opinion that the alfalfa management and production data previously obtained on varieties provides a realistic set of baseline data for judging the feasibility of the proposed Biomass System. However, it should be possible to increase the efficiency of the system by at least 25% if varieties similar to the proposed prototype variey were available. We believe this could be accomplished within a period of about 6 years (2000). It should be possible to develop varieties with a partial list of desired traits in a shorter period. Until new prototype varieties are available growers should grow current varieties that are tall, high yielding, and least prone to lodging. Available yield data from Morris and Lamberton can help delineate better varieties.

## 2.2 Seed Availability

Neal P. Martin and Craig C. Sheaffer
Department of Agronomy and Plant Genetics
University of Minnesota

Alfalfa varieties are developed and supplied primarily by commercial companies. Over 100 different varieties are available, in state, and have been tested in Minnesota. These varieties are distributed by more than 50 retail dealers throughout Minnesota and the Midwest. Minnesota producers annually seed about 425,000 acres at about 16 lb/A. Approximately, 6.8 million pounds of alfalfa seed are sold annually in Minnesota. The proposed "Alfalfa Biomass Energy Demonstration Project" will require 150,000 to 200,000 acres of alfalfa at full production. At the recommended seeding rate, an 8% to 11% increase in annual seed supply in Minnesota will be needed. Minnesota's seed requirements are less than 10% of the U.S. annual supply. Adequate supplies of alfalfa seed would be available even if the entire acreage were to be seeded in one year.

## 2.3 Establishment and Growth

Alfalfa establishment is a critical first step in insuring a profitable crop. In extreme situations, poor establishment may necessitate reseeding; however, more often poor establishment results in thin stands with decreased production potential. Steps for effective alfalfa establishment follow:

1. Select well drained soils which are free of perennial weeds such as quackgrass and free from herbicide carryover.

2. Test the soil to evaluate the fertility level and pH of the soil. Fertilizer and lime should be applied based on Minnesota soil testing recommendations. Lime, if required, should be applied and mixed within the soil plow-layer 12 months before seeding.

3. Select a disease resistant variety with sufficient winterhardiness to provide long-term persistence. Since the target area in western Minnesota includes regions with high winter injury potential, "fall dormant" varieties should be used with at least moderate levels of resistant to bacterial wilt, phytophthora root rot, fusarium wilt, anthracnose, and verticillium wilt. Select varieties with demonstrated high yield potential at Morris and Lamberton.

4. Seed in spring from April 15 to May 15 or in summer from August 1 to 15. Spring seedings are usually more successful because they occur during favorable periods of moisture and provide a full season for growth.

5. Prepare a firm seedbed. A firm seedbed insures good soil-seed contact and shallow seed placement enhances seedling establishment. Seed from 1/4 to 1/2 inch deep. A firm seedbed can be achieved by tillage of the seedbed followed by smoothing or by using minimum tillage procedures. Packing of the seedbed using press wheels or rollers enhances establishment.

6. Suppress weeds which interfere with alfalfa establishment. Perennial weeds should be controlled in the year before seeding and annual weeds can be controlled using herbicides. Details on herbicides for weed control in alfalfa are provided in the publication: Cultural and Chemical Weed Control in Field Crops, Minnesota Extension Bulletin AG-BU-3157.

7. Seed at rates between 12 and 15 pounds per acre, use 15 pounds when direct seeding without a companion crop. With a firm seedbed, these seeding rates will result in seeding year stand densities of greater than 30 plants per square foot.

8. Schedule the first cutting in the seeding year about 60 days following emergence.

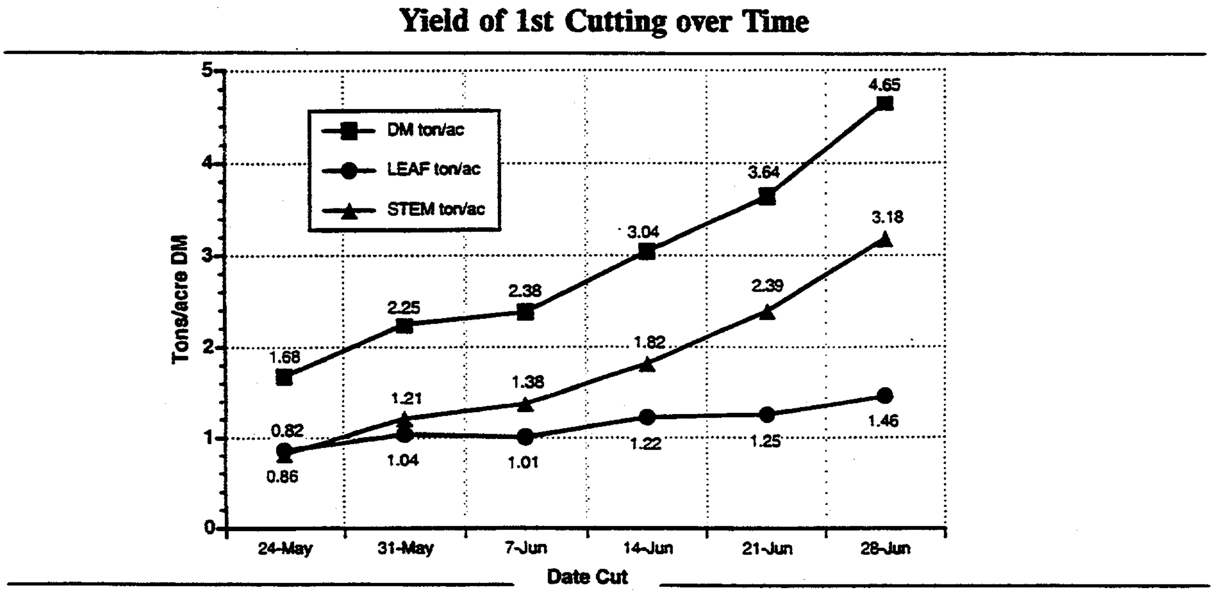
9. Companion crops such as oats or barley can be used as nurse crops on erodible soils and for weed suppression; however, alfalfa yields in the seeding year will likely be reduced by 60-70% compared to establishment using a herbicide.

## Alfalfa Growth Patterns

Alfalfa is a perennial crop which, following winter or cutting, regrows from the crown. A growth cycle consists of plant development from vegetative through bud and flowering stages. If uncut, new regrowth will occur from the crown when alfalfa flowers. As alfalfa proceeds through a regrowth cycle, forage yield or biomass accumulates rapidly until early or first flowering. Forage biomass accumulation continues until full flower, but often loss of mature leaves from lower portions of the canopy reduces the rate of yield increase after first flower. If uncut, alfalfa in southern Minnesota will go through two regrowth cycles.

The relative proportion of leaves and stems varies at different stages of growth. At vegetative stages, in late May, the leaf proportion is usually equal to or greater than that of stems; however, by first flower and sometimes earlier, stem proportion exceeds leaf proportion. Therefore, increases in alfalfa yield beyond early flowering are largely attributed to increases in stem proportion (**Fig 2.3-1**).

**Figure 2.3-1** Weekly harvest of alfalfa at the Rosemount Agricultural Experiment Station (1994, total dry matter yield per acre and relative yields of leaf and stem).




Alfalfa depends on root carbohydrate reserves for regrowth following winter and harvest. Storage and utilization of root reserves follows a cyclic pattern of decreasing during the initiation of regrowth and then accumulating until plants reach full flower. Since higher levels of carbohydrate reserves are associated with persistence, harvesting fewer times per year at more mature stages usually results in the greatest persistence.

## 2.4 Alfalfa Pests

### Yield Reducing Factors: Insects, Diseases, and Weed Competition

Insect pests

The alfalfa weevil and potato leafhopper are insect pests which have the potential to reduce alfalfa yield and quality in the biomass shed. Potato leafhoppers are small (1/8 inch) green insects which migrate into Minnesota on winds from the southern USA in about mid-June. They suck sap from plants and inject a toxin which causes leaves to turn yellow. Yield and quality losses occur before symptoms occur; therefore, scouting of fields beginning in June is essential. There is a 70% chance of potato leafhopper damage in the biomass shed with an average protein loss of about 500 lb/acre; dry matter yields are less affected. Several insecticides are available for control of leafhoppers. Insecticides should be applied only when populations reach the economic threshold control level.

The alfalfa weevil overwinters in Minnesota and lays eggs in the spring. Eggs hatch beginning in mid-May and larvae chew and skeletonize leaves. Damage is most often limited to growth during spring, as feeding falls off in mid-June and a harvest in early June usually removes most of the larvae. The alfalfa weevil is not a serious pest in the biomass shed with only a 10% probability of having weevil numbers sufficient to damage alfalfa. With routine scouting of alfalfa fields, populations can be monitored so that insecticides can be applied should populations reach economic threshold levels.

Diseases

There are many diseases which affect alfalfa yield and persistence. For most vascular and systematic diseases, the best control measure is to select a disease resistant variety. Varieties lack resistance to most of the leaf diseases. Leaf loss due to leaf disease is more severe as the canopy matures and becomes dense; therefore, delaying the first harvest beyond early June or extending harvest intervals beyond 40 days is likely to predispose the stand to greater leaf loss. The relatively dry climate in the biomass shed should reduce the severity of most alfalfa leaf diseases.

Weeds

Weed invasion can increase as stands of alfalfa age. Grasses that tolerate the frequency of alfalfa harvests can become invader species. Broadleaf species such as dandelion, with their ground-hugging profile can also invade and multiply as alfalfa stands age. Areas of fields with seasonally excessive wetness may lose alfalfa plants due to the lack of oxygen and also the prevalence of diseases. Areas of fields with dead or declining alfalfa stands are soon replaced by weeds that can tolerate those conditions such as quackgrass. Producer practices such as soil nutrient maintenance and timely harvests encourage healthy alfalfa stands.

## 2.5 Harvest

### Yields and Character of Yields Under Different Cutting Schedules

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Alfalfa yields in the state of Minnesota average about 3 ton per acre per year. Yield potential is influenced by soil and climatic conditions within a region. In long-term yield trials at Lamberton and Morris which are in and bordering the biomass shed, 'Vernal' alfalfa, a widely grown public variety, yielded an average of 4.1 tons per acre and had minimum and maximum yields of 1.6 and 6.7 tons per acre (dry weight). Extreme variation in yield is related to environmental conditions, especially moisture.

Based on the growing season temperature and rainfall in southern Minnesota, producers currently harvest alfalfa either three or four times per year when alfalfa is at bud to first flower stages. These schedules provide feed for beef and dairy cattle. Harvest schedules with only two cuts per season were routinely used before 1950 when varieties lacked persistence and yield but two-cut schedules are not currently used unless induced by weather.

We have summarized recent alfalfa cutting management research conducted in southern Minnesota (**Tables 2.5-1 and 2**). This research compared the effect of several 2, 3, and 4 cut schedules on leaf percentage, total forage yield, leaf yield, and stem yield of alfalfa. As the number of cuts increased from 2 to 4 per season, leaf percentage increased. Leaf yield was consistently lower for the 2-cut schedules than for the 3- and 4-cut schedules (**Fig 2.5-1**). Overall, dry matter yields were greatest for the 3-cut schedules with yields similar for some two and four cut schedules. Within the 2- and 3-cut schedules, there is considerable flexibility in selection of a harvest regime. Within the 4-cut schedule, schedule 7 which consists of cuttings at bud stage resulted in exceptional yields of total forage and leaves; however, this schedule might have very detrimental affects on nesting wildlife due to the early and frequent cutting.

Other cutting schedules are possible in addition to the ten shown. Such schedules may vary the interval between harvests during the season or focus on providing a very leafy forage at one harvest with a less leafy forage at subsequent harvests. Such a schedule would roughly involve harvests on 25 May at bud stage, 4 July at first flower, and 25 August at first flower.

**Table 2.5-1** Average cutting dates and alfalfa maturity for ten different cutting schedules in southern Minnesota.

**Cutting Date and Maturity**

| Cutting Schedule | Cutting Date[1] | | | | Maturity at cutting[2] 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|
| 1 | 25 June | 1 Sep. | | | Fl fl - Sd | Fl fl | | |
| 2 | 25 June | 15 Sep. | | | Fl fl - Sd | Sd | | |
| 3 | 25 June | 15 Oct. | | | Fl fl - Sd | Sd | | |
| 4 | 4 June | 14 July | 1 Sep. | | Lt bud | Fst fl | Fl fl | |
| 5 | 4 June | 14 July | 15 Sep. | | Lt bud | Fst fl | Fl fl | |
| 6 | 4 June | 14 July | 15 Oct. | | Lt bud | Fst fl | Fl fl | |
| 7 | 24 May | 25 June | 4 Aug. | 1 Sep. | Bud | Bud | Bud | Bud |
| 8 | 24 May | 25 June | 4 Aug. | 15 Sep. | Bud | Bud | Bud | Lt Bud |
| 9 | 24 May | 25 June | 4 Aug. | 15 Oct. | Bud | Bud | Bud | Fst fl. |
| 10 | 4 June | 14 July | 1 Sep. | 15 Oct. | Lt bud | Fst fl | Fl fl | Bud |

[1] Average dates are shown. Specific cutting dates varied +/- 1 day of average.
[2] Full flower (Fl fl) = >80% of stems with flowers; First flower (Fst fl) = 10% of stems with flowers; Bud = flower buds formed; Late bud (Lt bud) = flower buds formed and beginning to open on stems; Seed (Sd) = seed pods formed on 25% of stems
Source: Sheaffer and Martin (1990), J. Prod. Agric 3:486-491

A cutting schedule with harvests on 25 June and 1 September (**Table 2.5-1**) has been suggested to sustain and improve wildlife diversity and abundance. Because of the advanced maturity at harvest of current varieties, this schedule likely will result in a loss in dry matter and leaf yield using current alfalfa varieties. A two-cut schedule with harvests on 25 June and 1 September (cutting schedule 1) results in about 20% less leaf yield than a three-cut schedule with harvests on 4 June, 14 July, and 1 September (cutting schedule 4) as shown in **Table 2.5-2.**

Another option would be to develop a three-cut schedule with harvests on 25 June, 30 July, and early September. However, such a harvest schedule would likely result in very low yields at the second and third harvests due to soil moisture depletion during the first regrowth. While the aforementioned schedules with delayed first harvests are feasible, it is likely they would only be economically viable to producers using available varieties if subsidized to enhance wildlife populations.

**Table 2.5-2** Dry matter yield (tons per acre) of alfalfa under ten different cutting schedules[1] at the West Central Agricultural Experiment Station, Morris, MN.

**Yield by Cutting Schedule**

| Schedule[1] | | Total | Leaf | Stem |
|---|---|---|---|---|
| **1** | **2-cut** | **4.0** | **1.7** | **2.3** |
| 2 | 2-cut | 4.1 | 1.7 | 2.4 |
| 3 | 2-cut | 3.6 | 1.4 | 2.2 |
| **4** | **3-cut** | **4.4** | **2.1** | **2.3** |
| 5 | 3-cut | 4.3 | 2.1 | 2.2 |
| 6 | 3-cut | 4.2 | 2.0 | 2.2 |
| **7** | **4-cut** | **4.5** | **2.6** | **1.9** |
| 8 | 4-cut | 3.6 | 2.0 | 1.6 |
| 9 | 4-cut | 3.9 | 2.2 | 1.7 |
| 10 | 4-cut | 4.0 | 2.0 | 2.0 |

[1] Cutting Schedule from Table 2.5-1

Source: Sheaffer and Martin (1990, J. Prod. Agric. 3:486-491

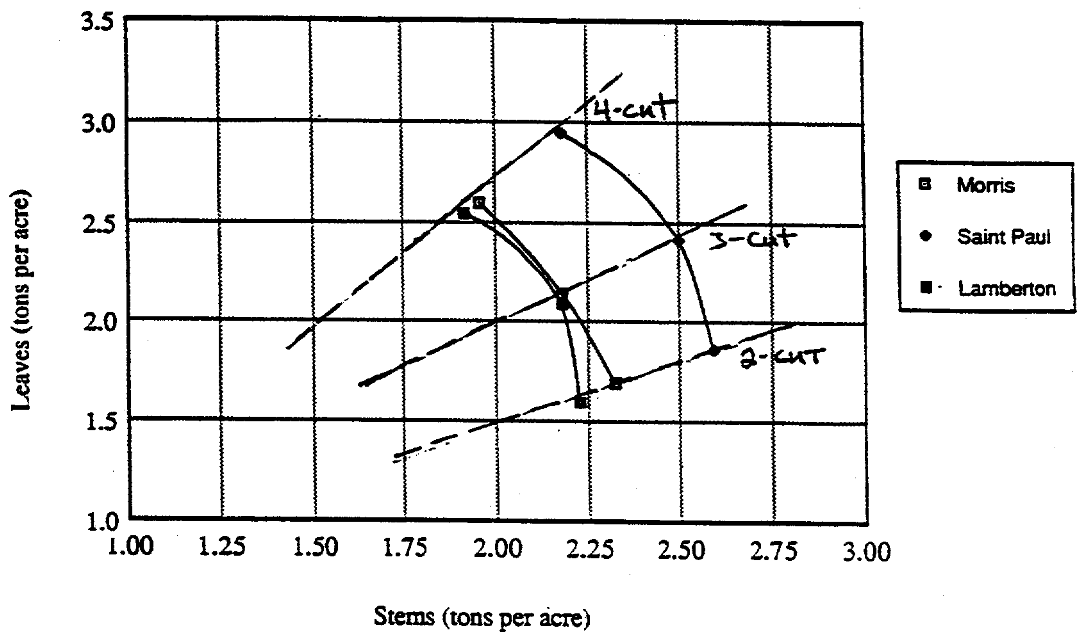
Cutting alfalfa after September 1 can pose a risk to the long-term persistence of alfalfa because fall cutting predisposes alfalfa to winter injury. This risk is associated with removal of stubble, which insulates the soil and catches snow, and by depletion of root reserves caused by regrowth. Cutting on September 15 is considered more detrimental to stand persistence than cutting on October 15 or later because after October 15 air temperatures are low enough to prevent regrowth and depletion of root reserves. Fall cutting also removes stubble and residue which provide feed, refuge, and spring nesting sites for wildlife. For these reasons, schedules 2, 5, and 8 shown in Tables 2.5-1 and -2, 15 September cutting date, would not be recommended and schedules 3, 6, 9 and 10 would be recommended only for producers who utilize excellent management practices.

<u>Summary</u>

Several alternative harvest schedules may be selected by producers. The most appropriate harvest schedule will maximize returns from both the leaf and stem components of the whole plant.

**Figure 2.5-1** The proportion of leaf and stem in alfalfa hay is dependent on cutting schedule. By location, the curve represents the combination of leaf and stem yields under different cutting schedules. Leaf yield declines and stem yield increases going from four-cut, to three-cut, to a two-cut schedule. The dashed line (trend line), shows expected leaf and stem yield at locations with higher and/or lower total average yields. For example, total yield in a three-cut system at St. Paul (the right hand curve) is (2.4 leaf + 2.5 stem) a total of 4.9 tons/acre. Morris and Lamberton locations (2.2 leaf + 2.2 stem) a total of 4.4 tons/acre.

**Relative Yields of Leaf and Stem by cutting and location**



# 2.6 FARM MACHINERY

## Basics of Hay Handling

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Alfalfa production requires the use of many different pieces of farm equipment. Some of the equipment can also be used for production of other crops. Although there are many possible options in choosing a complement of equipment for alfalfa production, specific machines have been identified in the following section for purposes of this study. Equipment selection impacts labor requirements and harvest losses. These issues, in turn, affect alfalfa production economics.

A requirement for this project is the use of technologies that are both proven and readily available. Machines identified in succeeding sections of this feasibility study are all readily available with proven performance histories. Certainly, there are new machines currently being developed that will improve the efficiencies and economics of alfalfa production. The participants in this project are likely to incorporate any new technologies and machines as they become available and prove practical.

Alfalfa production begins with seedbed preparation, which requires the use of both primary and secondary tillage equipment. A disk chisel, field cultivator and a spring tooth harrow provide adequate seedbed preparation. This tillage equipment is common and used for other crop production. A presswheel drill is used to plant the alfalfa seed, a sprayer is used to apply insecticides and herbicides while a broadcast fertilizer spreader is used to apply fertilizer. This equipment is also used to produce other crops.

Several pieces of equipment are specific to alfalfa production. Alfalfa is generally cut three times per year using either a mower/conditioner or swather/conditioner. The conditioning process crushes the alfalfa stems. Conditioned alfalfa will dry faster in the field than unconditioned alfalfa. The mower/conditioner or swather/conditioner will leave the alfalfa in the field in wide windrows. These windrows of alfalfa are then allowed to field dry to approximately 18-20% moisture. This drying process takes from two to three days depending on weather conditions. If rainfall occurs while alfalfa is in windrows or if poor drying conditions exist, a hay rake may be used to turn the windrow over to hasten the drying process. The final piece of equipment used in alfalfa production is the baler. A baler picks up the dried alfalfa from the field and forms it into one of several shapes. Bales can be formed into small rectangular bales (approximately 16"x16"x36"), large square bales (approximately 3'x4'x8'), or large round bales (approximately 5' dia. x 5' length). Bale size, shape, and density depends upon the brand and model of baler.

Although a variety of balers exist, this study recommends the use of large-round balers and a bale size of 6' diameter and 4' length. Bale dimensions are critical when transportation issues are considered (Chapter 5). Large square bales have not been recommended due to the lack of storage loss information for the geographic area proposed and because these bales have not been widely accepted by producers as a consequence of a poor reputation for maintaining hay quality under Minnesota conditions. Because of their lower density, large round bales facilitate drying "in the bale" to a greater degree than large square bales.

# CHAPTER 3 PRODUCTION RISKS

## 3.1 Alfalfa Producer Survey and Hay Sampling Research

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Forty-nine (49) farms currently producing alfalfa in the biomass shed were surveyed to assess current alfalfa production practices and to estimate the current state of quality for alfalfa in storage at the time of the survey (winter 93-94). Sixty-seven (67) alfalfa hay samples were collected and analyzed for quality and leaf content.

**Farm Characteristics**

The average farm size of the 49 sample farms in this study was 552 acres (farm size ranged from 240 to 3,260 acres). Farms in the survey were located in Renville, Swift, Chippewa, Yellow Medicine, Redwood, Lyon and Lac Qui Parle counties of southwestern Minnesota. Average alfalfa acreage per farm was 54 acres (range 11 - 160 acres per farm). Corn acreage per farm averaged 267 acres and soybeans averaged 256 acres per farm. The only other crop being produced by this group of alfalfa producers was wheat.

**Alfalfa Production**

Only two of the growers surveyed reported a value for alfalfa yield (6 t/a and 3.5 t/a). Most current alfalfa producers are internal users and commonly evaluate yield in terms of the number of bales produced per acre. Reported alfalfa yield from published agricultural statistics for the counties included in this survey averaged 3.11 t/a (range 4.6 to 1.9 t/a). Total alfalfa production in the seven counties surveyed has averaged just under 75,000 acres per year (last five years).

Alfalfa varieties have been performance tested at Morris (northern edge of biomass shed) and Lamberton (southeastern region of biomass shed) for the past 25 years. 'Vernal,' a winterhardy variety developed at University of Wisconsin, is the nationally identified check variety used in variety trials. Vernal has averaged 4.1 and 4.2 tons per acre of total dry matter (TDM) at Morris and Lamberton, respectively, over the past 25 years (non-establishment year average). The range of annual yields of Vernal is from 7.2 to 1.3 tons per acre. The highest yielding varieties in each trial averaged 13 to 14 percent greater than Vernal.

**Table 3.1-1** Average alfalfa yield of selected varieties at Minnesota Agricultural Experiment Stations, over 25 years. Average yields of alfalfa varieties expressed as a percentage of the variety "Vernal". Yield of "Vernal" is in tons/acre at 15% moisture (1967-1991) from four climatological regions in Minnesota. Morris is about 55 miles north-northwest of Granite Falls and the Lamberton station is about 40 miles south-southeast of Granite.

**Alfalfa Yield**

Average yields for years 1-2 and 3-4 after seeding per test location is given.

| LOCATION | Rosemount & Waseca | | Morris & Crookston | | Lamberton - | | Grand Rapids | | All Locations | | # of Tests |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REGION | Southeastern | | Northwestern | | Southwestern | | Northeastern | | Average | | |
| Selected Varieties | 1-2 | 3-4 | 1-2 | 3-4 | 1-2 | 3-4 | 1-2 | 3-4 | 1-2 | 3-4 | |
| **Vernal** | 5.97 | 5.39 | **5.40** | **4.54** | **5.11** | **4.86** | 4.12 | 3.80 | 5.15 | 4.62 | 62 |
| Wrangler | 105 | 107 | 106 | 101 | 98 | 102 | 100 | 95 | 103 | 102 | 7 |
| Baker | 99 | 105 | 97 | 102 | 107 | 103 | 89 | 82 | 98 | 100 | 17 |
| 636 | 110 | 107 | 99 | 104 | 101 | 106 | 103 | 103 | 105 | 106 | 6 |
| Clipper | 102 | 90 | 100 | 101 | 100 | 91 | 106 | 102 | 101 | 96 | 7 |
| Envy | 111 | 90 | 102 | 112 | 102 | 110 | - | - | 106 | 100 | 7 |
| Profit | 110 | 110 | 96 | 95 | 107 | 107 | 105 | 113 | 105 | 108 | 6 |
| Agate | 100 | 107 | 97 | 101 | 100 | 100 | 89 | 96 | 99 | 100 | 18 |
| Iroquois | 103 | 102 | 105 | 107 | 103 | 112 | 121 | 96 | 106 | 104 | 12 |
| Blazer | 108 | 114 | 95 | 104 | 102 | - | 100 | 104 | 104 | 111 | 10 |
| 5262 | 108 | 105 | 97 | 108 | 103 | 113 | 112 | - | 104 | 108 | 8 |
| WL 225 | 103 | 90 | 93 | 101 | 101 | 101 | 107 | 105 | 99 | 98 | 6 |
| 120 | 111 | 112 | 103 | 107 | 103 | - | 112 | 107 | 109 | 111 | 10 |
| Alpine | 110 | 104 | 101 | 106 | 115 | 113 | - | - | 107 | 107 | 5 |
| Ranger | 98 | 100 | 125 | 104 | 97 | 99 | - | - | 100 | 100 | 13 |
| Dart | 111 | 107 | 100 | 109 | 108 | 110 | 109 | 105 | 107 | 106 | 9 |
| Milkmaker | 106 | 99 | 100 | 93 | 98 | 101 | 104 | 106 | 104 | 100 | 8 |
| Arrow | 108 | 103 | 103 | 95 | 112 | 114 | 110 | 104 | 107 | 104 | 9 |
| GH 715 | 106 | 102 | 103 | 107 | 103 | 104 | 113 | 112 | 105 | 105 | 8 |
| Impact | 110 | 94 | 104 | 114 | 112 | 104 | 112 | 104 | 108 | 100 | 6 |
| Oneida | 105 | 106 | 102 | 107 | 94 | 97 | 105 | 107 | 100 | 106 | 10 |

The alfalfa variety trials have experienced complete winter kill once in twenty-five years at Morris and once at Lamberton; not the same year. Moderate winter injury was experienced 5 and 3 years of the 25 at Morris and Lamberton, respectively. Drought reduced yields by 20% in 6 and 5 of the 25 years at Morris and Lamberton, respectively. Yields often peak at 2 or 3 years after seeding. However, the performance of varieties is influenced more by weather than stand age (**Table 3.1-2** note: variety performance by stand age). Recently released varieties perform better than Vernal at older stand ages. Preliminary tests at the University of Minnesota's Rosemount Experiment Station of selected available varieties show significant differences in leaf retention. This characteristic could be an important selection criterion for biomass production.

**Table 3.1-2** The average yield of 'Vernal' (a common check variety) and of the highest yielding variety in alfalfa performance trials conducted at Lamberton and Morris from 1968 to 1993. Yield is given as total dry matter (TDM) per acre.

**Yield by Stand Age (0% moisture)**

| Morris | | | | Lamberton | | | |
|---|---|---|---|---|---|---|---|
| **Variety** | **Stand age** | **Number trials** | **Yield** | **Variety** | **Stand age** | **Number trials** | **Yield** |
| | - - - years - - - | | TDM/A | | - - - years - - - | | TDM/A |
| **Vernal** | 1 | 8 | 4.16 | **Vernal** | 1 | 8 | 4.40 |
| | 2 | 8 | 4.24 | | 2 | 8 | 4.49 |
| | 3 | 5 | 3.51 | | 3 | 6 | 4.31 |
| | 4 | 5 | 4.20 | | 4 | 6 | 3.05 |
| | | | | | 5 | 2 | 3.47 |
| **Top variety** | 1 | 1 | 4.58 | **Top variety** | 1 | 1 | 4.93 |
| | 2 | 1 | 4.83 | | 2 | 1 | 5.30 |
| | 3 | 5 | 4.11 | | 3 | 5 | 4.82 |
| | 4 | 5 | 4.96 | | 4 | 6 | 3.57 |
| | | | | | 5 | 2 | 3.81 |

## Management Practices

Seeding techniques and storage practices offer opportunities for significant improvements in curren alfalfa management practices. Stand establishment has a major impact on productivity and stand life Twenty-five (25) growers reported stand life after establishment for an average of 2.95 years (1 to year range in reported values). We expect growers in the proposed biomass shed will be able to plan varieties that will persist, on average, for 4 years after seeding.

Current storage methods for large round bales varies from farm to farm, however most large roun bales are stored outside without cover. Cooperative storage, provided by the alfalfa cooperative, shoul dramatically improve the quality stored alfalfa.

Alfalfa requires high levels of potassium and performs best under conditions of neutral soil pH. Th soils in the proposed biomass shed are characterized excellent for alfalfa. Within the biomass shed soi pH's approach 7.0 and are generally high in soil potassium. Yields will be dependent upon a specifi soil's water holding capacity more than nutrient levels or soil pH. Alfalfa is a heavy transpiring cro with a deep tap root. Alfalfa yields better than other crops during a drought, but its yield will b limited following drought years. In severe cases, the yield of the crop following alfalfa is reduced du to soil moisture depletion.

## Analysis of Alfalfa Samples

Fifty-two (52%) percent of the hay samples collected were alfalfa hay; 48% were alfalfa-grass mixtures Alfalfa-grass mixtures have less protein and more fiber than "pure" alfalfa. Alfalfa samples average 19.8% crude protein (CP), alfalfa-grass mixture averaged 17.6% CP (**Table 3.1-3**).

Alfalfa samples came from either the first, second, or third cutting of the previous season crop (1993 Third cutting alfalfa hay had the highest quality (% CP and relative feed value (RFV) and the highes percentage of leaf (**Table 3.1-3**). Relative feed value (RFV) is a standard index of forage quality. Lea percentage of alfalfa hay is influenced by percent alfalfa in the stand, stage of maturity at harvest, typ of bale, storage method, and rain damage.

Half of the hay analyzed was in small square bales (50 lb/bale) and half of the hay came from larg round bales (1000 lb/bale). Alfalfa hay samples from small square bales averaged higher in lea content than large round bales (44% vs 38% leaves). The majority of the small square bales wer stored inside (57%) and the majority of the large round bales were stored outside without cover (62%)

**Table 3.1-3** 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 |

**Analysis of Alfalfa Samples** (continued)

Large round bales stored inside were 47% leaf, bales stored outside with no cover were 37% leaf. All bales stored outside were stored on earth (storage losses from weathering can be reduced when bales are stored on gravel or other well-drained materials). Thirty-seven (37%) percent of the hay samples suffered from rain damage but only 5% of the samples were moldy. Best management practices for harvest and storage management would significantly improve alfalfa quality and returns.

Results of forage quality tests to determine crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), percent leaf (% Leaf), percent calcium (% Ca), percent phosphorus (% P), and percent potassium (% K) are shown in **Table 3.1-3.** The 67 hay samples were generally representative of alfalfa and alfalfa-grass mixtures grown in Minnesota. The relative feed value (RFV) index is a standard quality measure for alfalfa. RFV's from 140 to 160 are recommended for high producing dairy cattle or cows in early lactation. RFV's below 100 are used for livestock rations with low nutrient requirements. Hay rated below 100 RFV is used in rations for maintenance and often would require supplemental protein, energy, and mineral additions. Almost half of the samples tested analyzed below 100 RFV index. Fiber tests are used to predict digestibility (ADF) and potential dry matter intake (NDF). ADF and NDF are related. As fiber increases, animal digestibility and intake declines.

## 3.2 Harvest Losses

### Mechanical, Respiration, and Rainfall Losses

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Hay harvest can result in losses from 7 to 31% of standing forage dry matter (**Table 3.2-1**). Most of the dry matter loss is due to loss of the fragile leaf fraction, while stem material is usually retained. When unfavorable conditions for drying occur, losses can be as high as 100% of the leaf fraction. In haymaking, losses occur during harvesting operations and during field exposure prior to harvest. Field exposure losses are associated with respiration (**Figure 3.2-1**) and rain damage (**Figure 3.2-2**).

**Table 3.2-1** Losses from alfalfa during harvest operations.

**Harvest Losses**

| Operation | % of DM lost | % of Leaves lost |
|---|---|---|
| Mowing | 1 | 2 |
| Mowing/conditioning | 2 | 3 |
| reciprocating mower, fluted rolls | 3 | 4 |
| disc mower, fluted rolls | 3 | 4 |
| disc mower, flail conditioner | 4 | 5 |
| Raking: | | |
| at 70% moisture | 2 | 2 |
| at 60% moisture | 2 | 3 |
| at 50% moisture | 3 | 5 |
| at 33% moisture | 7 | 12 |
| at 20% moisture | 12 | 21 |
| Tedding: | | |
| at 70% moisture | 1 | 2 |
| at 60% moisture | 1 | 3 |
| at 50% moisture | 3 | 5 |
| at 33% moisture | 6 | 12 |
| at 20% moisture | 11 | 21 |
| Baling, pickup + chamber: | | |
| at 25% moisture[a] | 3 | 4 |
| at 20% moisture | 4 | 6 |
| at 12% moisture | 6 | 8 |
| Baling at 18% moisture: | | |
| conventional square baler/ejector | 5 | 8 |
| round, variable chamber | 6 | 10 |
| round, fixed chamber | 13 | 21 |
| Stack wagon | 15 | 24 |
| **Total** | **7-31** | **12-50** |

[a] Requires a preservative for safe storage.
Source: Kjelgaard (1979), Rotz (1989), Hundtoft (1965), in Pitt (1990)

Mechanical Losses

Losses in dry matter and leaves during harvesting operations can be large because of the necessity of handling forage low in moisture content and the fragile attachment of leaves to stems (**Table 3.2-1**). Dry matter losses average from 7 to 31 percent while leaf loss averages from 12 to 50 percent. Losses can be minimized if the number of field operations are minimized. For example, with good drying conditions brought about by low humidity and high temperatures raking can be eliminated. Tedding or fluffing the windrows to enhance air passage is seldom necessary if small windrows are initially formed. New machinery developments such as windrow inverters allow the turning of windrowed forage with negligible leaf loss.

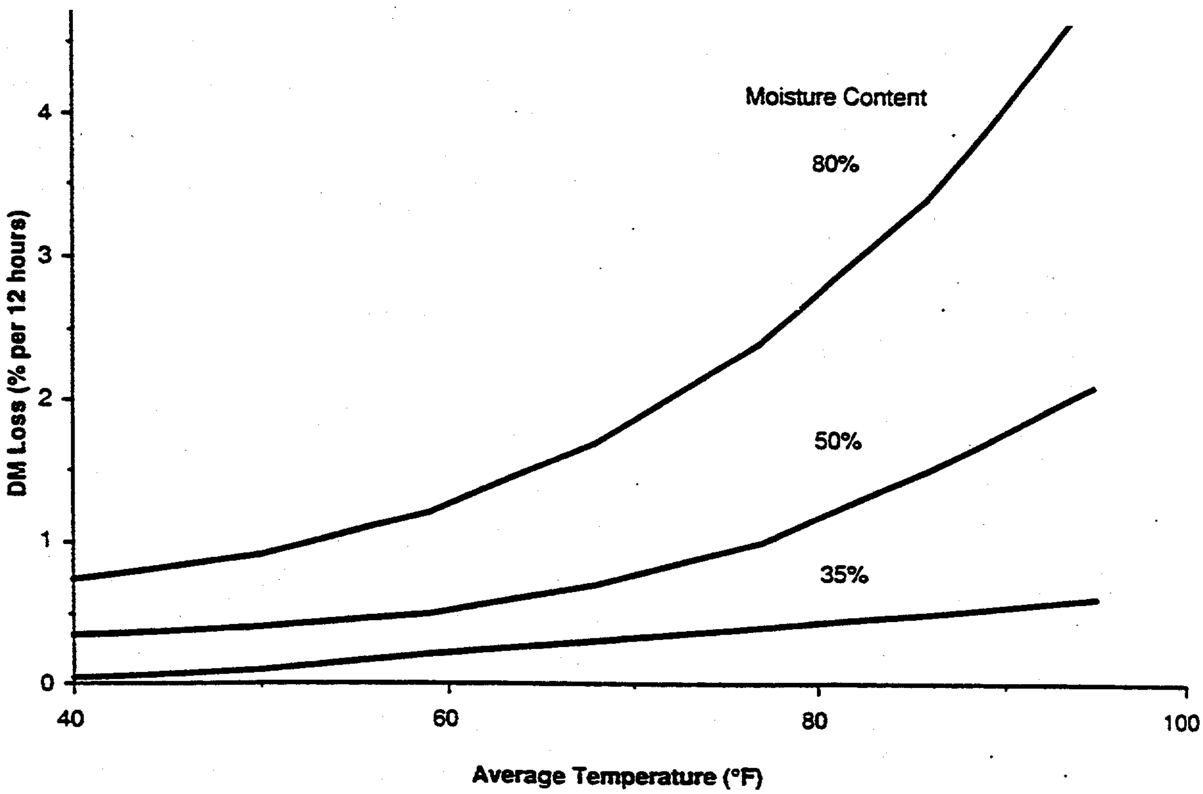
Because leaves dry to moisture levels suitable for storage faster than stems, they are prone to shattering. Therefore, turning of hay by raking should be conducted at moisture levels greater than 40% or in mornings when dew has moistened the leaves. Likewise, overdrying forage to moisture concentrations below 18% moisture enhances leaf and dry matter loss.

## Respiration Losses

Respiration losses are somewhat unavoidable in haymaking and represent biochemical burning of sugars, producing carbon dioxide and water, as alfalfa foliage "tries" to maintain itself after being severed at the lower stem. Respiration rates depend upon temperature levels and the moisture content of the forage (**Figure 3.2-1**). Respiration virtually stops when moisture content of the forage falls below 20%. Dry matter losses due to respiration can start at 3%-4% per day, with total losses ranging from 10% to 15% (Rotz et al. 1989). Strategies or circumstances that shorten the time necessary for alfalfa to reach 20% moisture result in reduced respiration losses (Pitt 1990). The crushing of alfalfa stems by conditioners facilitates faster drying and limits respiration losses in haymaking.

**Figure 3.2-1** Rate of dry matter (DM) loss from plant respiration in the field as dependent on forage moisture content and average air temperature.

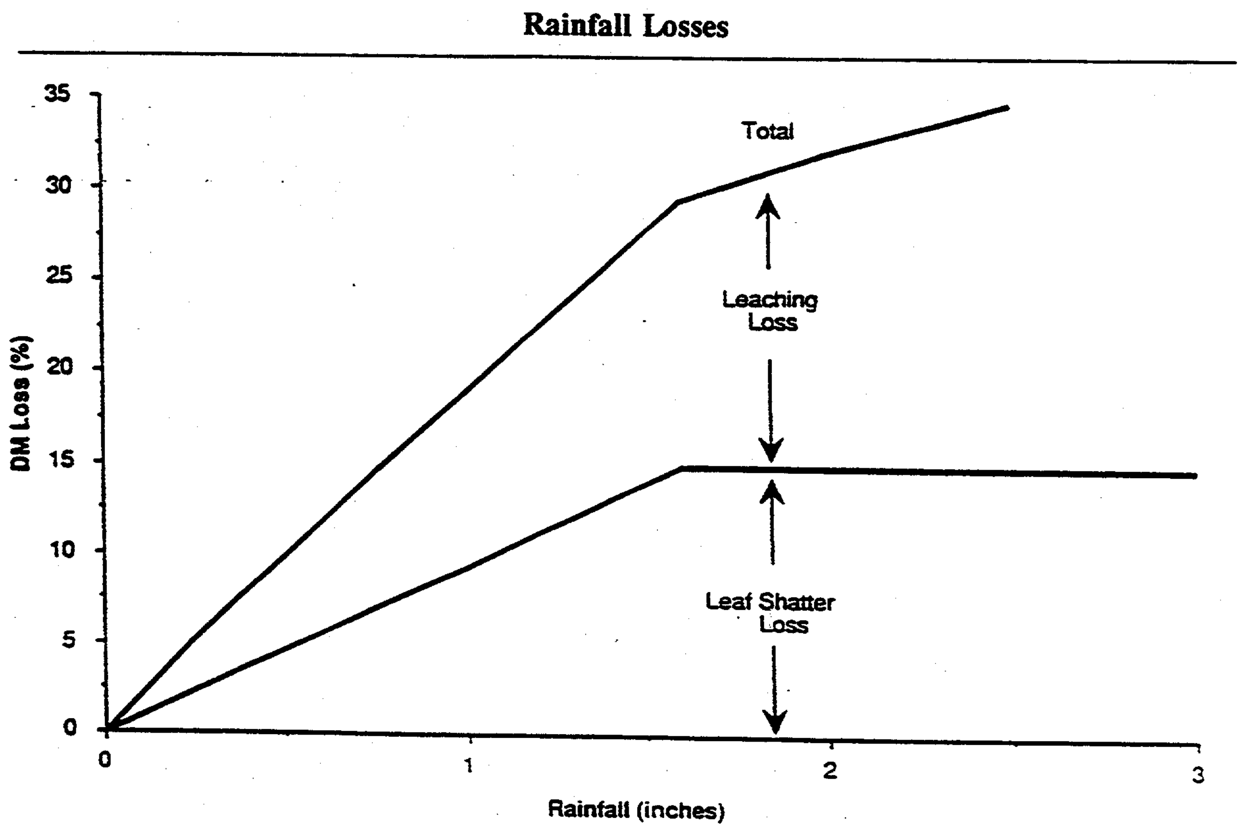
**Respiration Losses**



Rain Damage: Leaching and Leaf Shatter Losses

Rain reduces dry matter in hay by leaching soluble nutrients and shattering the fragile, nutritious leaves from the stems (**Figure 3.2-2**). This portion of harvest loss can be severe and its adverse impact is more readily recognized by farmers than dry matter losses due to respiration. Farmers feel extreme consternation or relief depending upon their success in baling dry hay before the rain. To understand the magnitude of potential losses due to rain, 30 years of weather data within the proposed biomass shed were analyzed and combined with published data relating dry matter losses and rainfall.

**Figure 3.2-2** Dry matter (DM) losses from leaching of nutrients and from leaf shatter during rainfall of varying amounts.

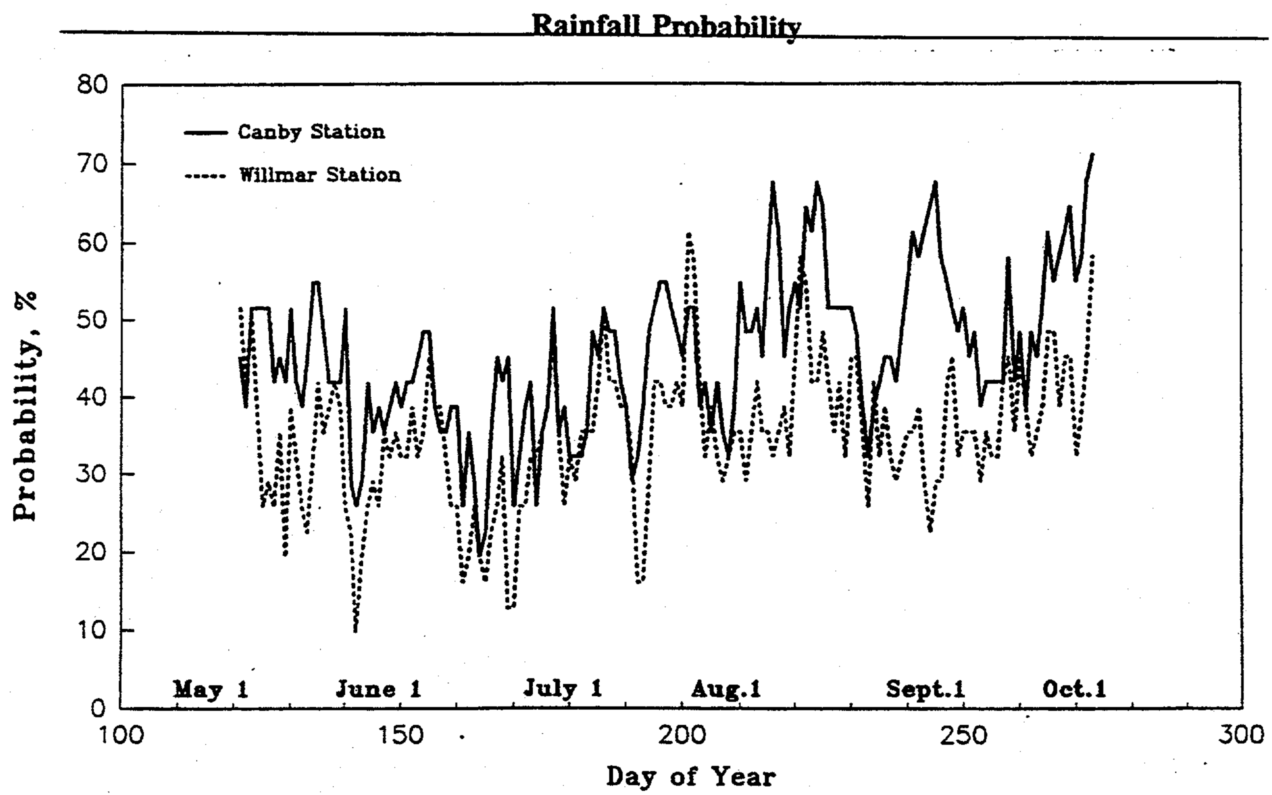



Source: Rotz et al. (1989) in Pitt (1990) Northeast Regional Agricultural Engineering Service, Ithaca, NY

## Rain Patterns in the Biomass Shed

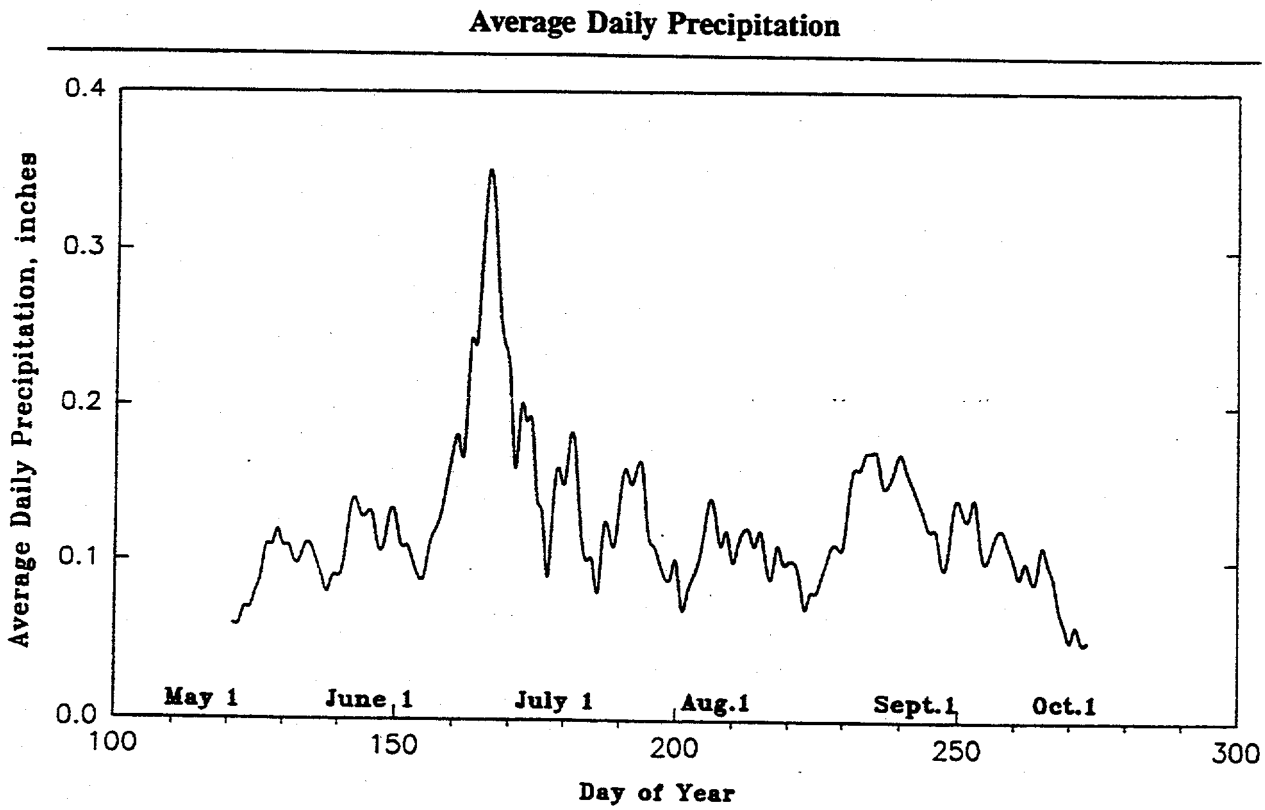
Rainfall data (1963-1993) for two locations in the biomass shed were manipulated in three different ways to ascertain probabilities of rain damage. First, cumulative probabilities were calculated for the chance of having three consecutive dry days (no measurable rainfall). **Figure 3.2-3** portrays the changing probability of having three consecutive dry days that would face a farmer choosing to cut hay with no other information on the likelihood of rain. Three days was chosen as an appropriate interval because that is the most typical period of time required to adequately dry alfalfa hay for baling. The data were "smoothed" by calculating a five day moving average. Cutting dates for harvest schedules conforming to 2-cut, 3-cut, and 4-cut systems were modelled.

**Figure 3.2-3** Comparison of probabilities (1963-1993) of 3 consecutive dry days between Canby weather station in Yellow Medicine county and Willmar weather station in Kandiyohi county, MN. Probability is defined as the number of years with occurrence of consecutive dry days divided by total years.



Second, daily average rainfall amounts were calculated for each day between May 1 and October 1. Because the Willmar station is a single point on the map with a unique history, the daily average rainfall amounts were also smoothed by calculating a five day moving average, as portrayed in **Figure 3.2-4.** This technique allows one to reduce the disproportionate effect on a daily average rainfall figure caused by a single major rainfall event.

**Figure 3.2-4** Average (1963-1993) daily precipitation at Willmar weather station in Kandihoyi county, MN, in inches. The plot line represents a five day smoothed value.



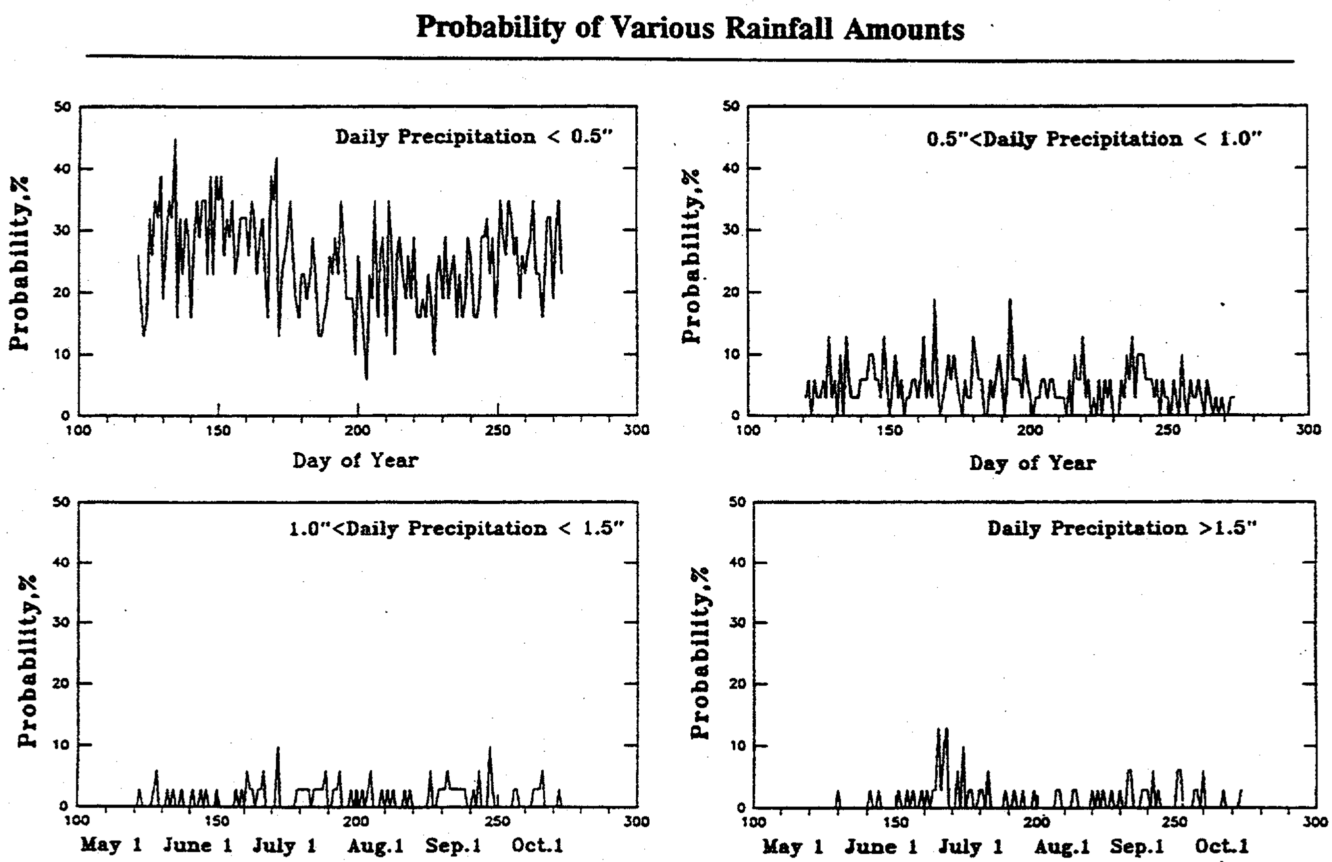

Figures 3.2-3 and 4 clearly show that the riskiest time for major rain damage occurs between June 4 and June 25. This reveals how farmers in a 3-cut system can get "caught" with hay down for an extended period with the potential to suffer high dry matter and quality losses. The study of both graphs reveals the phenomenon of the intervals between moisture-bearing weather systems coming up from the Gulf of Mexico and dry, high pressure systems sweeping down from the eastern slopes of the Canadian Rockies.

Daily rainfall events between May 1 and October 1 over thirty years were classified according to magnitude. The four classes utilized were the following:

1) Rainfall less than 0.5 in.
2) Rainfall of 0.5 in. to less than 1.0 in.
3) Rainfall of 1.0 in. to less than 1.5 in.
4) Rainfall or 1.5 in. or greater

The probabilities of each of these classified rainfall events were calculated for each day of the summer as portrayed in the four graphs in **Figure 3.2-5.**

**Figure 3.2-5** Probabilities (1963-1993) of various amounts of daily precipitation at Willmar weather station in Kandiyohi county, MN. Probability is defined as the number of years with occurrence of a given amount of precipitation divided by the total number of years.



The sum of the four classified rainfall probabilities and the smoothed cumulative probability of three consecutive dry days allow calculation of joint probabilities of "rain" or "no rain" as well as the magnitude of rainfall events.

Approximate probability of rain on a given day during the summer harvest season in the biomass shed:

1) The probability of rainfall greater than 0.5 inch is about 10%.
2) The probability of rainfall less than 0.5 inch is about 30%.
3) The probability of no rain is about 60%.

Putting these possibilities together, we can construct the likely incidence and magnitude of rainfall events in the alfalfa biomass shed. We must make one assumption, however. We shall assume that a farmer will take note that it is not raining when he starts cutting alfalfa and that he can successfully predict that it will not rain on the day when he cuts hay. After day one, he is at the mercy of the history of probabilities of classified rainfall events and the probability of rain or no rain. Here is how this construction works out. Recall that the farmer is 100% correct in predicting that day one is dry.

| Outcome | Probability |
|---|---|
| 1) No Rain | (1.0)(.6)(.6) = .36 |
| 2) Rain < 0.5" on one day | 2(1.0)(.3)(.6) = .36 |
| 3) Rain < 0.5" on two days | (1.0)(.3)(.3) = .09 |
| 4) Rain > 0.5" on two days | (1.0)(.1)(.1) = .01 |
| 5) Dry one day, rain > .5" one day | 2(1.0)(.6)(.1) = .12 |
| 6) Rain >.5" one day, rain <.5" the next | 2(1.0)(.1)(.3) = .06 |
| | = 1.00 |

Note: these probabilities model the situation on the evening of the third day. Hay that has been rained on is still in the field and has not yet been harvested. That hay must remain in the field until it is dry. We have determined the amount of hay that will get dry after two more days of potential drying or further rain. Because of additional projected damage during the succeeding two days, we end up with further losses on hay that does not get dry in three days. At the end of five days 74.4% of the hay has been harvested. Further damage is possible for the remaining 25.6 % but most has deteriorated to the quality of outcome 5 or below. The 25.6% has all been rained on at least twice in a five day period.

Combining the calculated joint probabilities of rainfall events with published data on dry matter losses due to rain (Rotz et al. 1989 in Pitt (1990)) allows one to calculate dry matter losses that would be due to rain. Here is how things work out with respect to dry matter and leaf shatter loss (after 5th day):

| Assumed outcome | Rain | Probability | DM Loss | Leaf Loss |
|---|---|---|---|---|
| 1 | -0- | .36 | -0- | -0- |
| 2 | .25" | .17 | .05 | .02 |
| 3 | .50" | .13 | .10 | .04 |
| 4 | .75" | .10 | .15 | .07 |
| 5 | 1.00" | .16 | .19 | .09 |
| 6 | 1.50" | .05 | .28 | .14 |
| 7 | 1.75" | .03 | .30 | .15 |

The summed probable dry matter losses due to rain that would befall alfalfa producers would average 8.99%. This conclusion represents an aggregate view of the risk and extent of rain damage over the proposed alfalfa biomass shed.

There will need to be management decisions regarding hay produced under the different outcomes in an alfalfa biomass project where revenues from leaf separation activities are crucial to profitability. Here are some preliminary judgements about the usefulness of hay produced under the various outcomes:

| | |
|---|---|
| Outcome 1; no problems, beautiful hay | 36% |
| Outcome 2; very nice hay, but .25" of rain | 17% |
| Outcome 3; .5" of rain sustained, fair quality | 13% |
| Outcome 4; .75" of rain, poor but usable | 10% |
| Outcome 5; 1.0" of rain, very poor | 16% |
| Outcome 6; 1.5" of rain, stems only | 5% |
| Outcome 7; 1.75" of rain, very poor quality | 3% |
| | 100% |

**Weather Risk and Management Expectations**

What should management at the alfalfa fractionation facility expect?

Management should expect that approximately 66% of the crop (Outcomes 1+2+3) will be in good condition. Therefore approximately 34% of the crop may be expected to be in poor condition reflecting Outcomes 4, 5, 6, and 7. Outcomes 4-7 have poor feed value but only moderately reduced biomass energy value. Supply management strategies may be implemented to further reduce rain damage losses by direct-delivery of high moisture rain damaged hay to the processing plant.

Additionally, a self-insuring strategy may be implemented to spread harvest dates over the biomass shed. Production dispersion spreads risk over time and location. Quality, condition, dry matter yield, and leaf losses are discussed further in Section 9.2 (Contracting for Production).

Chemical Preservation of Hay: Problems Solved and Created

Hay preservatives such as propionic acid and derived buffered products have been used successfully to preserve forages. They are effective at preventing mold growth and associated losses in forage quality in hay with moisture levels from 20 to 35%. Because they could allow harvest at higher moisture levels, they could reduce exposure to rain damage. Their use could also result in lower leaf and dry matter losses caused by machine operations. Recommended rates increase as hay moisture concentration increases (See Sheaffer and Martin, Minnesota Agric. Ext. Service Folder 489-1979). For hay with a 20-25% moisture level, 10 lb/ton of preservative should be applied; for hay of 30-35% moisture 30 lb/ton are required. At $.50 to $1.00 per pound, treatment of hay containing 22% moisture would require from $5 to $10 dollars of additional cost per ton.

Although sometimes useful for an individual producer, there are a number of reasons for prohibiting preservative use for hay involved in biomass production including the following:

1. Long-term storage of hay treated with organic acids has been poor.

2. Bales treated with preservatives tend to shrink, leading to loose twine and bale breakage.

3. Inconsistent application of preservatives to "high moisture" bales (20-25%) could pose storage hazards. If a farmer were to produce even a small number of bales without adequate preservative, those untreated or undertreated bales could easily heat and start a fire.

4. High moisture bales treated with preservatives will require more heat for drying before fractionating.

5. Preservative costs from $5-10/T are significant.

**Research Needs:**

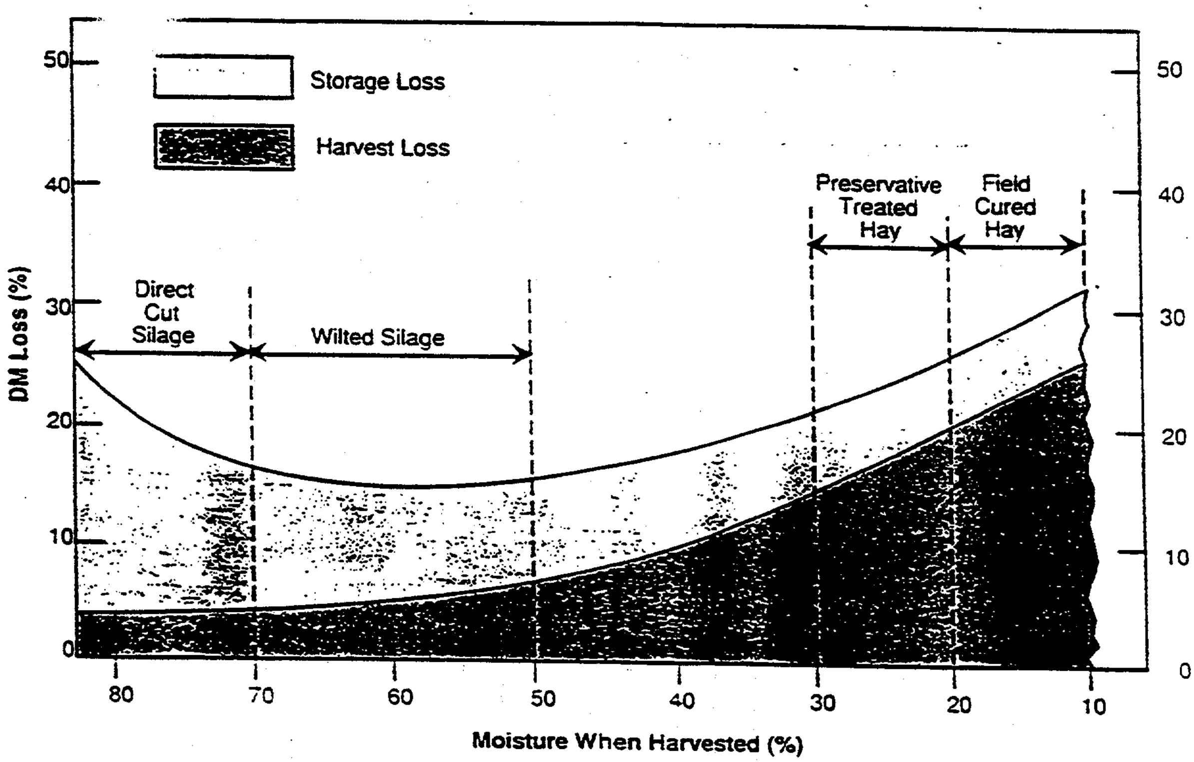
As documented, field and harvest losses of leaf and stem dry matter and forage quality can be large. While we have confidence in the data used in this study, we recognize that data was not available to most accurately describe the range in potential harvest schedules which will likely be used in the biomass shed. For example, if a two-cut schedule is used it is likely that leaf losses will be greater during some phases of the drying processes than for a four-cut schedule. In subsequent research, we propose to examine the effects of interactions of harvest schedules, harvesting equipment, and rainfall on leaf and stem yield and leaf quality.

## 3.3 Post-Harvest Losses

The fundamental strategy in preservation of forage as hay is to dry forage below 20% moisture content (Pitt,1990). Losses in forage quantity and quality increase as moisture levels remain above 20%. These losses are associated with the activity of molds, yeasts, and plant respiration, all of which are active in the presence of oxygen. Dry matter losses are primarily due to the degradation of sugars and other soluble carbohydrates and the production of carbon dioxide, water, and heat. In addition, vitamins and degradable protein concentrations may be affected (**Figure 3.3-1**).

**Figure 3.3-1** Dry matter losses during harvest and storage as dependent on forage moisture content at harvest (from Hoglund (1964) in Pitt (1990) Northeast Regional Agricultural Engineering Service, Ithaca, NY.

**Post-Harvest Losses**



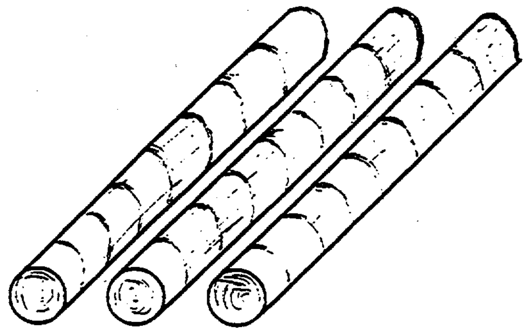
The extent of temperature rise and duration of heat production in baled alfalfa depend primarily on the moisture content at the time of storage. Heating will occur to some extent in all forage material unless it contains less than 15% moisture; heating potential increases as moisture concentrations increase. Heating to 60° C can result in a nonenzymatic browning reaction or carmelization. In this reaction, proteins and amino acids combine with plant sugars to form brown polymers resembling lignin. Heat damaged forage has very low feeding value due to reduced digestibility of protein and carbohydrates.

Mold growth on alfalfa, and the resulting dustiness, can create human and animal health problems. Farmers' lung disease, a form of pneumonia, is associated with the inhalation of dust containing spores and dried mycelia of fungi. Moldy and dusty forage is less palatable to animals. In addition, livestock illness can occur as a result of mycotoxins produced by microbes in moldy hay.

Dry matter storage losses are also a function of storage time. Bales stored for longer periods of time will experience greater dry matter losses. The rate of loss during the storage period will be fairly constant if bales are kept at a constant moisture content and temperature. Stored alfalfa moisture levels typically range between 8% and 15% and are influenced by humidity and temperature of surrounding air. During cold winter months, microbial activity slows, thus decreasing the rate of dry matter loss. Conversely, warm temperatures increase the rate of dry matter loss. Depending on storage method, bales may be subject to changes in moisture content. A combination of high moisture content and warm temperatures provide the best conditions for microbial growth, thus increasing the rate of dry matter loss. Therefore, it is important to prevent rehydration of bales during storage. Control of rehydration is a function of storage method.

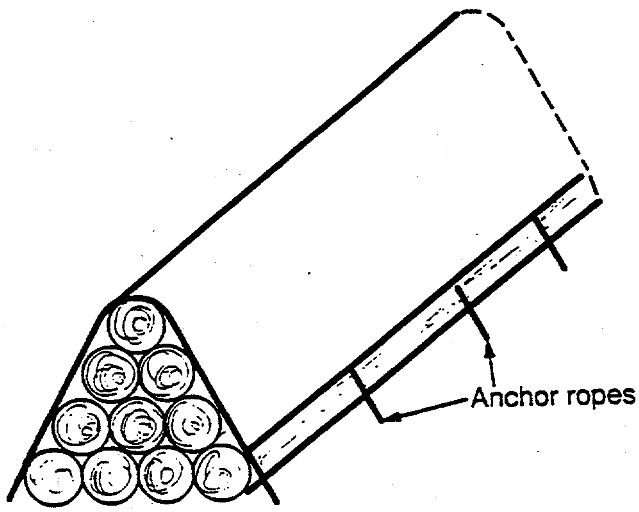
Several studies have documented dry matter losses as a function of storage method (Huhnke, 1988, Collins, 1987). Traditionally alfalfa was baled in small square bales and stored in a barn. Large round bales, because of their shape, were thought to shed water and were subsequently stored outdoors and not covered. Round bales absorb water from both rainfall and soil. This increased moisture content increases microbial growth, thereby increasing dry matter loss. To prevent some of these losses, bales should be placed end to end on a well drained or elevated surface (**Illustration 3.3-1**). This method protects the bale ends and keeps moisture away from the bottom of the bale. Bales stored outdoors in this fashion will typically incur dry matter losses of between 10% and 25%, if used before spring warm up. Dry matter losses for alfalfa stored outdoors are difficult to predict, primarily because dry matter loss is a function of weather conditions. In a cool dry year, losses will be significantly less than in a warm wet year.

**Illustrations 3.3-1** Bales stored with no cover.



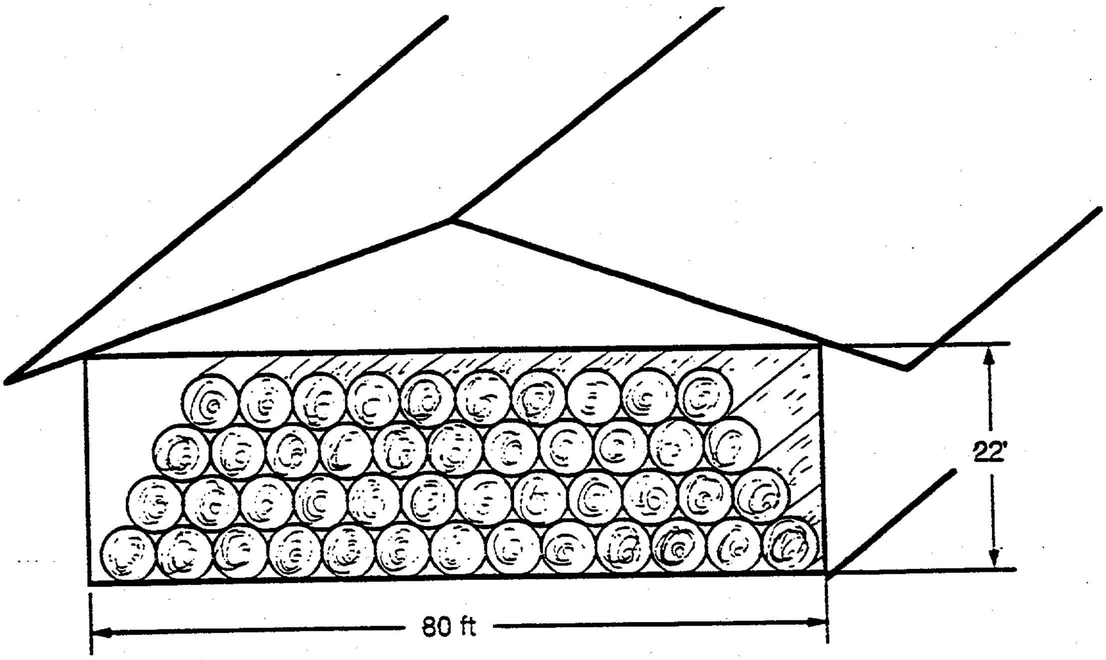
Reduction of dry matter losses in bales can be accomplished by covering bales with a plastic tarp. Plastic tarps protect bales from precipitation and rehydration, which lead to mold development. In addition excess water can leach nutrients. Bales covered with plastic tarps can be stacked in a pyramid three or four bales high (**Illustration 3.3-2**). This stacking method reduces both the amount of plastic used and the area needed to store the bales. Bales covered in plastic must also be stacked on a well drained or elevated surface. Dry matter losses for bales stored under plastic are reported to be between five and ten percent. A potential problem for bales stored under plastic is the condensation on the underside of the plastic resulting from moisture given off from plant enzymes and microbial activity. Alfalfa in contact with the plastic may become damp and subject to dry matter losses. Plastic tarps can be purchased specifically for covering bales. These tarps will last between one and four storage seasons.

**Illustration 3.3-2** Bales stored under plastic tarp.



The third option for alfalfa storage is an enclosed structure. An enclosed storage structure provides protection from rainfall, allows moisture to escape from the bales, and requires less land area per stored bale. Bales stored in such structures can be stacked in a pyramid three or four bales high and several bales wide (**Illustration 3.3-3**). Bales can also be stacked on end up to three bales high. Alfalfa properly baled and stored in an enclosed structure experience dry matter losses of between two and five percent.

**Illustration 3.3-3** Bales stored under steel-roofed structure.




Post harvest losses of alfalfa, both dry matter and quality, can be significant. Losses can be controlled by the basic management techniques of baling at the proper moisture content and then protecting bales from precipitation throughout the storage period. These techniques will reduce dry matter losses and improve the feed value of the alfalfa. Very little information is available to predict storage losses that accumulate over a storage period. For this study, the period of time bales will be stored ranges from a few weeks to ten months or more. In addition to time, the moisture content of the bales and their temperatures strongly affect storage losses. Alfalfa stored for a few weeks will incur very little dry matter loss while bales stored for the maximum time period will incur far greater losses. For purposes of evaluation an average storage time is estimated at five months with dry matter storage losses for no cover, plastic tarp, and roofed storage methods at 10%, 5%, and 2%, respectively. Costs for each type of storage method are evaluated in Chapter 5.2.

## 3.4 Rotational Effects

### Risk of Yield Loss Resulting from the Addition of Alfalfa to Corn and Soybean Rotations in Southwestern Minnesota

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INTRODUCTION:

Since rainfall in western Minnesota is low and other water sources are limited, the specific question posed in this part of the study was: how will crop yields be influenced by water consumption by alfalfa that is introduced into a corn and soybean rotation in western Minnesota?

Although many studies document the effects of water availability on crop yield, there is limited information on the effects of alfalfa on yield of subsequent crops. It is well established that crop yield increases with an increase in availability of soil water provided sufficient nutrients are available (Smika et al; 1965; Hanks, 1983; Power, 1983). The degree of increase, of course, depends upon the crop, soil and the climate of the area. Morey et al. (1980) showed that for every cm of water use above a threshold value, corn yield increased by 13.5 Bu/A (890 kg $ha^{-1}$) in western Minnesota. Similar rates of increase for soybean and alfalfa are 2.0 Bu/A (132 kg $ha^{-1}$) (Stegman, 1989) and 0.071 t/a (159 kg $ha^{-1}$) (Bauder et al, 1978), respectively. These studies were done in eastern North Dakota, an area with climate similar to that of western Minnesota.

Two studies report the direct effects of water consumption by alfalfa on yield of subsequent crops (Hobbs, 1953 and Voorhees and Holt, 1969). Hobbs (1953) studied the depletion of water in Kansas soils to a depth of 25 feet (7.5 m) both under conditions where alfalfa had been grown for 4 years following 12 years of cereal crops and where cereal grains have been grown for 12 years followings 4 years of alfalfa. The author concluded that (1) in four years of alfalfa, soil moisture was utilized to a depth of 18 feet (5.4 m), (2) the moisture reserve under fertilized alfalfa was lower than that of unfertilized alfalfa; and (3) there was partial restoration of soil moisture during the subsequent 12 years of cereal production, provided the rainfall was above normal. For western Minnesota, Voorhees and Holt (1969) reported that first year alfalfa extracted water from at least a depth of 9 feet (2.4 m) and summer fallowing was not an effective way of conserving rainfall prior to August because of higher evaporative losses compared to rainfall. In an earlier study, Holt et al (1964) showed that corn yield was critically linked with the soil moisture stored at planting and only above-average rainfall during the critical growth period minimized the effects of stored soil moisture. These authors concluded that there is a need for moisture conservation in areas of rainfall from 19 to 26 inches (48 to 66 cm) such as in western Minnesota.

Voss and Schrader (1984) reported the summary of 19 years of data on the effects of alfalfa management on soil water and following corn yield for northwest Iowa. Water available to corn was 4.2 inches (10.7 cm), 3.7 inches (9.4 cm) and 2.2 inches (5.7cm) after first cutting, second cutting and two years of alfalfa, respectively. Corn yields for these treatments were 66 (4.39), 62(4.08), and 45.5 Bu/A (3.01 Mg $ha^{-1}$). The authors concluded that in drought prone areas, a trade off between the current alfalfa crop and the following corn crop may have to be made to achieve maximum profit.

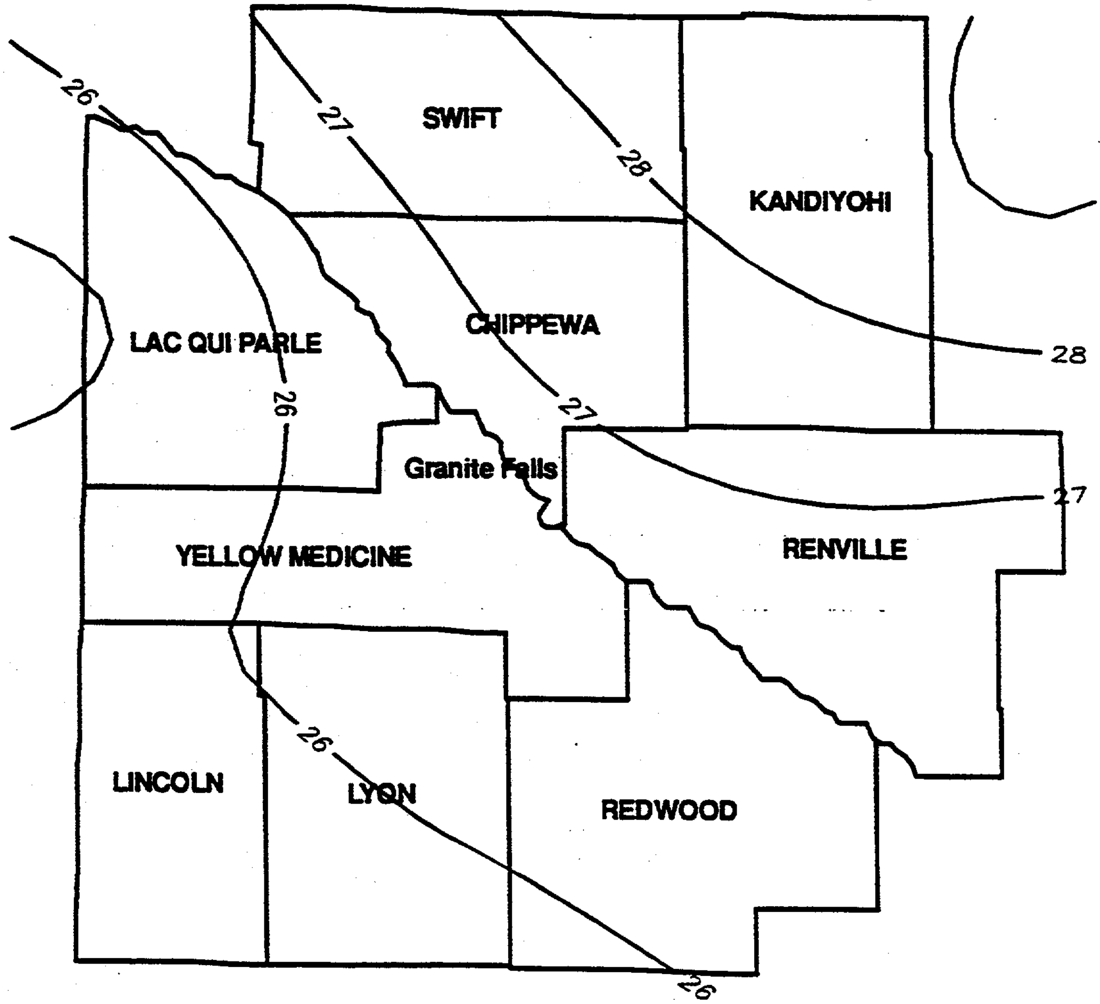
## PROCEDURES:

Water availability is the main limiting factor for crop growth in western Minnesota. Since water limitation could contribute to a reduction in yield of the following crops when alfalfa is in the rotation, a procedure was developed to estimate soil water reserves during corn and soybean growth with and without alfalfa in rotation. The estimated crop available soil water reserves are calculated using the inputs of rainfall and estimated evapotranspiration. When the estimated evapotranspiration is more than the soil water reserve, then evapotranspiration is set equal to soil water reserve. Seasonal cumulative evapotranspiration is then used to estimate crop yield. Evapotranspiration calculations are based on the Jensen-Haise's equation. Inputs needed for these calculations are the soil water holding capacity, daily precipitation, solar radiation and maximum and minimum air temperatures. Risk of yield loss of corn and soybean when alfalfa is introduced is assessed using the weather records from the past 31 years.

Since the NSP power plant under consideration for this feasibility study is located at Granite Falls, Minnesota, the biomass production area is projected to be within 50 miles of Granite Falls. This area includes nine entire counties: Chippewa, Lac Qui Parle, Lincoln, Lyon, Kandiyohi, Redwood, Renville, Swift, and Yellow Medicine and eight partial counties. Only the nine entire counties are considered in our calculations (**Figure 3.4-1a**).

**Figure 3.4-1a** Average (1963-1993) annual precipitation (inches) for the nine counties considered in this analysis of moisture effect on yield of crops following alfalfa in the rotation.

**Precipitation Contour**



At the latitude of Granite Falls in Minnesota, average annual rainfall varies from 29 inches in the east to 24 inches to the west (**Figure 3.4-1a and 1b**) and the corresponding mean annual pan evaporation is from 36 inches in the east to 43 inches in the west (**Figure 3.4-2**). Similarly, mean annual air temperatures decrease from 45 °F in the east to 43 °F in the west (**Figure 3.4-3**) and the corresponding Growing Degree Day (GDD) are 2600 °F in the east to 2300 °F in the west (**Figure 3.4-4**) (Baker and Crookston, 1991).

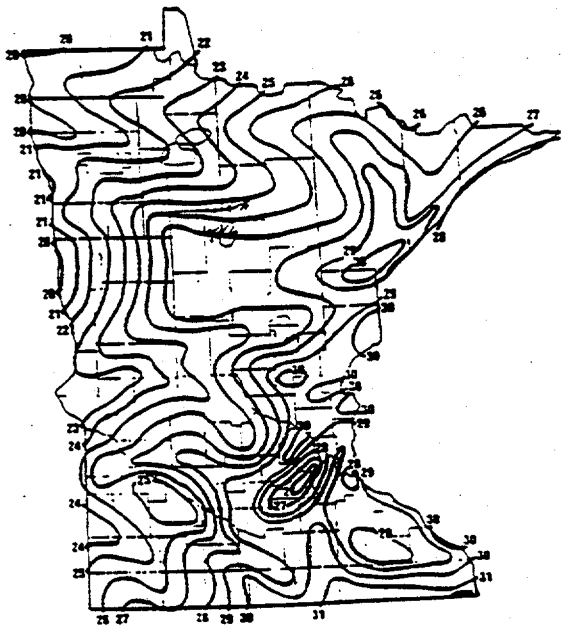


**Figure 3.4-1b** Normal annual total precipitation (inches).

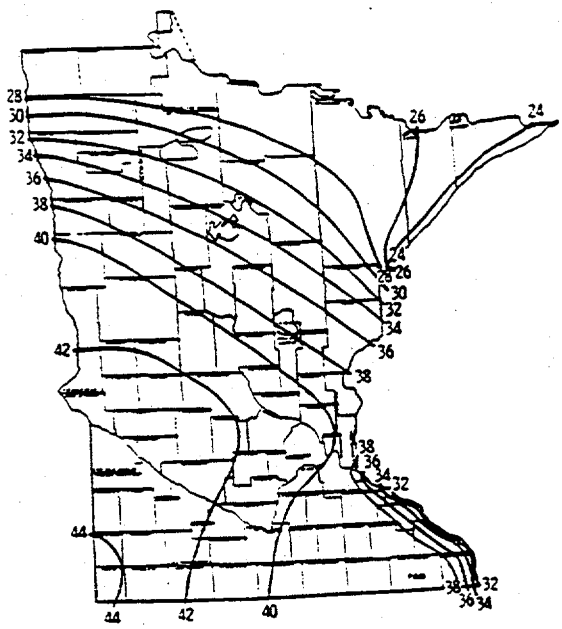



**Figure 3.4-2** Mean annual pan evaportation (inches) based upon records available (1960-1977).

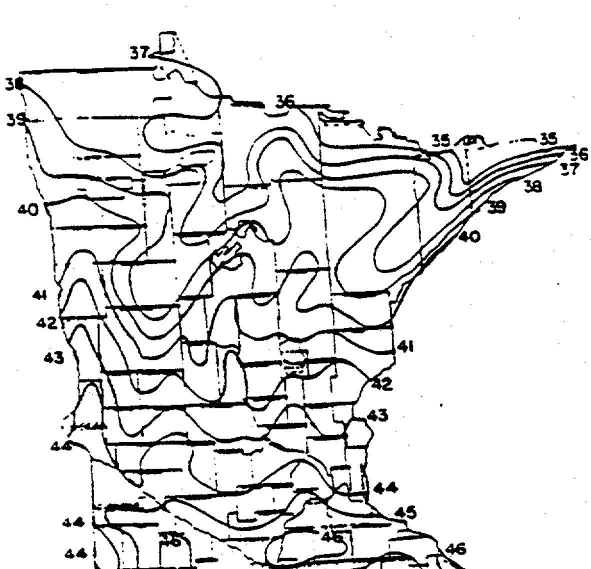



**Figure 3.4-3** Annual normal temperature.

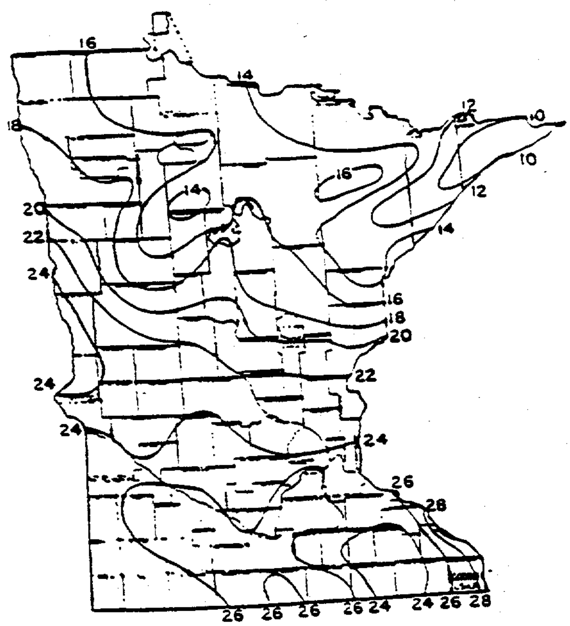
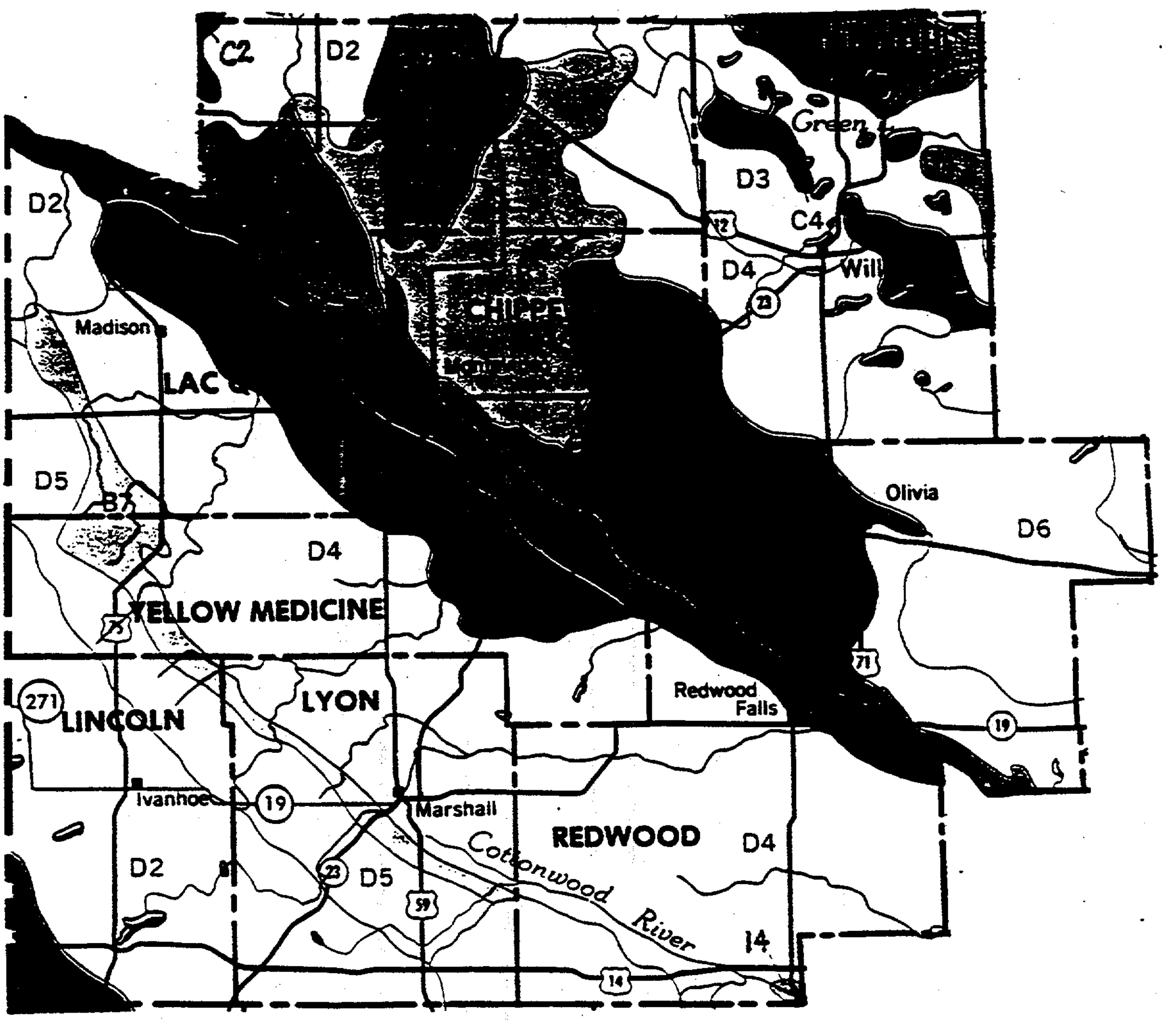



**Figure 3.4-4** Average total GDD in hundreds ($T_b$ = 50°F) accumulated during the warm season crop period (late spring through late fall).

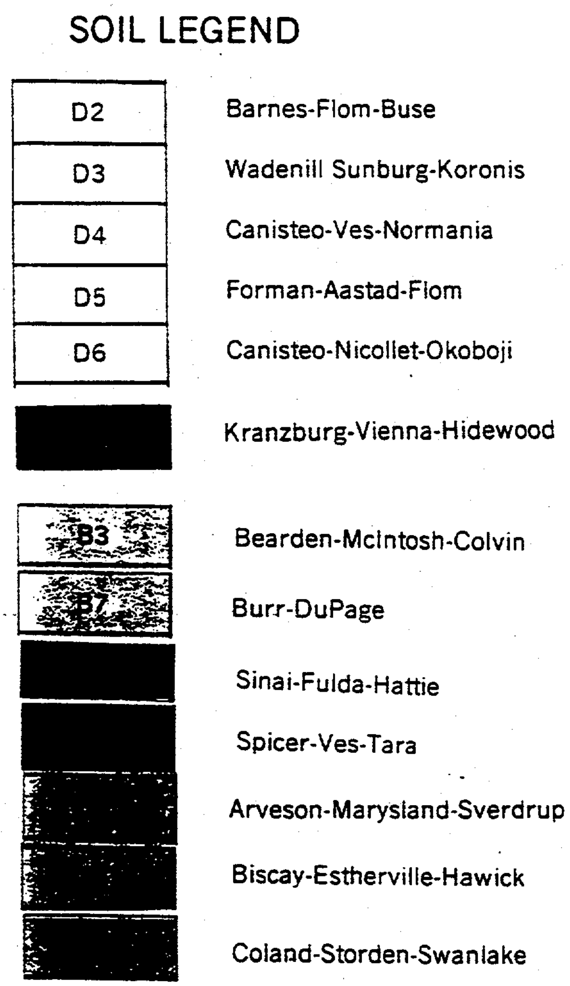
The major soil associations in the area are shown on **Figure 3.4-5**. Most of soils are formed in sandy to clayey lacustrine sediments, in very thin to thick lacustrine sediments overlaying glacial till or lacustrine modified glacial till overlying glacial till, and in calcareous loamy glacial till. For detailed soil description see Appendix A. Water holding capacities in a 6 foot soil profile in the area ranges from 3 to 13 inches. The combination of limited rainfall, high evaporation and lower soil water holding capacities are factors affecting the sustainability of alfalfa production in this area.

**Figure 3.4-5** Soil associations of the biomass shed (source: Minnesota Soil Survey Staff of the U.S. Department of Agriculture, Soil Conservation Service, Universtiy of Minnesota, Agricultural Experiment Station (October 1983 4-R-38340)). For soil water holding capacity infromation see Appendix A and for detailed soil association description see Appendix B.

**Soils Map of Biomass Shed**



Soil Legend for Figure 3.4-5



The water budget model developed in this study to predict corn and soybean yield with and without alfalfa in the rotation is a capacity type of model. When the rain water percolating to a given layer exceeds its water holding capacity, the excess water is percolated to the next soil layer. Weather is the driving force for crop water use (evapotranspiration (ET)). Soil provides water storage and is a limiting factor. When available soil water becomes less than ET then ET is set equal to the available soil water. If the soil available water becomes zero then ET becomes zero also. The water holding capacity of a soil profile is a function of crop rooting depth and is equal to the summation of the individual water holding capacity of the all soil layers in the rooting depth. **Runoff, snow catch, and improvements in soil water holding capacity that directly result from alfalfa production are not included in this model.**

Water balance is calculated using the follow equation:

**DS = P + dSW - ETa**

| where: | | |
|---|---|---|
| | DS | = soil water storage in crop rooting zone (in) |
| | P | = precipitation (in) |
| | dSW | = contribution of previous year's soil moisture |
| | | = dz*swcont |
| | swcont | = previous year soil water content |
| | | = DSend/Zend |
| | dz | = rooting depth increment in a given day |
| | ETa | = actual evapotranspiration (in) |

DSend and Zend are DS and are a function of root depth at the end of previous year.

DS and ETa are always positive

If DS > WHCRZ (the water holding capacity of the root zone)
then DR (deep drainage in inches) = DS-WHCRZ, and DS = WHCRZ

Evapotranspiration (ET) is calculated using the Jensen-Haise method:

$$ETa = ((0.014*Tm)-0.37)*(RAD*0.000673)*Kcrop$$

| | | |
|---|---|---|
| where: | ETa | = actual daily evapotranspiration (in) |
| | Tm | = daily mean air temperature (°F) |
| | RAD | = daily solar radiation |
| | Kcrop | = crop water use coefficient (different crops have different Kcrop values) |

Climate Input Data

A thirty-one year (1963-1993) solar radiation data set from St. Paul, MN was combined with air temperatures and precipitation data for the same period from a given location in each of the nine counties.

Soil Input Data

Only major soils are considered in the simulations. Major soils in this study are defined as the soils which occupy more than 2.5% of the total county area. This resulted in less than 12 soils per county. Soils considered in this analysis by each county are listed in Table B-1 in Appendix B. The soil's input included the soil water holding capacity and the depth of each layer. A total of three layers are considered. Water holding capacities by soil layer are taken from Soil Survey data for each of the nine counties. It is assumed that soils below the last layer reported in the soil survey have the same characteristics as the last layer. Also, we assumed that soil in each layer is homogeneous. It is also assumed that root restricting factors such as impermeable layers and shallow ground water tables do not exist in these soils. The soil water is recharged and consumed starting with the top layer. Any water retained in the soil profile in the previous year is evenly distributed in the soil profile before the next year's simulation, but the water content of each soil layer is not allowed to exceed the water holding capacity.

Crop Input Data

Each year, corn is assumed to be planted on May 1 and assumed matured when GDD reached 2254°F or when the minimum air temperature was lower than 28°F. The development of corn and the corresponding Kcrop values are based on the GDD. Each year, soybeans were also assumed to be planted on May 1. As stated earlier, it was assumed that the growth of soybeans was related to day length and not based on GDD. Therefore, the Kcrop value for soybean depended upon the calendar day and was thus the same for every year. Kcrop values of corn varied from year to year. The values of Kcrops for both corn and soybeans were taken from Seeley and Spoden (1982).

The growth of alfalfa is closely related to GDD, however, alfalfa can grow at lower temperatures in early spring and at higher temperatures during the rest of the season. Therefore, two base-temperature GDD values are used. The base temperature in spring is set at 36°F and the base temperature for the remainder of the growing season is set at 50°F (Sharratt et al. 1987). The number of alfalfa cuttings has a large impact on alfalfa yield and corn yield in the following year. All three crops die or become dormant when daily minimum air temperature is 28°F.

**Crop Yield Prediction:**

The model for predicting crop yield is based on the growing season ETa and utilizes the following equations:

| | | |
|---|---|---|
| Corn | $Y = -5840 + 890 * ETa$ | (Morey et al. 1980) |
| Soybean | $Y = -1654 + 132 * ETa$ | (Stegman 1989) |
| Alfalfa | $Y = -833 + 159 * ETa$ | (Bauder et al. 1978) |

The crop rotations considered in these simulations were corn-soybean (without alfalfa) and corn-corn-soybean-alfalfa-alfalfa-alfalfa-alfalfa (**Table 3.4-1**).

**Table 3.4-1** Crop rotations considered.

| Year | Future Rotation | Current Rotation |
|---|---|---|
| 63 | **C** A A A A S C | **C** S |
| 64 | C **C** A A A A S | S **C** |
| 65 | S C **C** A A A A | **C** S |
| 66 | A S C **C** A A A | S **C** |
| 67 | A A S C **C** A A | **C** S |
| 68 | A A A S C **C** A | S **C** |
| 69 | A A A A S C **C** | **C** S |
| 70 | **C** A A A A S C | S **C** |
| 71 | C **C** A A A A S | **C** S |
| 72 | S C **C** A A A A | S **C** |
| 73 | A S C **C** A A A | **C** S |
| 74 | A A S C **C** A A | S **C** |
| 75 | A A A S C **C** A | **C** S |
| 76 | A A A A S C **C** | S **C** |
| 77 | **C** A A A A S C | **C** S |
| 78 | C **C** A A A A S | S **C** |
| 79 | S C **C** A A A A | **C** S |
| 80 | A S C **C** A A A | S **C** |
| 81 | A A S C **C** A A | **C** S |
| 82 | A A A S C **C** A | S **C** |
| 83 | A A A A S C **C** | **C** S |
| 84 | **C** A A A A S C | S **C** |
| 85 | C **C** A A A A S | **C** S |
| 86 | S C **C** A A A A | S **C** |
| 87 | A S C **C** A A A | **C** S |
| 88 | A A S C **C** A A | S **C** |
| 89 | A A A S C **C** A | **C** S |
| 90 | A A A A S C **C** | S **C** |
| 91 | **C** A A A A S C | **C** S |
| 92 | C **C** A A A A S | S **C** |
| 93 | S C **C** A A A A | **C** S |

A = alfalfa, C = corn, and S = soybeans

The underlined and bolded letter **C** shows position in rotation of the year being considered.

Corn yield reduction due to moisture limitation resulting from the introduction of alfalfa into a corn-soybean rotation was calculated by subtracting the yield of first year corn (**C**) after four years of alfalfa under future rotation from the yield of corn (**C**) under current corn-soybean rotation.

## RESULTS AND DISCUSSIONS

### Model Testing:

Before running extensive calculations on the risk of yield loss due to addition of alfalfa in a rotation on nine counties, the model of corn yield prediction was tested against the county averages for Yellow Medicine and Stevens counties. Since some of the yield increase over years has been due to improvement in technology, the county averages of corn yields reported by the statistical reporting services were corrected to account for the technological developments over the 22 year simulation period. Baker (1990) showed that yield improvements due to technology were about 2.24 bushels per year. After adjusting for this correction, comparisons of predicted and measured (statistical reporting services) corn yield were made for Yellow Medicine (**Figure 3.4-6**) and Stevens (**Figure 3.4-7**) counties of Minnesota. Fourteen out of 22 years, the differences between predicted and reported county averages were within 25 bu/ac. For the remaining 8 years, corresponding differences are more than 25 bu/ac. The large differences between predicted and measured corn yields occur the year following dry periods.

**Figure 3.4-6** Comparison of simulated and measured (Statistical Reporting Services) county average corn yield for Yellow Medicine county, MN.

**Corn Yield (Yellow Medicine county)**

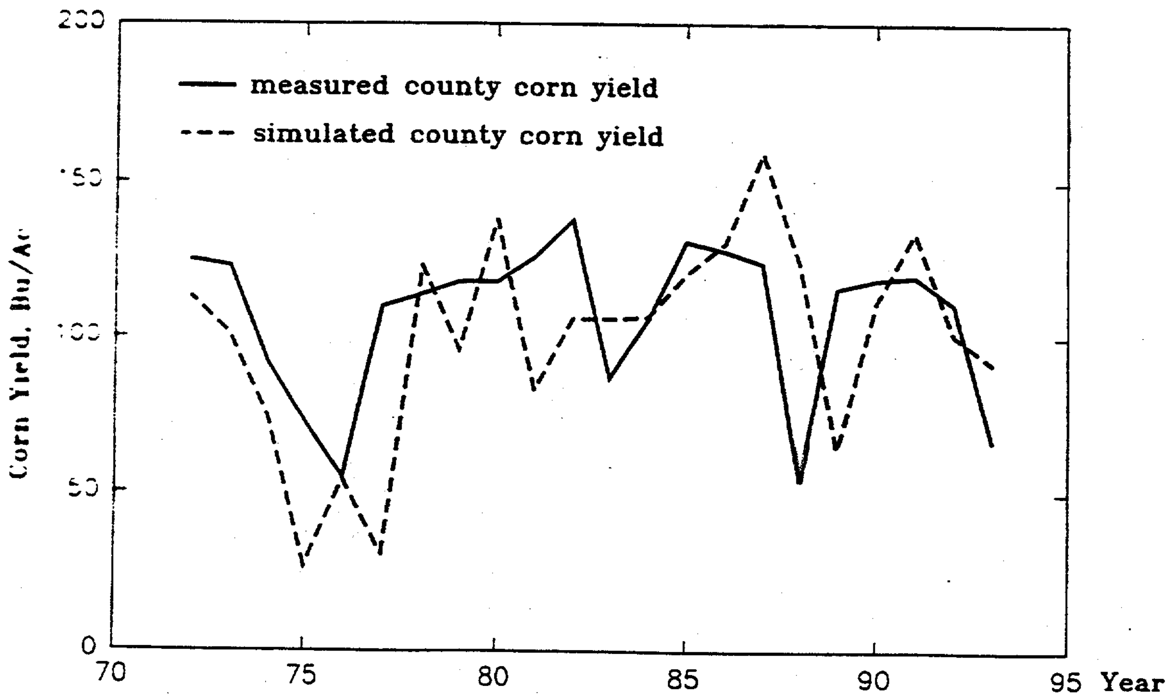
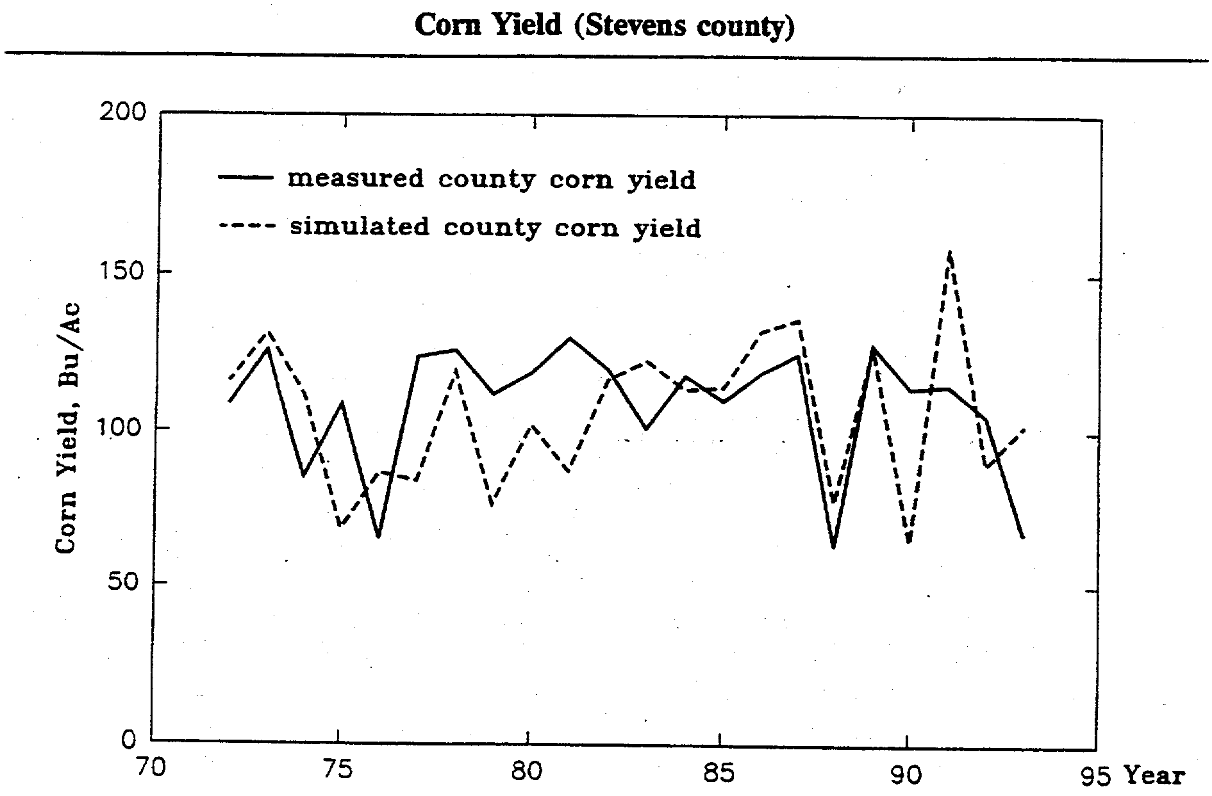


**Figure 3.4-7** Comparison of simulated and measured (Statistical Reporting Services) county average corn yield for Stevens county, MN.



**Risk Assessment of Introducing Alfalfa in a Corn-Soybean Rotation:**

Corn yield difference due to moisture limitation caused by the introduction of alfalfa into a corn-soybean rotation was calculated by subtracting the yield of first year corn after four years of alfalfa (C) as identified in Table 3.4-1 from the yield of corn in a corn-soybean rotation. Simulations of crop yield were run for all the nine counties in the bioshed. The model was run assuming two alfalfa cutting strategies. These strategies were fixed cuttings (first cutting on June 20 and second cutting on Sept. 1) and floating cuttings. Timing of floating cutting were based on GDD reported by Sharratt et al. (1987).

The timings for the fixed cutting strategy were selected such that there was minimal damage to the pheasant habitat especially during the first cutting. To protect pheasants and other wildlife that utilize alfalfa ground cover for nesting a delayed first cut of alfalfa may be warranted. June 20 was used as the earliest date for the first cutting in the fixed cutting strategy. In the case of floating cuttings, the first, second and third cuttings were made when GDD reached 1035, 1630, 2395, respectively (Sharratt et al., 1987). For the nine counties, the total number of floating cuttings varied between 3 to 4 per year depending on the air temperature. In general, the warmer the year the greater the number of cuttings. The number and the corresponding dates of floating cuttings strategies for Yellow Medicine County and Kandiyohi County are listed in the **Table 3.4-2**. In general, there are more cuttings in Yellow Medicine county than Kandiyohi. This is because Yellow Medicine County is warmer during the summer months than Kandiyohi County.

**Table 3.4-2** Number and date of cutting using a floating cutting schedule.

**Kandiyohi County**

| Year | 1st cut month | 1st cut day | 2nd cut month | 2nd cut day | 3rd cut month | 3rd cut day | 4th cut month | 4th cut day | # of cut |
|---|---|---|---|---|---|---|---|---|---|
| 1963 | 5 | 28 | 6 | 29 | 7 | 31 | 0 | 0 | 3 |
| 1964 | 5 | 26 | 6 | 30 | 7 | 31 | 0 | 0 | 3 |
| 1965 | 6 | 5 | 7 | 8 | 8 | 13 | 0 | 0 | 3 |
| 1966 | 6 | 7 | 7 | 6 | 8 | 7 | 0 | 0 | 3 |
| 1967 | 6 | 6 | 7 | 14 | 8 | 18 | 0 | 0 | 3 |
| 1968 | 5 | 27 | 7 | 3 | 8 | 7 | 0 | 0 | 3 |
| 1969 | 5 | 31 | 7 | 13 | 8 | 16 | 0 | 0 | 3 |
| 1970 | 6 | 4 | 7 | 2 | 8 | 4 | 0 | 0 | 3 |
| 1971 | 6 | 2 | 6 | 30 | 8 | 13 | 0 | 0 | 3 |
| 1972 | 6 | 2 | 7 | 8 | 8 | 16 | 0 | 0 | 3 |
| 1973 | 6 | 1 | 7 | 2 | 8 | 6 | 0 | 0 | 3 |
| 1974 | 6 | 5 | 7 | 6 | 8 | 8 | 0 | 0 | 3 |
| 1975 | 6 | 5 | 7 | 5 | 8 | 6 | 0 | 0 | 3 |
| 1976 | 5 | 25 | 6 | 24 | 7 | 28 | 9 | 6 | 4 |
| 1977 | 5 | 16 | 6 | 17 | 7 | 21 | 9 | 10 | 4 |
| 1978 | 6 | 1 | 7 | 3 | 8 | 11 | 0 | 0 | 3 |
| 1979 | 6 | 11 | 7 | 11 | 8 | 19 | 0 | 0 | 3 |
| 1980 | 5 | 26 | 6 | 27 | 7 | 31 | 0 | 0 | 3 |
| 1981 | 5 | 23 | 7 | 1 | 8 | 7 | 0 | 0 | 3 |
| 1982 | 6 | 2 | 7 | 17 | 8 | 23 | 0 | 0 | 3 |
| 1983 | 6 | 12 | 7 | 12 | 8 | 13 | 0 | 0 | 3 |
| 1984 | 6 | 5 | 7 | 9 | 8 | 13 | 0 | 0 | 3 |
| 1985 | 5 | 22 | 7 | 4 | 8 | 12 | 0 | 0 | 3 |
| 1986 | 5 | 30 | 6 | 29 | 8 | 2 | 0 | 0 | 3 |
| 1987 | 5 | 16 | 6 | 18 | 7 | 23 | 9 | 6 | 4 |
| 1988 | 5 | 26 | 6 | 20 | 7 | 19 | 8 | 21 | 4 |
| 1989 | 6 | 4 | 7 | 5 | 8 | 5 | 0 | 0 | 3 |
| 1990 | 6 | 2 | 7 | 3 | 8 | 13 | 0 | 0 | 3 |
| 1991 | 5 | 29 | 6 | 27 | 8 | 1 | 0 | 0 | 3 |
| 1992 | 6 | 3 | 7 | 12 | 9 | 4 | 0 | 0 | 3 |
| 1993 | 6 | 8 | 7 | 16 | 8 | 23 | 0 | 0 | 3 |

**Yellow Medicine County**

| Year | 1st cut month | 1st cut day | 2nd cut month | 2nd cut day | 3rd cut month | 3rd cut day | 4th cut month | 4th cut day | # of cut |
|---|---|---|---|---|---|---|---|---|---|
| 1963 | 5 | 24 | 6 | 24 | 7 | 24 | 8 | 31 | 4 |
| 1964 | 5 | 25 | 6 | 28 | 7 | 25 | 9 | 5 | 4 |
| 1965 | 6 | 2 | 7 | 5 | 8 | 6 | 0 | 0 | 3 |
| 1966 | 6 | 4 | 7 | 3 | 7 | 30 | 0 | 0 | 3 |
| 1967 | 6 | 2 | 7 | 8 | 8 | 12 | 0 | 0 | 3 |
| 1968 | 5 | 22 | 6 | 27 | 8 | 2 | 0 | 0 | 3 |
| 1969 | 5 | 30 | 7 | 12 | 8 | 11 | 0 | 0 | 3 |
| 1970 | 6 | 2 | 6 | 30 | 7 | 30 | 9 | 4 | 4 |
| 1971 | 5 | 29 | 6 | 26 | 8 | 4 | 9 | 10 | 4 |
| 1972 | 6 | 2 | 7 | 7 | 8 | 12 | 0 | 0 | 3 |
| 1973 | 5 | 30 | 6 | 26 | 7 | 30 | 9 | 1 | 4 |
| 1974 | 5 | 31 | 7 | 1 | 7 | 27 | 0 | 0 | 3 |
| 1975 | 6 | 3 | 7 | 2 | 7 | 30 | 9 | 6 | 4 |
| 1976 | 5 | 21 | 6 | 21 | 7 | 22 | 8 | 23 | 4 |
| 1977 | 5 | 14 | 6 | 11 | 7 | 15 | 8 | 25 | 4 |
| 1978 | 5 | 30 | 7 | 2 | 8 | 6 | 9 | 8 | 4 |
| 1979 | 6 | 10 | 7 | 8 | 8 | 11 | 0 | 0 | 3 |
| 1980 | 5 | 26 | 6 | 26 | 7 | 29 | 9 | 8 | 4 |
| 1981 | 5 | 17 | 6 | 25 | 7 | 26 | 9 | 8 | 4 |
| 1982 | 5 | 29 | 7 | 9 | 8 | 9 | 0 | 0 | 3 |
| 1983 | 6 | 10 | 7 | 8 | 8 | 4 | 9 | 6 | 4 |
| 1984 | 6 | 5 | 7 | 8 | 8 | 7 | 0 | 0 | 3 |
| 1985 | 5 | 19 | 6 | 30 | 8 | 4 | 0 | 0 | 3 |
| 1986 | 5 | 29 | 6 | 26 | 7 | 28 | 0 | 0 | 3 |
| 1987 | 5 | 14 | 6 | 16 | 7 | 20 | 8 | 23 | 4 |
| 1988 | 5 | 25 | 6 | 18 | 7 | 16 | 8 | 16 | 4 |
| 1989 | 5 | 31 | 7 | 2 | 8 | 1 | 0 | 0 | 3 |
| 1990 | 5 | 30 | 6 | 29 | 8 | 4 | 0 | 0 | 3 |
| 1991 | 5 | 25 | 6 | 22 | 7 | 25 | 9 | 4 | 4 |
| 1992 | 5 | 29 | 7 | 9 | 8 | 24 | 0 | 0 | 3 |
| 1993 | 6 | 6 | 7 | 13 | 8 | 19 | 0 | 0 | 3 |

The relationship between corn yield loss due to the introduction of alfalfa into a corn-soybean rotation and soil water holding capacity is shown in **Figure 3.4-8**. The reduction in corn yield due to the introduction of alfalfa into a corn-soybean rotation increases linearly with a decrease in soil water holding capacity down to 11 inches of water holding capacity. At 11 inches of soil water holding capacity, corn yield reductions vary from 7 to 30 bu/A. For soil water holding capacity less than 11 inches, the corn yield reductions increase from 1 to 7 bu/A with an increase in water holding capacity. This indicates that high water holding capacity soils, such as loams, experience a lingering effect from high consumptive water use of alfalfa for a longer period of time than soils with low water holding capacity, such as sands. Above 11 inches of water holding capacity, corn yield reductions increase rapidly without changes in water holding capacity. This is mainly because of significant differences in annual precipitation between counties. Corn yield reductions due to an introduction of alfalfa into a corn-soybean rotation increase linearly with a decrease in annual precipitation (**Figure 3.4-9**). In general, the greatest reductions in corn yield following alfalfa occur on soils of higher soil water holding capacity in areas of lower rainfall.

**Corn Yield**

Water Holding Capacity

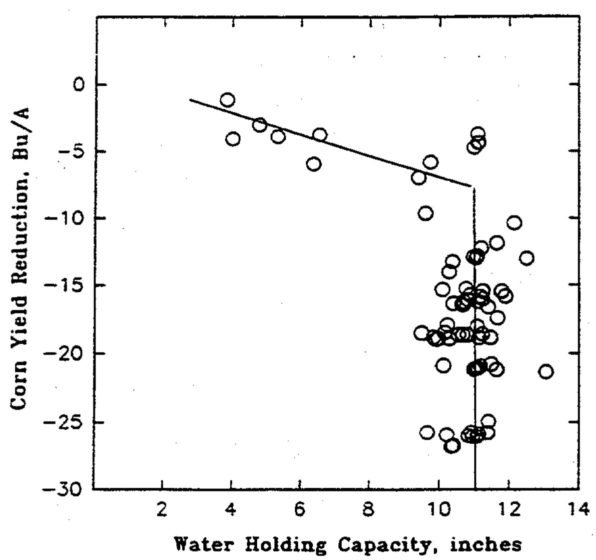



**Figure 3.4-8** Relationship of the first year corn yield reduction due to introduction of alfalfa into a corn-soybean rotation versus crop available soil water holding capacity.

Annual Precipitation

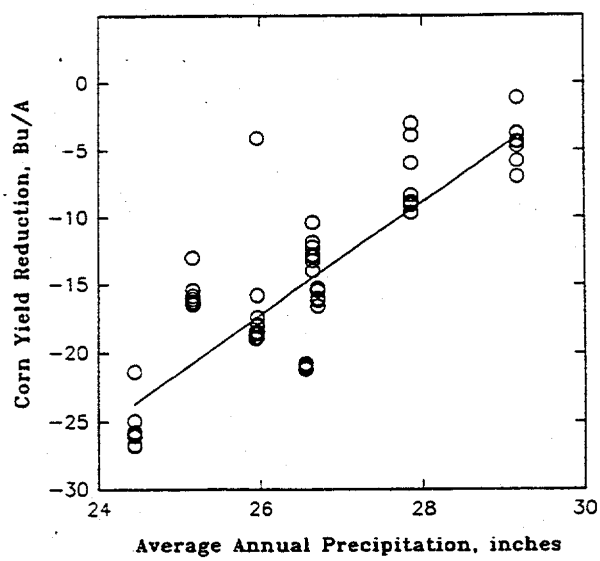



**Figure 3.4-9** Relationship of the first year corn yield reduction due to introduction of alfalfa into a cron-soybean rotation versus average (1963-1993) annual precipitation.

Corn and soybean yields for fixed and floating cutting strategies for the nine counties are shown in **Tables 3.4-3 and 4**, respectively. Detailed corn and soybean yields for fixed and floating cutting strategies for each soil in the nine counties are shown in Tables B-2 and B-3 in Appendix B. **Figures 3.4-10 and 11** show the contour lines of corn yield losses due to an introduction of alfalfa into the corn-soybean rotation for both fixed cutting and floating cutting strategies. For both fixed and floating cutting schedules, reductions in corn yield increase from the northeast to the west in the study area. This is mainly because the annual precipitation in the northeast (Kandiyohi) is about 5 inches higher than that in the west (Lac Qui Parle), and soil water holding capacity in the northeast (Kandiyohi) is about 2 inches lower than that in the west (Lac Qui Parle). Average corn yield reduction due to introduction of alfalfa in the nine counties varies from 6 to 24 bu/a and 4 to 12 bu/a for the fixed and floating cutting schedules, respectively.

**Corn Yield Reduction (fixed cutting schedule)**

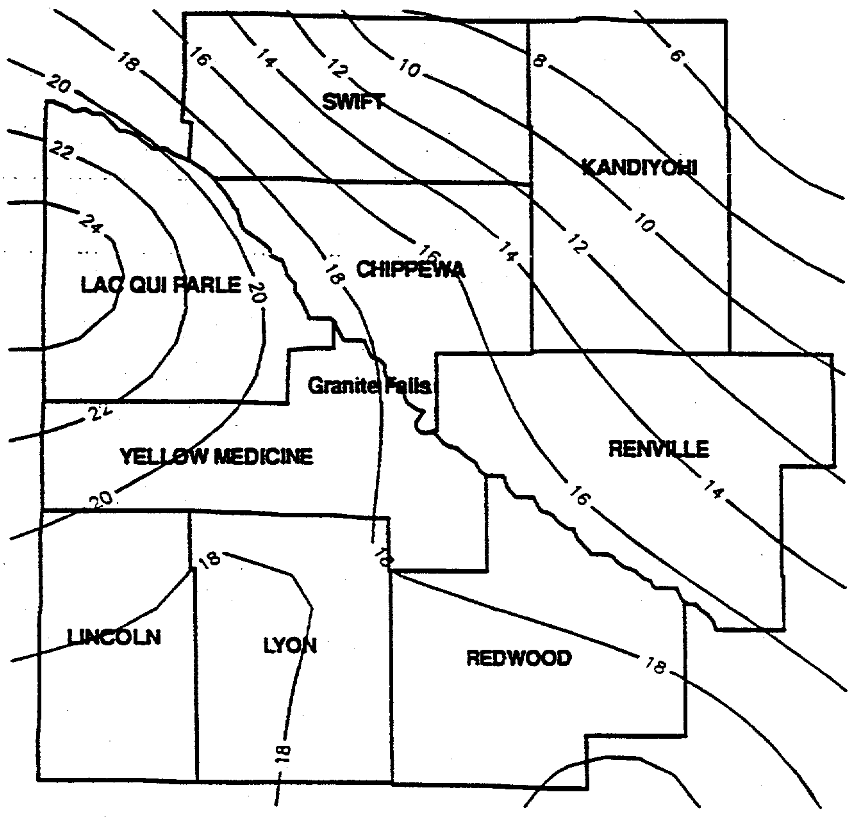



**Figure 3.4-10** Contour lines of average first year corn yield loss due to introduction of alfalfa with a fixed cutting schedule into a corn-soybean rotation (bu/a).

**Corn Yield Reduction (floating cutting schedule)**

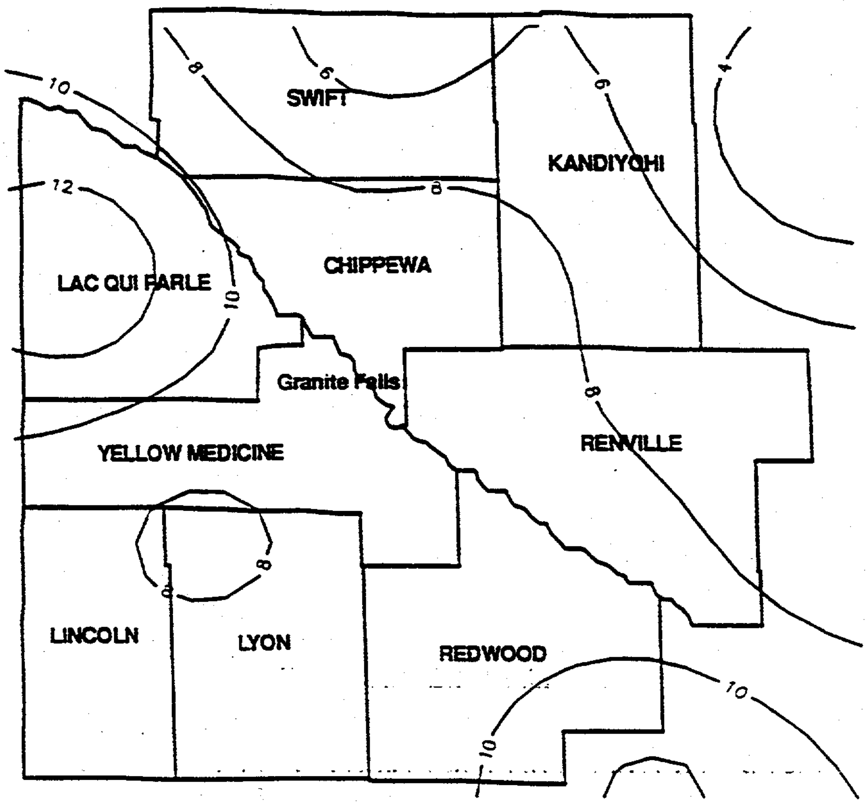



**Figure 3.4-11** Contour lines of average first year corn yield loss due to introduction of alfalfa with a floating cutting schedule into a corn-soybean rotation (bu/a).

**Table 3.4-3** **Simulated county mean corn and soybean yield and yield loss in fixed cutting schedule at various probability levels.**

| County | Corn Yield* (new) | | | Corn Yield (old) | | | Diff. Yield | | | Average Yield, Bu/A | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10%** | 50% | 90% | 10% | 50% | 90% | 10% | 50% | 90% | AvYnw | AvYod | AvDif |
| Chippewa | 123.15 | 98.03 | 63.78 | 128.20 | 107.03 | 91.78 | 0.00 | -3.37 | -51.28 | 96.90 | 112.51 | -15.62 |
| Kandiyohi | 114.66 | 93.78 | 66.21 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -17.07 | 94.41 | 98.55 | -4.14 |
| Lac Qui Parle | 111.68 | 82.92 | 49.55 | 127.66 | 108.85 | 84.89 | 0.00 | -24.17 | -60.66 | 84.53 | 110.32 | -25.80 |
| Lincoln | 122.24 | 85.31 | 45.62 | 128.18 | 97.71 | 73.78 | 0.00 | -1.16 | -44.33 | 87.45 | 103.34 | -15.89 |
| Lyon | 125.06 | 90.16 | 44.44 | 128.87 | 105.73 | 89.94 | 0.00 | -6.18 | -49.89 | 92.65 | 111.46 | -18.81 |
| Red Wood | 127.99 | 96.16 | 53.15 | 133.37 | 115.54 | 93.69 | 0.00 | -13.30 | -57.68 | 96.80 | 117.77 | -20.97 |
| Renvilley | 129.77 | 102.38 | 69.62 | 130.64 | 112.36 | 94.81 | 0.00 | 0.00 | -44.79 | 103.12 | 115.88 | -12.76 |
| Swift | 127.36 | 94.16 | 57.40 | 129.34 | 97.32 | 78.97 | 0.00 | 0.00 | -34.70 | 95.07 | 103.50 | -8.43 |
| Yellow Medicine | 123.67 | 95.86 | 55.78 | 131.49 | 106.48 | 87.98 | 0.00 | -10.04 | -41.72 | 94.11 | 111.76 | -17.65 |
| | Soybean Yield* (new) | | | Soybean Yield (old) | | | Diff. Yield | | | Average Yield, Bu/A | | |
| | 10% | 50% | 90% | 10% | 50% | 90% | 10% | 50% | 90% | AvYnw | AvYod | AvDif |
| Chippewa | 39.25 | 34.63 | 29.31 | 39.25 | 34.89 | 29.95 | 0.00 | 0.00 | 0.00 | 35.60 | 36.07 | -0.48 |
| Kandiyohi | 36.58 | 31.83 | 24.96 | 36.58 | 31.94 | 25.95 | 0.00 | 0.00 | 0.00 | 32.42 | 32.80 | -0.38 |
| Lac Qui Parle | 39.58 | 35.26 | 28.93 | 39.58 | 35.47 | 29.15 | 0.00 | 0.00 | 0.00 | 35.58 | 35.94 | -0.37 |
| Lincoln | 38.91 | 33.12 | 26.82 | 38.91 | 33.12 | 26.82 | 0.00 | 0.00 | 0.00 | 34.05 | 34.05 | 0.00 |
| Lyon | 39.33 | 34.94 | 29.51 | 39.33 | 34.94 | 29.51 | 0.00 | 0.00 | 0.00 | 35.89 | 35.88 | 0.01 |
| Red Wood | 42.39 | 37.04 | 30.76 | 42.39 | 37.05 | 30.76 | 0.00 | 0.00 | 0.00 | 37.58 | 37.67 | -0.10 |
| Renvilley | 41.71 | 35.75 | 29.89 | 41.71 | 35.89 | 29.93 | 0.00 | 0.00 | 0.00 | 36.74 | 37.13 | -0.39 |
| Swift | 38.88 | 32.79 | 26.40 | 38.88 | 33.19 | 27.51 | 0.00 | 0.00 | 0.00 | 33.81 | 34.28 | -0.46 |
| Yellow Medicine | 40.33 | 35.85 | 29.60 | 40.33 | 35.85 | 29.60 | 0.00 | 0.00 | 0.00 | 36.66 | 36.65 | 0.01 |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotatio
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

**Table 3.4-4** **Simulated county mean corn and soybean yield and yield loss in floating cutting schedule at various probability levels.**

| County | Corn Yield (new) | | | Corn Yield (old) | | | Diff. Yield | | | Average Yield, Bu/A | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 50% | 90% | 10% | 50% | 90% | 10% | 50% | 90% | AvYnw | AvYod | AvDif |
| Chippewa | 125.44 | 101.71 | 74.14 | 128.20 | 107.03 | 91.78 | 0.00 | 0.00 | -28.71 | 103.80 | 112.51 | -8.72 |
| Kandiyohi | 117.14 | 94.59 | 67.04 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -12.18 | 96.42 | 98.55 | -2.13 |
| Lac Qui Parle | 123.68 | 94.17 | 68.71 | 127.66 | 108.85 | 84.89 | 1.66 | -5.43 | -42.81 | 96.89 | 110.32 | -13.43 |
| Lincoln | 127.93 | 87.97 | 60.04 | 128.18 | 97.71 | 73.78 | 0.00 | 0.00 | -32.75 | 94.81 | 103.34 | -8.53 |
| Lyon | 128.30 | 101.59 | 52.92 | 128.87 | 105.73 | 89.94 | 0.00 | 0.00 | -40.11 | 102.55 | 111.46 | -8.91 |
| Red Wood | 133.96 | 104.23 | 66.25 | 133.37 | 115.54 | 93.69 | 0.00 | 0.00 | -35.05 | 105.47 | 117.77 | -12.30 |
| Renvilley | 135.17 | 105.20 | 74.98 | 130.64 | 112.36 | 94.81 | 0.00 | 0.00 | -37.28 | 108.56 | 115.88 | -7.32 |
| Swift | 129.34 | 95.16 | 63.45 | 129.34 | 97.32 | 78.97 | 0.00 | 0.00 | -29.34 | 98.24 | 103.50 | -5.26 |
| Yellow Medicine | 129.19 | 104.31 | 63.74 | 131.49 | 106.48 | 87.98 | 0.00 | 0.00 | -27.62 | 104.08 | 111.76 | -7.68 |
| | Soybean Yield (new) | | | Soybean Yield (old) | | | Diff. Yield | | | Average Yield, Bu/A | | |
| | 10% | 50% | 90% | 10% | 50% | 90% | 10% | 50% | 90% | AvYnw | AvYod | AvDif |
| Chippewa | 39.25 | 34.63 | 29.31 | 39.25 | 34.89 | 29.95 | 0.00 | 0.00 | 0.00 | 35.60 | 36.07 | -0.48 |
| Kandiyohi | 36.58 | 31.83 | 24.96 | 36.58 | 31.94 | 25.95 | 0.00 | 0.00 | 0.00 | 32.42 | 32.80 | -0.38 |
| Lac Qui Parle | 39.58 | 35.26 | 28.93 | 39.58 | 35.47 | 29.15 | 0.00 | 0.00 | 0.00 | 35.58 | 35.94 | -0.37 |
| Lincoln | 38.91 | 33.12 | 26.82 | 38.91 | 33.12 | 26.82 | 0.00 | 0.00 | 0.00 | 34.05 | 34.05 | 0.00 |
| Lyon | 39.33 | 34.94 | 29.51 | 39.33 | 34.94 | 29.51 | 0.00 | 0.00 | 0.00 | 35.89 | 35.88 | 0.01 |
| Red Wood | 42.39 | 37.04 | 30.76 | 42.39 | 37.05 | 30.76 | 0.00 | 0.00 | 0.00 | 37.58 | 37.67 | -0.10 |
| Renvilley | 41.71 | 35.75 | 29.89 | 41.71 | 35.89 | 29.93 | 0.00 | 0.00 | 0.00 | 36.74 | 37.13 | -0.39 |
| Swift | 38.88 | 32.79 | 26.40 | 38.88 | 33.19 | 27.51 | 0.00 | 0.00 | 0.00 | 33.81 | 34.28 | -0.46 |
| Yellow Medicine | 40.33 | 35.85 | 29.60 | 40.33 | 35.85 | 29.60 | 0.00 | 0.00 | 0.00 | 36.66 | 36.65 | 0.01 |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

Differences in available water content at the end of the year between the two cutting strategies are large. Floating cutting schedules alway result in higher available water content for the following year than levels predicted for the fixed cutting schedules. The reason for this difference is because in a floating cutting strategy alfalfa is cut right when it reaches its maximum yield versus allowing the alfalfa to remain at maximum growth for a longer period of time as in the fixed cutting strategy. Under fixed cutting dates prolonged periods of time at maximum growth rates result in higher levels of evapotranspiration and greater water consumption. Significant saving in stored water are captured by utilizing the floating strategy.

Differences in second year corn and soybean yields with and without alfalfa in the rotation and between fixed and floating alfalfa cuttings strategies were absent. This is because the rotation considered with alfalfa has two years of corn followed by one year of soybeans and four years of alfalfa. In this rotation after the first year of corn, the depletion of soil water due to alfalfa is nearly compensated for and thus second year corn and soybean yield differences are minimized.

**Management Strategies to Minimize Yield Loss due to Alfalfa:**

There are some data in the literature (Voorhees and Holt, 1969) that suggest that if soil water recharge is allowed during the fourth year of alfalfa by keeping the soil fallow, then corn yield in the following year is not significantly reduced. To test this concept, a sensitivity analysis of the model with five management strategies for alfalfa cuttings was considered. The management strategies are: fixed cutting, fixed cutting with fallow after the first cut on June 20, floating cutting, floating cutting with fallow after the first cut, and floating cutting with fallow after the second cut. The simulations for these five strategies were conducted on Lac Qui Parle and Kandiyohi Counties, since they are the two cases where extreme differences in loss in corn yield occurred in the previous analysis.

Results of this sensitivity analysis for Lac Qui Parle and Kandiyohi Counties are given in **Tables 3.4-5 and 6**, respectively. The detailed results of this sensitivity analysis for Lac Qui Parle and Kandiyohi Counties are given in Tables B-4 and B-5 in Appendix B. In general, corn yields following alfalfa in Lac Qui Parle and Kandiyohi counties were reduced by 26 and 4 bu/ac, respectively, for the first year corn. This is because soil water holding capacities in Lac Qui Parle are higher than those of Kandiyohi county and because Lac Qui Parle county has 5 inches less rainfall than Kandiyohi county.

**Table 3.4-5** Simulated Lac Qui Parle county mean corn yield and yield loss for different cutting strategies at various probability levels.

| Strategy | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fix | 111.84 | 82.92 | 49.23 | 127.66 | 108.85 | 84.89 | 0.00 | -24.13 | -60.95 | 84.56 | 110.32 | -25.76 |
| Fix1 | 132.16 | 99.27 | 77.18 | 127.66 | 108.85 | 84.89 | 11.30 | 0.00 | -41.49 | 102.55 | 110.32 | -7.78 |
| Float | 123.68 | 94.17 | 68.71 | 127.66 | 108.85 | 84.89 | 1.66 | -5.43 | -42.81 | 96.89 | 110.32 | -13.43 |
| Float1 | 132.21 | 104.77 | 78.00 | 127.66 | 108.85 | 84.89 | 11.30 | 0.00 | -41.49 | 106.05 | 110.32 | -4.27 |
| Float2 | 132.21 | 103.94 | 78.00 | 127.66 | 108.85 | 84.89 | 11.30 | 0.00 | -41.49 | 104.90 | 110.32 | -5.43 |

Fix = Fixed cuttings ( June 20 and Aug 31)
Fix1 = Fixed cuttings with killing alfalfa after 1st cut on June 20
Float = Floating cuttings
Float1 = Floating cuttings with killing alfalfa after 1st cut
Flaot2 = Floating cuttings with killing alfalfa after 2nd cut

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

**Table 3.4-6** Simulated Kandiyohi county mean corn yield and yield loss for different cutting strategies at various probability levels.

| Strategy | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fix | 114.66 | 93.78 | 66.28 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -16.99 | 94.45 | 98.55 | -4.10 |
| Fix1 | 117.49 | 96.57 | 68.34 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -0.08 | 97.87 | 98.55 | -0.68 |
| Float | 117.14 | 94.59 | 67.04 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -12.18 | 96.42 | 98.55 | -2.13 |
| Float1 | 117.49 | 96.57 | 69.66 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | 0.00 | 98.18 | 98.55 | -0.37 |
| Float2 | 117.49 | 95.88 | 69.34 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -0.71 | 98.02 | 98.55 | -0.53 |

Fix = Fixed cuttings ( June 20 and Aug 31)
Fix1 = Fixed cuttings with killing alfalfa after 1st cut on June 20
Float = Floating cuttings
Float1 = Floating cuttings with killing alfalfa after 1st cut
Flaot2 = Floating cuttings with killing alfalfa after 2nd cut

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

In Lac Qui Parle County, killing alfalfa after the first cut in the fourth year of alfalfa could reduce the corn yield loss from 25 to 8 and from 13 to 4 bu/a for fixed and floating cutting strategies, respectively (**Table 3.4-5 and 6**). This is because the high water holding capacity soils of this region recharge during the late summer and fall by rain, and this water becomes very important for the following year's corn. The same situation is true for Kandiyohi county; however, the degree of this effect is less since Kandiyohi has higher precipitation and less soil water holding capacity. There was no difference in soybean yield between the five strategies.

SUMMARY:

Fourteen out of 22 years, the differences between predicted and reported county averages are within 23%. The large differences between predicted and measured corn yield occur in the year following dry periods.

The reduction in corn yield due to introduction of alfalfa into a corn-soybean rotation increases linearly with an increase in soil water holding capacity up to 11 inches of water holding capacity, and with a decrease in annual precipitation. In general, the higher soil water holding capacity and lower reainfall, the greater is the reduction in corn yield following alfalfa.

In this paper, we outline floating cutting schedules as other management options that may facilitate alfalfa introduction in a corn-soybean rotation without significantly reducing subsequent corn yield. Average first year corn yield reduction due to introduction of alfalfa in the nine counties varies from 6 to 24 bu/a and 4 to 12 bu/a for the fixed and floating cutting schedules, respectively. The differences in second year corn and soybean yields with and without alfalfa in the rotation or between the fixed and floating cutting strategies were absent.

If the soil is allowed to recharge by leaving it fallow during the fourth year of alfalfa, the corn yield in the following year is not reduced significantly. In Lac Qui Parle, the county with the greatest corn yield reduction when alfalfa is introduced, killing alfalfa after the first cut in the fourth year of alfalfa could reduce the corn yield loss from 25 to 8 and from 13 to 4 bu/a for fixed and floating cutting strategies, respectively.

**FUTURE RESEARCH**

This simulation study points out the following areas where additional research is needed:

1. Since simulation models are based on data bases from a given location under a given climate, it is always prudent to validate the model before assuming that model predictions are accurate and applicable for a given scenario. Therefore, the modelled predictions of corn, soybeans and alfalfa yields in this study should be validated by conducting field experiments.

2. Calculations of alfalfa yield in this study are based on the relationship between dry matter production and seasonal consumptive use. The data base used to develop these relationships had seasonal consumptive values which were measured for three cutting schedules. Therefore for cutting schedules other than three cuttings, additional data bases and dry matter production functions are needed to test the effects of floating cutting schedules on alfalfa yield.

# CHAPTER 4 PRODUCTION ECONOMICS

## 4.1 Production Regions

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The biomass production area is described by a 50 mile radius around the city of Granite Falls, Minnesota. Fields of corn and soybeans dominate the agricultural landscape in this region. Other crops in the biomass shed include sugarbeets, oats, dry edible beans, sweet corn, peas, and wheat.

The geological history of this area resulted in the development of many different individual soil types. Climate and soil interactions affect crop yields. Additionally, drainage practices, the production of high value crops, and other factors result in different land values (rents) throughout the biomass shed. Thirteen regions within the shed have been identified and characterized with respect to their inherent productivity and to existing market levels of cash rents.

### Geology and Soils

The biomass shed is located in the upper Minnesota River Basin. The soils of this area developed in glacial material (Soil Association Map, Illustration 3.4-1). During the last glacier (Wisconsin) Glacial Lake Agassiz occupied most of Manitoba, the western half of Ontario, and the northern third of Minnesota. This was the largest fresh water lake known. A finger of this lake projected south roughly on the North Dakota-Minnesota border and then southeast along the present day MN River. This lake drained to the south by Glacial River Warren into the Mississippi watershed. As the ice receded and the lake level became lower it reached a point where the lake no longer drained south but north by the Red River. The Minnesota River still drained to the southeast and into the Mississippi Watershed.

Many of the soils of the bioshed have developed in the calcareous lake sediments from Glacial Lake Agassiz. The soil textures generally range from loam to clay with most classified as clay loam. The landscape is somewhat flat to gently rolling with islands of glacial till. This results in poor surface and internal soil drainage.

As the Des Moines Lobe (glaciated most of Minnesota and reached as far south as Des Moines, Iowa) of the Wisconsin Glacier retreated, the meltwaters deposited sandy material in outwash plains in Kandiyohi and Pope Counties. There are also soils which developed in calcareous sandy material from the shoreline beaches of Glacial Lake Agassiz as well as outwash plains in Chippewa, Lac Qui Parle, and Big Stone Counties. These soils range in drainage from poor to excessively well.

The rest of the soils in the bioshed developed in calcareous glacial till. They have somewhat poor internal drainage and predominately clay loam texture. The landscapes where these soils formed are steeper than the lake basins or outwash plains.

**Implications for Crop Production**

Water storage and internal drainage of soils within the shed vary widely (Chapter 3.4). Soils with somewhat poor internal drainage require tile drainage for optimal crop production. Introducing alfalfa into the rotation tends to enhance soil drainage and aeration. Cementing agents (such as polysaccharides and gels) are introduced directly from alfalfa root exudates which also stimulate microbial activity. The combination of root exudates and microbial activity enhances soil aggregation (binding together of individual soil particles which then act as a larger particle). The effect is to reduce soil bulk density, increase pore space and aeration, and create macropores that provide for better water flow. The absence of tillage on established alfalfa allows soil structure formation, increases soil organic matter, generally enhancing physical and biological soil properties.

Soils developed from calcareous parent material in relatively low rainfall areas do not require liming (pH adjustment) to achieve optimal alfalfa production. Soils with a pH below 7 result in reduced growth rates of alfalfa. Soils in the proposed biomass shed would not require lime for maximal alfalfa production. Soils in this part of the state test relatively low in phosporus and high in potassium. Phosphorus application may be needed to achieve maximum alfalfa yields.

**Crop Equivalent Rating**

A Crop Equivalent Rating (CER) represents the relative ranking of a soil series based on inherent capabilities for the production of crops in a given region.

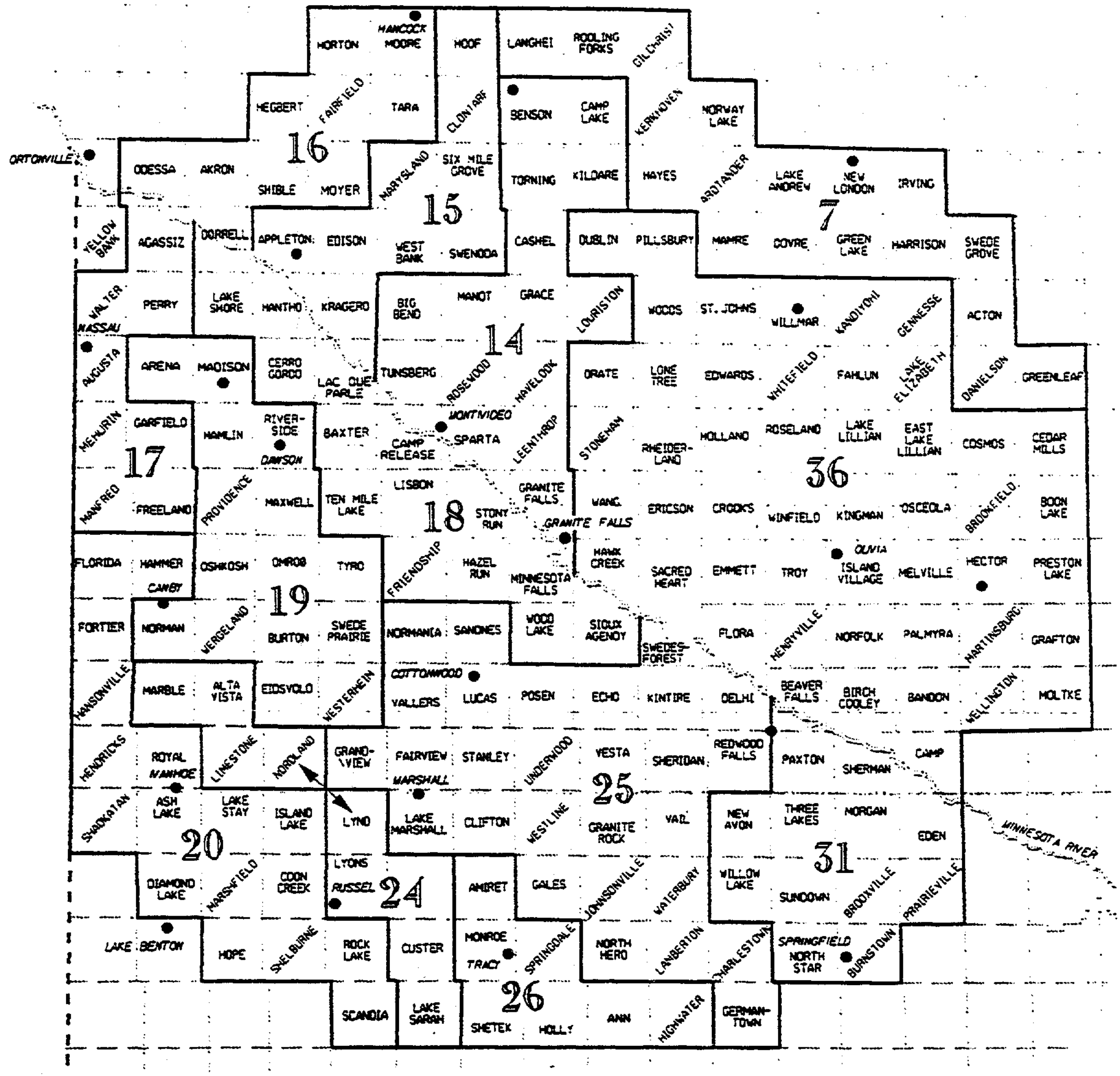
*Soils sharing a similar geological and developmental history are generally named after a location where a particular soil is dominant and easily characterized. There are hundreds of soil series in the Midwest; sometimes there are hundreds of different soil series within a county. The soil series nomenclature facilitates communication between soil scientists and others.*

Major soil series were compared with respect to likely economic returns. The highest ranked soil series was assigned a CER value of 100. Soils capable of producing economic returns at 75% of the highest rated soil are assigned a CER of 75. CER's are useful in farmland valuation because they represent the value of land with respect to inherent productivity. Locational factors, such as nearness to markets and land development potential are segregated from land value based on inherent productivity. CER's were calculated for all the tillable land within the proposed alfalfa biomass shed and are extracted for each production region. **Illustration 4.1-1** (following page) shows production regions in the biomass shed. **Table 4.1-1** shows average CER's by region. Average CER's range from 50 - 71, Region 7 to Regions 26 and 31, respectively.

**Table 4.1-1** Crop equivalent rating (CER) by region.

| **Region** | **Acres (w/i 50mi.)** | **Expected Yield** | | | **CER** |
|---|---|---|---|---|---|
| | | Alfalfa | Corn | Beans | |
| | | t/a | bu/a | bu/a | |
| 7 | 414,720 | 3.8 | 91 | 30.4 | 50 |
| 14 | 338,534 | 4.3 | 106 | 35.2 | 62 |
| 15 | 203,803 | 3.8 | 92 | 30.8 | 51 |
| 16 | 374,563 | 4.1 | 100 | 33.2 | 57 |
| 17 | 168,467 | 4.3 | 106 | 35.2 | 57 |
| 18 | 320,624 | 4.5 | 112 | 37.2 | 67 |
| 19 | 341,124 | 4.5 | 112 | 37.2 | 67 |
| 20 | 374,375 | 4.1 | 98 | 32.8 | 56 |
| 24 | 203,615 | 4.2 | 102 | 34.0 | 59 |
| 25 | 617,022 | 4.5 | 112 | 37.2 | 67 |
| 26 | 155,499 | 4.7 | 116 | 38.8 | 71 |
| 31 | 268,189 | 4.7 | 116 | 38.8 | 71 |
| 36 | 1,038,831 | 4.6 | 114 | 38.0 | 69 |

**Illustration 4.1-1** Map of production regions within the biomass shed.




| # | Region | # | Region |
|---|---|---|---|
| 7 | Green Lake | 20 | Lake Shaokaton |
| 14 | Benson-Lac Qui Parle Plain | 24 | Coteau Headwaters |
| 15 | Appleton-Clontarf Sands | 25 | Redwood-Cottonwood River Valley |
| 16 | Big Stone Moraine | 26 | Tracy |
| 17 | Marietta | 31 | Morgan |
| 18 | Lac Qui Parle | 36 | Olivia Till Plain |
| 19 | Dawson | | |

## Estimated Market Value

Estimated Market Value (EMV) is established for farmland for the purposes of property tax allocation. County Assessors scrutinize all free market farmland transactions for the purpose of estimating market value. Values are assigned to each parcel of land consistent with the quality of the land and market value. EMV's were extracted for each of the production regions and averages were computed. Average EMV's for the regions are found in **Table 4.1-2**.

**Table 4.1-2** Estimated market value (EMV) by region.

| Estimated Market Value | | | |
|---|---|---|---|
| # | Region | CER | EMV |
| 7 | Green Lake | 50 | 913 |
| 14 | Benson Lac. Plain | 62 | 813 |
| 15 | Appl-Clont. Sands | 51 | 725 |
| 16 | Big Stone Moraine | 57 | 675 |
| 17 | Marietta | 62 | 788 |
| 18 | Lac Qui Parle | 67 | 975 |
| 19 | Dawson | 67 | 1025 |
| 20 | Lake Shaokaton | 56 | 600 |
| 24 | Coteau Headwaters | 59 | 613 |
| 25 | Redwd-Cotwd R. Vals | 67 | 1088 |
| 26 | Tracy | 71 | 1038 |
| 31 | Morgan | 71 | 1313 |
| 36 | Olivia Till Plain | 69 | 1213 |

**Rental Returns**

Land Rental values are the level of annual payments to landlords needed to recruit land for a particular economic activity. Rental levels reflect the market influences of supply and demand for land with respect to specific uses. For example, land rents in Lincoln County may have been increased as the result of federal incentives aimed at enrolling land in the Conservation Reserve Program (CRP). In Lincoln county, 23% of the tillable farmland enrolled in CRP at an average annual payment level of $66.62 per acre. Removal of land from production by enrolling in the CRP program increases competition for land available for rent. High returns per acre from sugar beet production and other specialty crop production have also raised rents in some areas of the biomass production area. Competitive rental values range from 47 - 91 dollars per acre, Region 20 to Region 31, respectively. Averages can be deceiving if they, alone, are used to characterize regions. The Olivia Till Plain, the largest region identified in this study, has rents that range from over $120 per acre (ideal sugar beet production acres) down to $70.00 per acre for an overall average rent of $89.16 per acre.

Rental levels were derived from data supplied by two sources. Estimated market values developed by County Assessors and from capitalization rates for groups of counties (rent/estimated market value) by Lazarus, et al. (1993). Where production regions included portions of several counties with different capitalization rates, a weighted capitalization rate was developed based upon the proportion of land area from each county comprising the production region. By multiplying capitalization rate by EMV we calculate rental levels representing the weighted qualities of all lands within the production regions. **Figure 4.1-3** shows calculated rental levels by region.

**Table 4.1-3** Rental value by region.

| Rental Values | | | |
|---|---|---|---|
| # | Region | CER | RENT |
| 7 | Green Lake | 50 | 71.21 |
| 14 | Benson Lac. Plain | 62 | 65.53 |
| 15 | Appl-Clont. Sands | 51 | 60.18 |
| 16 | Big Stone Moraine | 57 | 58.05 |
| 17 | Marietta | 62 | 62.25 |
| 18 | Lac Qui Parle | 67 | 77.03 |
| 19 | Dawson | 67 | 80.98 |
| 20 | Lake Shaokaton | 56 | 47.40 |
| 24 | Coteau Headwaters | 59 | 48.43 |
| 25 | Redwd-Cotwd R. Vals | 67 | 80.51 |
| 26 | Tracy | 71 | 82.00 |
| 31 | Morgan | 71 | 90.60 |
| 36 | Olivia Till Plain | 69 | 89.16 |

## Conclusions

A number of factors govern the inherent productivity of soils in a given region. Soil productivity combined with economic forces that affect demand for land resources determine land value. Thirteen unique production regions have been described for the purpose of developing pro forma budgets for alfalfa biomass production. Budgets represent a relative advantage or disadvantage of an alfalfa biomass rotation versus a conventional corn-soybean rotation.

## 4.2 Pro Forma Budgets by Region

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### Alfalfa Biomass Rotation compared to a Traditional Corn/Soybean Rotation

Pro forma budgets are a means to portray alternative business plans. In the case of the proposed alfalfa biomass project based at Granite Falls, Minnesota, pro forma farm budgets were used to compare the net returns to farmers of rotations including alfalfa versus traditional corn-soybean rotations. To make comparisons one must accurately and systematically portray all streams of revenue or value and identify all costs, whether explicit or latent. All activities such as tillage, planting, harvest, etc. needed to produce various crops must be orchestrated with their costs being assigned to the proper crop year. In the case of the "biomass" rotation, or DFSS (Dedicated Feed Stock Supply) the sequence AAAACCS was assumed, which stands for a seven year rotation with four years of alfalfa followed by corn, corn, and then soybeans after which the sequence repeats.

Specific pro formas were generated for each of the thirteen production regions (Chapter 4.1) to accurately portray each region's crop yield potential and cash rent environment. Pro forma net returns identify the production regions where the alfalfa biomass rotation will best compete with the traditional corn-soybean rotation. It should be emphasized that comparisons are between the multi-year rotations, not the individual crops. Net income to producers is expressed on an annualized basis for the two competing rotations with different durations. DFSS has a seven year cycle, while C-S has a two year cycle.

Analysis was also performed based strictly upon CER score, which reflects the inherent productivity of soils. CER's are an index developed for Minnesota soils that measures relative net income of soils based on typical rotations and crop mixes found on different soils. Exogenous changes, such as elimination of feed grain deficiency payments or dramatic yield increases in alfalfa yields (perhaps due to future alfalfa breeding) were modelled. Rents were assumed to be zero at all CER's in order to demonstrate how effects can vary for soils across the range of relevant productivities. In this fashion it is possible to determine the effects of exogenous changes on breakeven alfalfa prices, as well as how these effects relate to inherent productivity.

The following list characterizes groups of pro formas:

1) Baseline production, 3 cut system at $60 /T. hay price and also the hay price necessary for DFSS returns to equal C-S returns for each production region. DFSS and C-S baseline net returns ($60/T., with deficiency payments) organized by CER as well as for hay prices of $70 and $80 per ton.

2) Three cut, $60 /T. hay price with elimination of deficiency payments on corn necessary to make DFSS returns equal C-S returns, organized by production region.

3) Plus 20% change in yields of alfalfa and necessary hay prices for DFSS to equal C-S net incomes, organized by CER.

4) Plus and minus 20% changes in net incomes from C-S and the resulting hay prices necessary for DFSS to equal C-S net incomes, organized by CER.

5) Two, three, and four cut system hay prices necessary for DFSS to equal levels of net income produced by C-S, organized by CER.

6) Necessary leaf meal prices with $30 stem prices for DFSS to equal C-S net incomes for 2,3,and 4 cut systems, organized by CER.

This assembled group of pro formas offers insight into the effects of elimination of corn deficiency payments, which represents a policy choice of the U.S. Congress. Changes in yields from average levels represented in the baseline proformas show the effect that enhanced yields could have on the profitability and competiveness of the alfalfa biomass rotation. Price fluctuations represent market and policy elements. Finally, the harvest schedules represent management choices that farmers might make to alter the leaf-stem ratios of their hay and perhaps capture more net profit for their efforts.

The following relational and logical assumptions are built into the pro formas:

<u>cash rents</u>

Cash rents were derived for each of the production regions by multiplying appropriate capitalization rates (rent/estimated market value) by known levels of estimated market value extracted for each region. University of Minnesota and Minnesota Department of Revenue published data were used in each case (Lazarus 1994 and Taff 1993).

The following list characterizes groups of pro formas:

1) Baseline production, 3 cut system at $60 /T. hay price and also the hay price necessary for DFSS returns to equal C-S returns for each production region. DFSS and C-S baseline net returns ($60/T., with deficiency payments) organized by CER as well as for hay prices of $70 and $80 per ton.

2) Three cut, $60 /T. hay price with elimination of deficiency payments on corn necessary to make DFSS returns equal C-S returns, organized by production region.

3) Plus 20% change in yields of alfalfa and necessary hay prices for DFSS to equal C-S net incomes, organized by CER.

4) Plus and minus 20% changes in net incomes from C-S and the resulting hay prices necessary for DFSS to equal C-S net incomes, organized by CER.

5) Two, three, and four cut system hay prices necessary for DFSS to equal levels of net income produced by C-S, organized by CER.

6) Necessary leaf meal prices with $30 stem prices for DFSS to equal C-S net incomes for 2,3,and 4 cut systems, organized by CER.

This assembled group of pro formas offers insight into the effects of elimination of corn deficiency payments, which represents a policy choice of the U.S. Congress. Changes in yields from average levels represented in the baseline proformas show the effect that enhanced yields could have on the profitability and competiveness of the alfalfa biomass rotation. Price fluctuations represent market and policy elements. Finally, the harvest schedules represent management choices that farmers might make to alter the leaf-stem ratios of their hay and perhaps capture more net profit for their efforts.

The following relational and logical assumptions are built into the pro formas:

<u>cash rents</u>

Cash rents were derived for each of the production regions by multiplying appropriate capitalization rates (rent/estimated market value) by known levels of estimated market value extracted for each region. University of Minnesota and Minnesota Department of Revenue published data were used in each case (Lazarus 1994 and Taff 1993).

support payments

The federal government pays farmers deficiency payments based on established yields for corn and acres of corn raised on a farm over a certain period. Assuming established corn yields represent 80% of average yields and that payments will soon be based on 77.5% of corn base acres (versus 85% of corn base acres used currently) we can calculate that current deficiency payments of $.40 per established bushel will next year translate into $.29 per bushel of average yield. Considering the vulnerability of deficiency payments to the budgetary ax and the fact that not all farmers participate in government programs, we have assumed $.20 per bushel of predicted corn yields.

corn yields

Corn yields are based are CER's. A linear regression was derived to predict corn yield based on CER. The model was based on soils having their locational reference within the biomass shed.

soybean yields

Soybean yields have a remarkably consistent relationship to corn yields at 1/3 of corn yields. State of Minnesota yield data by county was analyzed to establish this relationship.

alfalfa yields

Alfalfa yields are based on CER's and a three cut harvest. A regression was derived relating hay yields to CER's. The establishment year of alfalfa is assumed to produce 45% of the predicted yields for years 2,3, and 4 of the stand. Years 2, 3, and 4 are assumed to have equal yields. The magnitudes and leaf:stem ratios of hay produced under two cut or four cut harvests were based on University of Minnesota Agronomy Department research (Sheaffer and Martin 1990).

nitrogen credits

Based on University of Minnesota soil fertility recommendations, it is assumed that first year corn following alfalfa will have 150 lb. of available nitrogen from the alfalfa. Second year corn will have 75 lb. of available nitrogen from the alfalfa (**UofM BU-6240-E**).

nitrogen application and prices

Due to the small amount of nitrogen needed on the second year of corn in the DFSS rotation, nitrogen in the urea form was assumed to be applied. In contrast, corn in the corn-soybean rotation was assumed to receive its nitrogen as anhydrous ammonia, the cheapest form. In both cases these are assumed to be the most cost effective methods, considering cost of material and application. Anhydrous ammonia prices are $ 0.12 per pound of nitrogen, while urea is $ 0.22 per pound of nitrogen. Nitrogen rates were based on predicted corn yields and University of Minnesota recommendations.

phosphorous and potash applications

Phosphorous and potash were assumed to be applied at the same rate they were removed from the field by a particular crop in all cases. The replacement costs were charged to the crop responsible for the removal of nutrients.

hauling costs

For both rotations, hauling costs are calculated from the field to market. For alfalfa, the crop is assumed to be hauled five miles, while the corn and soybeans are assumed to be hauled twelve miles.

storage costs

In order for a farmer to capture season average prices for corn and soybeans, it was assumed that half the crop was stored an average of six months with those attendant costs.

The rest of the assumptions and sources used in the development of the pro formas are contained in the appendix for this section. Our source for machine costs was Univerity of Minnesota economic cost estimates (Fuller, AG-FO-2308-C). Costs for herbicides and chemicals were based upon University of Minnesota data (UofM BU-3157-S). The purpose of the relational assumptions and the others was to accurately portray all the necessary field operations, inputs, and costs to produce the crops in the two competing rotations.

Baseline situations were established to give reference points against which to judge sensitivities when assumptions were altered. Baseline conditions are: predicted yields of corn, soybeans, and alfalfa (based on the CER), \$60/ton hay price (farm level - delivered to remote storage site), corn deficiency payments included, and a three-cut harvest schedule. **Table 4.2-1** show the difference (Diff) between net returns for the DFSS rotation compared to the traditional corn soybean rotation (C-S) at a conservative price of \$60/ton for alfalfa by region within the biomass shed.

**Table 4.2-1** contains pro forma results by the 13 land valuation regions within the biomass shed for the difference (Diff) between annual net returns for a traditional corn-soybean rotation (C-S) and the DFSS (dedicated feedstock supply system) rotation. Estimated average annual net returns per acre are after all expenses including land rent and farm labor. Pro forma budgets assume a wage of $11.00 per hour for farm labor for crop production.

**Baseline Pro forma by Region at $60/ton for Alfalfa**

**Estimated Net Return per acre**

| # | Region | CER | DFSS | C-S | Diff |
|---|---|---|---|---|---|
| 7 | Green Lake | 50 | -24.49 | -12.75 | (11.74) |
| 14 | Benson Lac. Plain | 62 | 3.14 | 18.60 | (15.46) |
| 15 | Appl-Clont. Sands | 51 | -11.63 | .42 | (12.05) |
| 16 | Big Stone Moraine | 57 | 1.48 | 15.38 | (13.90) |
| 17 | Marietta | 62 | 6.42 | 21.88 | (15.46) |
| 18 | Lac Qui Parle | 67 | .79 | 17.80 | (17.01) |
| 19 | Dawson | 67 | -3.16 | 13.85 | (17.01) |
| 20 | Lake Shaokaton | 56 | 10.30 | 23.89 | (13.59) |
| 24 | Coteau Headwaters | 59 | 14.75 | 29.28 | (14.53) |
| 25 | Redwd-Cotwd R. Vals | 67 | -2.69 | 14.32 | (17.01) |
| 26 | Tracy | 71 | 3.13 | 21.39 | (18.26) |
| 31 | Morgan | 71 | -5.47 | 12.79 | (18.26) |
| 36 | Olivia Till Plain | 69 | -7.68 | 9.95 | (17.63) |

**Baseline Analysis**

At $60 per ton of alfalfa, DFFS rotation returns to the farmer are lower than C-S returns in every production region. Therefore, a hay price of $60 per ton would be too low to attract farmers to the DFSS rotation (given our underlying assumptions). The highest net returns per acre for both rotations occurs in Region #24, Coteau Headwaters, a region described here as having low rents relative to soil productivity. The disadvantage of the DFSS rotation ($60/ton for alfalfa) compared to the C-S rotation in region 24 is $14.53.

The lowest returns for both rotations were recorded in Region #7, whose geography is dominated by Green Lake. This region has low soil productivity and rental levels near mid range. This region has the highest rainfall of any region in the biomass shed and soils with low water-holding capacity (Section 3.4).

Baseline pro forma results are consistent. DFSS rotations range from $14.75 in Region #24 to -$24.49 in Region #7 (a range of $39.24), while C-S rotations range from $29.28 in #24 to -$12.75 in Region #7 (a range of $42.03). Baseline results portray very poor returns throughout the biomass shed for the C-S rotation. Unfortunately, these numbers accurately portray the low per acre returns for farms in the biomass shed dependent solely on corn and soybean production.

Returns are particularly low in areas where land rental levels are bid up by farmers involved in production of crops with higher returns than corn or soybeans such as sugar beets, canning crops, and seed production. The differences between the competing rotations in the regions are also quite consistent. Differences are greatest in Region #31 (where land values and productivity are highest) and lowest in Region #7 (where productivity is lowest). The range in the differences (Diff) is from $11.74 to $18.26, also revealing consistency between regions.

Baseline data suggest no major advantages that would favor one region over another for DFSS production. C-S returns are the major income source in all the regions. **DFSS returns must equal or surpass C-S returns for a DFSS rotation to be economically feasible.**

Region #20 is dominated by Lake Shaokatan in its center and sits on the southwest edge of the biomass shed (Lincoln county). Lincoln county has the highest participation in the CRP program of any county in the biomass shed at 23.13% ( 25% is the maximum permitted ) with CRP payments averaging $66.62 per acre being paid by the federal government. Predicted average rent for this region is $47.40. The land markets in this region are poised to make a substantial correction to even lower rental levels if the CRP ends without some payment mechanism to smooth the transition to less insulation from market forces.

The breakeven price for alfalfa, by region, where DFSS returns equal C-S returns are shown in **Table 4.2-2**. Breakeven alfalfa hay prices also betray surprising similarity among the regions, ranging from $66.30/ T. in region #7 to $68.05/T. in region #31, a difference of $1.75/T. **The average breakeven price for alfalfa in the biomass shed is calculated at $67.44 per ton.**

Breakeven hay prices are dependent upon productivity, with the lower breakeven prices occuring in areas with the lower CER's. If corn deficiency payments were eliminated, net returns from corn would be reduced, lowering the breakeven hay price necessary for the DFSS rotation to equal returns from C-S. In the case of our extreme regions, Region #7 would shift down $2.05/ton to $64.25 while Region #31 would shift down $2.15/T. to $65.77.

**Table 4.2-2** Alfalfa price ($/ton) needed for the DFSS rotation to equal returns from a corn-soybean rotation, with and without deficiency payments for corn.

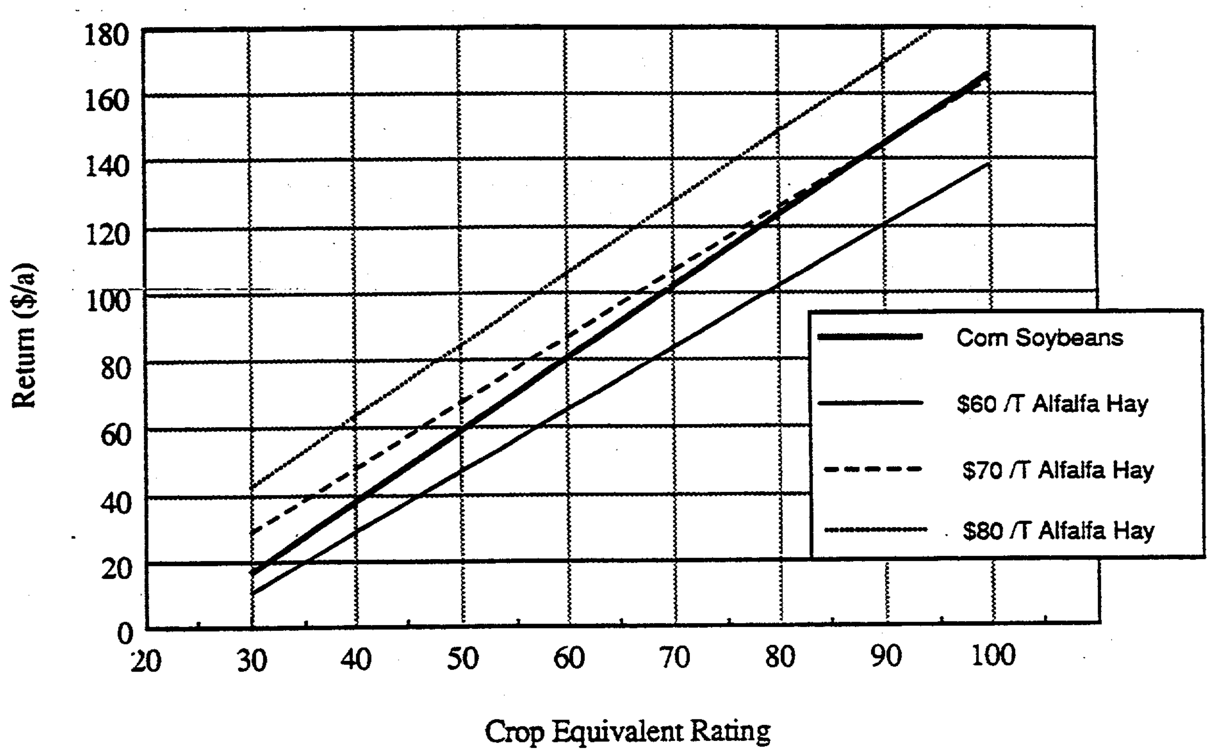
| | | Alfalfa Price ($/ton) | |
|---|---|---|---|
| **#** | **Region Name** | **Breakeven $/ton w/defs** | **Breakeven $/ton w/o defs** |
| 7 | Green Lake | 66.30 | 64.25 |
| 14 | Benson Lacustrine Plain | 67.39 | 65.27 |
| 15 | Appleton-Clontarf Sand Plain | 66.41 | 64.35 |
| 16 | Big Stone Moraine | 66.97 | 64.88 |
| 17 | Marietta | 67.39 | 65.27 |
| 18 | Lac Qui Parle | 67.77 | 65.63 |
| 19 | Dawson | 67.77 | 65.63 |
| 20 | Shaokatan | 66.88 | 64.79 |
| 24 | Coteau Headwaters | 67.14 | 65.04 |
| 25 | Redwd-Cottnwd River Valleys | 67.77 | 65.63 |
| 26 | Tracy | 68.05 | 65.90 |
| 31 | Morgan | 68.05 | 65.90 |
| 36 | Olivia Till Plain | 67.91 | 65.77 |

From this point on, analysis of pro formas will take place based on CER's and do not reflect the unique rents of each region. Although price changes for hay, exogenous yield increases, and cutting strategies will affect net income differentially in each region, the impacts due to these changes will occur in proportion to their CER. The relative attractiveness of the DFSS rotation versus C-S rotation will remain consistent with the baseline analysis in relative terms. By considering various impacts solely on the basis of CER (land productivity), producers may judge how well a particular farm will fare relative to the inclusion of alfalfa in a DFSS rotation.

**Hay Prices of $60, $70, $80 in a DFSS rotation compared to a C-S Baseline**

**Figure 4.2-1** portrays net returns of DFSS rotations on three-cut schedules with farm level hay prices of $60, $70, $80, and net returns for the C-S rotation. For all CER's, DFSS returns are less than C-S retuns at $60 per ton for alfalfa. At $70 per ton for alfalfa, lands rated at a CER less than 90 yield DFSS net returns greater than C-S returns. Lower quality lands (lower CER) have a slight advantage in the DFSS rotation compared to a C-S partly because of the reduced expenses of growing a perennial crop.

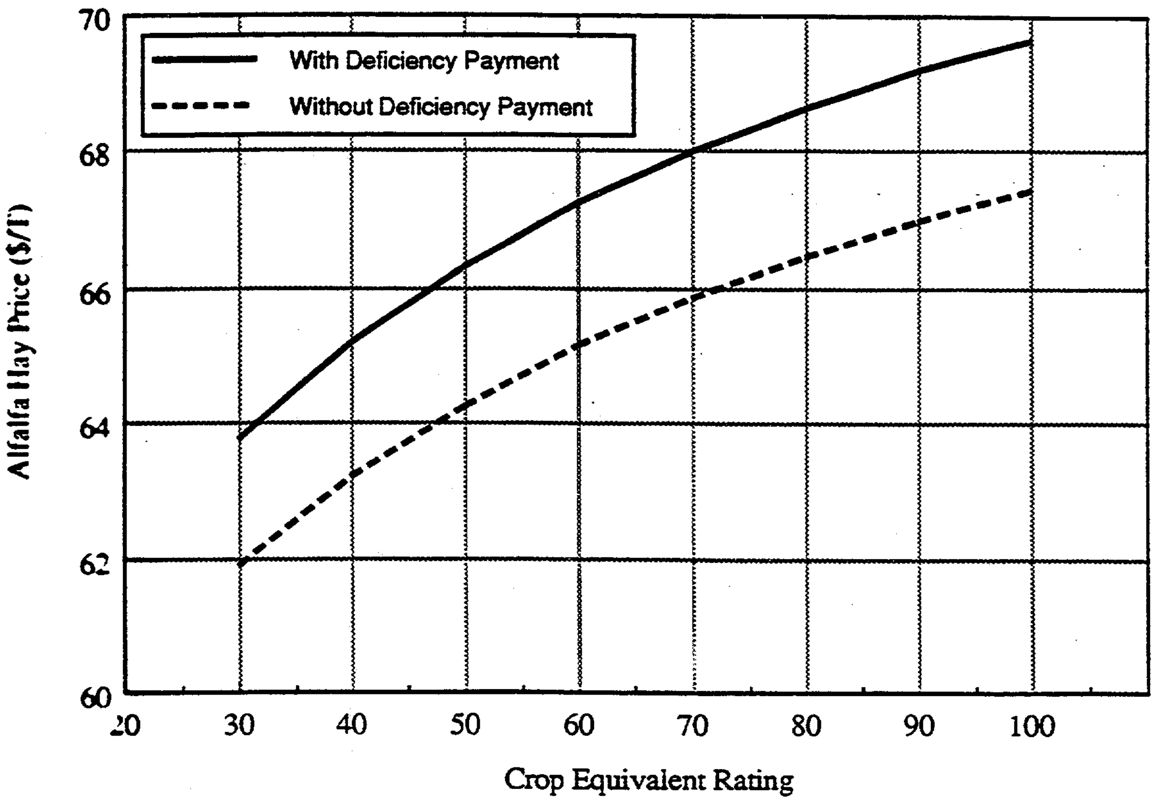
**Comparison of Returns between DFSS rotation at Various Alfalfa Prices to a Baseline Corn-Soybean Rotation**



**Elimination of Corn Deficiency Payments**

**Figure 4.2-2** portrays the change in breakeven hay prices necessary for DFSS to equal C-S returns if corn subsidies through the price deficiency program were eliminated. Alfalfa prices necessary for DFSS net returns to equal C-S net returns drop by approximately $2.00/ton for most CER's. Clearly, DFSS rotation returns become closer to C-S rotation returns, however, net farm income per acre is lower under both rotations by approximately $10 per acre per year.

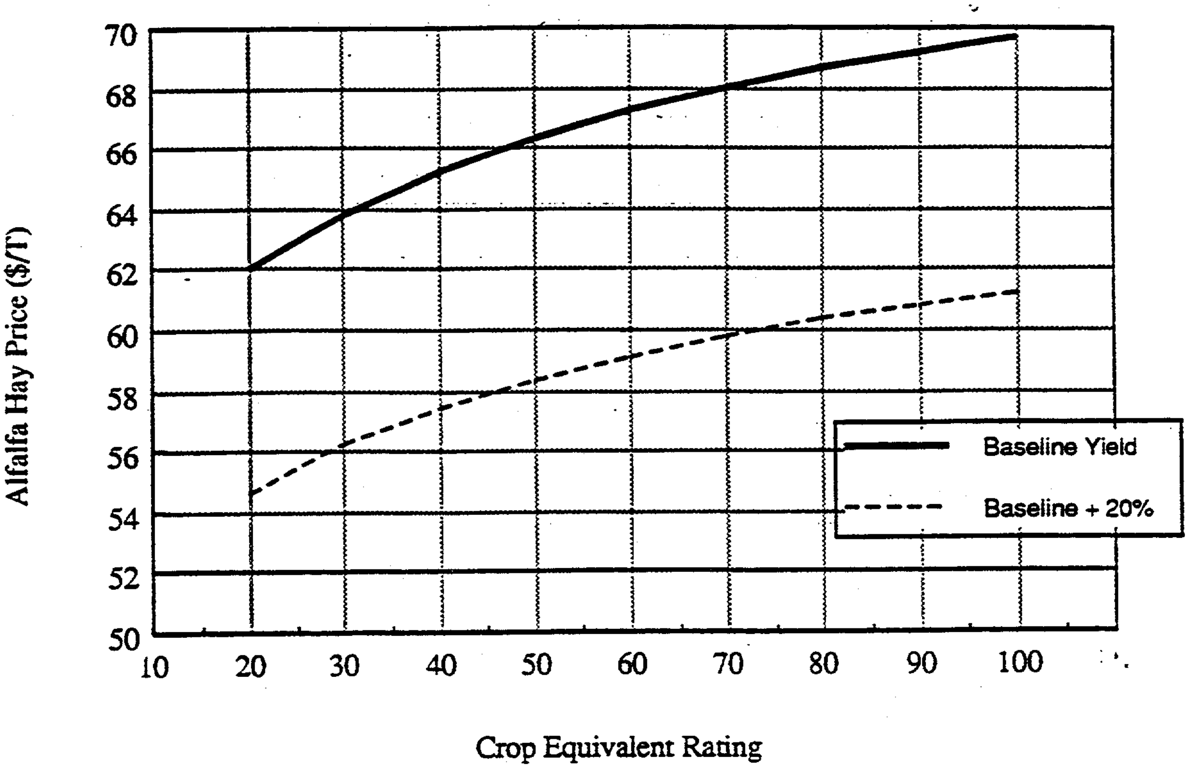
**Breakeven Price for Alfalfa**
**(with and without deficiency payment)**



**Effect of Exogenous Yield Enhancement on Breakeven Hay Prices**

**Figure 4.2-3** shows the impact on breakeven hay price if through breeding efforts, growth regulators, better harvesting machines,or some other means, alfalfa yields could "suddenly" be increased 20% without any cost. The breakeven price of hay would be lowered $8 per ton on lands with CER's of 60. This graphic shows the potential payoff of research advances on alfalfa biomass.

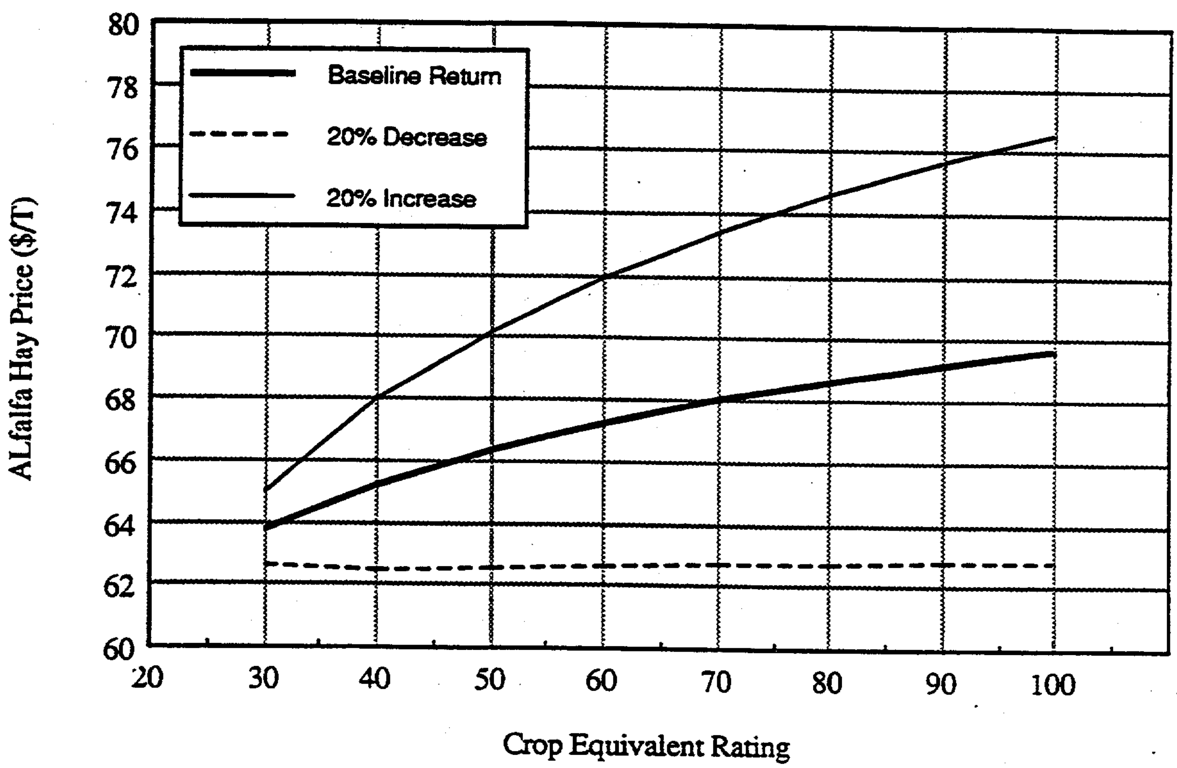
**Breakeven Price for Alfalfa**
**(with 20% alfalfa yield improvement)**



**Effect of Net Incomes Changes for Corn and Soybeans on DFSS**

**Figure 4.2-4** portrays how 20% increases and 20% decreases in net income from corn and soybeans through market forces or farm policy would affect the requisite breakeven price of hay on a three cut system. The effects vary across the range of CER's. With declines in net farm income from C-S the breakeven price of alfalfa declines to a lower level that is nearly constant across the range of CER's at \$62.57/ T. When net incomes from C-S increase by 20% the higher producing lands require higher breakeven alfalfa prices in order for the DFSS to equal C-S. At CER of 60, alfalfa hay prices must rise by \$5/ T. to keep DFSS returns equal to C-S. This situation suggests that producers on higher productivity soils will have a greater tendency to flee from participation in DFSS rotations when net incomes from C-S increase from baseline levels. It will cost less per ton in hay price bid to hold the interest of farmers with lower productivity soils if net income from C-S should rise.

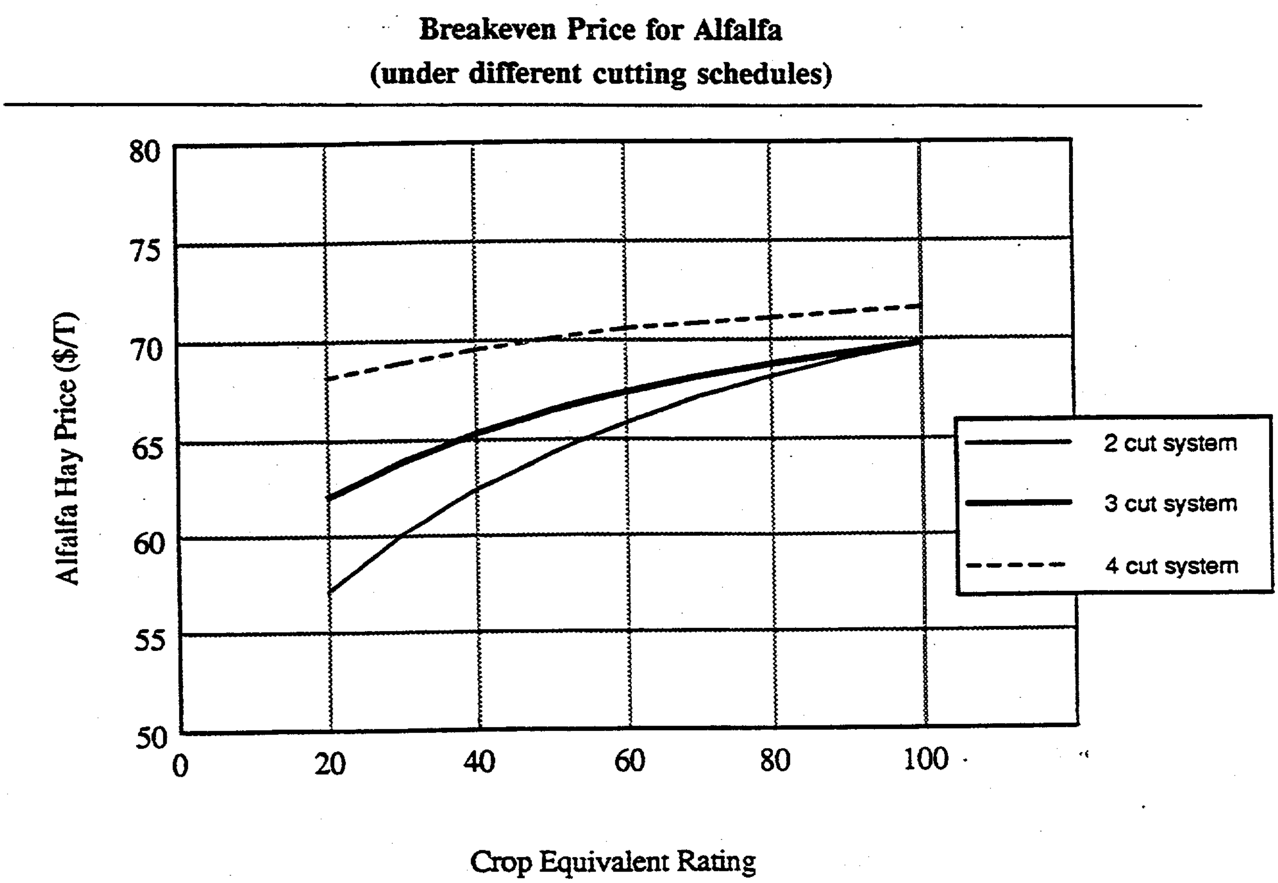
**Breakeven Price for Alfalfa**
**(with changes in corn and soybean returns)**



**Effect of Cutting Schedules**

**Figure 4.2-5** portrays the farm level prices of alfalfa hay necessary to breakeven with C-S when a farmer chooses to cut at schedules other than the baseline 3-cut system. He incurrs more costs when he cuts four times instead of three. Hence the breakeven hay price for each CER is higher when he cuts more often. A farmer will expect to be paid more to compensate for the addition costs incurred per ton. Note how the curves start far apart and narrow as one goes from low CER land to high CER land. Farmers on high quality land can be induced to shift to more intensive cutting schedules for a smaller alfalfa price increase than can farmers on low quality land. However, this graph also shows how producers on lower productivity land will be most competitive by cutting twice versus three or four times. If alfalfa can be bred that will stand well and retain leaves well in a two cut regime, that will benefit farmers on poor quality land. Lands of higher productivity will permit additional cutting operations because of the greater yields per cutting.

**Figure 4.2-5** Breakeven price under different harvest schedules.

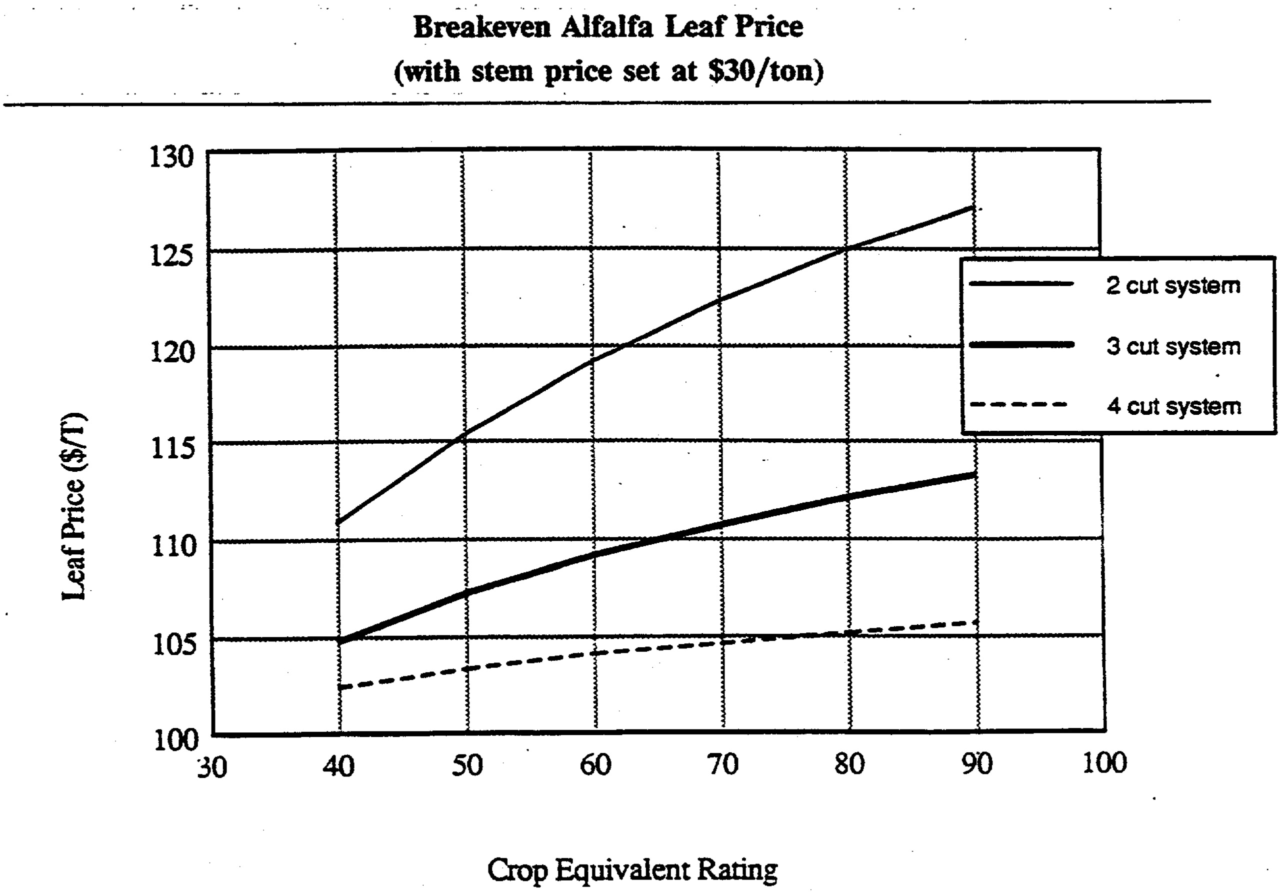


**Interactions: Hay Harvests, Stem Prices, & Needed Leaf Prices**

Farmers considering alternative harvest schedules must be aware of the character of hay that they will harvest from each (Chapter 2). Following all the likely losses of dry matter and leaves from cutting to baling, farmers should theoretically find large round bales containing 40.09%, 47.07%, and 54.63% of leaves on a dry matter basis for 2,3, and 4 cut systems, respectively.

If a cooperative or utility were bidding a fixed price per ton of stems at $30/ton then **Figure 4.2-6** portrays the leaf prices that will be necessary for DFSS to equal C-S. The message from this graph is that leaf prices will have to be higher for hay produced under a two-cut system than under a three- or four-cut system in order to equal the net returns from C-S. This is due to a lower leaf content of alfalfa hay harvested under a two-cut system.

**Figure 4.2-6** Breakeven price for alfalfa leaf fraction with stem price set at $30/ton under two- three- and four-cut harvest systems.



Different cutting strategies on different qualities of land may produce alfalfa leaf fractions (under a set stem price) that result in equivalent net returns for the DFSS rotation and the C-S rotation. For example, at a leaf price of $105/ton to the farmer (with stem price set at $30/ton), a three-cut system on 40 CER soils would be equivalent to a four-cut system on 80 CER soils. Each would each capture returns that would make the net DFSS rotation returns equal to the net returns from a C-S rotation. Higher productivity lands in general will require higher aggregate alfalfa prices to be competitive with current rotations.

**Major Conclusions from Pro formas:**

The alternative assumptions modelled in the proformas offer many useful perspectives on alfalfa price levels and net DFSS returns across the biomass shed. Here are the major lessons from these exercises:

1) The production regions within the biomass shed are remarkably similar with respect their propensity to produce alfalfa for the DFSS rotation. Breakeven hay prices on three cut systems range from $66.30/ T. to $68.05/ T.

2) Elimination of corn deficiency payments would allow the DFSS rotation to equal C-S at lower hay prices by about $2/T.; however, net annual income would be lower for both rotations in the absence of corn deficiencies.

3) The breakeven price for alfalfa on lower quality lands is lower than on higher quality lands.

4) Increases in alfalfa yield per acre can dramatically reduce per ton alfalfa breakeven prices needed to be competitive with corn and soybeans.

5) When net returns for C-S increase, higher quality lands will be the first to leave DFSS. When net returns for C-S fall, there is little difference in breakeven hay price for all qualities of land.

6) When farmers cut their hay more often, they need to receive higher prices for the hay they produce. Farmers on higher quality land need less price inducement to change to a four-cut system than farmers on poorer quality land.

7) Since the cutting schedule influences the stem and leaf proportion, cutting schedule impacts farm price if pricing is based on percent leaf/stem.

# 4.3 BIOMASS SUPPLY CURVE

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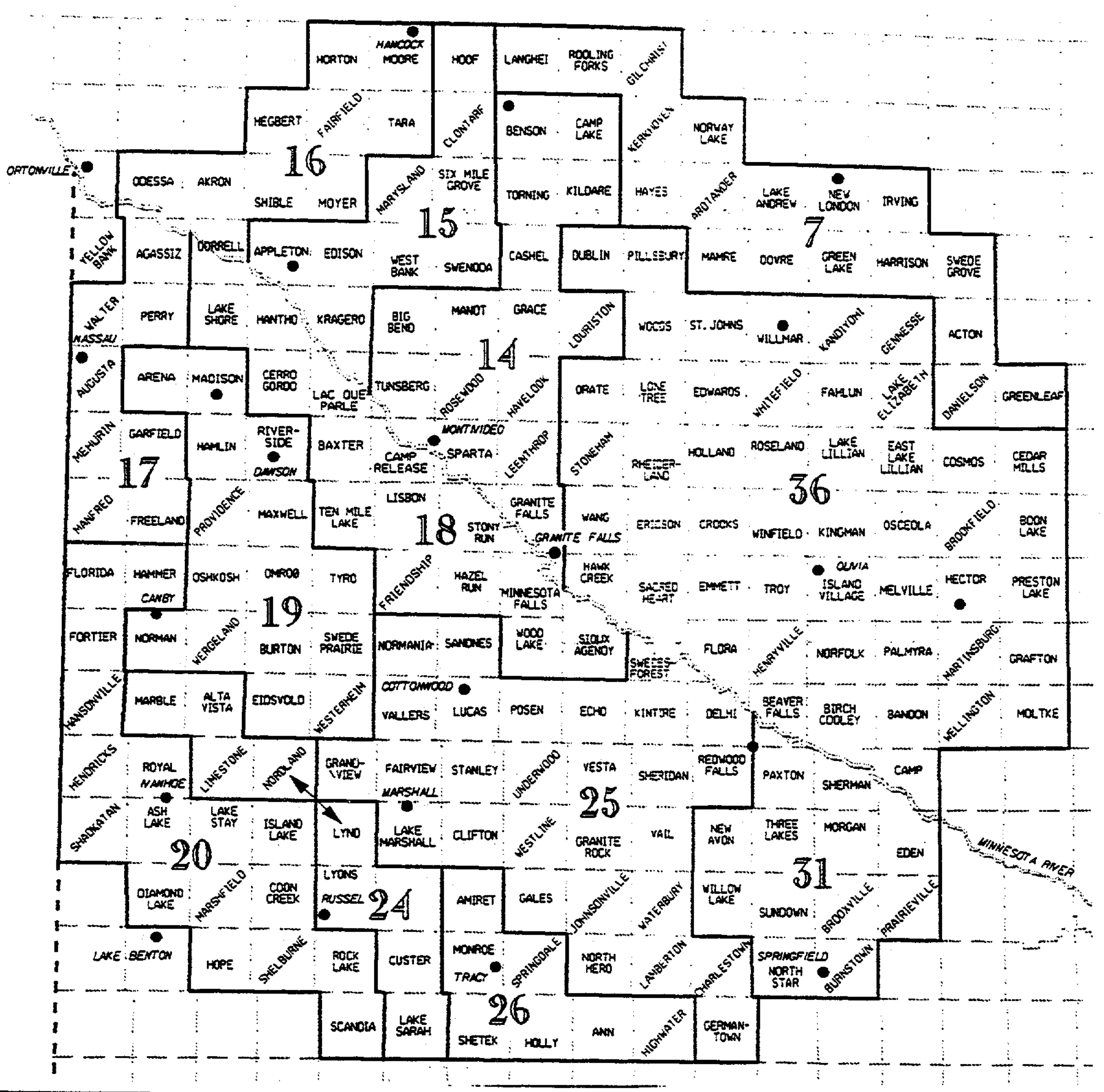
A supply curve is a schedule that relates a quantity offered to a stated price. All other variables -- technological, institutional, financial -- are suppressed or embedded in the supply schedule. Any changes to these variables are evidenced by "shifts" in the supply curve -- essentially by a new curve with new embedded parameter values.

There is an implicit supply schedule associated with each exchangeable product, whether or not that product is actually offered for sale. In our case, there is a supply schedule for acres of hay, for bales of hay, for tons of hay, for leaves, for stems, for BTUs, or for ash. For present purposes, we will estimate a supply schedule for tons of hay (of a "typical" moisture and protein content) delivered to the regional storage sites. The price will be that which producers expect to be offered in a "typical" year. All transport and preparation costs prior to the regional site are assumed borne by the producers and excluded from the offer price calculation. **All costs at and from the regional sites are assumed borne by the alfalfa cooperative or joint-venture and so are embedded in the offer price itself.**

What we seek are estimates of the number of tons of hay that will be offered by producers in exchange for a stated set of prices. Because climate and land productivity vary throughout the biomass shed, we need to estimate the production decisions of a range of farmers. Our approach is to divide the biomass shed into homogeneous production districts, within which producers are asserted to face similar land quality, land markets, and production constraints. A budget is constructed for a representative farm within each district with the relative returns for corn-soybean (C-S) and the biomass (DFSS) rotation for a range of hay prices are compared. An adoption-rate algorithm is applied to this comparison, and total hay production responses are derived for each district at each hay price level. The aggregate of these relationships constitutes the regional biomass supply curve.

The production district boundaries used in this analysis are adapted from those used by the Minnesota Department of Revenue for property tax equalization purposes. These, in turn, had their origins in geomorphological and soil association maps. The biomass production districts used here are divided along township lines as shown in **Illustration 4.3-1.**

## Illustration 4.3-1 Map of production regions.




| # | Region | # | Region |
|---|---|---|---|
| 7 | Green Lake | 20 | Lake Shaokaton |
| 14 | Benson-Lac Qui Parle Plain | 24 | Coteau Headwaters |
| 15 | Appleton-Clontarf Sands | 25 | Redwood-Cottonwood River Valley |
| 16 | Big Stone Moraine | 26 | Tracy |
| 17 | Marietta | 31 | Morgan |
| 18 | Lac Qui Parle | 36 | Olivia Till Plain |
| 19 | Dawson | | |

A representative farm proforma budget was constructed for each region (for budget details, see Chapter 4.2 and Appendix Volume 1(4). Alfalfa production potential for each region is specified in Table 4.3-1.

**Table 4.3-1** Alfalfa production potential by region.

| Region # | Total Acres w/i 50 miles | Alfalfa Yield | Production Potential (80%) alfalfa in tons |
|---|---|---|---|
| 7 | 414,720 | 3.8 | 1,260,749 |
| 14 | 338,534 | 4.3 | 1,161,849 |
| 15 | 203,803 | 3.8 | 626,083 |
| 16 | 374,563 | 4.1 | 1,225,570 |
| 17 | 168,467 | 4.3 | 578,179 |
| 18 | 320,624 | 4.5 | 1,154,246 |
| 19 | 341,124 | 4.5 | 1,228,046 |
| 20 | 374,375 | 4.1 | 1,212,975 |
| 24 | 203,615 | 4.2 | 679,260 |
| 25 | 617,022 | 4.5 | 2,221.279 |
| 26 | 155,499 | 4.7 | 579,700 |
| 31 | 268,189 | 4.7 | 999,809 |
| 36 | 1,038,831 | 4.6 | 3,806,277 |
| TOTAL | 4,819,366 | 4.3 | 16,734,021 |

The critical analysis variable is the ratio of net returns from the two rotations (DFSS:C-S), given each hay price level. At some level of this ratio, producers are assumed to switch from one rotation to another. To approximate our expectation that this transition point would be different for different producers, even within the same region, we asserted an "Adoption Rate" schedule. For each hay price ($/ton), we have calculated a DFSS:C-S returns ratio, which in turn generates a biomass rotation adoption rate (**Figure 4.3-1**). The adoption rate is multiplied by hay potential for the region (hay potential is 80% of the land in the region times the hay yield for the region) to give the total hay production associated with each hay price by region.

**Figure 4.3-1** Baseline DFSS rotation adoption rate.

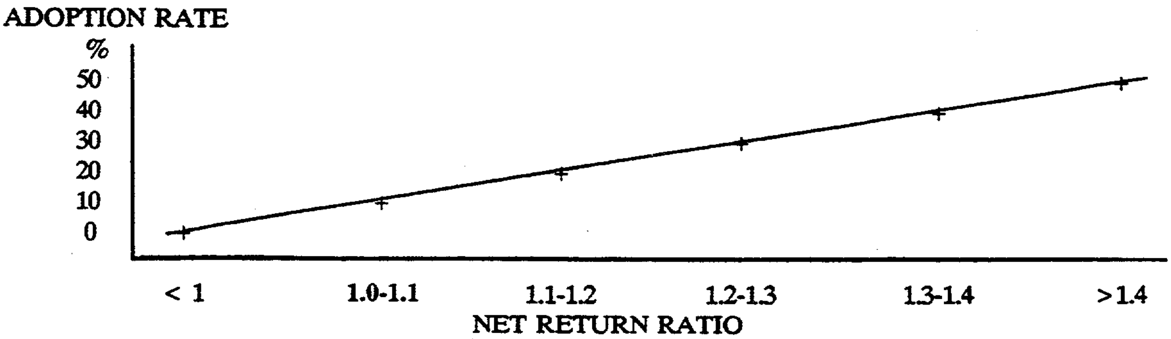


**Table 4.3-2** Regional Supply (base scenario).

| pay price | Region 7 | Region 14 | Region 15 | Region 16 | Region 17 | Region 18 | Region 19 | Region 20 | Region 24 | Region 25 | Region 26 | Region 31 | Region 36 | TOTA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 70 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,928 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,40 |
| 75 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,928 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,40 |
| 80 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,928 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,40 |
| 85 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,928 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,40 |

**Figure 4.3-2** Regional Biomass Supply Curve (base scenario).

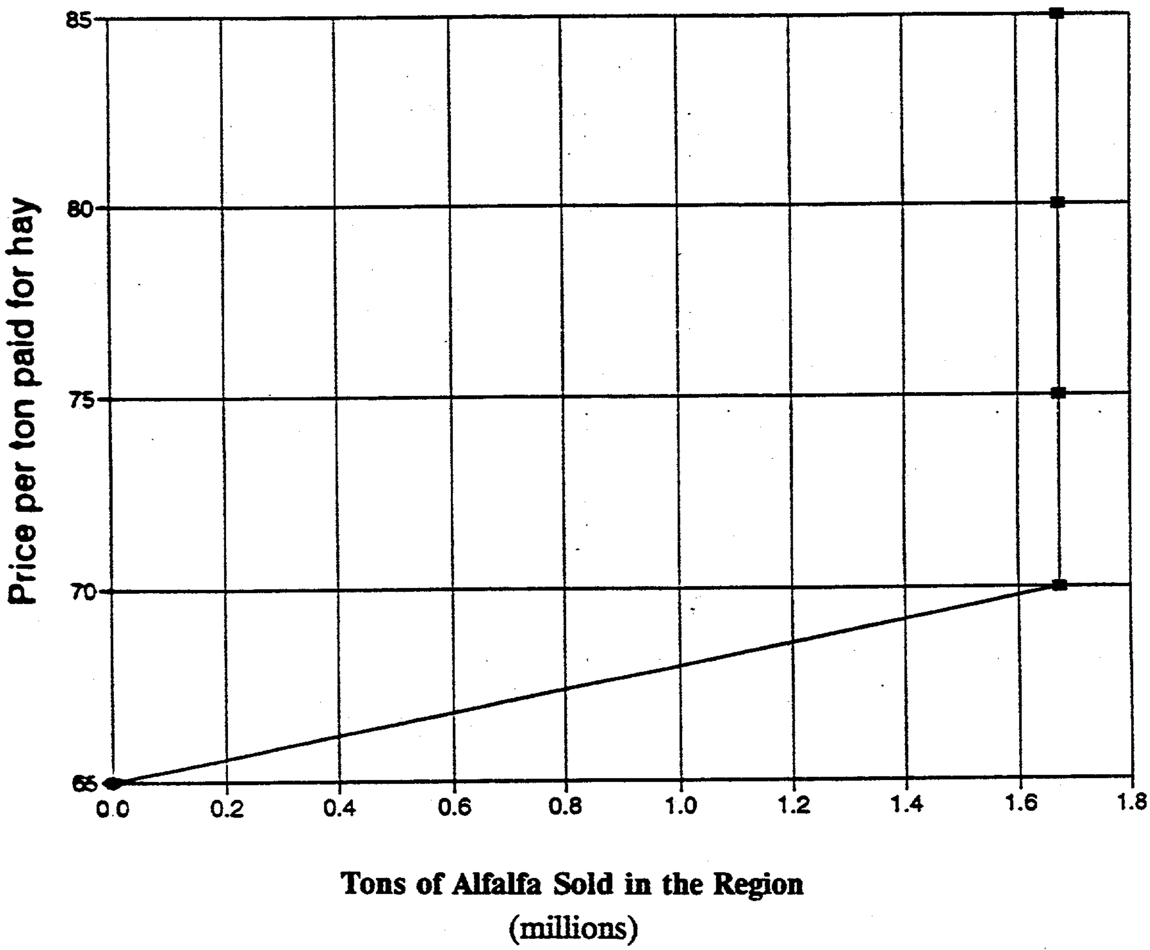



**Table 4.3-2** shows the resulting allocation of hay production across the districts at different hay prices. **Figure 4.3-2** plots hay prices against total production of biomass in the shed. Hay prices below $65/ton result in no hay being offered; prices of $70/ton and above result in all districts providing maximum production, according to the adoption rate schedule.

**Table 4.3-3** Regional Supply (w/o corn deficiency payment).

| pay price | Region 7 | Region 14 | Region 15 | Region 16 | Region 17 | Region 18 | Region 19 | Region 20 | Region 24 | Region 25 | Region 26 | Region 31 | Region 36 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 126,075 | 0 | 62,608 | 122,557 | 0 | 0 | 0 | 121,298 | 67,926 | 0 | 0 | 0 | 0 | 500,464 |
| 70 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,926 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,402 |
| 75 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,926 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,402 |
| 80 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,926 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,402 |
| 85 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,926 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,402 |

**Figure 4.3-3** Regional Biomass Supply Curve (w/o corn deficiency payment).

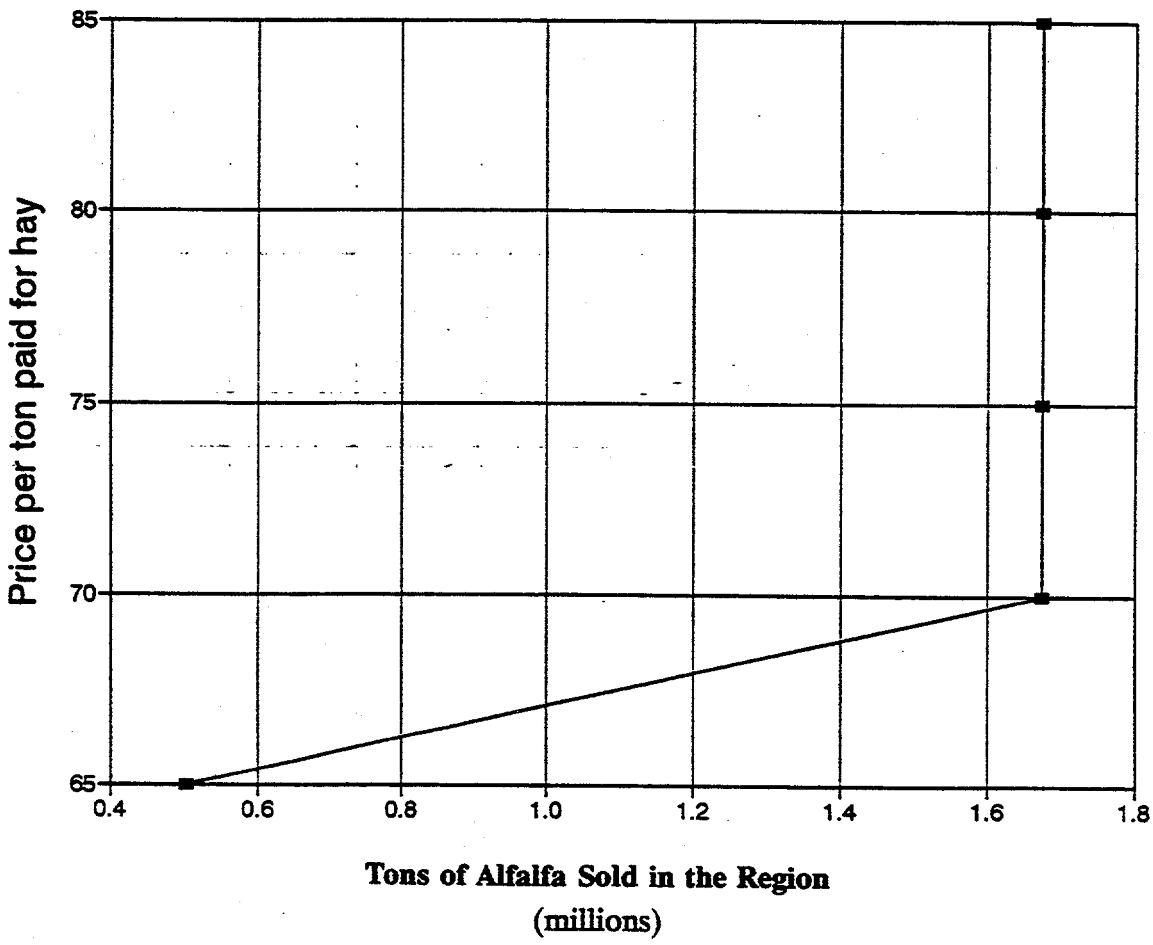


**Table 4.3-4** Regional Supply (high hay yield).

| pay price | Region 7 | Region 14 | Region 15 | Region 16 | Region 17 | Region 18 | Region 19 | Region 20 | Region 24 | Region 25 | Region | Region 31 | Region 36 | TOTA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 65 | 138,682 | 127,803 | 68,869 | 134,813 | 63,600 | 128,967 | 135,085 | 133,427 | 74,719 | 244,341 | 63,767 | 109,979 | 418,690 | 1,840,74 |
| 70 | 138,682 | 127,803 | 68,869 | 134,813 | 63,600 | 128,967 | 135,085 | 133,427 | 74,719 | 244,341 | 63,767 | 109,979 | 418,690 | 1,840,742 |
| 75 | 138,682 | 127,803 | 68,869 | 134,813 | 63,600 | 128,967 | 135,085 | 133,427 | 74,719 | 244,341 | 63,767 | 109,979 | 418,690 | 1,840,742 |
| 80 | 138,682 | 127,803 | 68,869 | 134,813 | 63,600 | 128,967 | 135,085 | 133,427 | 74,719 | 244,341 | 63,767 | 109,979 | 418,690 | 1,840,742 |

**Figure 4.3-4** Regional Biomass Supply Curve (high hay yield).

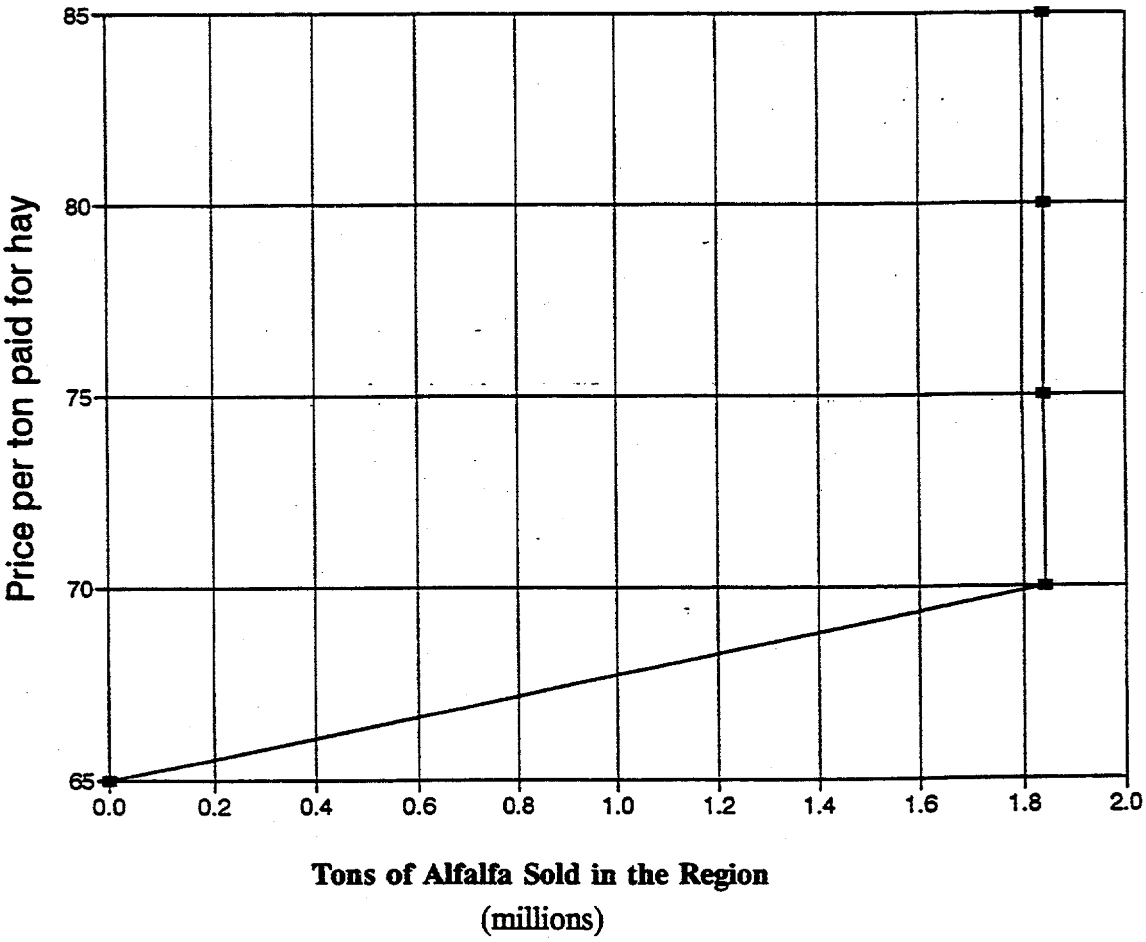


**Table 4.3-5** Regional Supply (low hay yield).

| pay price | Region 7 | Region 14 | Region 15 | Region 16 | Region 17 | Region 18 | Region 19 | Region 20 | Region 24 | Region 25 | Region 26 | Region 31 | Region 36 | TO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 75 | 113,467 | 104,586 | 56,347 | 110,301 | 52,036 | 0 | 0 | 109,168 | 61,133 | 0 | 0 | 0 | 0 | 607, |
| 80 | 113,487 | 104,566 | 56,347 | 110,301 | 52,036 | 103,882 | 110,524 | 109,168 | 61,133 | 199,915 | 52,173 | 89,983 | 342,565 | 1,506, |
| 85 | 113,467 | 104,566 | 56,347 | 110,301 | 52,036 | 103,882 | 110,524 | 109,168 | 61,133 | 199,915 | 52,173 | 89,983 | 342,565 | 1,506, |

**Figure 4.3-5** Regional Biomass Supply Curve (low hay yield).

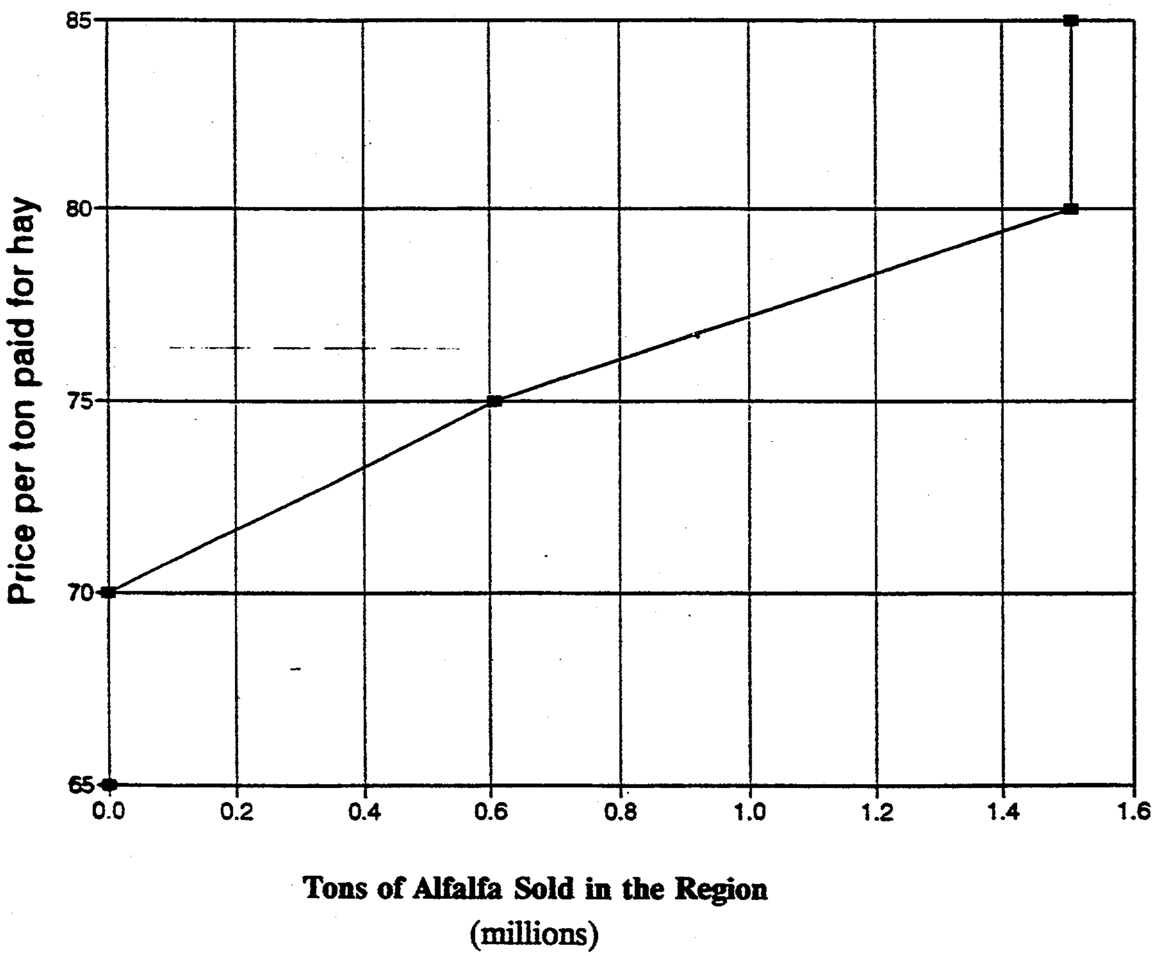


**Table 4.3-6** Regional Supply (low adoption rate).

| pay price | Region 7 | Region 14 | Region 15 | Region 16 | Region 17 | Region 18 | Region 19 | Region 20 | Region 24 | Region 25 | Region 26 | Region 31 | Region 36 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 75 | 12,607 | 0 | 6,261 | 12,256 | 0 | 0 | 0 | 12,130 | 6,793 | 0 | 0 | 0 | 0 | 50,04 |
| 80 | 126,075 | 58,092 | 62,608 | 61,279 | 28,909 | 11,542 | 12,280 | 60,649 | 33,963 | 22,213 | 5,797 | 9,998 | 38,063 | 531,46 |
| 85 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,926 | 222,128 | 28,985 | 49,990 | 190,314 | 1,404,11 |
| 90 | 126,075 | 116,185 | 62,608 | 122,557 | 57,818 | 115,425 | 122,805 | 121,298 | 67,926 | 222,128 | 57,970 | 99,981 | 380,628 | 1,673,40 |

**Figure 4.3-6** Regional Biomass Supply Curve (low adoption rate).

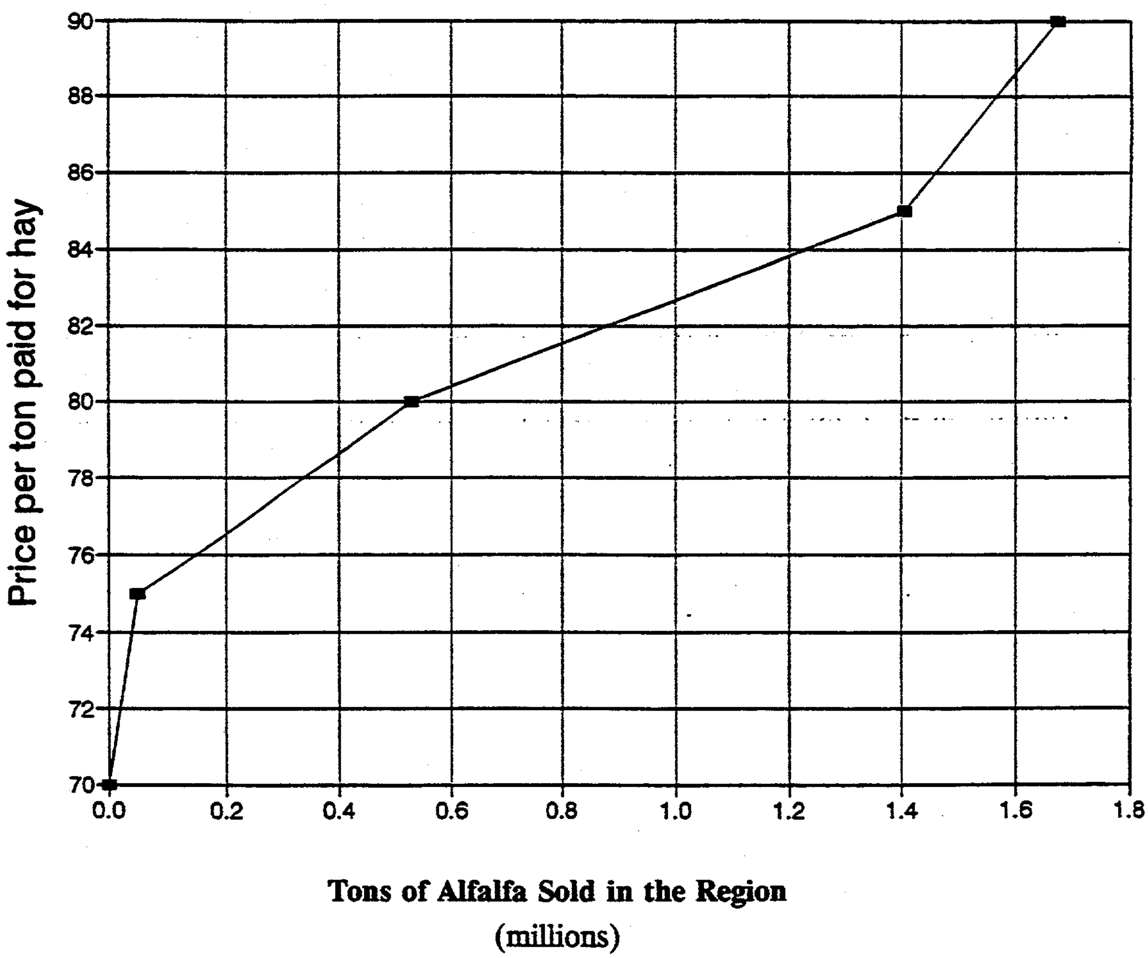
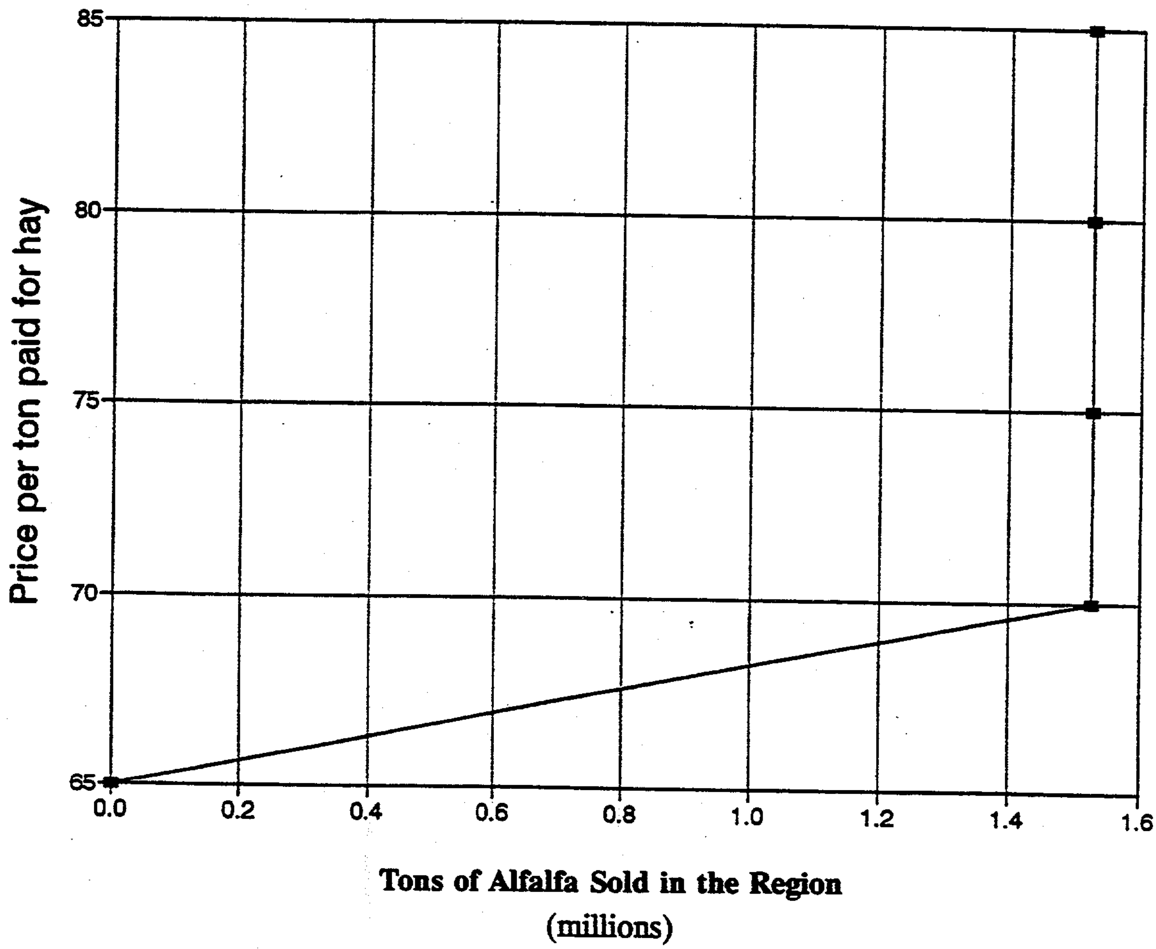


**Table 4.3-7** Regional Supply (2-cut system).

| pay price | Region 7 | Region 14 | Region 15 | Region 16 | Region 17 | Region 18 | Region 19 | Region 20 | Region 24 | Region 25 | Region 28 | Region 31 | Region 36 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 | 114,854 | 105,844 | 57,036 | 111,649 | 52,672 | 105,152 | 111,875 | 110,502 | 61,881 | 202,359 | 52,811 | 91,083 | 346,752 | 1,524,469 |
| 75 | 114,854 | 105,844 | 57,036 | 111,649 | 52,672 | 105,152 | 111,875 | 110,502 | 61,881 | 202,359 | 52,811 | 91,083 | 346,752 | 1,524,469 |
| 80 | 114,854 | 105,844 | 57,036 | 111,649 | 52,672 | 105,152 | 111,875 | 110,502 | 61,881 | 202,359 | 52,811 | 91,083 | 346,752 | 1,524,469 |
| 85 | 114,854 | 105,844 | 57,036 | 111,649 | 52,672 | 105,152 | 111,875 | 110,502 | 61,881 | 202,359 | 52,811 | 91,083 | 346,752 | 1,524,469 |

**Figure 4.3-7** Regional Biomass Supply Curve (2-cut system).



## Supply Schedule Shifters

How stable are these production estimates? We here examine the effects of four separate changes in our baseline assumptions. Each change is but one example of several that might be posed within that general category. While the baseline incorporates our best estimates of the various parameter values, this sensitivity analysis can help the reader decide which of our initial estimates need further specification. We will see that relatively small changes in the baseline assumptions lead to relatively large swings in the regional biomass supply schedule. This is because the relative net returns to the two rotations are so similar in the baseline.

### Prices

There are many events that might lead to a shift in our most fundamental variable, the DFSS:C-S returns ratio. What happens to the supply schedule, which relates hay production and hay prices, if the expected price of corn were reduced (i.e. due to the abolition of deficiency payments)? The price change alters the DFSS:C-S return ratios, which in turn alter the adoption ratios (**Table 4.3-3**). This exercise is charted in **Figure 4.3-3**, which shows the zero deficiency payment supply curve. At a $67.50/ton hay price, the lower expected corn price would result in over 1.2 million tons of hay being offered, a large increase over the baseline of 800,000 tons at this price.

### Yields

What if plant breeders succeed in developing varieties that yield more biomass per acre? Or, what if our hay yield estimates prove overly optimistic? In this exercise, we vary the hay yields by 10% in each production district. **Table 4.3-4** and **Figure 4.3-4** show that a 10% increase in hay yield increases overall hay production at the $67.50/ton level to 900,000 tons,

A 10% reduction in alfalfa yield, at the same price level ($67.50/ton) as shown in **Table 4.3-5** and **Figure 4.3-5**, results in no hay offered. Under low yield expectations, farmers would expect a price over $75.00/ton before our assumptions would yield a production level sufficient to supply the needs of the alfalfa processing plant.

## Behavior

What if our biomass rotation "adoption-rate" schedule turns out to be incorrect? After all, it is based on expected producer responses and our judgment of "typical" producer behavior. Because this schedule is critical to the development of the regional biomass supply curve, it warrants special attention. Here, we show the effects of specifying a lower, more "pessimistic" adoption rate as shown in **Table 4.3-8**. The lower adoption-rate increases the price necessary to elicit 700,000 tons of production from \$67/ton (baseline scenario) to \$81/ton as shown in **Table 4.3-6** and **Figure 4.3-6**.

**Table 4.3-8** Biomass adoption-rate schedules based on the ratio of net returns between the DFSS rotation and traditional corn-soybean rotation at both a low and a baseline level of producer acceptance.

| | **Adoption Rate Schedule** | |
|---|---|---|
| Net Return Ratio[1] | Low Adoption Rate[2] | Baseline Adoption Rate[3] |
| < 1.0 | 0 | 0 |
| 1.0 - 1.1 | 0 | 0.10 |
| 1.1 - 1.2 | 0 | 0.10 |
| 1.2 - 1.3 | 0.01 | 0.10 |
| 1.3-1.4 | 0.05 | 0.10 |
| > 1.4 | 0.10 | 0.10 |

1- Net return ratio is the ratio between net returns from the DFSS rotation and a Corn-soybean rotation.
2- Low adoption rate reflects poor acceptance by producers.
3- Baseline adoption rate expected level of producer acceptance.

Regulations

All prices and costs a have an institutional, as well as a technological basis. For example, holding farmers responsible for the off-farm costs of soil erosion could dramatically affect the costs of row-crop production on erodible soils and, as result, shift the geographical focus of production.

In the present setting, we examine the implication of one such rule change: requiring contracted hay producers to delay their first cutting of hay until late June (late June harvest would extend the period of favorable habitat for nesting birds on these lands). This "habitat-constrained" system where the first cutting is delayed until late June results in a two-cut harvest system due to seasonal constraints. The baseline supply curve assumes a three-cut harvest system, with the first cutting in early June.

The "habitat-constrained" system results in reduced total annual yield but also reduces annual harvest costs (one less cutting per year). We estimate that hay yield be reduced by almost 9%, however net biomass rotation returns actually increases due to lower production costs. The net effect on both the aggregate supply schedule and on geographic distribution of production is modest as shown in **Table 4.3-7** and **Figure 4.3-7**, respectively.

CONCLUSIONS:

The exercise of generating a regional biomass supply curve, even though it necessarily requires several assumptions that can be tested only in actual system operation, forces us to confront certain aspects of the decision environment faced by potential hay producers. In particular, the exercise demonstrates the effects of hay yields, federal corn subsidies, and producer attitudes toward risk. Relatively small changes in any of these parameters in our baseline assumptions lead to relatively large swings in the volume of hay production in the biomass shed. In general, we are led to conclude that hay prices above $67/ton will most likely elicit enough hay production in the region to fuel the design power plant. One might expect a disproportionate amount of this production will come from farms with lower productivity corn land and few other competing market opportunities. However, even high productivity corn land might be turned to the DFSS rotation at hay prices above $70/ton or as the result of other considerations.

# CHAPTER 5. TRANSPORTATION AND STORAGE

## 5.1 Transportation and Storage Logistics

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**Introduction**

The efficiency of using biomass as an energy source is often limited by the cost of biomass transportation and handling. Two common concerns associated with biomass transportation are that biomass tends to have a low bulk density and high moisture content. This report outlines a cost effective design to provide a steady supply of alfalfa biomass to the processing plant. The economics of transportation and storage for both alfalfa producers and for a proposed Alfalfa Cooperative (AC) are included. Harvest, transportation, and storage of alfalfa is accomplished through the use of existing equipment and technologies. Technological advances will likely improve overall system efficiency.

**Overview of Logistics**

Alfalfa is harvested over approximately a three month period. The power plant is designed to operate at least ten months per year. Therefore, a significant portion of the total crop (60%) must be stored for a period of time. Maintaining alfalfa quality throughout storage is critical. Storage losses can reduce both total dry matter and alfalfa quality. Two options exist for protecting alfalfa in storage; roofed structures and plastic tarps are both readily available to protect alfalfa from quality and dry matter losses.

Alfalfa storage could be accomplished either on-farm or at remote storage locations. Currently very few producers have facilities for on-farm alfalfa storage. Because comparable storage cost per ton is independent of storage location, on-farm storage of alfalfa is possible; however, the existence of farm size quantities of baled alfalfa scattered throughout the production area presents certain difficulties. Road restrictions, quality monitoring, night hauling on country roads, and simply finding the stored alfalfa on the farm are a few of the transportation problems that would be encountered with on-farm storage. Properly sited regional storage sites will be easy to find and accessible day or night year round. Loading and unloading equipment, weigh scales, and alfalfa testing equipment will be located at the regional facilities.

Harvest dates initiate the tidal flows of alfalfa from fields to storage sites. Alfalfa may be harvested as early as late May and as late as early October. This report utilizes data for standard three-cut harvest systems.

The biomass power plant is designed to operate at least 300 days per year. Power companies traditionally plan for power plant routine maintenance during either the spring or fall periods of lighter power loads. To minimize storage costs, the biomass power plant could schedule "down time" for the 65 day period preceding hay harvest. The plant should be ready for full and continuous operation beginning June 1. The power plant would then be constantly consuming alfalfa stems during the entire harvest season and beyond with minimal storage costs or post-harvest losses on direct-haul biomass. This report anticipates that 40% of total production will be direct-haul (no storage) from June through September.

Bale size and density is specified for consistency and efficiency throughout the operation. Large high-density square bales offer transportation and storage advantages however large square balers are relatively new to the production area. Small-square bales require additional labor both in the field and at the storage facilities. The large-round bale (4'x6') specified for this study is widely utilized by farmers in the area.

Transportation costs from the field to a remote storage site are considered to be the responsibility of the producer. Farm to regional storage transport could be done using wagons, trucks, or special hay hauling equipment. Simple efficiencies of transportation reward growers hauling more tons per load. Bales move from the regional storage sites to the processing plant on specially designed flat- bed trucks.

### Storage Options

Three basic storage options were analysed. The "no cover" option indicates that bales are stored outdoors without protection. The "plastic" option indicates bales stored in a 10 bale pyramid and covered with a specially designed plastic tarp. The "roofed" option indicates bales stored in a pyramid four rows high in a pole barn type structure with a roof and two or three sides enclosed (Section 3.3). The current analysis is limited to using only one storage option for storing all of the alfalfa in the bioshed. Most likely, some combination of storage sytems will give a best case scenario. Long-term storage of alfalfa may be in a roofed structure and short-term storage may be with no cover. Plastic tarps may be used as short or long-term storage or even for years in the event of an oversupply situation.

Method of storage and resulting storage losses determine the level of production needed to satisfy the fuel needs of the power plant. Production, transportation, and storage are linked. Dry matter and quality loss under different storage scenarios affect farm level production requirements and transportation costs. Spreadsheets were developed to facilitate comparisons of storage and transportation systems.

### Logistical Considerations

The year's supply of alfalfa will be delivered to regional storage sites during a four month period. This will require a seasonal work force. Storage sites may need to be open and staffed daily to facilitate the delivery of alfalfa from the growers. Sites must be staffed by at least one, and possibly two, qualified persons to provide timely weighing, testing, unloading, and stacking of the alfalfa bales. The flow of alfalfa from farm fields to remote storage sites will fluctuate with weather conditions. Therefore, the demand on the labor force will also fluctuate with the weather.

The logistics of transport of alfalfa to the processing plant requires planning and coordination. Approximately 750,000 tons of alfalfa must be transported from 50 to 80 remote storage sites to the processing plant annually (ca. 2500 t/d). This requires approximately 20 trucks hauling 16 hours per day, 6 days a week.

**Equipment Needs**

As stated previously, a condition of this study was to utilize proven and available equipment. The farm equipment needed for alfalfa production is common and familiar to many farmers in the area. Such equipment includes tractors, tillage equipment, fertilizer spreaders, boom sprayers, cultivators and planters, mower conditioners, swather conditioners, hay rakes, and round balers. The only piece of production equipment that must be specified is the round baler. The size and type of bale produced is a critical factor in providing a least cost system for transportation and storage.

Current methods used by farmers for transporting alfalfa from field to the storage sites include many sizes of trucks, tractors, and hay wagons. Generally volumes and distances moved are low for most farmers. In recent years, some specialized equipment has been developed to accomplish the transportation task more efficiently. Specialized trucks and wagons are available to pick up bales in the field, transport them, and unload rapidly at a storage area. Fork lifts/loaders that extend up to 20 feet will be used to stack and handle bales at the storage site.

Bales are cored and sampled upon delivery at the regional storage site. Grower's name or identification number, and alfalfa weight, quality, and moisture are recorded by a computerized data collection system. Weighing and testing needs to be done rapidly and accurately. An automated process for testing alfalfa is not currently available. Automated systems in use for sampling and weighing grains and sugar beets may be modified for this specific purpose.

## 5.2 Transportation and Storage Costs

### Introduction

A spreadsheet was developed to estimate the cost of different options for the transportation and storage of the baled alfalfa. Three basic costs were analyzed in the calculations: transportation costs from the farm to the regional storage site, storage costs, and transportation costs from the regional storage site to the processing plant (**Table 5.2-1**).

**Table 5.2-1** Summary of transportation and storage costs under the assumptions described on the following pages.

| STORAGE METHOD | No Cover | Plastic | Roof |
|---|---|---|---|
| Tons alfalfa per year (15% moisture) | 679,016 | 656,680 | 644,372 |
| Number of bales | 1,200,765 | 1,161,266 | 1,139,501 |
| Alfalfa acres in bioshed | 178,688 | 172,811 | 169,572 |
| % alfalfa acres in bioshed | 6.9 | 6.7 | 6.6 |
| Optimum storage sites | 83 | 80 | 79 |
| Haul days per site | 2.3 | 2.3 | 2.3 |
| **COSTS** | | | |
| Transport to regional storage | $2,285,456 | $2,210,277 | $2,168,851 |
| Storage | $4,880,494 | $4,854,087 | $7,151,448 |
| Transport to plant | $2,401,528 | $2,322,530 | $2,279,001 |
| Total costs | $9,567,478 | $9,386,894 | $11,599,300 |
| Cost per ton (after loss) | $15.03 | $14.75 | $18.22 |

## General Assumptions

| | |
|---|---|
| Tons of stems delivered per day to the gasifier: | 992 t/d (dw), 1167 t/d (15%) |
| Alfalfa dry matter storage losses: | 2% - roofed structure<br>5% - plastic cover<br>10% - no cover |
| Alfalfa yield per acre in the biomass shed: | 3.8 tons per acre |
| Bale moisture content: | 15% |
| Bale density (large round bale): | 10 lbs/$ft^3$ (15% moisture) |
| Bale size (based on maximum truck capacity): | 4'x6' (length x diameter) |
| Leaf:Stem ratio: | 45:55 |
| Direct-haul (no storage): | 40% of total production |
| Tillable acres in biomass shed: | 80% |
| Labor charge (including benefits): | $11.00/hr |
| Depreciation, interest, repairs, taxes, insurance on capital investment: | 15% |

## Transportation from Farm to Storage Site Assumptions

| | |
|---|---|
| Number of bales per load: | 10 |
| Average delivery speed: | 15 mph |
| Cost per mile (equipment, maintenance and fuel): | $0.50 per mile logged |
| Hauling distance: | variable |

## Storage Assumptions

| | |
|---|---|
| Annual land value: | $100 per acre per year |
| Site preparation and gravel base: | $20,000 per acre |
| Plastic tarps: (includes tarp, springs, clamps and tarp disposal) | $1.00/bale--3 year life |
| Steel storage structure (cost per square foot): | $5.50/ft² |
| Miscellaneous equipment at regional storage site: (includes weigh scale, office space, and computerized bale testing equipment) | $100,000 per site |
| Loading equipment: | $70,000 |
| Storage site hours of operation in peak season: | 16 hours |
| Percent of total harvest as first cutting : (three-cut schedule) | 33% |
| Time to get first cutting from field to storage: | 15 days |
| Labor per bale: (includes weighing, testing, unloading, stacking) | 3 minutes |
| Additional labor per bale for plastic cover: (covering and uncovering) | 1.5 minutes/bale |

## Transportation to Processing Plant Assumptions

| | |
|---|---|
| Processing plant operations: | 7 days per week |
| Delivery from remote storage: | 6 days per week |
| Average road speed: | 40 mph |
| Time on road per day: | 16 hours |
| Loading time: | 0.50 minutes per bale |
| Unloading time: | 0.33 minutes per bale |
| Bales per truck load: | 30 |
| Cost per mile: (labor, fuel, maintenance, purchase) | $0.75 per mile logged |

**Discussion**

The costs of farm transportation, storage, and transportation to the processing plant range from 9.4 to 11.6 million dollars per year (**Table 5.2-1**). The price per ton (including storage loss) ranges from \$14.75 to \$18.22.

Many factors impact the cost of transportation and storage. **Figure 5.2-1** indicates the effect of production area on transportation and storage costs by representing a biomass shed with a 30, 40, and 50 mile radius. The most compressed biomass shed (30 mile) results in cost savings of \$2.73/ton of alfalfa compared to a biomass shed with a 50 mile radius. Achievement of these savings in transportation costs requires increasing the percentage of alfalfa in the landscape from 5% of tillable acres (50 mile radius biomass shed) to 20% (30 mile radius biomass shed). Note: approximately 5% of the tillable land within a 50 mile radius of the processing plant is currently enrolled in the Conservation Reserve Program (CRP).

**Figure 5.2-1** Predicted per ton cost for transportation and roofed storage of alfalfa per number of storage sites.

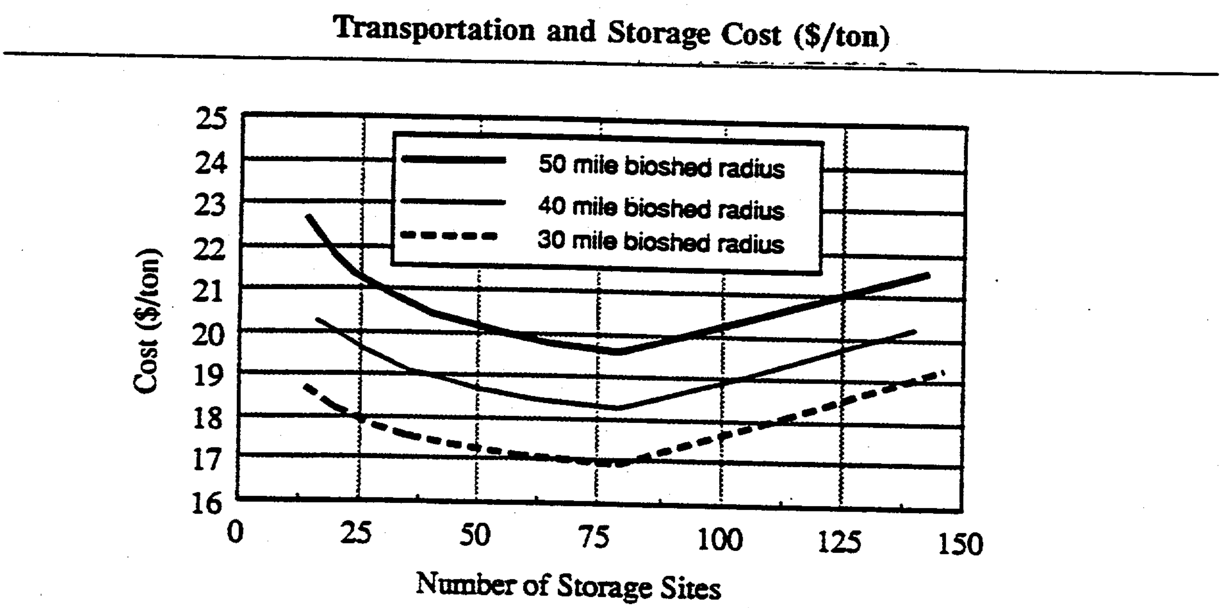
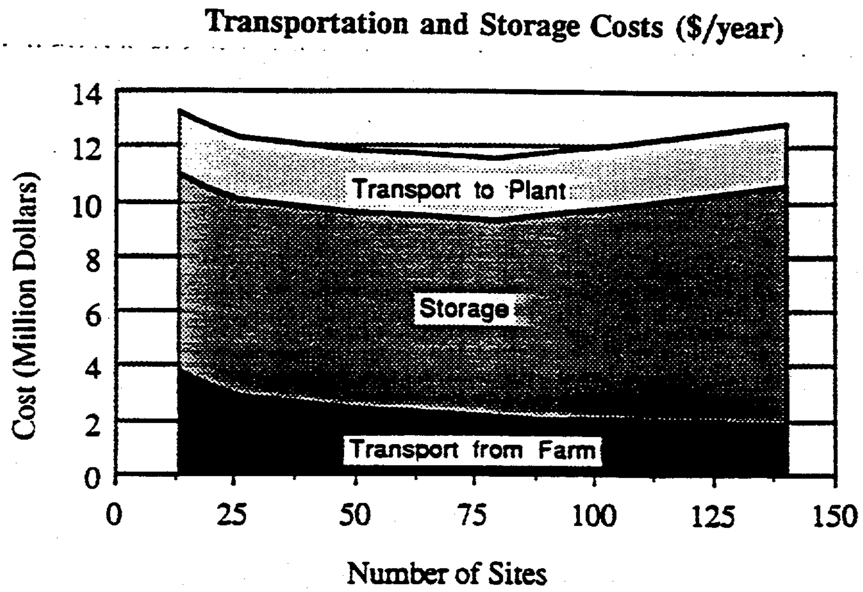


**Figure 5.2-1** also indicates an optimum number of storage sites (80 sites) and that the optimum number of sites is independent of biomass shed radius. The optimum number of storage sites is dependent on the time needed for bale processing and storage. We assumed that 33% of the alfalfa crop will cross the scales at a regional storage site within a 15 day period. Each regional site must have at least one set of equipment (set = 1 loader, 1 weigh scales, and 1 bale sampler system).

Decreasing the number of storage areas does not decrease the number of sets of equipment needed to handle the flow of alfalfa in a timely manner. However, since each storage site needs at least one set of equipment, as the number of storage sites increases beyond the minimum equipment requirement, the cost of storage increases. The minimum equipment requirement is based on the assumption that it takes an average of 30 minutes to weigh, sample and unload a 10 bale load of alfalfa per set of equipment. Increasing the efficiency of the equipment or expanding the time frame available for bale handling reduces the optimum number of storage sites. The relationship between number of storage sites and storage costs is shown in **Figure 5.2-2.**

**Figure 5.2-2** Predicted costs for transportation and roofed storage in millions of dollars.

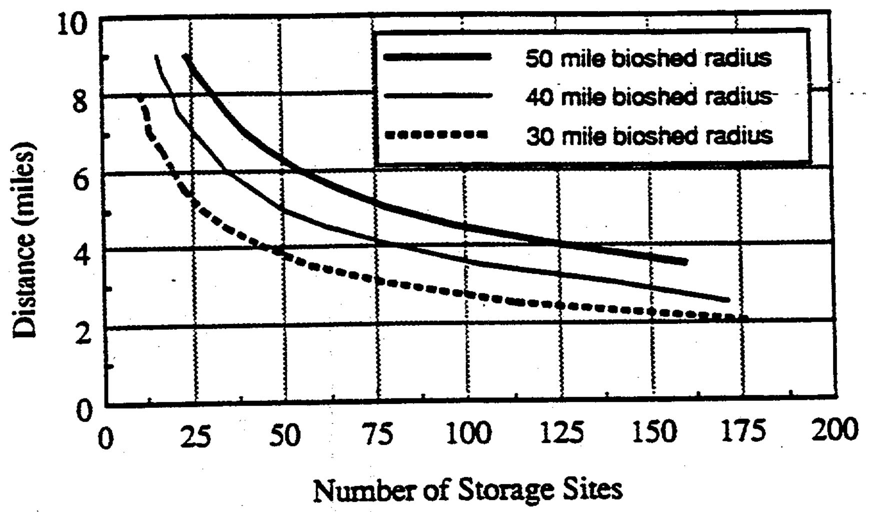


Changing storage method from "roof" to "plastic" to "no cover" decreases the cost of storage structures, but increases equipment needs slightly. Changing storage method from "roof" to "plastic" to "no cover" increases storage area land requirements and increases the total number of bales handled which increases labor costs.

Decreasing the number of storage sites increases the cost of transportation from the field to remote storage. This is due to the increased hauling distance for the producer. The relationship between number of storage sites and average distance a grower must haul alfalfa is depicted in **Figure 5.2-3**. Increased cost of farm transportation is due to increased farm labor, and equipment use. Farm transportation costs are also affected by storage method because storage method (losses) determine how many bales must be hauled.

**Figure 5.2-3** Relationship between biomass shed radius, number of storage sites, and the average distance producers must transport alfalfa.

**Producer Transport Distance to Remote Storage**




A least cost transportation and storage system results when bales are stored under plastic. Bales stored with "no cover" should not be stacked, therefore a larger storage area is needed. "Plastic" is less expensive than "no cover" because of the increased amount of acreage needed to store bales with no cover, and the high cost of land preparation for storage sites.

Storage and transport costs of alfalfa $15.03/ton (no cover), $14.75/ton (plastic) and $18.22/ton (roof) are also linked to production costs. Total production of 679,016 tons/year (no cover), 656,680 tons/year (plastic), 644,372 tons/year (roof) reflect losses of dry matter in storage. Using a $60.00 per ton as the cost of production plus transportation, and storage costs, total costs for production, transportation, and storage are approximately $48.0 million (no cover), $46.6 million (plastic), and $48.1 million (roof). Total costs are within 3% indicating no significant cost difference between storage methods. However, as cited in section 3.3, storage losses include not only dry matter loss but also quality losses. Quality losses in alfalfa stored without protection would largely impact leaf meal products rather than energy production characteristics. Therefore, although cost per quantity of alfalfa may be similar for all storage options, quality considerations for leaf meal are important (see section 6.3, and section 7.3).

A remaining storage consideration is that alfalfa stored without a cover has a significant potential to increase in moisture content. Increased moisture increases transportation and drying costs.

**Conclusions**

* All storage methods analyzed result in nearly the same cost when production aspects are considered. Therefore, storage method should be dictated by the quality of alfalfa leaf meal desired.

* The cost of transportation from the farm to the storage area is dictated by the producers hauling distance. Hauling distance is a result of the number of storage sites. The number of storage sites significantly impacts the farm to storage transportation costs. The optimum number of storage sites is dictated by the amount of equipment needed to process the alfalfa in a given time frame.

* The cost of transportation from the storage site to the processing plant increases as the biomass shed radius increases. Therefore, it is important to restrict the biomass shed radius.

*note: all weights expressed as tons are U.S. tons (2000 pounds)*

## 5.3 Transportation Infrastructure

The trunk highway network in the project area consists of 1,172 miles of federal and state highways. The federal and state roads are all paved and are maintained year round. There are also over 4,500 miles of county and county state aid roads and over 7,000 miles of township roads laid out in a square mile grid system. Consequently there is a road almost every mile throughout the area.

Fifty-five percent or 2,498 miles of the county and county state aid roads in the biomass shed are paved (**Table 5.3-1**). All county and county state aid roads are maintained year round. Township roads vary widely in quality and level of maintenance. Most township roads are graveled and passable in all seasons. A limited number of township roads have dirt surfaces and are not maintained or snow-plowed. A small number of gravel township roads do not receive snow-plowing; however, there are typically no residences or building sites on roads that are not snow-plowed.

Traffic counts on the county roads within this region are typically less than 100 per day. Township traffic counts are even less. There are no short or long-term capacity problems that would develop on the township and country roads as a result of traffic to and from remote storage sites.

The number of paved county and all-weather county roads is such that selection of remote storage sites can be easily accomplished. The criteria for adequate transportation from the remote storage sites to the processing facility are that there be an all-weather road (preferably paved), routine snow-plowing, and no permanent obstructions or hazards (e.g., narrow bridges or low hanging wires) that would cause indirect routing from the remote site to the power plant.

The NSP power plant site and potential processing station are located on U.S. Highway 212 and Minnesota #23. U.S. 212 is a major east-west artery from Minneapolis to Yellowstone National Park. It is the main access from the Granite Falls area to the Twin Cities. Minnesota #23 cuts from the southwest corner of Minnesota to the Twin Ports of Duluth and Superior. Both roads are considered strategic thoroughfares by the Minnesota Department of Transportation. Both are excellent two lane highways in the Granite Falls area. A passing lane is in place to the east of the plant. The highway widens to four lanes as it goes west into and through Granite Falls.

**Table 5.3-1** Description of roads in the biomass shed and length of road by type in miles.

**Roadways in the Biomass Shed**

| | Dirt | Gravel | Hard | Total |
|---|---|---|---|---|
| Chippewa Township | 16 | 689 | 3 | 707 |
| County | - | 43 | 12 | 55 |
| CSAH | - | 80 | 164 | 244 |
| Trunk | - | - | 133 | 133 |
| Kandiyohi Township | 13 | 675 | 30 | 719 |
| County | - | 188 | 31 | 219 |
| CSAH | - | 50 | 373 | 422 |
| Trunk | - | - | 171 | 171 |
| Lac Qui Parle Township | 38 | 793 | 1 | 833 |
| County | - | 133 | 2 | 135 |
| CSAH | - | 149 | 218 | 367 |
| Trunk | - | - | 111 | 111 |
| Lincoln Township | 35 | 524 | 1 | 560 |
| County | - | 129 | 6 | 135 |
| CSAH | - | 55 | 201 | 256 |
| Trunk | - | - | 84 | 84 |
| Lyon Township | 36 | 666 | 1 | 704 |
| County | - | 140 | 37 | 176 |
| CSAH | - | 40 | 280 | 320 |
| Trunk | - | - | 145 | 145 |
| Redwood Township | 25 | 948 | 1 | 974 |
| County | 1 | 126 | - | 127 |
| CSAH | 12 | 79 | 295 | 386 |
| Trunk | - | - | 142 | 142 |

| | | | | |
|---|---|---|---|---|
| Renville Township | 8 | 964 | - | 972 |
| County | - | 260 | 6 | 266 |
| CSAH | - | 36 | 413 | 449 |
| Trunk | - | - | 123 | 123 |
| Swift Township | 61 | 722 | 1 | 784 |
| County | - | 129 | 3 | 132 |
| CSAH | - | 117 | 213 | 331 |
| Trunk | - | - | 128 | 590 |
| Yellow Medicine Tnshp | 21 | 777 | 2 | 800 |
| County | - | 163 | 1 | 164 |
| CSAH | - | 103 | 243 | 347 |
| Trunk | - | - | 135 | 135 |
| **Total Township** | 253 | 6,758 | 40 | 7,055 |
| **County** | 1 | 1,311 | 98 | 1,410 |
| **CSAH** | 12 | 790 | 2,400 | 3,121 |
| **Trunk** | - | - | 1,172 | 1,172 |
| **GRAND TOTAL** | **266** | **8,778** | **3,710** | **12,758** |

At the proposed site for fractionation of the bales of alfalfa, combined trunk highway 212/23 has an average daily traffic count of 3,250 vehicles. This includes 650 heavy commercial vehicles. (Heavy commercial vehicles includes semi and other vehicles over 26,000 pounds of gross weight.) The busiest section of commercial traffic in the vicinity of the fractionating plant is the portion of U.S. 212 and Minnesota #23 that runs two miles east from Granite Falls to the point where MN #23 separates and continues to the north and east. The increase in total heavy commercial traffic on this road is estimated to be 250 vehicles per day (loaded and empty vehicles for feedstock and leaf meal) or a 7% increase in total traffic and a 37% increase in total heavy commercial traffic. A similar stretch of U.S. 212 and MN 71 near Olivia (30 miles east) currently handles 775 commercial vehicles and 5,800 total vehicles per day. Highway 212/23 provides adequate capacity for the collection of hay and excellent access to feed processors and to livestock feeders for the leaf meal.

**Rail Infrastructure**

Adequate rail service exists to support the proposed biomass facility. There are a total of 434 miles of railroad in the 9 county biomass shed (**Table 5.3-2**). A map of the active rail network in the biomass shed is contained in **Illustration 5.3-1**. The power plant site is located on and currently served by the Twin City and Western Railway (TC&W), a regional railroad which was formed from part of the old Milwaukee Road mainline.

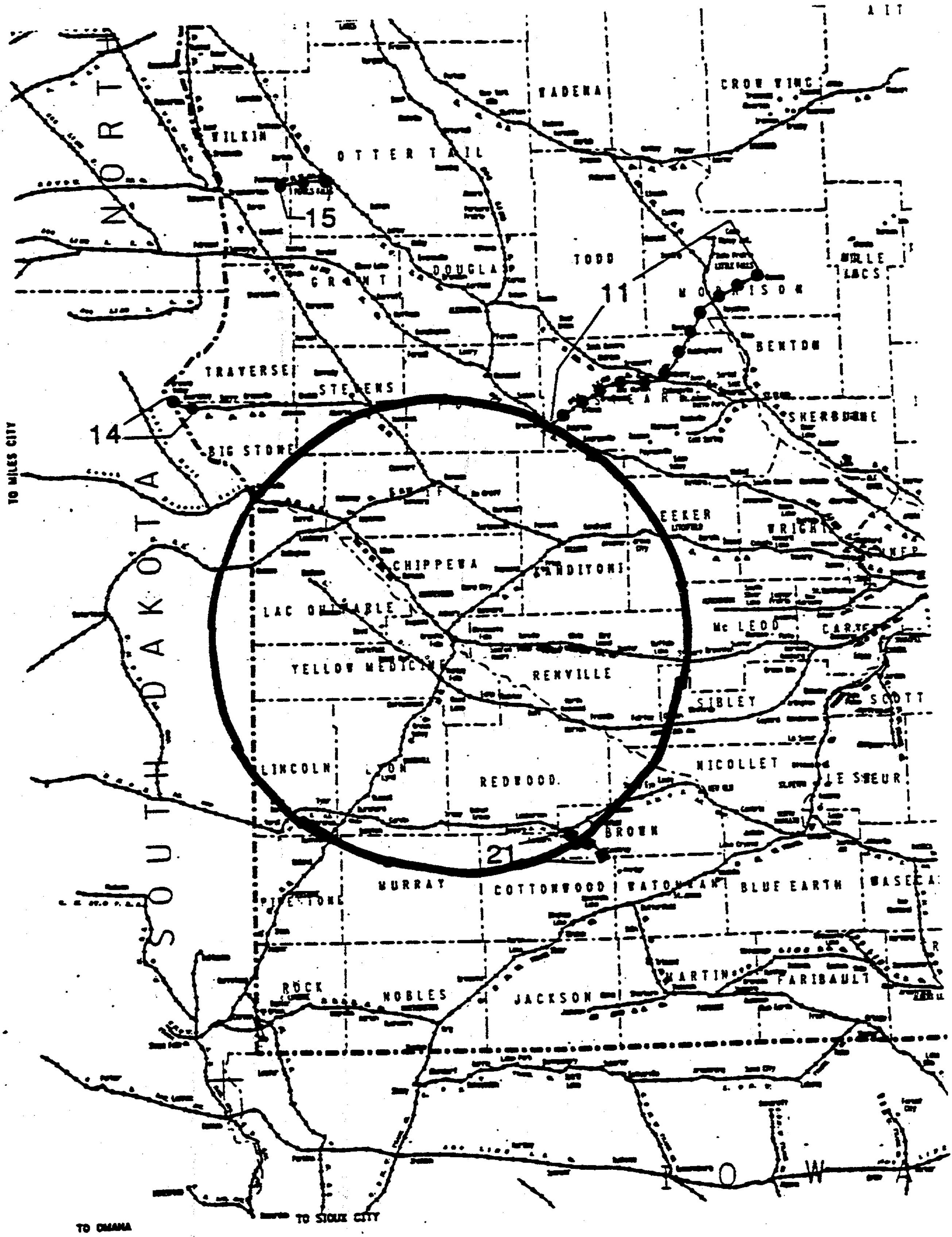
**Table 5.3-2** Railroads in the biomass shed and length of tracks in miles.

**Railroads in the Biomass Shed**

| | Regional | Burlington Northern<br>Mainline | Burlington Northern<br>Other |
|---|---|---|---|
| Chippewa | 34.70 (TC&W) | 21.13 | - |
| Kandiyohi | - | 34.40 | - |
| Lac Qui Parle | 22.04 (LQP) | - | 20.1 |
| Lincoln | 21.68 (DME) | 1.3 | - |
| Lyon | 25.75 (DME) | 37.48 | - |
| Redwood | 24.49 (DME)<br>19.41 (MNVA) | - | - |
| Renville | 49.15 (TC&W)<br>18.52 (MNVA) | -<br>- | -<br>- |
| Swift | 5.45 (TC&W) | 28.89 | 25.85 |
| Yellow Medicine | 13.66 (LQP)<br>14.26 (MNVA) | 15.44 | - |
| Total | 249.11 | 138.64 | 45.95 |
| **Grand Total** | 433.7 | | |
| TC&W Total | 89.30 | | |

TC&W = Twin City & Western Railway.
LQP = Lac Qui Parle Regional Railroad Authority.
DME = Dakota, Minnesota & Eastern Railroad Corp.
MNVA = MNVA Railroad Incorporated.

**Illustration 5.3-1** Map of regional railroad routes in the biomass shed.



The TC&W goes from Appleton to the Minneapolis-St. Paul area and has further trackage rights to Mississippi River ports such as Savage, Shakopee and Hastings. This line would provide access to barge transportation if the alfalfa leaf meal is to be marketed internationally. The TC&W connects to the Burlington Northern (BN) at its western terminus in Appleton. The BN owns that portion of the old Milwaukee Road mainline. This connection would provide access to West Coast markets and Pacific Northwest ports for leaf meal.

Excellent mainline service to the region is provided by the BN which has a north-south mainline that goes through Granite Falls. This BN mainline connects with the east-west BN mainline from the Twin Cities to the West Coast at Willmar. The TC&W can switch to the N-S mainline at Granite Falls. Because of these connections, the power plant site at Granite Falls is well suited for rail transportation of alfalfa leaf meal into statewide, national, and international markets.

The other railroads in the region are either shortline or regional railroads without direct connections to Granite Falls, (i.e., traffic to and from Granite Falls generally is switched outside of the biomass shed in the Twin Cities or other rail centers). The NMVA railroad is a regional railroad that goes east from Hanley Falls to Norwood with trackage rights on into the Twin Cities. The Dakota Minnesota and Eastern railroad is a regional railroad through the southern part of the biomass shed from South Dakota to the Mississippi River. Its traffic is oriented to the Mississippi River or switching points outside of the biomass shed. The BN manages a branchline for the Lac Qui Parle Regional Railroad Authority that runs from Madison to Hanley Falls. The BN has a local line runs that from the west border of the biomass shed to Benson where it terminates.

**Rail Collection of Biomass**

The use of rail to transport alfalfa biomass from remote transfer stations to the separator was analyzed. Approximately 44% of the biomass shed could be served by rail from remote sites established on the railroads. Twelve percent of the biomass shed could be served directly by the TC&W. Another ten percent of the biomass shed could be served by switching from the BN mainline to the TC&W at Granite Falls. Another 22 percent could be served by other railroads but would require 2 or more switches and/or movement of up to 200 miles more than by road. It was determined that the rail transportation of round bales would have lower line haul labor and fuel cost and have less environmental impacts for at least 22% of the biomass shed. However, total handling and transportation costs even for that 22% would be higher for rail than truck.

Cost factors impacting the rail transportation of biomass:

a. The estimated time to load a bale on a rail car is 3 times that of trucks because of the need to move bales greater distances to rail cars, to load three-high and to load from only one side. Trucks can go closer to stored bales and are loaded only two-high from both sides. The unloading time would also be greater for rail than trucks.

b. Cost of rail sidings would average $250,000 per remote rail site. This is in addition to land and warehouse cost.

c. A larger investment in rail rolling stock would be required proportionately than for trucks for that portion of the shed served by rail. This is because of the slower turnaround time of rail, even though standard flat cars loaded 3 high are able to carry twice as many bales as a lowboy semi trailer and specially designed flat beds would have a capacity 3 times that of a truck. Only two rail turns a day would be possible on the TC&W, 1 turn a day from the BN, and less than 1/2 turn a day from the lines where 2 switches are required.

d. A dual system for both truck and rail unloading facilities at Granite Falls would add to the cost and complexity of the unloading facility at the separator.

Rail Transportation of Stems

Under some conditions, it may be desirable to have one or more separator units located away from the Granite Falls plant. (For example, a feed mill or processor that has contracted to use or sell the leaf meal.) Rail hopper cars will be the most cost effective way to move stems from a remote separator to a plant located on the TC&W or the BN to the Granite Falls facility.

## 5.4 Vehicle Regulations

### Limits, Weights, and Permits

Minnesota law places restrictions on the size and configuration of trucks on public roads. The limits pertinent to the transportation of hay are generally width, length, and height, but not weight, due to the low density of the product. Straight trucks cannot exceed 40 feet in length. The combined length of semi-tractor and trailers cannot exceed 65'. The standard width for all vehicles is 8' 6", which may be exceeded only by permit. There is a round bale permit that allows a maximum width of 11'6" for travel during daylight hours, only. There is annual cost for such a permit of $15. Height limit is 13' 6". Regulations for tractor-drawn implements would apply to the use of equipment such as specially designed hay hauling trailers. Lighting, width, and signing regulations would apply as they do to other farm implements travelling on public roads.

Road and bridge weight restrictions also limit total vehicle weight and the maximum weight per axle. Additionally, more restrictive seasonal weight restrictions on some roads during the spring thaw period are imposed. Virtually all county roads have limits of seven or nine tons per axle. Normally, state and federal roads are all nine or ten ton roads. Vehicles on ten ton roads are limited to 80,000 lbs. gross weight, 34,000 lbs per tandem axle, and 20,000 lbs. per single axle. Vehicles on nine ton roads are limited to 73,280 lbs. gross weight, 32,000 lbs. per tandem axle and 18,000 lbs. per single axle. Limits on 7 ton roads are approximately 62,000 gross weight, 26,440 lbs per tandem axle and 14,000 lbs. per single axle. Limits on 5 ton roads are approximately 46,000 lbs gross weight, 18,889 lbs. per tandem axle and 10,000 lbs. on single axles. Maximum payloads then are approximately 28 tons, 24 tons, 18 tons, and 12 tons, for roads rated 10 tons, 9 tons, 7 tons, and 5 tons, respectively. Based on the density of alfalfa in round bales, weight limits won't be exceeded on county, state, or federal roads with seven ton or higher limits.

Township roads, have nine ton limits for most of the year. However, during the six week spring thaw period, township roads have five ton limits, unless otherwise posted. Some county roads are also posted at lower levels during the spring thaw. It is imperative that remote storage sites of large round bales be located on roads that will have at least seven ton limits year round. As noted in section 5.3, an adequate network of local roads exists so that numerous locations will be available. A few rural bridges have been posted for gross weights less than our expected truckload weights; however, the redundancy of the square mile network is adequate to avoid any costly detours. The impact of such bridge restrictions may also be minimized by careful selection of transfer/storage sites.

# 5.5 Site Regulations

### Dust, Noise, Runoff, Vermin, and Fire

State laws and local building codes and ordinances must be met before an alfalfa processing facility could be built. The following issues are judged to be the most significant for this type of plant. Efforts to control the noted issues are not judged expensive and can be accomplished on any site.

Fugitive Dust

State environmental air quality regulations require that not only emissions from a process be controlled but that fugitive dust external to the process be controlled. Process emissions are controlled by equipment selection and good maintenance practices.

Fugitive dust in the vicinity of the plant will be caused from truck traffic into the plant, the pellet truck load-out facility, and the alfalfa truck unloading building. Except for the road traffic, these sources can be characterized as the entry and exit points of the system. Road dust will be minimized by cleaning and wetting. It is assumed that hay debris that may drop from a truck is not an environmental problem because it is heavy enough that it will settle along roadways and not threaten environmental air quality. Airborne dust that is stirred up by passing trucks could carry some distance and cause discomfort for area residents and plant employees. A program of sweeping or vacuuming the roadways around the plant will need to be implemented if dust becomes a problem. The plant will need to develop a policy regarding spraying the roadways with water in the summer when dry conditions are creating a dust problem.

Some dusting is expected at the pellet load out facility. The dusting will be controlled by a dust collector which pulls a vacuum around the pellet stream and carries away the dust. This equipment is common throughout the grain industry. The alfalfa unloading area will minimize the fugitive dust by using low impact methods of moving the bales off the trucks and into the conveyor feed to the bale buster. The dust generated at the bale buster will be captured by an airflow that pulls air and alfalfa through the bale buster. The air steam will go to a cyclone separator where the dust material will be removed and the air exhausted to the outside. The dust generated at this point has value because much of it will be leaf material.

## Noise Levels

The main source of noise from the plant will be from trucks delivering alfalfa and exiting. It is expected adherence to local noise ordinances for vehicular traffic will keep the noise to a tolerable level. Since the plant is in a valley, there will be only slight exhaust noise as the trucks come downhill. Most exhaust noise will come with unloaded trucks as they climb the hill on Hwy 212 leaving the plant.

Most of the noise created within the processing plant will be contained by the building. For people working in the plant, warning signs will be posted in areas where OSHA noise limits are sometimes exceeded and protective equipment will be issued. The potential sources of higher noise levels are rotating equipment where the alfalfa is impacted or squeezed such as the bale buster, the hammermill, and the pellet mill. Fans can often be noisy from harmonics in the casing sheetmetal and ductwork. Good design practices and noise attenuators are two methods for minimizing fan noise.

## Runoff Control

It is expected that no unusual runoff collection basins will be required for the alfalfa processing plant because of the biodegradable - non hazardous waste nature of the material. Normal good plant design practice will raise the building slightly above the surroundings so that rainfall will flow away from it. The roadway and staging area for trucks will be crested so that rainfall will flow away to ditches along side. Most of the rain will be absorbed into the soil on the site. Unusually heavy rainfalls may see some water reaching the river. This is not a problem for the reasons stated earlier.

## Vermin Control

The plant will have on-site long term storage of stems sufficient to supply the gasifier for one week. To remove the opportunity for infestation of vermin, the storage area will be enclosed.

The plant will also have an active storage pile of bales to be processed during the night shift. The rotation of the pile will be daily and no additional vermin protection is required.

Fire Protection

The alfalfa processing plant will be equipped with wall hydrants and hose stations at strategic locations. The water supply will be from the city of Granite Falls.

The building housing the processing equipment will be constructed of nonflammable material, primarily steel and concrete. The facility is expected to be very clean with daily cleanup so that no accumulation of combustible material is allowed to develop. Good maintenance practices will prevent equipment from leaking combustible material onto the floor or into the building air space.

Equipment will be selected that has surface temperatures far below the ignition temperature of the alfalfa stem and leaf even during upset conditions. The dryer heat source (burner) will include safeguards to automatically shut down if temperatures limits are exceeded. All motors will be equipped with overload protection to prevent overheating. Since the dryers are a potential major source of fires, the entire line including fans, hammer mills, and pelletizer will shutdown automatically at preset temperature levels and an extinguishing system will be activated. Temperature sensors throughout the system will monitor for high temperatures and alert the operator if encountered.

## 5.6 PRIVATE CONTRACTOR OPPORTUNITIES

Typically a farmer will handle alfalfa production from seedbed preparation to market. This need not be the case. Many aspects of alfalfa production on a large scale could involve the use of specialty equipment, custom operators, and consultants. The following is a partial list of some of the areas where private contractors could become involved.

**Seedbed Preparation and Alfalfa Seeding**

Success in establishing alfalfa stands is sometimes elusive for farmers. Alfalfa seed is expensive on a per acre basis relative to other crops, and seedbed preparation requires some care. Quality seedbed preparation, alfalfa seeding with specialized equipment, and guaranteed results might emerge as packaged services offered by private contractors. These processes are required only once per field planted in a seven year biomass rotation. Although growers would typically be seeding some fields each year, individual ownership of specialized equipment is not economic, if underutilized. Therefore, the seedbed preparation and the alfalfa seeding phase of production could be an attractive contracting opportunity.

**Crop Consultants**

Maintaining the quality of an alfalfa stand requires expertise in weed control, pest management, and soil fertility. Crop consultants may also be needed to advise growers of possible crop rotations, cutting schedules, and alfalfa varieties.

**Alfalfa Harvest**

The major labor and equipment requirement for alfalfa production occurs with the cutting and baling operations. Producers may choose to have private contractors come in to harvest their alfalfa. Custom contractors may be able to economically justify larger, more specialized equipment and maintain a labor force by contracting for full utilization of their equipment and moving from farm to farm.

**Alfalfa Transport from Field to Remote Site**

The transportation of alfalfa from the farm to remote storage areas may be most efficiently accomplished through the use of specialized bale handling equipment. Hauling bales from the field to remote storage sites is most cost effective as the number of bales hauled per load increases. Because most standard farm equipment is not geared to transporting several round bales at a time, there may be a market for contractors to handle/haul ten or more bales per load from the field to the remote storage area with specialized trucks or tractor-drawn equipment.

**Alfalfa Storage**

Although an alfalfa cooperative will most likely be involved in choosing appropriate sites for the remote storage areas, it is possible that these storage areas may be located on private lands and operated privately.

**Alfalfa Testing**

Quality of alfalfa will be a major factor in the economics of growing alfalfa. Laboratories will need to test the alfalfa and characterize the protein percentage as well as leaf and stem fractions. Growers will be paid based on the results of the testing. Testing laboratories may be owned privately or by an established alfalfa growers' cooperative.

**Alfalfa Transport from Remote Sites to the Processing Plant**

At maximum capacity, about 2500 tons per day of alfalfa will need to be transported from remote storage sites to the power plant or fractionation facility during 300 days of the year. This transportation may be done by the cooperative or by private trucking companies.

**6.1 Separation Process and Facilities and 6.2, Processing Costs.**

Pages 127-133 have been intentionally left blank. The information initially contained on these pages can be found in Volume 4, Site Considerations, Chapter 3, Processing and Chapter 4, Maintenance and Operating Costs. respectively.

# CHAPTER 6. PROCESSING

## 6.3 EXPERIMENTAL SEPARATION STUDY

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### Rationale

Studies of alfalfa development have demonstrated that the above ground biomass is predominately leaf material (58% leaf: 42% stem) at the pre-bud stage of growth, but that the leaf proportion declines with maturity to about 38% leaf: 62% stem at the early seed pod stage (Albrecht et al., 1987). Overall nutritional quality of the alfalfa plant for cattle feeding declines during this maturation process; however, this decline in feeding value is restricted to the stem portion of alfalfa. Fiber content increases and digestibility decreases for alfalfa stems from pre-bud through early pod development (34 to 51% and 75 to 52%, respectively) whereas leaf quality remains almost constant (18-19% fiber and 81-80% digestibility) during this same period (Albrecht et al., 1987). These data indicate that if alfalfa leaves can be effectively separated from stem material, regardless of the maturity stage of the alfalfa, a high quality animal feedstuff could be produced as a value added by-product from the biomass energy system.

Unlike research plot samples, field cured hay often suffers from leaf loss and reduction in protein content during the drying and baling operations of commercial farming. It was necessary to determine the leaf proportion and quality of the alfalfa leaves from typical hays to establish if constant feeding values of alfalfa leaf product can be expected from a commercial operation as have been observed under research conditions. An experimental separation and quality analysis of alfalfa hay was conducted to address this question.

**Protocol**

Alfalfa hay samples were collected from four commercial hay auctions (Sauk Center [2x], Houston county, and Goodhue county) held in Minnesota during December 1993 and January 1994. Hays sold at these auctions were produced throughout Minnesota, the Dakotas, and southern Canada. Hay is routinely sold at auction under six quality grades (prime and standards one, two, three, four, & five) determined by their relative feed value (RFV). Lots of hay are sampled upon arrival at auctions by taking core samples with a special drill. These samples are then analyzed for neutral and acid detergent fiber concentration by near-infrared reflectance spectroscopy (NIRS). The fiber values determined by NIRS are then used to calculate RFV for the hay lot. The alfalfa biomass project purchased one hay bale from each of 38 hay lots identified by the seller as being alfalfa hay. Hay lots sampled were nine prime, 12 standard one, nine standard two, six standard three and one each from standards four and five. These hay bales were small rectangular bales rather than the large round bales envisioned for the biomass energy system. It was not technically feasible for us to conduct the necessary separations of leaf and stem on large round bales. However, by sampling all the quality grades we have acquired data which is applicable to any hay package.

The sorting system employed was a combination of mechanical and hand separation. Three slugs (small rectangular bales are divided into slugs of hay by the plunger mechanism of the baler) were collected from each bale, roughly equally spaced along the bale's length. These hay slugs were then dried in a 100$^{o}$F oven over-night to aid separation. Dried hay slugs were initially beaten with a baseball bat to dislodge most of the leaf material. The coarse stems were then removed and weeds, mostly grasses, were also separated from the alfalfa. Based on their weed content, 11 of the hay samples were excluded from the following analyses as they were greater than 10% weeds. While some weediness can be expected in alfalfa hay, the principal investigators decided that questions of how weeds impacted the separation of alfalfa leaves and stems, and altered leaf meal quality, were beyond the scope of this feasibility study. The leaves and small pieces of broken stem remaining after the hand separation were then subjected to a mechanical sieving. The sieving mechanism was an oscillating screen separator developed by researchers to assess mean particle length of forage that has been chopped by silage choppers. There are five screens and a collection pan for the fines in this separator. The screen holes are square in shape and have nominal openings of 0.75, 0.50, 0.25, 0.156, and 0.046 inches. Screen thickness decreases from the largest screen size (0.50 in.) to the smallest (0.025 in.) to reduce passage of long, narrow particles through the screens. The leaf meal and small stem fragment samples from the bales were oscillated on this sieve for one minute. All screens and the pan contained three largest screens contained primarily stem material, which was added to the coarse stems collected during the hand separation. The two smallest screens and pan were identified as being the leaf fraction, with the pan being the most pure leaf meal. Leaf, stem and weed fractions were determined for each of the three slugs from each bale, corrected to a 100°C dry matter basis, and then subsampled for nutritional analysis. The three subsamples from each bale were composited prior to grinding to pass a 1-mm screen in a Wiley mill.

The hays were relatively dry as sampled (10.8% moisture) and easily separated after the minor additional drying. This additional drying may or may not be necessary in an industrial facility.

**Results**

Based on the analysis of fiber content of these hays, relative feed values (RFV) were recalculated and each hay bale was assigned to its appropriate quality grade. As expected, there was some shifting of hays from the originally assigned quality grade for the hay lot compared to the actual quality of the bale as sampled. The correlation between the hay lot quality grade and the actual bale quality grade was $r = 0.55$ ($P<0.01$). All subsequent discussion is based on these actual quality grades for the bales with the following representation among the grades: five prime bales, six standard one, six standard two, eight standard three, and two standard five (**Table 6.3-1**).

**Table 6.3-1** Proportions of leaf, stem and weeds in commercial alfalfa hay bales from five of the six common quality grades.

| Quality Grade | Number of Bales | Alfalfa | | |
|---|---|---|---|---|
| | | Leaf | Stem | Weeds |
| | | ------------ % dry matter ------------ | | |
| Prime | 5 | 60.5[a] | 36.8[a] | 2.6 |
| Standard One | 6 | 49.3[b] | 47.9[b] | 2.9 |
| Standard Two | 6 | 49.9[b] | 47.9[b] | 2.3 |
| Standard Three | 8 | 38.6[c] | 57.9[c] | 3.5 |
| Standard Four | | ------------ not sampled ------------ | | |
| Standard Five | 2 | 31.3[c] | 68.2[d] | 0.5 |
| Combined | 27 | 47.0 | 50.3 | 2.7 |

[abcd] Means in the same column not sharing a superscript differ ($P<0.05$).

**The hay quality grades largely reflect differences in proportions of leaf (Table 6.1-1). The highest quality hay had the largest proportion leaf, which declined markedly in the lower quality grades. Overall, the alfalfa hay contained 47.0% leaf, 50.3% stem and 2.7% weed. Based on these results, we conclude that the higher the quality grade of the hay provided to the biomass separation facility, the higher the expected yield of leaf meal.**

The reader is reminded that 11 of 38 alfalfa hay bales collected were excluded from the analysis because they contained greater than 10% weeds. **It must also be emphasized that the yield of leaf meal, and its subsequent nutrient content, is directly a function of the separation procedure employed.** The presence of leaves on the stem screens and stem fragments on the leaf screens have caused some undetermined bias in the results for leaf meal yield and quality. Compared to careful hand separation of research plot alfalfa samples, the leaf yields seem quite reasonable. But as reported in the nutritional analysis section 7.3, the presence of even small amounts of stem in the leaf meal results in significant reductions in leaf meal quality. **Actual leaf meal yield and quality depend directly on the effectiveness of the industrial separation procedure developed for the biomass energy system.**

# CHAPTER 7. PRODUCT CHARACTERISTICS

## 7.1 Electricity

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Quantity:

The biomass energy production system will produce 75 MW of electricity and is designed to operate at a capacity factor of 80% or higher. The electricity produced has access to the grid at the existing NSP power plant sub-station in Granite Falls. Significant sub-station upgrade is not anticipated to be necessary for this additional electric power output.

75 MW of electricity amounts to about 1% of NSP's current system capacity of approximately 7000 MWe. The proposed cost-shared demonstration of sustainable biomass energy production will result in a cost of electricity that is competitive with `new generation' power plants and may be accomplished at a much smaller scale. Smaller scale electric power production can benefit utilities by reducing the need for grid and capacity upgrades of their distribution systems and by stimulating economic development within their service territories. New business, new customers, and new technologies will help maintain a competitive edge for progressive power companies in an increasingly competitive marketplace.

Quality:

The proposed biomass electric power production system is designed to supply baseload power. Baseload power is the backbone of a power supply system. Baseload power systems are designed to operate at maximum efficiency on a nearly continuous basis. The proposed system has a design capacity factor of 80%. This means that this system would operate 80% of the time, day and night, year round.

Baseload power production systems are said to be dispatchable. Power production systems are dispatched relative to the cost of electricity (COE) that they are producing. This results in the lowest rates for utility customers and the highest marginal returns for the utility.

Cost of Electricity:

Many factors determine the overall COE including the capital cost of the power plant, the cost of fuel, and environmental considerations such as sulfur dioxide offset credits, potentially carbon dioxide offset credits and other real costs of electric power production. The COE for the proposed biomass power plant will likely be around 6.5 cents per kilowatt hour (kWh). See **Volume 3 - Business Plan** for details. This is comparable to todays average retail price of electricity in the Upper Midwest. Many regions of the country currently pay much higher retail rates, for example, over 10 cents on the east and west coasts.

The COE for this first of a kind biomass power plant may be higher than 2nd generation biomass power plants. However, 6.5 cents/kWh is a very reasonable cost for the demonstration of `new generation' renewable biomass electric production. The actual effect on consumer rates based on 75 MW of biomass power production in NSP's 7000 MW system would be about a 1% increase on the difference between NSP's average COE (around 3.5 cents/kWh) and the biomass COE of 6.5 cents/kWh (about 1% of 3 cents/kWh = 0.03 cents/kWh to the customer).

The benefits to Minnesota agriculture, our rural economy, our environment, and to NSP far outweigh an estimated increase of 0.03 cents/kWh on our electric bills. The real issue is not the COE but of the risk involved in a new venture. Carefull analysis of risk by the biomass producers and by the utility is the next step.

By-products:

The ash remaining after gasification of alfalfa is expected to returnable to the land and may have value as a soil ammendment or fertilizer. The character and value of this by-product of electricity production needs to be determined. Although the creation of a hazardous waste product like coal ash is not expected, thorough economic and environmental analysis cannot be made without more information on the compositon and plant availability of the ash. The following study has been designed to answer those questions.

# Ash By-product

## Characterization and Agronomic Use of Ash Generated from Alfalfa Biomass Gasification

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### Background and Rationale

Alfalfa biomass has been proposed to be used as feedstock material for the production of electrical power by gasification and combustion. Innovative combustion turbine technology designed for biomass has been developed by the Institute of Gas Technology (IGT) in Chicago. Unlike conventional combustion turbines that operate under oxidizing conditions, the unit developed by IGT operates under reducing conditions. Advantages of this technology include more efficient energy production and reduced air emissions. However, as with conventional combustion technology, an ash residue remains after the material is gasified. The characteristics of the ash are dependent on the material used and the conditions of combustion/gasification.

With limited landfill space, one of the major challenges in society today is to recycle or find beneficial uses of generated wastes. Sustainability of the alfalfa gasification process is partially dependent upon finding a suitable end use for the ash. An ultimate intent of using alfalfa biomass as an energy source is to apply the ash generated from the gasification process on land to recycle nutrients for crop production. Thus, a nearly complete nutrient cycle can be achieved.

Before land application of the ash can be made, physical and chemical properties of the ash need to be known. While numerous studies have been conducted evaluating the use of various ash products as soil amendments, there is no information related to ash that has been generated under reducing conditions. It is therefore impossible to extrapolate results from previous studies to predict whether beneficial or potentially harmful effects of alfalfa gasification ash might occur if applied to soil.

Physical characterization and mineralogical make up of the ash needs to be known so that estimates of weathering of the ash can be made. Information on mechanisms controlling the solubility of elements present in waste materials can be used to determine the long term behavior of both beneficial and potentially deleterious elements in the environment. If the solubility controlling mechanisms are known, informed management decisions can be made to maximize the benefits and minimize the problems resulting from waste product application to agricultural land. The effect of the ash on soil chemical properties and crop response needs to be known so that predictions can be made for appropriate rates to apply as well as frequency of application.

**Objectives**

1) Physically and chemically characterize the ash.

2) Model secondary solid formation and elemental solubilities in ash-amended soils.

3) Evaluate crop response to ash-amended soil in greenhouse experiments.

4) Determine effects of land application of ash on crop production and the environment.

**Expected Results**

From this research, an economic projection on the value ($/ton) of the ash based on nutrient availability and shipping costs will be made. Enough information will be obtained to develop best management practices for use of the ash in crop production.

## 7.2 Co-products

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Alfalfa leaves may be processed into many valuable products. Alfalfa leaf meal protein for cattle feed is the basic alfalfa leaf product focused on in this study. But just like we process corn and soybeans into many renewable products, we can process alfalfa leaves into many valuable renewable products. Other alfalfa leaf products currently being produced at some level include: alfalfa leaf pigments (xanthophylls), liquid protein products for human and animal consumption, fragrances for shampoos and cosmetics, and natural biological molecules for pharmaceuticals. Further investigation of these and other alternative products will proceed as a natural research and development activity of alfalfa biomass energy production.

Alfalfa has also been used extensively in research for the production of "secondary plant metabolites", essentially using the machinery of the plant to produce specific high value biological molecules, such as the enzymes needed for processing plant material into ethanol. Using plants as factories for the production of everything from plastics to pharmaceuticals is well underway. Renewable plant derived products may someday soon replace many synthetic and petroleum-derived fuels and feedstocks. The commercial production of secondary plant metabolites has been demonstrated, but not to my knowledge commercially in alfalfa, yet. This is an exciting area of research and development, but not something to build a business on. I include this here to allow speculation on how biomass energy production and agricultural processing may continue to be integrated in the future. The processing of high value plant products and biomass energy production can provide potent economic synergy, as demonstrated by alfalfa biomass energy production.

The production of only electricity from a biomass energy crop is not economically viable, has not been demonstrated, and is likely a wasteful use of renewable plant resources. Dedicated energy crops like alfalfa also provide other valuable feedstock resources. The 'best use' of biomass resources can and will result in sustainable biomass power production and improve the sustainability of current agricultural systems through the integration of energy and agricultural production. This concept may be adapted for many different agricultural cropping systems. 'Best use' of crop resources, not the singular use of crops for energy production, but an integrated approach that maximizes energy and co-product value.

# 7.3 Nutritional Characteristics

## Stem and Leaf Meal Nutritional Characteristics

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### Rationale

The economic value of the alfalfa leaf meal co-product will be a function of its nutritional characteristics. Ultimately, feeding value of a new feedstuff can only be accurately assessed through animal feeding trials. Because of the unavailability of an alfalfa leaf meal product in bulk at this time, and the short time frame for the current feasibility study, a number of laboratory measurements of nutrient content and value were utilized to provide an estimate of the nutritional value of the alfalfa leaf meal to livestock feeding. The alfalfa stem material was also analyzed to provide further information on its composition and to evaluate the efficiency of leaf-stem separation.

The primary objective of the analysis for leaf meal quality was to determine if leaf meal quality varies depending on the overall quality of the hay produced. As pointed out in section 6.3, alfalfa leaves do not change appreciably in quality with time while they are alive. However, it is uncertain if differences in leaf quality are generated during the harvesting, drying and storage phases of hay production. This portion of the study addresses this point using samples of commercial hays.

**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 7.3-1** Nutrient composition and digestibility of alfalfa leaves and stems.

| | Leaves | | |
|---|---|---|---|
| Component[1] | Total | Pan | Stems |
| 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 7.3-1** 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 7.3-2.** 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 7.3-2** Elemental composition of alfalfa leaves and stems.

| | Leaves | | |
|---|---|---|---|
| Element | Total | Pan | Stems |
| 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.**

# 7.4 Ration Formulation

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## Rationale

To determine an economic value for the leaf meal by-product in livestock feeding, this new feedstuff must be evaluated in typical diet formulations that will meet the nutritional requirements of the target livestock species and be acceptable to the producer. This is accomplished by formulating rations to meet the requirements of the animals and forcing the new feedstuff to compete with the typical ingredients available, and at realistic prices for those ingredients. We have taken this approach for dairy cattle feeding in the Upper Midwest.

While alfalfa leaf meal could be effectively fed to poultry and swine, consultation with experts for these species suggest that producer acceptance of this new feedstuff would be poor. The problem is primarily one of energy content. The moderate fiber concentration of the leaf meal reduces the energetic value of the feed for nonruminant livestock and, therefore, will slow their growth rate. Reductions in growth rate have serious economic repercussions. The requirement for supplemental protein for beef cattle feeding is relatively small. They could certainly utilize alfalfa leaf meal, but generally the lowest cost protein supplement is adequate. Non-protein nitrogen, such as urea, is often fed and is very inexpensive. As a result of this information we chose not to evaluate alfalfa leaf meal for species other than dairy cattle at this time.

## Protocol

Rations were formulated for dairy cows in early (90 lb of milk/day) and mid (60 lb of milk/day) lactation, as nutrient requirements differ substantially. The nutrient constraints included in the diet formulations are listed in **Table 7.4-1**. Feed ingredient combinations of formulated rations meet or exceed these constraints. High producing, early lactation cows require more feed, higher concentrations of protein, energy (net energy for lactation, $NE_L$), and minerals, and lower concentrations of fiber than do cows with lower levels of milk production. Feedstuffs available for inclusion in formulated rations are listed in **Table 7.4-2** and are typical of those currently utilized in the Upper Midwest. The average published nutrient content of the feed ingredients is shown. For alfalfa leaf meal we used the average composition based on all the samples we tested. The hay and haylage represent high protein, moderate energy forage sources while corn silage is a low protein, high energy forage. Corn and fat supplements are low protein, high energy feeds. Soybean meal is a high protein, high energy supplemental feedstuff, whereas cottonseed and distillers grains are moderate protein, high energy feeds. **Alfalfa leaf meal is a moderate protein, moderate energy feed with high levels of calcium.**

**Table 7.4-1** Nutrient constraints used in ration formulation.

**Ration Formulation Constraints**

| | Milk Production[1] | |
|---|---|---|
| Constraint | 60 lb/day | 90 lb/day |
| Dry matter intake, lb/day | 44 | 56 |
| Crude protein, % DM | 15.5 | 18.0 |
| Net energy for lactation, Mcal/lb | 0.72 | 0.79 |
| Acid detergent fiber, % DM | 20.0 | 18.0 |
| Neutral detergent fiber from forage, % DM | 22.0 | 19.5 |
| Calcium, % DM | 0.65 | 0.90 |
| Phosphorus, % DM | 0.38 | 0.45 |

[1] Formulated for a cow weighing 1350 lb and producing the indicated amount of milk with a 3.8% fat content.

Rations were formulated using the "Consulting Nutritionist" software package (Dalex Corp., Mound, MN). All feed prices were held constant except for corn and soybean meal. For these two feeds both the common high and low prices were used in calculating possible value of the alfalfa leaf meal. Possible inclusion rates of leaf meal were evaluated for high haylage vs. high corn silage diets. The potential price for alfalfa leaf meal was allowed to float in competition with the other feed ingredients. Rations were formulated to meet the nutrient constraints at the lowest possible total feed cost.

**Results**

All rations were forced to include 5 lb/cow/day of hay. While there is some debate as to whether hay is really required in a dairy cow diet, the inclusion of some hay is such an ingrained practice in the industry that we felt any realistic ration formulation must include some dry hay.

**Table 7.4-2** Feeds available for inclusion in the ration formulations and their price.

**Available Feeds**

| Feed | DM % | CP % | ADF % | Ca % | P % | $NE_L$ Mcal/lb | Price $/ton |
|---|---|---|---|---|---|---|---|
| Hay (prime) | 88 | 23.0 | 28.0 | 1.60 | 0.35 | 0.68 | 120.00 |
| Haylage (standard one) | 50 | 20.0 | 31.0 | 1.30 | 0.25 | 0.61 | 45.00 |
| Corn silage | 35 | 8.1 | 22.0 | 0.25 | 0.23 | 0.73 | 22.00 |
| Corn | 88 | 10.0 | 3.0 | 0.03 | 0.32 | 0.92 | 71.43 or 89.29 |
| Soybean meal | 90 | 50.0 | 10.0 | 0.41 | 0.72 | 0.84 | 160.00 or 200.00 |
| Distillers grains | 92 | 25.0 | 18.0 | 0.29 | 0.83 | 0.96 | 145.00 |
| Cottonseed | 92 | 24.0 | 26.0 | 0.17 | 0.54 | 1.02 | 180.00 |
| Fat | 99 | --- | --- | --- | --- | 2.65 | 360.00 |
| Ca-P mineral | 100 | --- | --- | 22.00 | 18.0 | --- | 360.00 |
| Ca-mineral | 100 | --- | --- | 36.00 | --- | --- | 80.00 |
| Vitamin-mineral premix | 100 | --- | --- | --- | --- | --- | 1200.00 |
| Salt | 100 | --- | --- | --- | --- | --- | 120.00 |
| Alfalfa leaf meal | 92 | 25.2 | 21.5 | 1.88 | 0.33 | 0.69 | Floating |

A major difference was found in the amount of alfalfa leaf meal that would be included in a ration for diets high in haylage vs. those high in corn silage (**Table 7.4-3**). **For cows producing 60 lb of milk/day, on a high haylage diet there would be no inclusion of alfalfa leaf meal because the major feed ingredients could supply all of the required protein. Because of the low protein content of corn silage compared to haylage, the high corn silage diet allowed up to 10.5 lb of alfalfa leaf meal in the daily ration when soybean meal is not an economical alternative protein source compared to leaf meal.**

A somewhat different picture is seen for the high producing cow where even on the high haylage diet some leaf meal would be included. This is because early lactation cows need more protein, but cannot consume as much hay and haylage because of their high energy requirements. **However, on the high corn silage diet less leaf meal was included than for the mid lactation cow. This is because of the only moderate energy content of the alfalfa leaf meal.** The other potential protein supplements would be included in the diets because they provide protein in combination with higher energy values.

**Table 7.4-3** Inclusion rates of alfalfa leaf meal in rations with different amounts of haylage or corn silage.

**Inclusion Rate for Leaf Meal in Rations**

| | Milk Production[1] | | | |
|---|---|---|---|---|
| Feed | 60 lb/day | | 90 lb/day | |
| | lb/cow/day | | | |
| Hay | 5.0 | 5.0 | 5.0 | 5.0 |
| Haylage | 40.0 | 14.1 | 29.3 | 12.5 |
| Corn silage | 15.0 | 42.4 | 15.0 | 40.0 |
| Corn | 15.7 | 8.5 | 19.7 | 13.6 |
| Fat | 0 | 0 | 0.3 | 0.4 |
| Mineral | 0.6 | 0.6 | 0.9 | 0.9 |
| Soybean meal | 0 | 0 | 3.1 | 4.3 |
| Cottonseed | 0 | 0 | 5.0 | 3.6 |
| Distillers grains | 0 | 0 | 3.1 | 4.3 |
| Alfalfa leaf meal | 0 | 10.5 | 3.2 | 7.6 |

[1] Formulated for a cow weighing 1350 lb and producing the indicated amount of milk with a 3.8% fat content.

**Table 7.4-4** shows the range in possible value of alfalfa leaf meal for dairy cattle. **The leaf meal could sell for as little as $93.88 for feeding to high producing cows when both corn and soybean meal are low in price and up to $108.84 when corn and soybean meal are expensive and the leaf meal is fed to mid lactation cows.** The prices shown are the maximum price that a farmer should consider paying for alfalfa leaf meal given the nutrient composition assumed in this study, the prices used for the other feed ingredients, and the cow's ability to utilize the nutrients in alternative feeds.

**Table 7.4-4** Economic value of alfalfa leaf meal in rations balanced for either 60 or 90 pounds of milk per day with variable corn and soybean meal prices.

**Leaf Meal Value ($/ton)**

| | Soybean meal, $/ton | 160.00 | 160.00 | 200.00 | 200.00 |
|---|---|---|---|---|---|
| Milk, lb/day | Corn, $/bushel | 2.00 | 2.50 | 2.00 | 2.50 |
| | | | ------------- $/ton ------------- | | |
| 60 | | 96.64 | 94.07 | 108.84 | 106.26 |
| 90 | | 93.88 | 95.18 | 102.87 | 104.17 |

The livestock industries have been open to incorporating nontraditional feeds into their animal rations if a few important requirements are satisfied. Acceptance of alfalfa leaf meal as a feedstuff by dairy producers will depend on year-round availability of the leaf meal, a large volume of this feedstuff, and a consistent leaf meal quality. The biomass energy project has the potential to satisfy these requirements.

All of the preceding is based on the nutrient content of the alfalfa leaf meal as determined in this study. As indicated earlier, our leaf meal was not pure and this contamination with stem material reduced its nutrient density. If we assumed that pure leaves were available through the separation facility, then the nutrient content of the leaf meal would be greater (CP=30%, $NE_L$=0.77 Mcal/lb). **To evaluate the potential impact of a more efficient leaf/stem separation, we reformulated the high producing dairy cow rations using the pure leaf nutrient values. Under this scenario the value of the alfalfa leaf meal increased from $93.88 to $106.40/ton under cheap corn and soybean meal prices, and increased from $104.17 to $123.36/ton under the high corn and soybean meal price case.** These results indicate very clearly the great importance of developing an effective separation system for the alfalfa biomass if maximum economic value of the leaf by-product is to be realized.

**It must be emphasized that the alfalfa leaf meal is not a hay product and cannot replace hay in the diet of cattle.** Hay has value for its fiber effect or "scratch factor" which is needed to maintain proper rumen function and animal health. Long hay particles are needed to achieve this fiber effect. The alfalfa leaf meal may have adequate fiber content for a hay substitute, but its particle size is much too small to have an effective fiber effect on rumen function.

# 7.5 Bypass Protein Enhancement

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**Rationale**

The preceding ration formulation was based on total protein content of the feedstuffs and animal requirements for protein concentration. This is the most common manner in which rations are currently formulated; however, many of the larger and more productive dairy herds are now also considering protein digestibility characteristics of their feeds in formulating diets. There are two primary concerns with protein digestibility of feeds for dairy cattle. First, for some feeds such as alfalfa haylage, too much of the protein is digested in the rumen by the microorganisms residing there. The result is that too little intact feed protein is available for intestinal digestion and absorption. Feeding of protein sources with reduced ruminal digestion has shown increased milk production because the amino acid requirements of the cow are more completely satisfied. These proteins are often referred to as bypass proteins because their low ruminal digestibility. The second concern about protein digestibility relates to these bypass proteins. Some proteins are so effectively protected from digestion that they not only bypass ruminal digestion, but are also not digested in the small intestine. This results in a wastage of protein and added feed costs.

Numerous chemical treatments, including use of compounds such as formaldehyde, have been used to increase the bypass protein value of alfalfa. However, these chemical treatments often raise questions of safety and environmental pollution. There is one report of heat treatment of alfalfa hay to increase protein bypass (Yang et al., 1993). These workers reported that heat treatment significantly decreased ruminal protein digestibility in an *in vitro* system. Steam heating of the hay increased the bypass value more quickly than dry heat, but a large amount of heat damaged (ADIN), and presumably unavailable, protein was formed by extended heat treatment. A companion animal study (Broderick et al., 1993) found an improvement in protein utilization after steam heating of alfalfa, but a decline in energy availability from the hay. However, the degree of reduction in ruminal degradability of this heat treated hay was insufficient to convert it into a bypass protein feedstuff.

Because the combined-cycle power generation system planned for this alfalfa biomass energy system would have some waste heat available after electricity generation, the research team decided to evaluate the potential of using heat to increase the protein bypass value of the alfalfa leaf meal to increase its nutritional and economic value. The pan fraction of the leaf meal was chosen for heat treatment, as a bypass protein source should have not only a low ruminal protein digestibility, but also a high protein concentration.

**Protocol**

A composite sample of alfalfa leaf meal was made from the hay bales sampled and separated. This hay was heated in a forced air oven for 0, 15, 30, 60 or 120 minutes at 150°C. This temperature was chosen, as it is the approximate temperature of the waste heat stream available from the steam turbine generator. The treatments were done on three separate batches of leaf meal to allow statistical evaluation of the effectiveness of the treatment. The control (0 minutes heating) and treated leaf meal samples were evaluated for unavailable protein (ADIN), soluble protein content, ruminal rate and extent of digestion using nylon bags suspended in the rumen of a dairy cow, and *in vitro* intestinal protein digestion of the residual protein after ruminal incubation. From these measurements intestinally absorbable dietary protein and total tract unavailable protein were calculated.

**Results**

As expected, heating of the alfalfa leaf meal increased the proportion of the protein which was heat damaged and unavailable for digestion (**Table 5.3-1**). The soluble protein also declined as a result. Ruminal protein digestibility was reduced from 64.9% in the control to 53.5% after 120 minutes of heating. Rate of protein digestion was only reduced at the longest treatment time. Most of the increase in the amount of protein that bypassed ruminal digestion was protein that was available for intestinal digestion, as shown in the increased intestinal protein digestibility. The net result was an increase in intestinally available dietary protein after heat treatment. There was no increase in protein wastage as total tract unavailable protein proportion did not change due to treatment.

**Our results, plus those published previously (Broderick et al., 1993; Yang et al., 1993), indicate that alfalfa leaf protein can be partially protected from ruminal digestion. However, this decrease in protein digestibility was insufficient to qualify the alfalfa leaf meal as a bypass protein feedstuff.** Generally, the ruminal digestibility of bypass proteins is 40% or less. The alfalfa leaf meal only declined to a ruminal digestibility of 53.5% after extended heat treatment. This is very similar to the approximately 50% ruminal digestibility of the alfalfa hay treated with dry heat or steam. Modification of the heat treatment or addition of some chemical treatment will apparently be necessary for leaf meal to be converted to a bypass protein feed.

**Table 7.5-1** Effect of heat treatment of alfalfa leaf meal (pan fraction) on ruminal and intestinal protein digestibility.

**Results of Heat Treatment**

| | Time of Heat Treatment (minutes) | | | | |
|---|---|---|---|---|---|
| Trait[1] | 0 | 15 | 30 | 60 | 120 |
| ADIN, % CP | 3.8[a] | 3.3[a] | 5.1[ab] | 6.7[b] | 15.1[c] |
| Soluble protein, % CP | 25.3[a] | 22.0[b] | 21.0[b] | 19.1b[c] | 17.6[c] |
| Ruminal Digestion | | | | | |
| Rate, %/hour | 6.9[a] | 7.0[a] | 6.8[a] | 6.2[a] | 4.6[b] |
| Extent, % | 64.9[a] | 64.0[a] | 62.7[ab] | 60.1[b] | 53.5[b] |
| Intestinal Digestion | | | | | |
| Extent, % | 48.4[a] | 50.2[ab] | 54.7[bc] | 58.9[cd] | 60.8[d] |
| IADP, % CP | 16.9[a] | 18.0[ab] | 20.4[b] | 23.5[c] | 28.3[d] |
| TTUP, % CP | 18.2 | 18.0 | 16.9 | 16.3 | 18.2 |

[1] Intestinally absorbable dietary protein (IADP), total tract unavailable protein (TTUP).
[abcd] Means in the same row not sharing a superscript differ (P<0.05).

While we were unable to convert the alfalfa leaf meal to a bypass protein source with the heat treatment utilized, it was decided to evaluate the economic value of such a product if it could be developed. A diet was formulated using $2.50/bushel corn and $200/ton soybean meal for a cow producing 90 lb of milk/day. Blood meal at $450/ton was included as a competing high protein, high bypass feed (30% ruminal digestibility) in a diet formulated to contain 37.5% undegradable intake protein. The alfalfa leaf meal was assumed to have a ruminal protein digestibility of 40% in this scenario. Rations were formulated for the 25.2% CP leaf meal we found in our separation study and for the pure leaf meal (30% CP). **Under these conditions the alfalfa leaf meal would increase from $104.17 to $165.56/ton for the low protein leaf meal, and from $123.36 to $187.39/ton for the high protein leaf meal.**

**The reader is warned that these economic values for treated alfalfa leaf meal based on ration formulation for bypass protein may be over-estimates.** While the theoretical basis for the importance of bypass protein is well established in dairy cattle nutrition, there is still some concern with how well we have characterized the actual bypass protein requirement of dairy cattle and how accurate our laboratory methods are at evaluating protein bypass. Formulating rations on bypass protein requirements in addition to those of basic protein, energy and fiber concentrations often leads to unrealistic feeding programs in terms of cost and practicality. **Our suggestion is that the increased value of a bypass alfalfa protein leaf meal product might best be estimated as half of the observed increase derived in this formulation exercise.** Whether the costs of converting leaf meal to a bypass protein feedstuff prove economic is unknown at this time.

## 7.6 Future Nutritional Evaluation and Products

There are several additional nutritional evaluations that will need to be done before an alfalfa leaf meal product can be released to the marketplace with expectations of achieving maximal prices. Prior to the initiation of such studies, it is absolutely imperative that the leaf/stem separation technology be developed and standardized. There is little, if any, point to conducting further nutritional evaluation with anything other than the actual leaf meal that can be produced in bulk by the biomass energy system. Otherwise, all the evaluation may need to be re-done if the leaf meal product changes after construction of the biomass power plant.

While laboratory analyses such as those done for this feasibility study are useful and necessary, farmer acceptance of the leaf meal product will require actual animal performance data. Several lactation trials will need to be done utilizing a number of different mixes of feed ingredients. Producers will want to know how readily the leaf meal is consumed by cattle, how much milk the cows produce in comparison to control diets containing standard protein supplements such as soybean meal, and whether the usefulness of the leaf meal is limited to certain dietary conditions. To conduct a dairy trial will require approximately 20 cows per treatment, with a control treatment and then replacement treatments of the protein supplement with 1/3, 2/3 and 100% alfalfa leaf meal, as an example. These cows would need to start the trial in early lactation and be on trial for a minimum of 60 days. Such a trial would involve an expenditure of about $20,000 (80 cows x 60 days x $4/d), using the University of Minnesota herd as an example. As indicated earlier, several such trials would be needed to establish credibility with producers and to insure that resulting feeding recommendations are valid.

Further work on identifying a treatment for producing a bypass protein form of alfalfa leaf meal should receive attention because of the opportunity to add significantly to the economic value of the leaf meal. There are numerous avenues to explore with regard to heating (temperature, time, form, etc.) as well as the addition of chemicals such as formic acid, ethanol, etc. There was insufficient time to pursue this topic in depth in the current study. We expect there are several avenues for producing a viable bypass protein. A major question will be which of these is economically attractive.

Opportunities should be explored for combining the alfalfa leaf meal with other products to increase its value. One possibility would be to add whey, a waste product of the cheese industry, to increase the energy content of the final product. The final product of a combination with whey would probably also have a caramel type color and taste which is relished by cattle. In handling the leaf meal, using soybean oil or molasses would reduce dust and at the same time add energy to the product. If the leaf meal could be converted to a bypass protein source, then a combination with a corn-based bypass feed like distillers grains may be worthwhile to provide a better amino acid profile in the total bypass protein. Any of these combination products would need some nutritional evaluation, both laboratory and animal feeding.

Looking beyond the dairy industry, if the energy and/or protein concentration of an alfalfa leaf meal based product could be increased, then the poultry and swine industries may provide a further outlet for this product. Obviously nutritional testing would be needed. The equine feeding market should be a potential industry that could use significant amounts of leaf meal. For this market, development of complete feeds or combined energy and protein supplements would be needed. Unlike the food animal industries where many producers buy ingredients and mix their own diets, horse owners rely more heavily on premixed diets. Based on the nutrient content of alfalfa leaf meal, it could be used in the dog food industry. However, for this species animal trials to evaluate acceptability are critical. Vegetable proteins are often excluded from dog food because of taste and aroma problems that make the feeds unpalatable to dogs, or the presence of fermentable oligosaccharides cause flatus problems that make the feeds unacceptable to owners. These characteristics of feedstuffs can only be evaluated in animal trials.

Finally, the biomass energy system should consider production of high quality (prime or standard one) hay as a product. The ability to remove a portion of the stem material from poor quality hay would allow the production of high quality, high value hay from almost any quality hay delivered to the biomass project. Such a product would be of value for dairy and beef throughout the U.S. and could also be exported to regions of the world deficient in high quality forage such as Asia. Such a product would reduce the quantity of stem material available from the biomass and, therefore, the tonnage of alfalfa produced would need to increase dramatically to insure the power plant's needs would be fulfilled.

# CHAPTER 8. MARKET ANALYSIS

## 8.1 Electricity

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### Demand

NSP anticipates a need for additional peaking power[a] in 1996, additional intermediate power[b] by 2001, and 500 MW of baseload[c] power by the year 2005. Additional biomass energy baseload power on-line by the year 2000 would obviate the need for a portion of the peaking and intermediate power requirements scheduled in that timeframe. **Table 8.1-1** below shows NSP's projected electric power needs in the near future.

**Table 8.1-1** NSP's projected electric power needs by resource type from 1996 to 2008.

**Schedule of Expected Electricity Needs**

| Year | Resource Type | Nominal Amount (MW) |
|---|---|---|
| **1996** | **[a]Peaking** | **125** |
| 1999 | Peaking | 125 |
| 2000 | Peaking | 125 |
| **2001** | **[b]Intermediate** | **200** |
| 2002 | Intermediate | 200 |
| 2003 | Peaking | 125 |
| 2004 | Peaking[1] | 125 |
| 2004 | Intermediate[2] | 200 |
| **2005** | **[c]Baseload** | **500** |
| 2008 | Baseload[3] | 500 |

[1]Total NSP peaking power requirements are 625 MW through the year 2004.
[2]Total NSP intermediate power requirements are 600 MW through 2004.
[3]Total NSP baseload power needs are anticipated at 1000 MW by the year 2008.
Source: Documents filed with the Public Utilities Commission by NSP.

**Marketing**

In a joint venture between a producers cooperative and NSP the marketing of electricity may likely be the responsibility of NSP. Certain advantages for the production of renewable baseload power would likely figure in the marketing and public relations strategy for the joint venture.

Other marketing opportunities exist within marketing pools that dispatch electric power generated in the Midwest and potentially with Rural Electric Cooperatives or Municipal Utilities in the region. Independent electricity marketing may also be undertaken by forming marketing alliances with other renewable energy producers.

PURPA Legislation

This federal legislation requires that public utilities purchase electricity from independent power producers at a price that is described as the avoided cost for comparable power generation. A question arises as to whether a difference exists between renewable avoided cost and the avoided cost for conventional power production systems and whether the avoided cost should be based on current systems or 'new generation' systems. This question will likely require resolution before the Public Utilities Commission.

The best case marketing scenario may well be established as the result of a long-term joint venture with NSP. NSP's expertise in the electric power generation and distribution business would certainly be a major asset to the joint venture.

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The following two pages contain excerpts from

INVESTING IN THE FUTURE, A Regulators Guide to Renewables
by Dr. Jan Hamrin and Nancy Rader,
published by National Association of Regulatory Utility Commissioners,
February 1993.

**Summary Observations**

The main lessons learned from assessing renewable resource development in all 50 states and specific programs in 26 states are:

- **State utility regulatory policy is critically important** to renewable energy development.

- To the extent that **renewable resource attributes are undervalued** in utility resource planning, **more costly non-renewable resources will be selected.**

- **The full value[1] of renewable resource investments** is not presently recognized in many resource planning and acquisition processes.

- **Individual renewable resource technologies should be examined and evaluated separately** in order to design effective programs.

- Most **competitive bidding programs** have not been designed in a manner that allows renewable technologies to successfully compete.

- Renewable resources developed under different **industry structure and ownership patterns** will have different ratepayer impacts which will also differ by technology.

- Unlike fossil and nuclear technologies, many renewable technologies have **geographic-specific research, development & demonstration (RD&D) and commercialization issues** which must be addressed before sustainable development can occur.

- Though **local RD&D and commercialization activities** are of critical importance to the sustainable development of many renewable technologies, **few states or utilities have planned for or funded** such activities.

- As the **electric utility industry changes**, renewable resource technologies offer attractive options for diversifying the energy services a utility can offer.

**State utility regulatory policy is critically important to renewable resource development.** Regardless of federal rules, regulations and policies, it is at the state level where the "rubber meets the road." Though all 50 states were under the same federal regulations and policies (i.e., the Public Utility Regulatory Policies Act, PURPA, which was designed, in part, to encourage greater use of conservation and renewables) and all 50 states have renewable resources, only a few states have successfully moved forward with the development of their renewable energy resource base. For those states, specific utility regulatory policy was the important link to success.

There are certain elements of utility planning and acquisition programs that are essential to the proper assessment of all resources that states should employ whether or not they have a specific interest in promoting renewables. Beyond that, there are various strategic programs that states interested in accelerating renewables development can pursue. There is no single "correct" strategy—the path to follow depends on the characteristics of a state's need for power and its renewable resource base, as well as its resource planning goals—different goals will lead to quite different programs.

Strategies for accelerating renewables fit within the regulatory framework for sound resource planning and acquisition, but further develop the framework in key areas. These strategies are not mutually exclusive, and, by combining strategy "building blocks," appropriate pathways can be created for different situations.

The strategies outlined in this report draw on the policies and programs that have been successfully implemented in the states that lead in renewables development. Also drawn on are programs that are currently being developed to encourage renewables and that appear to appropriately address identified barriers or issues. The basic strategies for accelerating renewables, which overlap and interconnect in some cases, include:

- **Use of appropriate planning tools**
- **Environmental compliance and risk avoidance**
- **Resolution of transmission issues**
- **Appropriate acquisition programs**
- **Local RD&D/commercialization programs**
- **Resource assessment/confirmation activities**
- **Identification of cost-effective end-use, niche, and utility applications**
- **Regulatory treatment appropriate to utility structure**

Numerous sample pathways are developed that can be pursued by states interested in adding renewable energy technologies to their electric resource base. The program elements to include and emphasize—elements from both the regulatory framework and strategy sections—should be selected on the basis of the timing of a state's need for power, its renewable resource base, and its resource planning goals. Individual states must therefore conduct an accounting of their own situation in these areas and create a suitable pathway designed to meet specific goals.

**Conclusion**

All states, even those that are relatively advanced in the development of renewables for electric generation, could employ strategies to more effectively incorporate the attributes of renewable resources into planning and acquisition methodologies, plan for the sustained development of renewables, and further their integration into the utility system. Utility regulatory policies are the key to advancing these resources, which can bring substantial benefits to ratepayers in the near future and over the long term.

## 8.2 Leaf Meal Markets

# Alfalfa Leaf Meal Market Research Report

**Alfalfa Production and Supply: A Marketing Perspective**

Su Ye, Principal Researcher,
Minnesota Department of Agriculture

**Introduction**

As the 5th largest alfalfa producer in the U.S., Minnesota harvested 4.8 million tons of alfalfa hay from 1.6 million acres in 1993. The four top producing states, California, South Dakota, Wisconsin, and Michigan, produced 6.4 million tons, 6.0 million tons, 5.1 million tons, and 5.0 million tons, respectively.

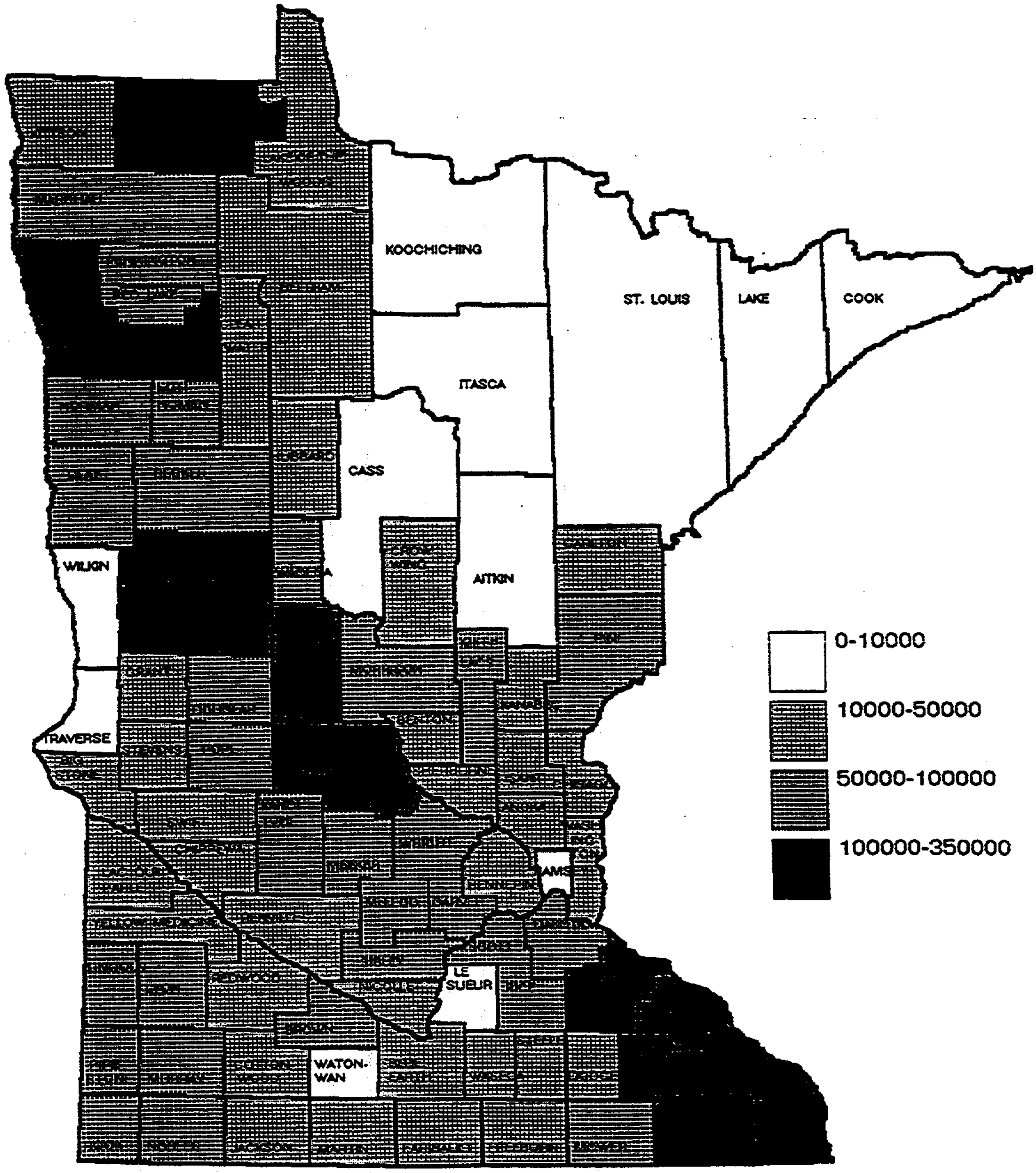
From 1974 to 1993, Minnesota's alfalfa production ranged from 7.6 million tons (1986) to 4.4 million tons (1989). Production acreage ranged from 2.4 million acres (1988) to 1.5 million acres (1992). The highest average yield during the same period was 3.9 tons per acre (1986), while the lowest was 1.9 tons per acre (1988). In an average year, however, Minnesota produces approximately 6 million tons of alfalfa hay, or 7% of the U.S. total production, from 1.9 million acres of land. The average yield is 3.1 tons per acre. The two biggest alfalfa-producing regions in the state are central and southeastern Minnesota, where nearly one-half of Minnesota's alfalfa hay is produced. Over 80% of Minnesota's alfalfa production is consumed on-farm, and the rest is sold commercially in Minnesota or elsewhere. Minnesota alfalfa growers receive about $76 per ton for their alfalfa hay (10-year average from 1984-1993), less than the national average of $79 per ton.

In Minnesota's alfalfa hay market, inter-state trading has increased during the last few years. Minnesota both imports and exports alfalfa hay. The volume of imports and exports vary from year to year, depending on alfalfa crop conditions, supply and demand in Minnesota and the surrounding states.

The following tables, figures and illustrations reflect Minnesota alfalfa production, acreage, yield, and price trends. National production and price data are also included.

**Illustration 8.2-1** Minnesota alfalfa production (1992) by county (in tons).

**Minnesota Alfalfa Production by County (1992)**
*(Tons)*




*Source: Minnesota Agriculture Statistics; Market Development & Promotion Division, Minnesota Department of Agriculture.*

**Table 8.2-1** Minnesota alfalfa production, acreage, and yield (1974-1993).

**Minnesota Alfalfa Production, Acreage, and Yield (1974-1993)**

| Year | Acres | Yield | Production | % of U.S. Total |
|---|---|---|---|---|
| | *1,000 Acres* | *Tons/Acre* | *1,000 tons* | *%* |
| 1974 | 2,080 | 2.85 | 5,928 | 7.97% |
| 1975 | 2,200 | 2.95 | 6,490 | 8.30% |
| 1976 | 2,190 | 2.10 | 4,599 | 6.57% |
| 1977 | 2,200 | 3.10 | 6,820 | 8.44% |
| 1978 | 2,140 | 3.40 | 7,276 | 8.34% |
| 1979 | 2,150 | 3.40 | 7,310 | 8.30% |
| 1980 | 2,100 | 2.70 | 5,670 | 7.09% |
| 1981 | 2,000 | 3.20 | 6,400 | 7.65% |
| 1982 | 1,950 | 3.20 | 6,240 | 7.06% |
| 1983 | 1,900 | 3.30 | 6,270 | 7.62% |
| 1984 | 1,900 | 3.40 | 6,460 | 7.17% |
| 1985 | 1,825 | 3.30 | 6,023 | 7.08% |
| 1986 | 1,950 | 3.90 | 7,605 | 8.28% |
| 1987 | 1,700 | 3.50 | 5,950 | 7.06% |
| 1988 | 2,400 | 1.90 | 4,560 | 6.58% |
| 1989 | 1,700 | 2.60 | 4,420 | 5.71% |
| 1990 | 1,600 | 3.20 | 5,120 | 6.13% |
| 1991 | 1,700 | 3.70 | 6,290 | 7.51% |
| 1992 | 1,500 | 3.50 | 5,250 | 6.59% |
| 1993 | 1,600 | 3.00 | 4,800 | 5.93% |
| **Average** | **1,939** | **3.11** | **5,974** | **7.27%** |

*Source: Minnesota Agriculture statistics; USDA, NASS.*

**Figure 8.2-1** Minnesota alfalfa production and acreage (1974-1993).

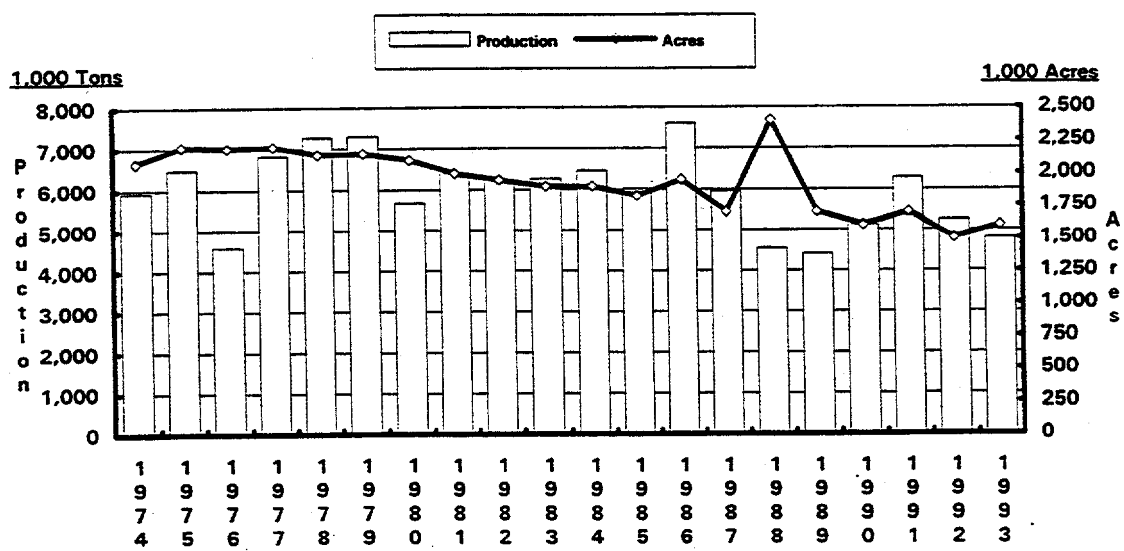


**Figure 8.2-2** Minnesota alfalfa production by region.

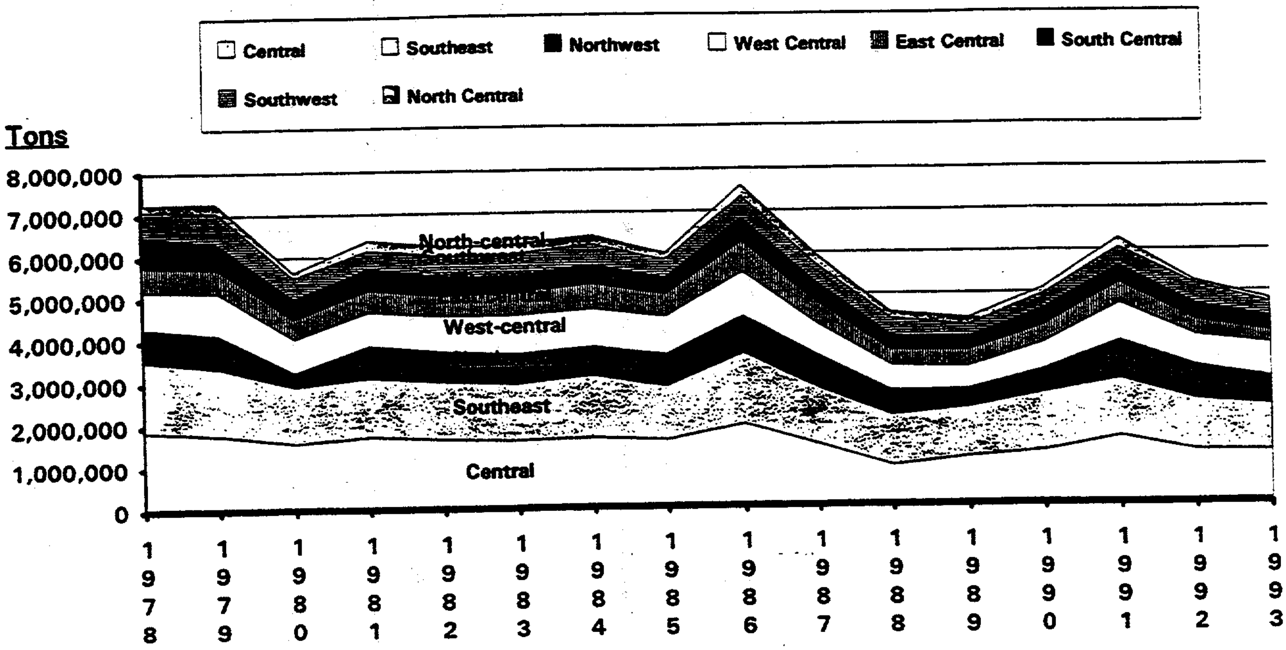
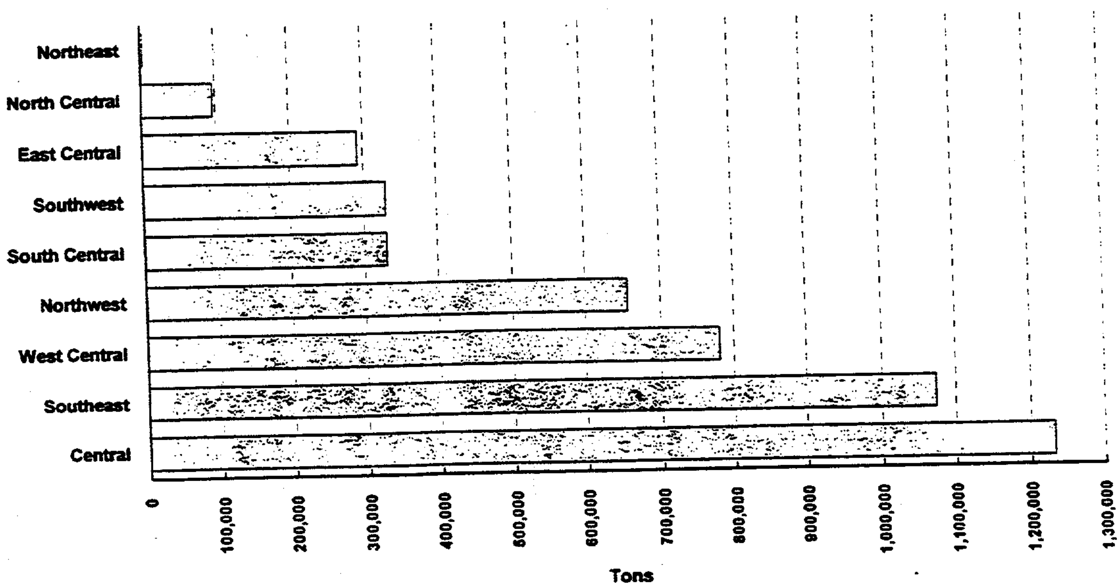



**Figure 8.2-3** Alfalfa production ranking by region (1993).




*Source: Minnesota Agriculture Statistics.*

**Table 8.2-2** Minnesota alfalfa hay prices from 1974 to 1994. Note: alfalfa hay prices are based on the value of small square bales.

**Minnesota Alfalfa Hay Prices**

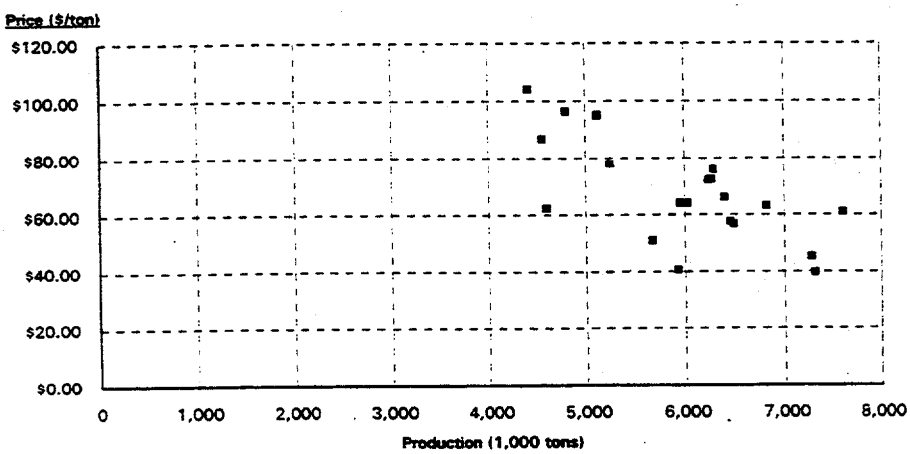
*(Baled, $/ton)*

| Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 32.50 | 38.00 | 37.00 | 37.00 | 36.00 | 35.00 | 37.00 | 46.00 | 46.00 | 48.00 | 46.00 | 50.00 | 40.71 |
| 1975 | 51.50 | 54.00 | 56.00 | 67.50 | 75.00 | 56.00 | 50.50 | 55.00 | 52.50 | 54.50 | 53.50 | 54.50 | 56.71 |
| 1976 | 53.50 | 55.00 | 51.50 | 46.00 | 46.00 | 73.00 | 66.00 | 64.00 | 68.50 | 72.00 | 74.00 | 78.50 | 62.33 |
| 1977 | 80.00 | 80.00 | 84.00 | 79.50 | 74.00 | 62.00 | 58.00 | 52.50 | 45.00 | 47.00 | 49.00 | 46.50 | 63.13 |
| 1978 | 45.00 | 46.00 | 45.00 | 45.50 | 50.00 | 44.50 | 47.00 | 47.00 | 45.50 | 41.50 | 43.50 | 43.50 | 45.33 |
| 1979 | 42.00 | 42.00 | 42.00 | 43.00 | 44.50 | 36.00 | 37.00 | 34.50 | 36.50 | 38.50 | 40.50 | 40.50 | 39.75 |
| 1980 | 38.00 | 39.00 | 37.00 | 38.00 | 41.50 | 52.00 | 47.00 | 59.00 | 68.00 | 62.00 | 68.00 | 62.00 | 50.96 |
| 1981 | 64.00 | 60.00 | 54.00 | 60.00 | 58.00 | 65.00 | 63.00 | 66.00 | 71.00 | 70.00 | 74.00 | 87.00 | 66.00 |
| 1982 | 76.00 | 85.00 | 80.00 | 74.00 | 80.00 | 70.00 | 58.00 | 64.00 | 60.00 | 66.00 | 77.00 | 80.00 | 72.50 |
| 1983 | 80.00 | 76.00 | 75.00 | 80.00 | 81.00 | 68.00 | 63.00 | 69.00 | 70.00 | 70.00 | 80.00 | 62.00 | 72.83 |
| 1984 | 59.00 | 68.00 | 54.00 | 71.00 | 64.00 | 53.00 | 45.00 | 51.00 | 48.00 | 59.00 | 50.00 | 70.00 | 57.67 |
| 1985 | 60.00 | 61.00 | 58.00 | 51.00 | 60.00 | 60.00 | 72.00 | 74.00 | 67.00 | 67.00 | 67.00 | 71.00 | 64.00 |
| 1986 | 74.00 | 75.00 | 79.00 | 77.00 | 72.00 | 48.00 | 50.00 | 45.00 | 43.00 | 56.00 | 55.00 | 58.00 | 61.00 |
| 1987 | 62.00 | 56.00 | 60.00 | 60.00 | 62.00 | 62.00 | 67.00 | 69.00 | 67.00 | 69.00 | 67.00 | 67.00 | 64.00 |
| 1988 | 65.00 | 70.00 | 66.00 | 74.00 | 70.00 | 72.00 | 98.00 | 111.00 | 112.00 | 106.00 | 100.00 | 100.00 | 87.00 |
| 1989 | 106.00 | 118.00 | 123.00 | 128.00 | 124.00 | 112.00 | 95.00 | 87.00 | 90.00 | 86.00 | 87.00 | 94.00 | 104.17 |
| 1990 | 95.00 | 101.00 | 102.00 | 101.00 | 103.00 | 106.00 | 97.00 | 89.00 | 88.00 | 84.00 | 85.00 | 90.00 | 95.08 |
| 1991 | 90.00 | 89.00 | 85.00 | 85.00 | 82.00 | 63.00 | 68.00 | 67.00 | 68.00 | 73.00 | 71.00 | 71.00 | 76.00 |
| 1992 | 72.00 | 74.00 | 71.00 | 74.00 | 81.00 | 81.00 | 83.00 | 79.00 | 78.00 | 75.00 | 83.00 | 86.00 | 78.08 |
| 1993 | 91.00 | 93.00 | 95.00 | 97.00 | 95.00 | 92.00 | 88.00 | 100.00 | 101.00 | 98.00 | 98.00 | 110.00 | 96.50 |
| 1994 | 104.00 | 110.00 | 109.00 | | | | | | | | | | |

*Source: Minnesota Agriculture Statistics.*

**Figure 8.2-4** Statistical correlation between alfalfa production and alfalfa price (1974-1993).

**Correlation: Alfalfa Production & Price (1974-1993)**




*Source: Market Development and Promotion Division, Minnesota Department of Agriculture.*

Minnesota's alfalfa hay prices are generally lower than the national average. During the past 10 years, alfalfa prices in Minnesota averaged $76.6 per ton, compared to $78.9 per ton national average. However, from 1989 to 1993, higher prices of alfalfa were recorded in Minnesota, as shown in **Table 8.2-3**. This is due to several reasons: drought and subsequent hay shortage caused by lower carry-over and supply, and flood in 1993.

**Table 8.2-3** Minnesota and U.S. alfalfa prices (1984-1993). Note: alfalfa hay prices are based on the value of small square bales.

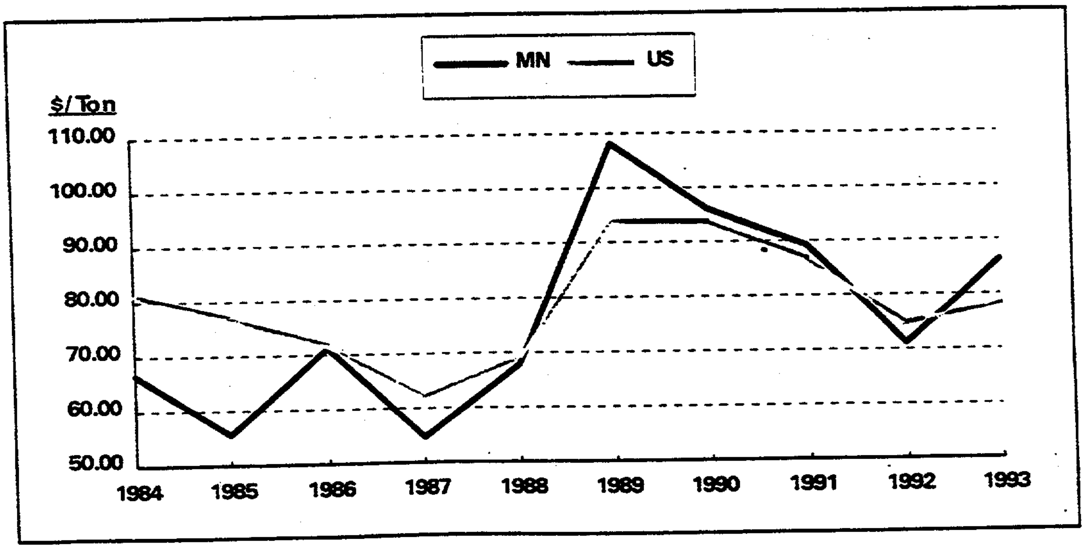
**Minnesota and U.S. Alfalfa Prices, 10-Year Trend**

$/Ton

| Year | MN | US |
|---|---|---|
| 1984 | 66.50 | 81.33 |
| 1985 | 55.50 | 76.93 |
| 1986 | 71.25 | 71.85 |
| 1987 | 54.58 | 61.92 |
| 1988 | 67.75 | 69.31 |
| 1989 | 108.17 | 93.83 |
| 1990 | 96.08 | 93.80 |
| 1991 | 89.17 | 86.60 |
| 1992 | 71.08 | 74.60 |
| 1993 | 86.33 | 78.40 |
| 84-93 Ave. | 76.64 | 78.86 |

*Source: USDA, NASS.*

**Figure 8.2-5** Alfalfa price trend (Minnesota and U.S.) from 1984-1993.

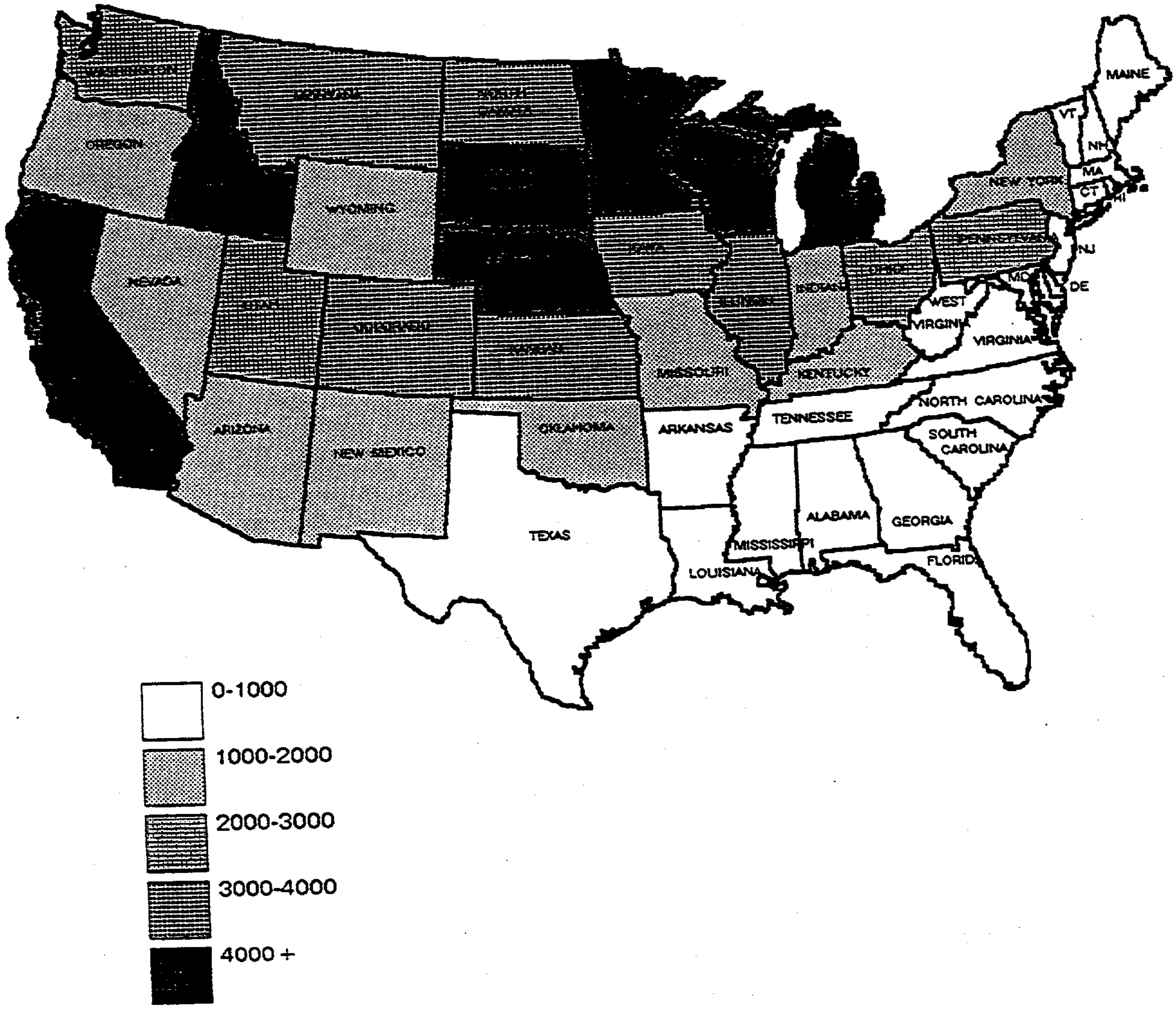



*Source: Minnesota Agriculture Statistics and USD*

**Illustration 8.2-2** Alfalfa production in the U.S (1993) in 1,000's of tons.

**Alfalfa Production in the U.S. (1993)**

*(1,000 Tons)*




*Source: USDA.*

**Table 8.2-4** Total production from the top ten alfalfa producing states (1974-1993).

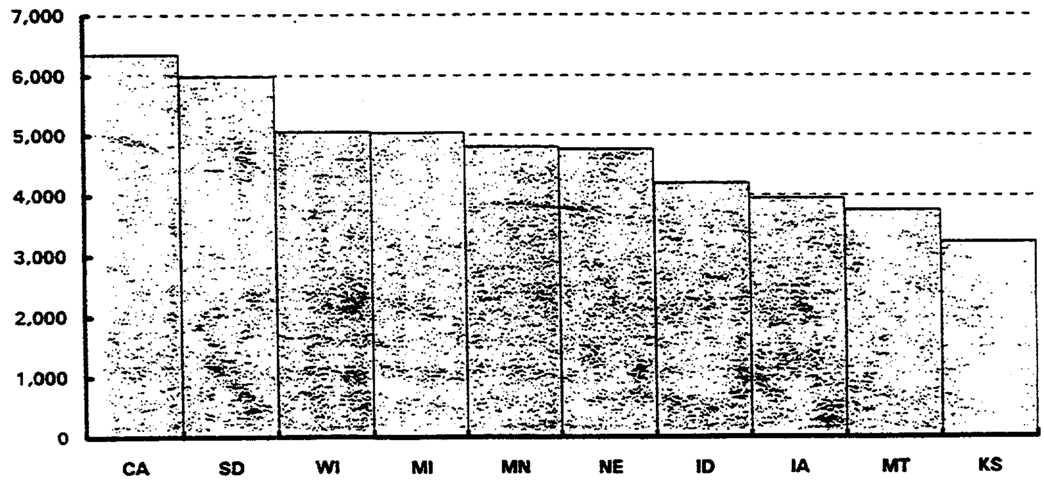
**Production History of Top 10 Alfalfa Producing States in the U.S. (1974-1993)**

*1,000 tons*

| Year | CA | SD | WI | MI | MN | NE | ID | IA | MT | KS |
|---|---|---|---|---|---|---|---|---|---|---|
| **1974 Ranking** | 2 | 7 | 1 | 10 | 3 | 5 | 6 | 4 | 9 | 8 |
| 1974 | 6,785 | 3,389 | 8,700 | 2,450 | 5,928 | 4,335 | 3,885 | 5,430 | 2,623 | 2,729 |
| 1975 | 6,608 | 3,900 | 8,607 | 2,750 | 6,490 | 4,590 | 3,811 | 5,429 | 2,829 | 2,793 |
| 1976 | 6,600 | 1,840 | 6,622 | 2,548 | 4,599 | 4,125 | 3,621 | 5,246 | 2,574 | 2,750 |
| 1977 | 6,669 | 4,026 | 10,075 | 2,450 | 6,820 | 5,440 | 3,852 | 6,125 | 2,516 | 3,182 |
| 1978 | 5,941 | 6,000 | 9,610 | 3,306 | 7,276 | 5,280 | 4,050 | 7,200 | 3,036 | 2,900 |
| 1979 | 6,300 | 5,500 | 10,230 | 3,224 | 7,310 | 5,363 | 3,631 | 7,421 | 2,925 | 3,500 |
| 1980 | 6,592 | 3,220 | 10,675 | 3,264 | 5,670 | 5,033 | 3,815 | 6,864 | 2,820 | 2,779 |
| 1981 | 6,615 | 3,300 | 9,405 | 3,500 | 6,400 | 4,960 | 3,960 | 7,000 | 3,536 | 3,600 |
| 1982 | 6,432 | 4,950 | 11,133 | 3,675 | 6,240 | 5,440 | 3,774 | 6,630 | 3,375 | 3,650 |
| 1983 | 6,080 | 5,382 | 10,880 | 3,960 | 6,270 | 5,115 | 4,017 | 4,805 | 2,691 | 2,790 |
| 1984 | 6,630 | 5,704 | 11,340 | 4,620 | 6,460 | 5,280 | 3,938 | 6,600 | 2,415 | 3,264 |
| 1985 | 6,695 | 3,230 | 9,920 | 5,040 | 6,023 | 4,760 | 3,570 | 5,813 | 1,710 | 3,705 |
| 1986 | 7,128 | 6,250 | 9,450 | 5,040 | 7,605 | 4,658 | 4,180 | 6,080 | 2,990 | 3,510 |
| 1987 | 7,236 | 5,060 | 7,840 | 3,520 | 5,950 | 4,615 | 3,978 | 5,438 | 2,860 | 3,230 |
| 1988 | 7,260 | 2,310 | 4,340 | 3,380 | 4,560 | 4,050 | 3,496 | 5,640 | 2,090 | 2,475 |
| 1989 | 6,834 | 2,400 | 7,130 | 4,680 | 4,420 | 3,900 | 3,720 | 5,700 | 2,970 | 3,060 |
| 1990 | 6,996 | 3,780 | 8,400 | 4,875 | 5,120 | 4,785 | 3,744 | 6,375 | 3,375 | 3,040 |
| 1991 | 7,035 | 5,405 | 8,400 | 4,680 | 6,290 | 4,785 | 3,914 | 5,550 | 3,750 | 2,480 |
| 1992 | 6,432 | 4,620 | 5,290 | 4,140 | 5,250 | 5,550 | 3,367 | 5,735 | 3,360 | 3,570 |
| 1993 | 6,348 | 5,980 | 5,060 | 5,040 | 4,800 | 4,760 | 4,200 | 3,953 | 3,750 | 3,230 |
| **1993 Ranking** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Source: USDA.*

**Figure 8.2-6** Alfalfa production in the top ten producing states (1993).



# Market Potentials of Minnesota Alfalfa Leaf Meal

Alfalfa leaf meal is not currently available in Minnesota. Based on the consumption of alfalfa hay and various protein feeds by dairy, hog, poultry and other ruminant livestock, alfalfa leaf meal will be a readily acceptable feed ingredient, especially for dairy operations in Minnesota. Preliminary estimates show that of the 1.8 million tons of processed feeds (including protein meals) consumed by Minnesota livestock every year, over 1/3 are fed to dairy cows. These feeds include soybean meal, DDG, mill-feeds, other by-product meals, and miscellaneous feeds including molasses and beet pulp. Potential markets for alfalfa leaf meal are ranked in the following order:

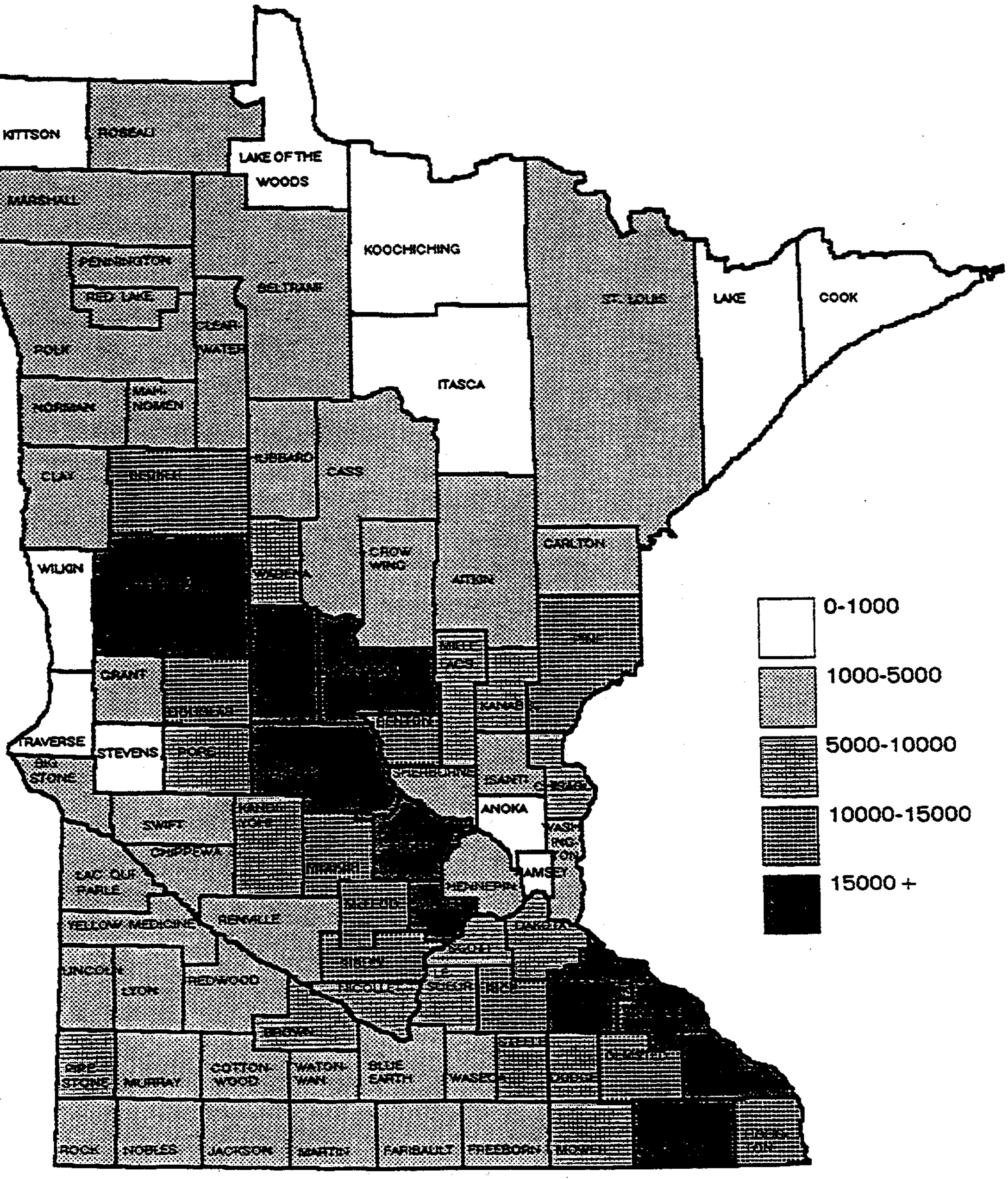
**1. Primary market -- Minnesota dairy industry.**

> Minnesota is the fourth largest dairy producing state in the U.S. It has a dairy herd of 648,000 thousand cows, or 7% of the U.S. total. Dairy production in Minnesota is concentrated in the central and southeastern regions of the state, followed by the west-central, south-central, east-central, northwest, and southwest.

The following charts show the geographic regions of dairy production in Minnesota and locations of potential consumption.

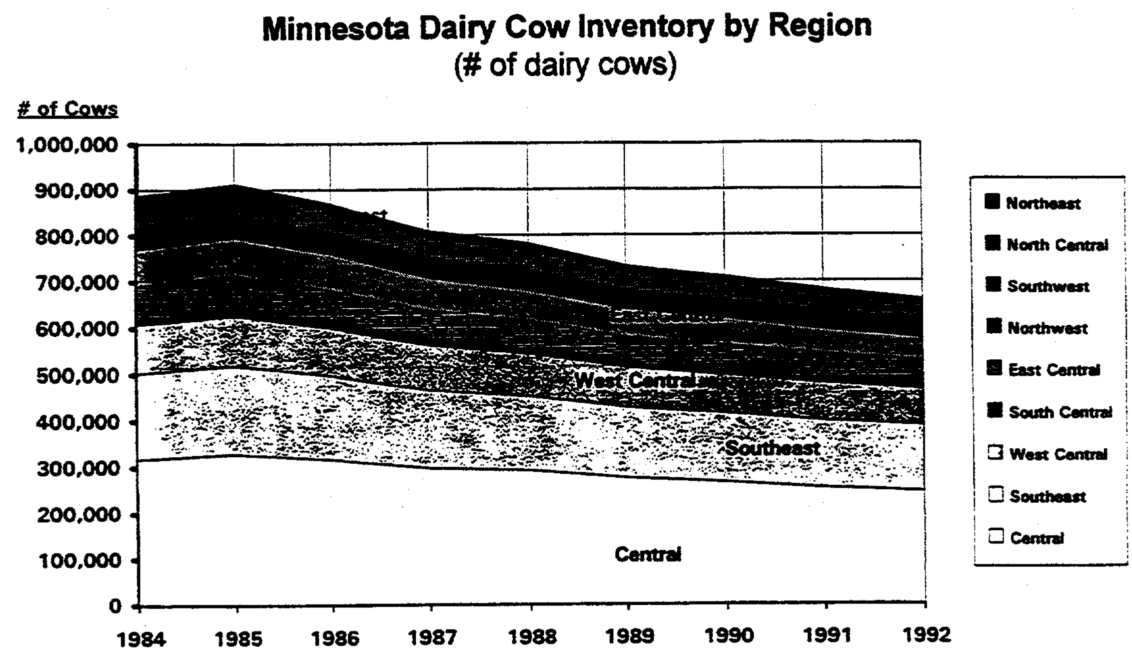
**Illustration 8.2-3** Minnesota dairy cow inventory by county (1992).

**Minnesota Dairy Cow Inventory, 1992**
(# of Dairy Cows)




*Source: Minnesota Agriculture Statistics.*

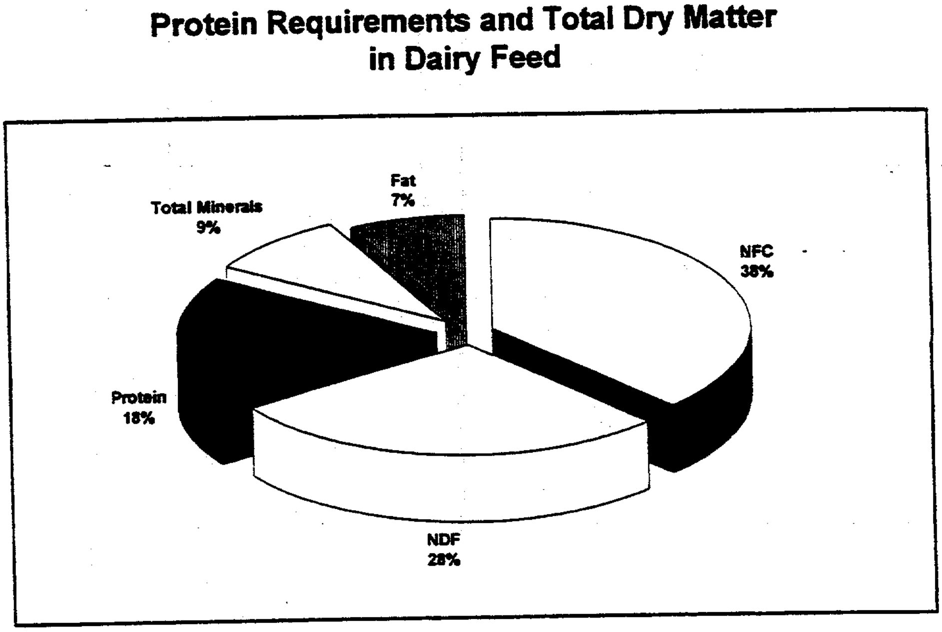
**Figure 8.2-7** Minnesota dairy cow inventory trend by region (1984-1992).




*Source: Minnesota Agriculture Statistics.*

Every year, Minnesota dairy producers feed approximately 383,000 tons of protein meals (including all types) to dairy cows. The projected annual production of 225,000 tons of alfalfa leaf meal from the NSP energy plant would be the equivalent of an average of 2 lb. alfalfa leaf meal per day for all dairy cows in Minnesota, or 2.6 lb. per day for the top 3 dairy regions in central, southeast, and west-central Minnesota. Potential consumption will depend on the feed efficiency, nutritional value and economic cost/benefit of alfalfa leaf meal to the producer. Dairy feed ration requires 18% crude protein for high-producing milk cows. The 2 pound/day consumption of alfalfa leaf meal provides roughly 0.5 pound protein for each dairy cow, which needs 8 pounds crude protein per day. Currently, soybean meal and other protein supplements are used in dairy feed. The most efficient and economical level of substitution and utilization of alfalfa leaf meal requires further research.

**Figure 8.2-8** Pie chart showing the important components in a typical dairy rations.




*NFC: Non-fiber carbohydrate (starch, sugar, etc.). NDF: Neutral detergent fiber.*

*Source: Market Development and Promotion Division, Minnesota Department of Agriculture.*

The analysis of potential consumption of alfalfa leaf meal by Minnesota dairy industry is not complete at this time pending research findings on dairy feed and nutrition formulation from the University of Minnesota. The following table shows a hypothetical consumption volume of alfalfa leaf meal by county and region in Minnesota. The calculation is based on the assumptions that each dairy cow may consume 2-5 pounds of alfalfa leaf meal per day. At each consumption level, the total volumes for counties, regions, and the entire state are calculated.

**Table 8.2-5** Potential consumption of alfalfa leaf meal by dairy cows in Minnesota.

*lb./day: 730 lb./cow/year*
*lb./day: 1095 lb./cow/year*
*lb./day: 1460 lb./cow/year*
*lb./day: 1825 lb./cow/year*

| County | # Cows | 2 lb.-day | 2 lb.-year | 3 lb.-day | 3 lb.-year | 4 lb.-day | 4 lb.-year | 5 lb.-day | 5 lb.-year |
|---|---|---|---|---|---|---|---|---|---|
| | | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* |
| ecker | 11,300 | 11 | 4,125 | 17 | 6,187 | 23 | 8,249 | 28 | 10,311 |
| lay | 3,500 | 4 | 1,278 | 5 | 1,916 | 7 | 2,555 | 9 | 3,194 |
| learwater | 3,000 | 3 | 1,095 | 5 | 1,643 | 6 | 2,190 | 8 | 2,738 |
| ittson | 400 | 0 | 146 | 1 | 219 | 1 | 292 | 1 | 365 |
| lahnomen | 2,100 | 2 | 767 | 3 | 1,150 | 4 | 1,533 | 5 | 1,916 |
| larshall | 1,800 | 2 | 657 | 3 | 986 | 4 | 1,314 | 5 | 1,643 |
| lorman | 2,100 | 2 | 767 | 3 | 1,150 | 4 | 1,533 | 5 | 1,916 |
| ennington | 2,300 | 2 | 840 | 3 | 1,259 | 5 | 1,679 | 6 | 2,099 |
| olk | 4,900 | 5 | 1,789 | 7 | 2,683 | 10 | 3,577 | 12 | 4,471 |
| ed Lake | 2,400 | 2 | 876 | 4 | 1,314 | 5 | 1,752 | 6 | 2,190 |
| oseau | 4,400 | 4 | 1,606 | 7 | 2,409 | 9 | 3,212 | 11 | 4,015 |
| lorthwest | 38,200 | 38 | 13,943 | 57 | 20,915 | 76 | 27,886 | 96 | 34,858 |
| eltrami | 3,500 | 4 | 1,278 | 5 | 1,916 | 7 | 2,555 | 9 | 3,194 |
| ass | 3,400 | 3 | 1,241 | 5 | 1,862 | 7 | 2,482 | 9 | 3,103 |
| lubbard | 1,300 | 1 | 475 | 2 | 712 | 3 | 949 | 3 | 1,186 |
| asca | 900 | 1 | 329 | 1 | 493 | 2 | 657 | 2 | 821 |
| oochiching | 400 | 0 | 146 | 1 | 219 | 1 | 292 | 1 | 365 |
| ake of the Woods | 400 | 0 | 146 | 1 | 219 | 1 | 292 | 1 | 365 |
| **lorth Central** | **9,900** | **10** | **3,614** | **15** | **5,420** | **20** | **7,227** | **25** | **9,034** |
| t. Louis | 2,600 | 3 | 949 | 4 | 1,424 | 5 | 1,898 | 7 | 2,373 |
| **lortheast** | **2,600** | **3** | **949** | **4** | **1,424** | **5** | **1,898** | **7** | **2,373** |
| ig Stone | 2,000 | 2 | 730 | 3 | 1,095 | 4 | 1,460 | 5 | 1,825 |
| hippewa | 1,400 | 1 | 511 | 2 | 767 | 3 | 1,022 | 4 | 1,278 |
| ouglas | 13,700 | 14 | 5,001 | 21 | 7,501 | 27 | 10,001 | 34 | 12,501 |
| rant | 1,800 | 2 | 657 | 3 | 986 | 4 | 1,314 | 5 | 1,643 |
| ac Qui Parle | 2,000 | 2 | 730 | 3 | 1,095 | 4 | 1,460 | 5 | 1,825 |
| tter Tail | 39,000 | 39 | 14,235 | 59 | 21,353 | 78 | 28,470 | 98 | 35,588 |
| ope | 10,000 | 10 | 3,650 | 15 | 5,475 | 20 | 7,300 | 25 | 9,125 |
| tevens | 1,000 | 1 | 365 | 2 | 548 | 2 | 730 | 3 | 913 |
| wift | 3,000 | 3 | 1,095 | 5 | 1,643 | 6 | 2,190 | 8 | 2,738 |
| raverse | 700 | 1 | 256 | 1 | 383 | 1 | 511 | 2 | 639 |
| Vilkin | 800 | 1 | 292 | 1 | 438 | 2 | 584 | 2 | 730 |
| ellow Medicine | 2,700 | 3 | 986 | 4 | 1,478 | 5 | 1,971 | 7 | 2,464 |
| **Vest Central** | **78,100** | **78** | **28,507** | **117** | **42,760** | **156** | **57,013** | **195** | **71,266** |
| enton | 14,900 | 15 | 5,439 | 22 | 8,158 | 30 | 10,877 | 37 | 13,596 |
| arver | 17,600 | 18 | 6,424 | 26 | 9,636 | 35 | 12,848 | 44 | 16,060 |
| andiyohi | 9,800 | 10 | 3,577 | 15 | 5,366 | 20 | 7,154 | 25 | 8,943 |
| lcLeod | 14,800 | 15 | 5,402 | 22 | 8,103 | 30 | 10,804 | 37 | 13,505 |
| leeker | 10,500 | 11 | 3,833 | 16 | 5,749 | 21 | 7,665 | 26 | 9,581 |
| lorrison | 29,900 | 30 | 10,914 | 45 | 16,370 | 60 | 21,827 | 75 | 27,284 |
| enville | 3,900 | 4 | 1,424 | 6 | 2,135 | 8 | 2,847 | 10 | 3,559 |
| cott | 8,300 | 8 | 3,030 | 12 | 4,544 | 17 | 6,059 | 21 | 7,574 |
| herburne | 2,300 | 2 | 840 | 3 | 1,259 | 5 | 1,679 | 6 | 2,099 |
| ibley | 11,700 | 12 | 4,271 | 18 | 6,406 | 23 | 8,541 | 29 | 10,676 |
| tearns | 64,600 | 65 | 23,579 | 97 | 35,369 | 129 | 47,158 | 162 | 58,948 |
| odd | 29,000 | 29 | 10,585 | 44 | 15,878 | 58 | 21,170 | 73 | 26,463 |
| Vadena | 7,200 | 7 | 2,628 | 11 | 3,942 | 14 | 5,256 | 18 | 6,570 |
| Vright | 19,800 | 20 | 7,227 | 30 | 10,841 | 40 | 14,454 | 50 | 18,068 |
| **entral** | **244,300** | **244** | **89,170** | **366** | **133,754** | **489** | **178,339** | **611** | **222,924** |

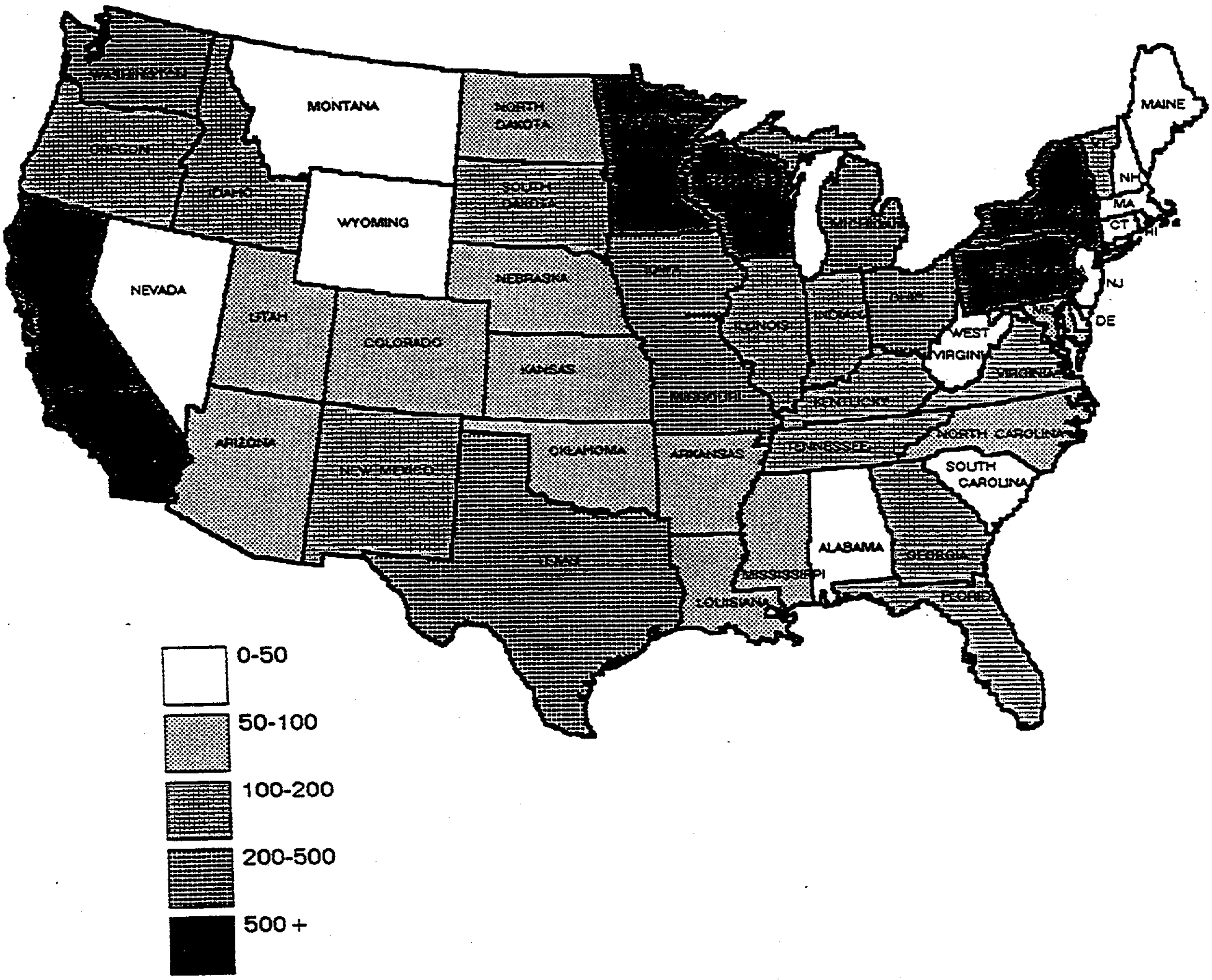
| County | # Cows | 2 lb.-day | 2 lb.-year | 3 lb.-day | 3 lb.-year | 4 lb.-day | 4 lb.-year | 5 lb.-day | 5 lb.-year |
|---|---|---|---|---|---|---|---|---|---|
| | | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* | *Tons* |
| Aitkin | 2,400 | 2 | 876 | 4 | 1,314 | 5 | 1,752 | 6 | 2,190 |
| Anoka | 800 | 1 | 292 | 1 | 438 | 2 | 584 | 2 | 730 |
| Carlton | 3,400 | 3 | 1,241 | 5 | 1,862 | 7 | 2,482 | 9 | 3,103 |
| Chisago | 5,200 | 5 | 1,898 | 8 | 2,847 | 10 | 3,796 | 13 | 4,745 |
| Crow Wing | 2,800 | 3 | 1,022 | 4 | 1,533 | 6 | 2,044 | 7 | 2,555 |
| Hennepin | 4,500 | 5 | 1,643 | 7 | 2,464 | 9 | 3,285 | 11 | 4,106 |
| Isanti | 3,400 | 3 | 1,241 | 5 | 1,862 | 7 | 2,482 | 9 | 3,103 |
| Kanabec | 5,700 | 6 | 2,081 | 9 | 3,121 | 11 | 4,161 | 14 | 5,201 |
| Mille Lacs | 9,400 | 9 | 3,431 | 14 | 5,147 | 19 | 6,862 | 24 | 8,578 |
| Pine | 11,000 | 11 | 4,015 | 17 | 6,023 | 22 | 8,030 | 28 | 10,038 |
| Ramsey | 100 | 0 | 37 | 0 | 55 | 0 | 73 | 0 | 91 |
| Washington | 2,100 | 2 | 767 | 3 | 1,150 | 4 | 1,533 | 5 | 1,916 |
| **East Central** | **50,800** | **51** | **18,542** | **76** | **27,813** | **102** | **37,084** | **127** | **46,355** |
| Cottonwood | 2,700 | 3 | 986 | 4 | 1,478 | 5 | 1,971 | 7 | 2,464 |
| Jackson | 1,400 | 1 | 511 | 2 | 767 | 3 | 1,022 | 4 | 1,278 |
| Lincoln | 4,700 | 5 | 1,716 | 7 | 2,573 | 9 | 3,431 | 12 | 4,289 |
| Lyon | 2,900 | 3 | 1,059 | 4 | 1,588 | 6 | 2,117 | 7 | 2,646 |
| Murray | 4,700 | 5 | 1,716 | 7 | 2,573 | 9 | 3,431 | 12 | 4,289 |
| Nobles | 4,600 | 5 | 1,679 | 7 | 2,519 | 9 | 3,358 | 12 | 4,198 |
| Pipestone | 5,800 | 6 | 2,117 | 9 | 3,176 | 12 | 4,234 | 15 | 5,293 |
| Redwood | 3,600 | 4 | 1,314 | 5 | 1,971 | 7 | 2,628 | 9 | 3,285 |
| Rock | 3,700 | 4 | 1,351 | 6 | 2,026 | 7 | 2,701 | 9 | 3,376 |
| **Southwest** | **34,100** | **34** | **12,447** | **51** | **18,670** | **68** | **24,893** | **85** | **31,116** |
| Blue Earth | 2,300 | 2 | 840 | 3 | 1,259 | 5 | 1,679 | 6 | 2,099 |
| Brown | 9,300 | 9 | 3,395 | 14 | 5,092 | 19 | 6,789 | 23 | 8,486 |
| Faribault | 2,700 | 3 | 986 | 4 | 1,478 | 5 | 1,971 | 7 | 2,464 |
| Freeborn | 4,500 | 5 | 1,643 | 7 | 2,464 | 9 | 3,285 | 11 | 4,106 |
| Le Sueur | 5,400 | 5 | 1,971 | 8 | 2,957 | 11 | 3,942 | 14 | 4,928 |
| Martin | 2,200 | 2 | 803 | 3 | 1,205 | 4 | 1,606 | 6 | 2,008 |
| Nicollet | 6,600 | 7 | 2,409 | 10 | 3,614 | 13 | 4,818 | 17 | 6,023 |
| Rice | 13,200 | 13 | 4,818 | 20 | 7,227 | 26 | 9,636 | 33 | 12,045 |
| Steele | 8,100 | 8 | 2,957 | 12 | 4,435 | 16 | 5,913 | 20 | 7,391 |
| Waseca | 4,300 | 4 | 1,570 | 6 | 2,354 | 9 | 3,139 | 11 | 3,924 |
| Watonwan | 1,400 | 1 | 511 | 2 | 767 | 3 | 1,022 | 4 | 1,278 |
| **South Central** | **60,000** | **60** | **21,900** | **90** | **32,850** | **120** | **43,800** | **150** | **54,750** |
| Dakota | 6,100 | 6 | 2,227 | 9 | 3,340 | 12 | 4,453 | 15 | 5,566 |
| Dodge | 8,100 | 8 | 2,957 | 12 | 4,435 | 16 | 5,913 | 20 | 7,391 |
| Fillmore | 18,600 | 19 | 6,789 | 28 | 10,184 | 37 | 13,578 | 47 | 16,973 |
| Goodhue | 27,400 | 27 | 10,001 | 41 | 15,002 | 55 | 20,002 | 69 | 25,003 |
| Houston | 14,200 | 14 | 5,183 | 21 | 7,775 | 28 | 10,366 | 36 | 12,958 |
| Mower | 6,400 | 6 | 2,336 | 10 | 3,504 | 13 | 4,672 | 16 | 5,840 |
| Olmsted | 14,400 | 14 | 5,256 | 22 | 7,884 | 29 | 10,512 | 36 | 13,140 |
| Wabasha | 20,000 | 20 | 7,300 | 30 | 10,950 | 40 | 14,600 | 50 | 18,250 |
| Winona | 26,800 | 27 | 9,782 | 40 | 14,673 | 54 | 19,564 | 67 | 24,455 |
| **Southeast** | **142,000** | **142** | **51,830** | **213** | **77,745** | **284** | **103,660** | **355** | **129,575** |
| **State Total** | **660,000** | **660** | **240,900** | **990** | **361,350** | **1,320** | **481,800** | **1,650** | **602,250** |

*Source: Market Development and Promotion Division, Minnesota Department of Agriculture.*

Potential markets of alfalfa leaf meal also include other major dairy states in the U.S. such as Wisconsin, California, New York, Pennsylvania, Texas, Michigan, Ohio, Iowa, and Washington. About two-thirds of all U.S. dairy cows come from the top 10 dairy states, where highly concentrated dairy production may utilize at least a portion of Minnesota's alfalfa leaf meal.

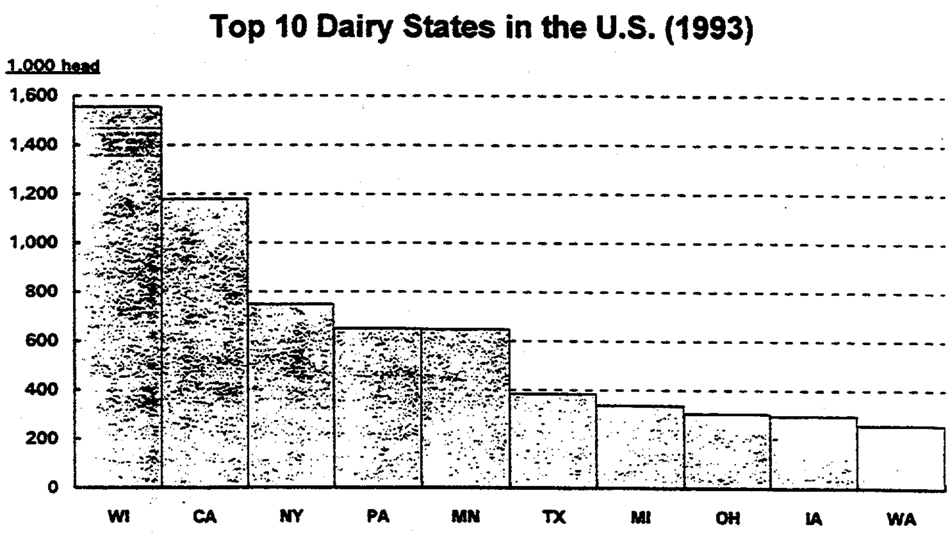
**Illustration 8.2-4** Map showing U.S. dairy production by state (1992).

**U.S. Dairy Production, 1992**
(Dairy Cows, 1,000)




*Source: Minnesota Agriculture Statistics.*

**Figure 8.2-9** Top ten dairy states in the U.S. (1993).




*Source: USDA.*

## 2. Secondary markets -- other ruminant animals, hogs, poultry, etc.

Statistical information has been prepared on the production and inventory of beef cattle, hogs, chicken, and turkey in Minnesota. However, due to unavailable information on feed and nutrition formulation, the analysis of potential consumption and market is not complete at this time. Other animals, such as horses and sheep, represent a much smaller and more scattered market. We recommend that research and marketing efforts focus on large and high volume users to best utilize the limited resources.

The following table (**Table 8.2-6**) shows a production history of non-dairy animals in Minnesota. This can be used as an indicator of potential consumption of alfalfa leaf meal by a secondary market if the animal feed and nutrition analysis being conducted at the University of Minnesota finds leaf meal an efficient feed ingredient for non-dairy animals.

**Table 8.2-6** Minnesota livestock production.

**Minnesota Livestock Production***

*1,000 head*

| Year | Beef Cow | Dairy Cow | Calf | Hog | Broilers | Spent Hen | Turkey |
|---|---|---|---|---|---|---|---|
| 1973 | 602 | 911 | 1,480 | 6,103 | 11,149 | 6,875 | 23,323 |
| 1974 | 708 | 890 | 1,525 | 6,020 | 10,815 | 9,727 | 21,934 |
| 1975 | 739 | 884 | 1,596 | 4,585 | 10,092 | 7,377 | 22,752 |
| 1976 | 751 | 878 | 1,450 | 5,757 | 15,200 | 7,997 | 24,370 |
| 1977 | 640 | 866 | 1,390 | 6,498 | 14,200 | 7,247 | 22,739 |
| 1978 | 550 | 837 | 1,280 | 6,649 | 15,100 | 7,824 | 21,238 |
| 1979 | 530 | 843 | 1,290 | 8,006 | 17,000 | 7,556 | 24,666 |
| 1980 | 560 | 862 | 1,350 | 8,937 | 19,400 | 7,115 | 25,500 |
| 1981 | 570 | 886 | 1,370 | 7,601 | 21,500 | 6,400 | 25,700 |
| 1982 | 585 | 903 | 1,300 | 6,933 | 23,700 | 8,900 | 26,000 |
| 1983 | 481 | 899 | 1,360 | 7,559 | 24,400 | 7,900 | 27,000 |
| 1984 | 477 | 887 | 1,230 | 6,807 | 25,600 | 8,575 | 28,500 |
| 1985 | 420 | 915 | 1,320 | 7,017 | 26,900 | 7,500 | 30,400 |
| 1986 | 396 | 891 | 1,270 | 6,764 | 29,700 | 7,700 | 34,200 |
| 1987 | 405 | 823 | 1,180 | 7,400 | 31,700 | 7,700 | 40,500 |
| 1988 | 385 | 783 | 1,130 | 7,971 | 33,100 | 6,500 | 38,500 |
| 1989 | 315 | 734 | 1,075 | 7,942 | 37,700 | 6,200 | 43,100 |
| 1990 | 350 | 710 | 1,040 | 7,863 | 41,300 | 6,000 | 46,300 |
| 1991 | 375 | 683 | 1,030 | 8,326 | 45,100 | 5,500 | 44,000 |
| 1992 | 375 | 660 | 1,040 | 8,389 | 45,300 | 6,200 | 43,000 |
| 1993 | 410 | 648 | 980 | 8,287 | 46,600 | 5,200 | 42,000 |

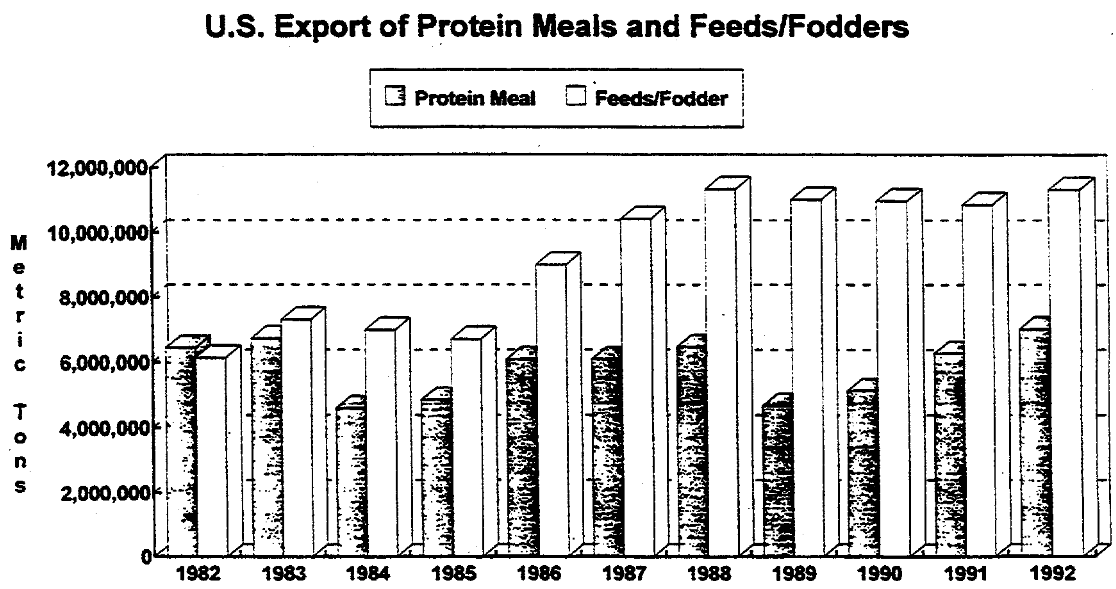
**Beef cow: January 1 inventory. Dairy cow: Number on farm, annual average. Calf: Annual production. Hog: annual production. Spent hen: # sold. Broilers: # raised. Turkey: # raised.*

*Source: Minnesota Agriculture Statistics.*

**3. Other markets -- export market.**

The U.S. exported a total of 7.2 million tons of protein meals in 1993. About 95% of the export is soybean meal, the rest included cottonseed meal, peanut meal, etc. The top 10 buyers of U.S. protein meals in 1993 were: the Netherlands, Canada, former USSR, Venezuela, Mexico, Spain, the Philippines, Algeria, France, and Japan. The U.S. protein meal export has been increasing steadily, and there are many fast-growing markets, especially in Asia and Europe. During the past few years, Mexico, Venezuela, Spain, Germany, the Philippines, Japan and Korea significantly increased their purchase of U.S. protein meals. The largest and most stable markets, however, are Canada and the Netherlands, who have strong purchasing power and an efficient market infrastructure. It is expected that protein meal export will continue to grow, and most of the current top 10 buyers will remain as high potential markets. Exporting alfalfa leaf meal should focus on expanding current markets and exploring new buyers and uses, not competing with other protein meals currently being exported from the U.S. Generally, export price of protein meals is about 30% higher than the U.S. domestic prices. Although export brings higher economic returns, it can be a risky and unstable market. One of the best examples is the former USSR: in 1992, the U.S. sold 2.4 million tons of protein meals to the former USSR; in 1993, the volume dropped to 0.6 million tons, a 75% decrease.

**Figure 8.2-10** U.S. export of protein meals and feeds/fodders.




*Source: USDA, ERS.*

**Table 8.2-7** U.S. protein feed export markets by country of destination ($1,000).

**U.S. Protein Feed Export to Largest Markets (Country Destination, By Value)**

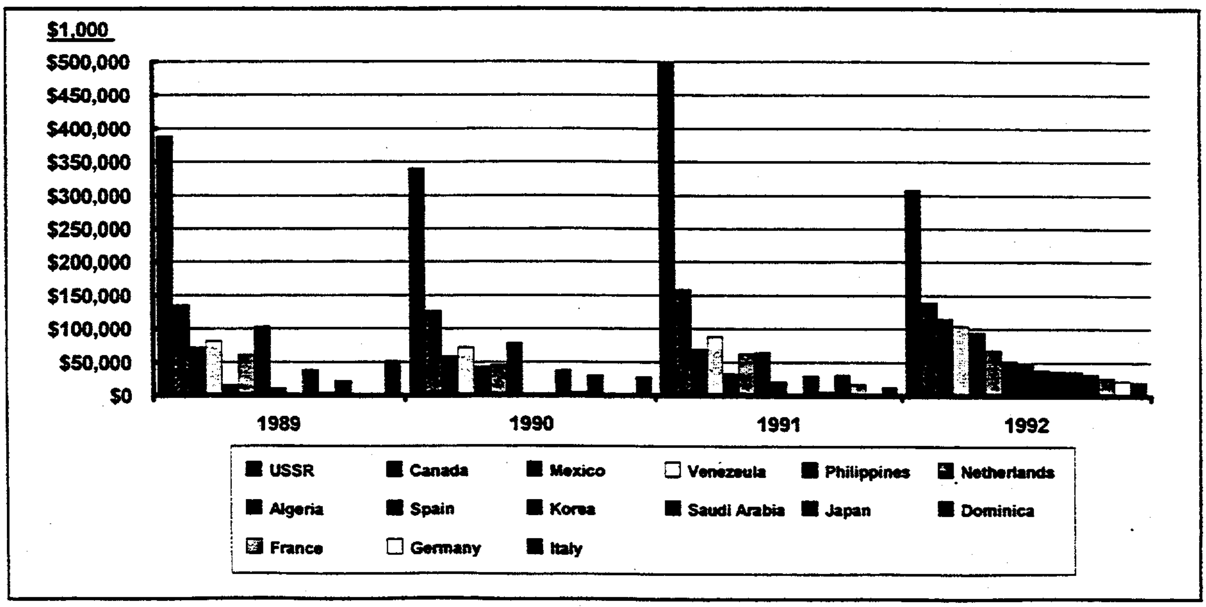
*$1,000*

| Country | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|
| USSR | $388,552 | $340,544 | $499,803 | $309,000 |
| Canada | $135,467 | $127,069 | $159,277 | $139,536 |
| Mexico | $72,582 | $60,047 | $69,696 | $115,400 |
| Venezuela | $82,052 | $72,600 | $88,146 | $104,097 |
| Philippines | $15,468 | $43,575 | $32,925 | $94,910 |
| Netherlands | $61,615 | $46,937 | $63,397 | $68,358 |
| Algeria | $103,838 | $78,757 | $65,891 | $52,522 |
| Spain | $11,357 | $1,424 | $21,605 | $49,229 |
| Korea | $172 | $170 | $138 | $39,583 |
| Saudi Arabia | $38,984 | $38,512 | $30,478 | $37,481 |
| Japan | $4,540 | $5,077 | $5,474 | $37,156 |
| Dominican Rep. | $21,801 | $30,491 | $31,795 | $32,804 |
| France | $6 | $769 | $17,370 | $27,100 |
| Germany | $271 | $248 | $1,609 | $21,911 |
| Italy | $52,618 | $28,277 | $12,810 | $20,928 |

*Source: USDA, ERS.*

**Figure 8.2-11** Largest markets for U.S. protein meals from 1989-1992 ($1,000).

**Largest Markets for U.S. Protein Meals (By Value)**




*Source: USDA, ERS.*

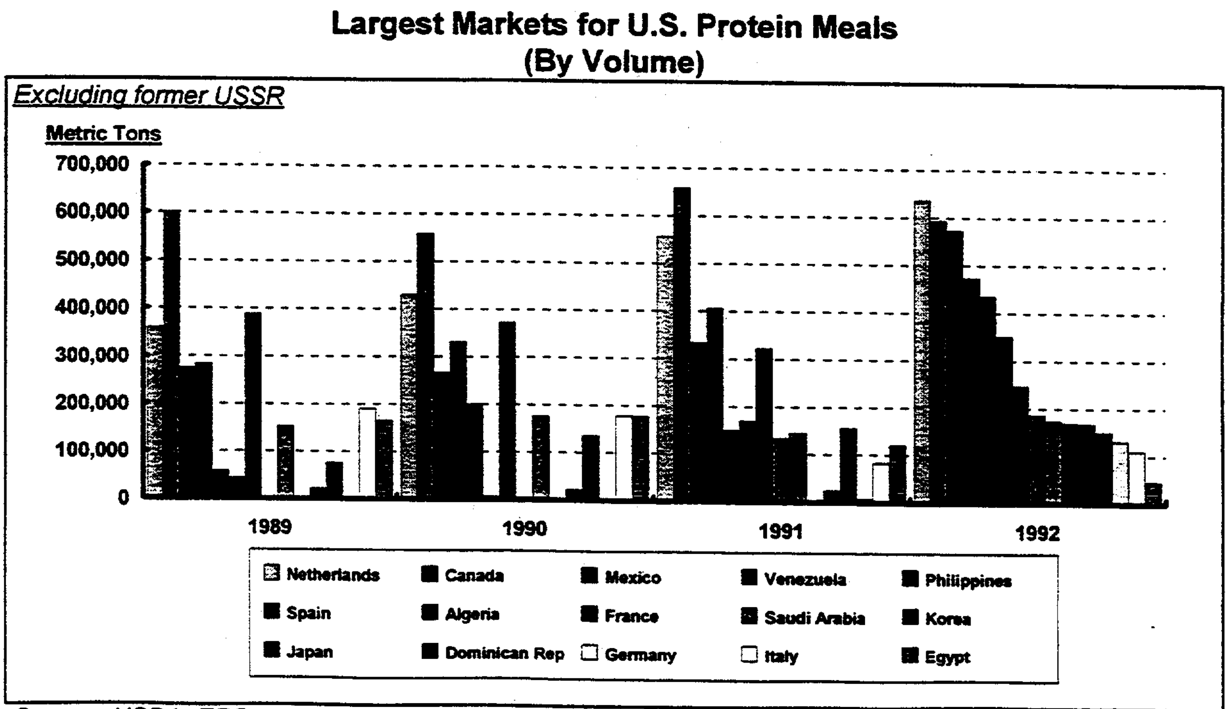
**Table 8.2-8** U.S. protein feed export markets by country of destination (volume).

**U.S. Protein Feed Export to Largest Markets**
**(Country Destination, By Volume)**

*Metric Tons*

| Destination | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|
| World | 4,860,680 | 5,137,503 | 6,273,832 | 7,019,755 |
| USSR | 1,417,887 | 1,581,944 | 2,322,016 | 1,438,192 |
| Netherlands | 359,164 | 430,063 | 555,954 | 635,755 |
| Canada | 599,480 | 559,015 | 659,095 | 594,557 |
| Mexico | 274,847 | 267,134 | 334,253 | 572,771 |
| Venezuela | 283,853 | 331,892 | 406,204 | 473,915 |
| Philippines | 59,070 | 200,887 | 150,360 | 434,848 |
| Spain | 44,309 | 7,017 | 169,936 | 352,063 |
| Algeria | 389,062 | 373,514 | 323,485 | 247,802 |
| France | 43 | 4,444 | 134,414 | 186,188 |
| Saudi Arabia | 152,615 | 175,583 | 145,071 | 174,265 |
| Korea | 447 | 1,021 | 319 | 169,844 |
| Japan | 22,237 | 22,322 | 25,427 | 168,031 |
| Dominican Rep | 76,452 | 136,582 | 156,977 | 150,994 |
| Germany | 1,557 | 1,640 | 7,824 | 131,998 |
| Italy | 190,395 | 178,024 | 83,824 | 109,982 |
| Egypt | 165,934 | 177,606 | 121,384 | 46,456 |

**Figure 8.2-12** Largest markets for U.S. protein meals from 1989-1992 (volume).




Source: USDA, ERS.

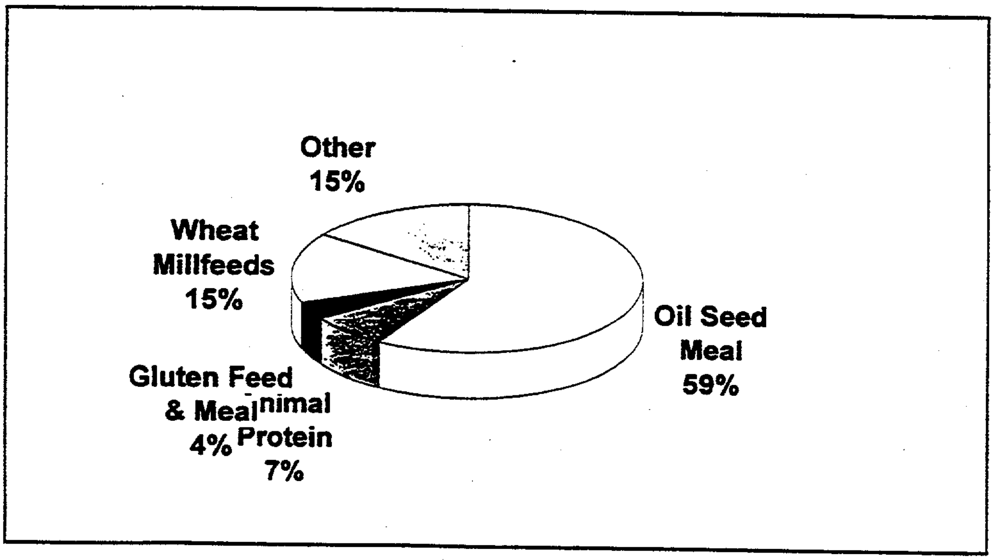
# Competing Feeds and Protein Meals

Alfalfa leaf meal with 28% protein will be competing with so-called "mid-level" protein feeds such as corn gluten feed, DDG, sunflower meal and linseed meal, all of which are currently produced in Minnesota. DDG and corn gluten feed are the biggest potential competitors due to the construction of new corn processing plants for ethanol and other corn-based products. Large quantities of corn by-products would be coming into Minnesota's feed market in the next 2-3 years, and would coincide with the 667-ton-per-day supply of alfalfa leaf meal. By 1997, there will be at least 112,326 tons of DDG produced annually in Minnesota, compared to the 25,116 tons of current production.

In some states in the U.S., alfalfa hay is processed into another form of feed -- alfalfa meal -- which is a de-hydrated and pelletized product with 15-17% crude protein. It is sold commercially both in the U.S. and overseas. In 1993, the U.S. consumption of alfalfa meal totaled 375,000 tons, while another 225,000 tons were exported. However, the U.S. domestic consumption of alfalfa meal was much higher in 1985 -- at about 856,500 tons. In 1993, less than 1% of U.S. alfalfa production was processed into alfalfa meal.

**Figure 8.2-13** Pie chart showing consumption of feed and meal in the U.S. (1993).

**Consumption of Processed Feed & Protein Meals in the U.S. (1993)**




*Oil seed meal -- soybean, linseed, sunflower, canola, cottonseed, and peanut meals, etc.*
*Animal protein -- meat & bone meal, fishmeal & solubles, milk products, etc.*
*Other -- alfalfa meal, inedible molasses, fats & oils, dried & molasses beet pulp, rice millfeeds, and other miscellaneous by-product feed.*

*Source: USDA.*

## Prices of Competing Protein Meals and Alfalfa Meal

Since alfalfa leaf meal is not currently available in the feed market, price analysis was performed using price trends of competing feeds and protein meals. Competing feeds include dehydrated alfalfa meal (17% protein) and sun-cured alfalfa meal (15% protein). Protein meals include corn gluten feed (21% protein), distillers dried grains (DDG, 28% protein), sunflower meal (28% protein), linseed meal (34% protein), and soybean meal (44% protein). Other protein meals, such as canola meal, and cottonseed meal, etc., are not included in the research because they are not currently produced in Minnesota. The biggest competition for alfalfa leaf meal is the locally produced protein meals. Research on historical prices and price comparisons has been completed.

**Table 8.2-9** Processed feed and protein meal prices (1975-1993). Note: price for sun-cured alfalfa is based on small square bales.

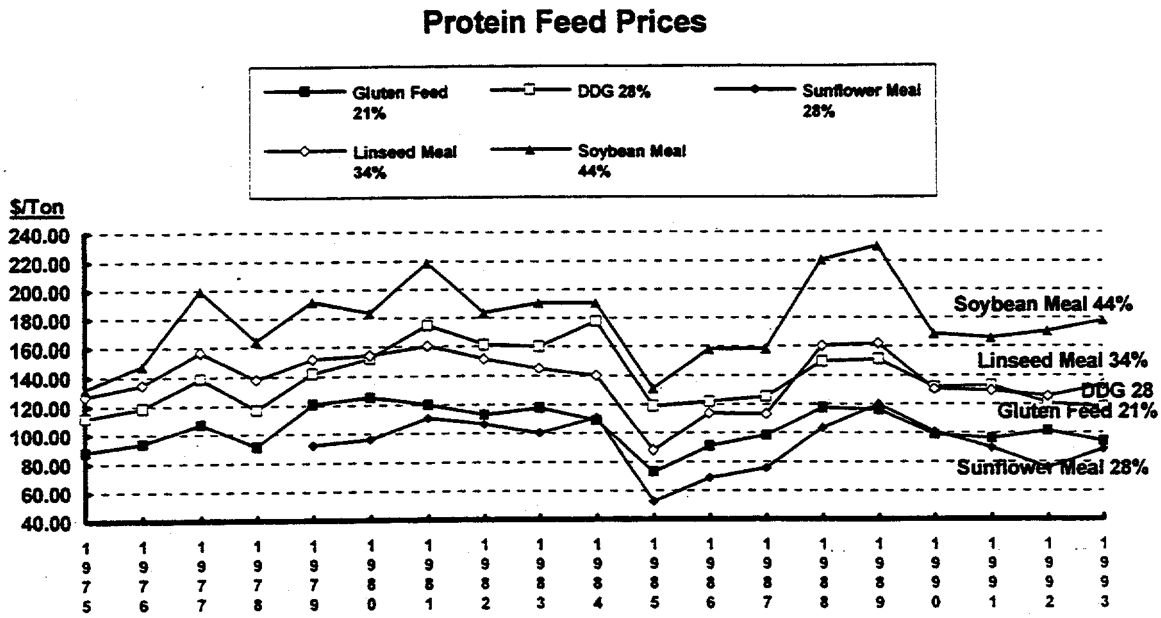
### Processed Feed and Protein Meal Prices

*$/Ton*

| Year | Sun-cured Alfalfa 15% | De-hy Alfalfa 17% | Corn Gluten Feed 21% | DDG 28% | Sunflower Meal 28% | Linseed Meal 34% | Soybean Meal 44% | Soybean Meal 48% | Corn Gluten Meal 60% |
|---|---|---|---|---|---|---|---|---|---|
| 1975 | 73.73 | 81.03 | 88.20 | 111.90 | | 126.66 | 131.78 | 141.50 | 234.1 |
| 1976 | 91.09 | 101.69 | 93.80 | 118.70 | | 134.55 | 147.90 | 157.60 | 230.4 |
| 1977 | 84.27 | 95.36 | 107.20 | 138.60 | | 156.87 | 199.78 | 213.90 | 208.4 |
| 1978 | 67.54 | 75.98 | 91.30 | 117.10 | | 137.75 | 164.18 | 175.35 | 235.7 |
| 1979 | 86.66 | 100.76 | 120.80 | 142.10 | 92.30 | 152.18 | 192.02 | 204.96 | 276.0 |
| 1980 | 92.37 | 109.64 | 125.30 | 152.10 | 96.00 | 154.39 | 183.61 | 198.18 | 222.4 |
| 1981 | 108.66 | 122.38 | 120.20 | 174.80 | 110.92 | 160.53 | 218.89 | 236.50 | 262.4 |
| 1982 | 93.59 | 105.63 | 113.00 | 161.40 | 106.46 | 151.73 | 183.70 | 197.88 | 249.3 |
| 1983 | 104.36 | 120.59 | 117.80 | 160.10 | 100.06 | 145.06 | 190.97 | 209.32 | 272.2 |
| 1984 | 114.91 | 129.48 | 109.10 | 177.80 | 111.15 | 140.18 | 190.71 | 204.83 | 245.3 |
| 1985 | 88.31 | 99.16 | 73.10 | 118.80 | 52.35 | 87.91 | 130.87 | 144.09 | 241.9 |
| 1986 | 82.35 | 92.70 | 90.90 | 121.80 | 68.80 | 113.95 | 158.35 | 165.64 | 269.1 |
| 1987 | 85.30 | 93.07 | 98.30 | 125.20 | 75.86 | 113.24 | 158.45 | 170.04 | 203.1 |
| 1988 | 105.17 | 110.73 | 117.60 | 149.80 | 103.42 | 160.27 | 220.58 | 233.03 | 209.3 |
| 1989 | 130.57 | 136.16 | 116.30 | 151.40 | 120.02 | 162.04 | 230.37 | 247.22 | 230.5 |
| 1990 | 121.09 | 125.88 | 98.80 | 131.70 | 100.61 | 130.42 | 168.49 | 180.37 | 303.1 |
| 1991 | 103.19 | 109.68 | 96.00 | 132.80 | 89.54 | 129.47 | 165.85 | 175.93 | 282.4 |
| 1992 | 95.86 | 101.53 | 101.50 | 120.70 | 76.06 | 125.32 | 170.32 | 180.75 | 258.0 |
| 1993 | 103.78 | 112.02 | 93.88 | 118.00 | 88.59 | 133.36 | 177.88 | 190.02 | 237. |
| 5-year Average | 110.90 | 117.05 | 101.30 | 130.92 | 94.96 | 136.12 | 182.58 | 194.86 | 262.3 |
| 10-year Average | 103.05 | 111.04 | 99.55 | 134.80 | 88.64 | 129.62 | 177.19 | 189.19 | 248.0 |
| **74-93 Average** | **96.46** | **106.50** | **103.85** | **138.15** | **92.81** | **137.68** | **178.14** | **190.90** | **284.** |

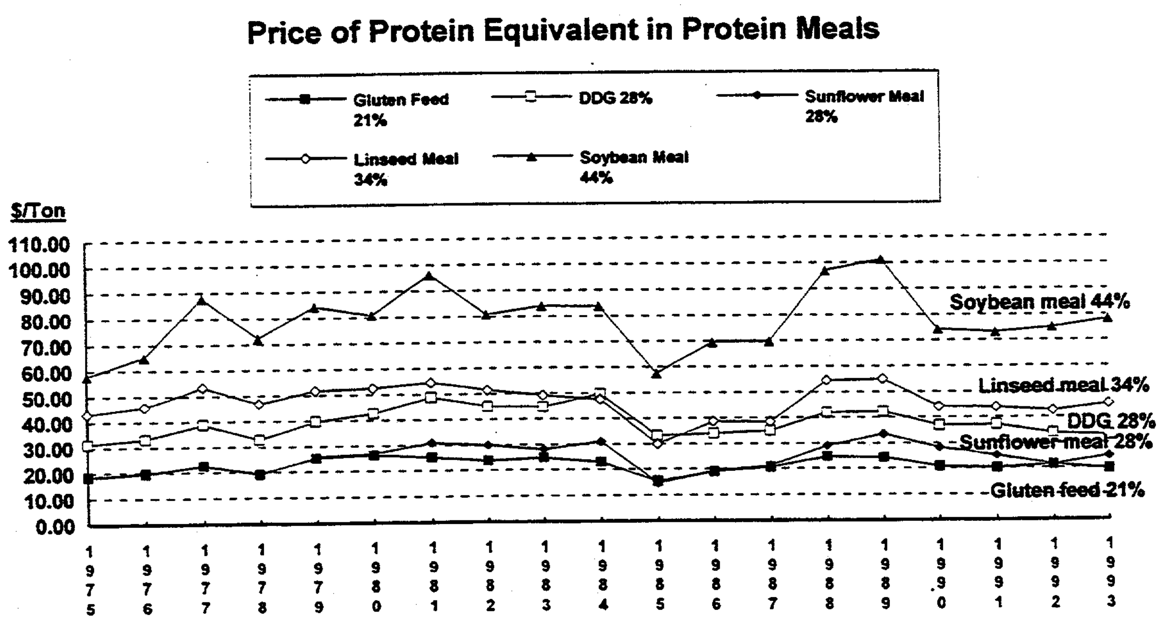
*Source: USDA.*

**Figure 8.2-14** Protein feed prices (1975-1993).



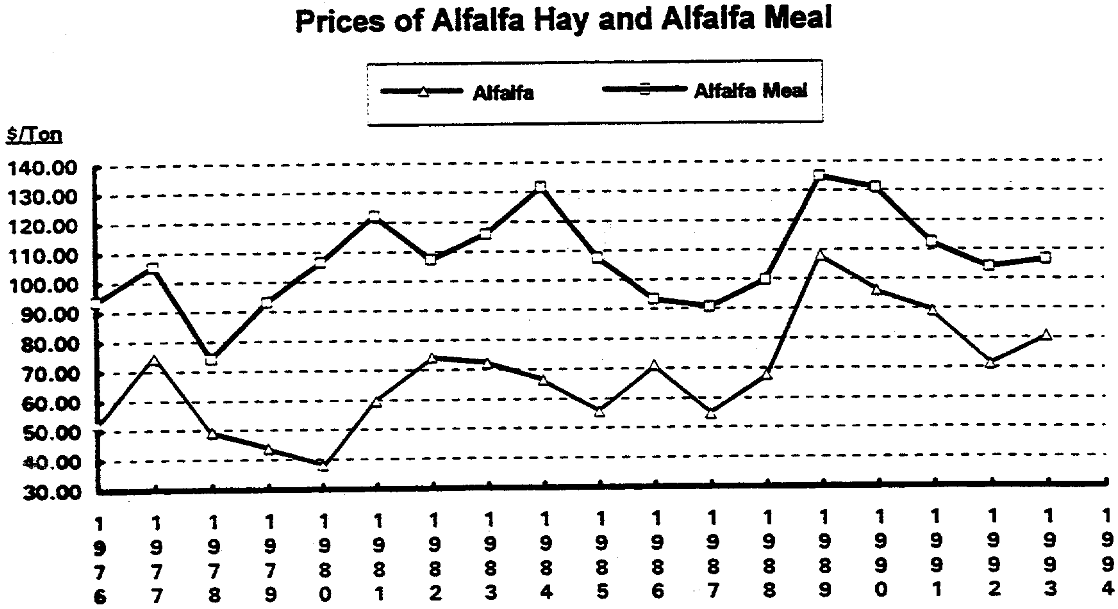

*Source: USDA.*

**Figure 8.2-15** The price of protein equivalent in different protein meals (1975-1993).




*Source: Marketing Development and Promotion Division, Minnesota Department of Agriculture.*

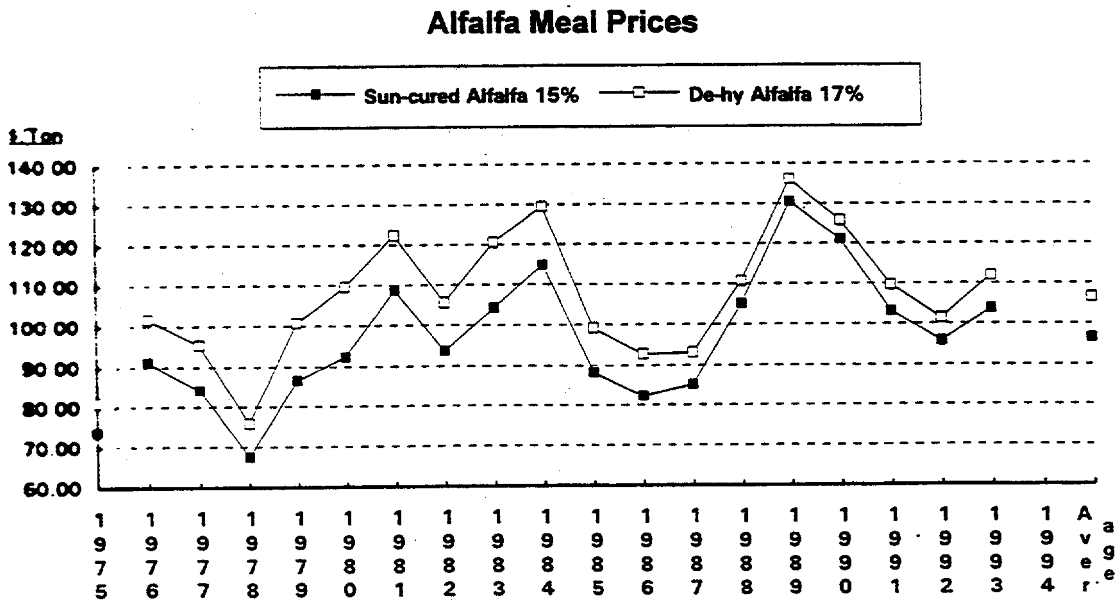
**Figure 8.2-16** Price of alfalfa hay and alfalfa meal (1976-1993). Note that alfalfa meal is a 17% protein meal produced by dehydrating the bulk product (leaves and stems) and that hay price is based on small square bales.




*Alfalfa meal 17% protein, de-hydrated bulk..*

*Source USDA.*

**Figure 8.2-17** Comparison between sun-cured and dehydrated alfalfa meal prices (1975-1993).




*Source: USDA.*

## Marketing Alfalfa Leaf Meal

Alfalfa leaf meal is a new product that could potentially benefit livestock growers, especially dairy operations, in Minnesota and nationwide. A comprehensive marketing strategy needs to be developed with a detailed assessment of required marketing mechanism and infrastructure.

To create demand and a niche market for alfalfa leaf meal, the following tasks should be accomplished prior to implementing a marketing plan.

**Research and dissemination of information:** Information on alfalfa leaf meal's nutritional characteristics and feed conversion efficiency should be made available to livestock producers. Potential consumption depends on the producers' decision to use the product. Such decisions will only be made when there is sufficient information and knowledge about the products and the expected payoffs. Producers need to be convinced of the benefits of alfalfa leaf meal such as by-pass protein and other feed qualities, and increased production potentials, etc. Technical assistance will be essential to the success of the product, and should be made available as part of the marketing support package.

**Analysis of cost competitiveness and feasibility of feed substitution:** Determine the producers' cost of using alfalfa leaf meal, and whether there are cost advantages when substituting other protein feeds with alfalfa leaf meal in livestock production. The analysis should be based on the nutritional value, conversion efficiency, and overall livestock productivity of alfalfa leaf meal and other protein supplements. Identify the protein feeds that are imports from other states but can be replaced by Minnesota-grown alfalfa leaf meal.

**Pricing:** As co-product of the alfalfa bio-mass energy plant, the pricing of alfalfa leaf meal must be based on at least 2 factors: the break-even price for energy generation and acceptable price to livestock producers.

## Recommendations

Our analysis suggests that opportunities for the successful marketing of alfalfa leaf meal do exist. However, significant challenges also exist; the magnitude of these challenges must not be under-estimated. If this project is to proceed further, we recommend the following steps be strongly considered:

**Focus on the dairy industry**: The dairy industry alone is large enough to consume the projected output of this plant. Scarce product and market development resources should be concentrated on meeting the needs of this industry, focusing first on the Minnesota industry, then on the regional, national, and international markets. In marketing to the Minnesota industry, it would be desirable to attempt to substitute for other imported feeds and meals such as canola and alfalfa.

**Demonstrate the value of the product to dairy producers:** Industry will be unfamiliar with this product, and will need to be shown the benefits of using it. Applied research on nutritional content/relative feed value/ration balancing must be completed and verified. On-farm testing, perhaps through the Extension Service, would be very desirable to demonstrate benefits of use.

**Produce and ensure consistent product quality:** It is not enough to demonstrate value only in small tests. The product must produce consistent results on a continuous basis. To this point, scale-up work has not be completed to ensure consistent quality on a mass-produced basis. Conducting this research is critical to achieving the high degree of market penetration required for ultimate success.

**Consider strategic alliances/joint ventures for marketing and distribution:** In addition to consistent quality assurance, high market penetration requires efficient product distribution. Rather than create a distribution network, producers might consider a partnership/joint venture with an entity that already controls feed distribution in targeted market areas. Properly structured, such a partnership should decrease time lags in getting product to market, improve early cash flow, provide early product exposure and credibility, and reduce overall project risk. Producers must weigh the cost of partnership against the risks of setting up their own supply network and not getting rapid, early product distribution and payment. Because of the co-operative nature of the project, producers should seek to leverage that advantage, where possible, by considering alliances/ventures with other cooperatively organized distribution entities.

# CHAPTER 9. BUSINESS ANALYSIS

## 9.1 Organizational Structure

### Organizational Options for Alfalfa Biomass Energy Production

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### Introduction

The purpose of this chapter of the feasibility report is to identify and evaluate organizational structure options for the proposed biomass plant in Granite Falls. The chapter focuses on potential relationships between Northern States Power (NSP) and alfalfa growers within a fifty mile radius of Granite Falls.

Most of the conclusions and recommendations in this chapter derive from two meetings with the Agriculture Advisory Council for this project (for a list of participants see Appendix 9.1). The Ag Advisory Council is comprised of farmers and other residents of southwestern Minnesota.

The chapter is divided into four sections: review of organizational options; comparison of options; evaluation of options; and investment and contractual issues.

### Review of Organizational Options

There are many possible ways to structure the ownership and operation of the proposed biomass plant. This section of the chapter reviews four options: 100% ownership by NSP; 100% ownership by an alfalfa growers' cooperative; and two joint venture options between NSP and a growers' co-op. These options are intended to represent key points along a continuum of possible ownership models.

## A. Organizational Options:

### 1. NSP Ownership

One key feature of the NSP ownership option is that the utility would be responsible for accessing all of the capital required to build and maintain the plant. It would, thus, take all of the financial risks and receive all of the profits. The estimated capitalization cost for the plant is around $130 million dollars. In this scenario, NSP would contract with growers in the region to secure an adequate supply of alfalfa for the plant.

### 2. Producer Cooperative Ownership

The following three options all involve the formation of a "limited membership" cooperative which would either own the biomass plant outright or as part of a joint venture with NSP. The key features of a "limited membership" cooperative are: there is a specified number of shares available for purchase by producers (and, in some cases, other investors); the number of shares is based on the processing and marketing capabilities and goals of the co-op; members purchase shares in the co-op in proportion to the volume of product they agree to sell to the co-op; and members get a return on their investment based on the profitability of the co-op and on the value of product they sell to the co-op.

"Limited membership" cooperatives provide a means for farmers to secure market outlets for their products and to share in the value added to their products through processing and marketing. This approach also provides a means to raise equity capital for cooperative investment in processing and other activities that enhance the value of agricultural products. There are numerous successful examples of this type of cooperative in Minnesota and North Dakota, including a number in the Granite Falls area, such as Minnesota Corn Processors and several nearby sugar beet cooperatives.

Following are the main features of the organizational option based on 100% ownership by a producer cooperative.

* Producers would need to secure all of the estimated $130 million for the plant. Between 30% and 40% of this (approximately $40-50 million) would probably need to be in the form of member equity and the remainder in debt financing.

* The plant would need an estimated 700,000 tons of alfalfa per year. If farmers invest in the plant based on the tonnage of alfalfa they agree to sell to the plant each year, they would need to invest an estimated $60 to $85 per ton.

* Producer members would receive a share in the profits of the cooperative proportional to the value of alfalfa each member sells to the co-op. Members would also be risking their equity in the event the cooperative were not profitable.

### 3. Joint Ownership Option I

There are many possible variations on joint ownership of the biomass plant by NSP and a producers' cooperative. The specific option presented here would involve NSP ownership of the gasification and electricity generating components of the plant; co-op ownership of the alfalfa leaf meal processing and marketing components; and joint ownership of the remote storage sites, the transportation system, storage at the central facility and the separator. The major characteristics of this option are:

* Depending on the specific terms of the joint venture agreement, the co-op's share of capitalization costs may be around $15 million with the remainder being capitalized by NSP. Assuming 30-40% equity capitalization for the co-op, this comes out to an investment of between $6 and $9 per ton of alfalfa committed to the joint venture by the co-op's members.

* Co-op members would get a return on their equity proportionate to the value of the alfalfa they sell to the joint venture. The return would be based on two components: The purchase price paid by NSP for alfalfa stems; and the value added by the co-op's leaf processing and marketing.

#### 4. Joint Ownership Option II

This option would be based on joint ownership of the entire operation by NSP and the growers' co-op. Joint ownership would cover storage, transportation, separation, leaf processing and marketing, gasification and electrical generation. The percentage of ownership would be determined jointly by the two parties. NSP and the co-op could each own half of the business; or one party or the other could own a majority of the company. The key features of this option are the following:

* Investment capital, risk and return would be shared proportionately by the joint venture partners. For example, in a 50-50 joint venture model, producers would invest $30 to $43 per ton of alfalfa committed to the co-op (half of the investment that would be required if the co-op owned the entire plant).

* This option could include a division of responsibility within the joint venture, for example the co-op managing the leaf processing operation and NSP managing the electricity generating operation.

* Return on investment for co-op members would be based on the value of the alfalfa each member had sold to the joint venture and the profitability of the entire operation.

### B. Comparison of Options

An advantage of the **NSP ownership option** from the producers' point of view is that there is minimal up-front risk. Producers would agree to grow a specified amount of alfalfa and would receive a specified price or a price based on an index. This contractual approach requires on-farm expenditures, but does not require an investment in the biomass plant and, thus, does not involve the risk of such an investment. On the other hand, producers would not participate in the upside of these investments. That is, they would not realize a return on the value added to their alfalfa either through electrical generation or through conversion into leaf meal or other co-products.

The primary advantage of a **producers' co-op owning the entire biomass facility** is that producers would share in a return on all the value added to alfalfa as a result of electricity generation and leaf processing and marketing. The downside, of course, is that they would also have to come up with a large amount of equity and would have all of the risk if the biomass plant should run into trouble.

**Joint Ownership Option I** (co-op ownership of the leaf processing operation, NSP ownership of the electricity generating component, and shared ownership of the remainder of the operation) has the advantages of providing some value-added return to producers, while at the same time limiting their initial investment and their risk exposure. One disadvantage is that the co-op would own the part of the business with the greatest price volatility because leaf meal would be sold into an unstable feed market. The co-op would, therefore, be facing greater economic risks than NSP, which would receive a stable, long term price for electricity generated by the plant.

**Joint Ownership Option II** (proportional ownership between the co-op and NSP of the entire company) has the primary advantage of sharing risks and returns in proportion to investments for both the leaf processing and electricity generating parts of the business. There are a range of potential disadvantages depending on the division of ownership between the two parties. For example, too high a capitalization requirement for the co-op may make it difficult to sell enough shares to producer members. Another potential problem is lack of control by the minority partner, if ownership is not equally divided (although this problem can be addressed through legal agreements that protect the minority partner's rights).

## C. Evaluation of Options

At its August 8 meeting in Granite Falls, the Agricultural Advisory Council strongly favored Joint Ownership Option II, a proportional joint venture with NSP.

Participants commented that the NSP ownership option would preclude farmers from getting additional value from their alfalfa crops resulting from leaf processing and electricity generation. Their experience with other limited membership co-ops, particularly corn processing and sugar beets, cause them to favor an arrangement with NSP in which they would be more than commodity producers.

The option involving sole ownership by an alfalfa growers' co-op was opposed by meeting participants primarily because of the size of the investment required, the lack of knowledge among agricultural producers about high technology electricity generation, and the desire to share the risk with an established power generator.

Several participants expressed reservations about the other joint venture option in which a co-op would own the leaf processing and marketing operation and NSP the electricity generating component. The major concern was that the co-op would be selling leaf meal into a volatile feed market, while NSP would receive a stable price for electricity generated from alfalfa stems. They argued that the joint venture partners should share more equitably in the returns from the volatile leaf product sales and the stable electricity sales.

In the end, the option involving proportional ownership of the entire biomass plant was clearly favored by the participants in the meeting. Although there was no detailed discussion on the shares of ownership between the two joint venture partners, several people commented that they would like to see minority ownership by a co-op and majority ownership by NSP (for example, a 25-75 split) as long as an equitable decision making procedure between the two parties could be worked out.

### D. Investment and Contractual Issues

Participants in the August 8 meeting commented on a number of issues related to the biomass project, particularly related to investing in the co-op and contracting with the joint venture.

1. **Leaf meal market.** When asked what the major issues are that need to be resolved before the biomass plant is developed, the biggest concern raised was the need to identify a firm market for leaf products.

2. **Acreage per producer.** There were differences of opinion among the group about the average number of acres farmers would be willing to commit to the biomass plant. If the average of grower contracts was 100 acres per member then approximately 1,800 grower-owners would be needed. Some participants thought that the average number of acres per farmer would be under 100 acres probably in the range of 60 to 80 acres. If this estimate is correct, over 2,250 members would be needed to meet the plant's feedstock demand (coop membership estimates are based on a production average of 3.9 tons per acre, annual feedstock demand for 700,000 tons {leaves and stems}, yielding an acreage requirement of ca. 180,000 acres).

3. **Contracts based on tons/acres.** Participants favored sales agreements to the biomass plant based on tons and quality. Stock purchases in the co-op could be based on tons or by the acre. Minnesota Corn Processors (MCP), a local corn wet-milling cooperative, has stock purchases and production commitments based on bushels. Southern Minnesota Sugarbeet Growers Association (SMSBG), a local sugarbeet cooperative, bases

membership shares on acres. Participants expressed concerns about having sales agreements that are too complicated, for example requiring cutting at specific times of the year or requiring only two cuttings.

4. **Price per ton.** Several participants are currently selling prime hay at $100 per ton. One of these growers commented that he would accept $80 per ton from the co-op because he could reduce labor and transportation costs below those he experiences with his current baling and marketing approach. Assuming that the co-op will pay differential prices based on hay quality, an $80 price for prime hay probably translates into a average price for hay of different qualities in the mid to low $70's.

5. **Amount of equity per farmer.** There was general agreement that an average of $15,000 to $20,000 in stock purchases was a reasonable investment level for the co-op. If the investment is considered a good one by the producer's bank, it will accept the stock certificate as the collateral for a loan of that size.

6. **Return on investment.** Based on returns being received by members of other limited membership co-ops, participants in the meeting would like to see returns of 15 to 20% on their investments in the alfalfa co-op. One of the financial advisors pointed out that projected returns would have to be that high if farmers were to borrow in order to buy co-op shares.

7. **Length of contracts.** Most participants favored a contracting system similar to those used by other limited membership co-ops. Farmers could sell their shares in the co-op to another producer at any time, thus passing on the production contract to that producer. If a farmer were not able to sell his shares to another farmer, he could submit a notice of termination to the co-op. However, he would need to continue to meet his contractual obligation for a specified period of time after his notice of termination (e.g., 3 years, 5 years). Participants also reported that many limited membership co-ops are not obligated to buy product from their members (although members have priority over non-members). Participants thought that because of the long term production needs of a biomass energy plant; however, the contract between the co-op members and the joint venture should be more of a long term reciprocal agreement than in the case of some other limited membership co-ops.

8. **Adjustment of prices.** There was no clear agreement on how to adjust alfalfa prices from year to year. Suggestions included using hay auction prices, a formula based on soybean and corn prices, and a formula based on sale prices of leaf meal/other feeds.

9. **Insurance against crop losses.** Many participants expressed a concern about weather-related risks of growing alfalfa. One person reported that USDA crop insurance is available in some areas for alfalfa. There was also some discussion of the biomass plant not obligating producers to meet their contracts if they could certify their crop loss. The possibility of some type of risk sharing pool among co-op members was also discussed.

## Conclusion

Agricultural Advisory Council participants clearly favor a joint venture model between NSP and a growers' cooperative in which investments, risks and returns are equitably shared among the two venture partners.

The Agricultural Advisory Council also identified a number of specific marketing, financial and contractual issues that should be taken into account in the development of the co-op and the joint venture. These issues are described in the preceding section.

It is worth noting that the Agricultural Advisory Council meeting on August 8 concluded with the formation of an alfalfa growers' cooperative steering committee. Ten participants agreed to meet to discuss the next steps alfalfa producers should take in order to prepare for further development of the biomass plant as well as for other processing and marketing opportunities for alfalfa. Subsequent meetings resulted in the formation of the Minnesota Valley BioPower Cooperative (BPC). The BPC is a grower-owned cooperative formed to evaluate the opportunity for sustainable biomass energy production from alfalfa. BPC Board members are listed in Chapter 1.

## 9.2 Contracting for Production

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Establishing contract terms that clearly communicate how growers will be paid is crucial. By definition, contracts are designed to guide the performance of two parties and protect each through the course of a transaction. Regardless of to whom growers sell their alfalfa, the following issues will need to be clearly understood by each party:

1) the quantity of alfalfa to be delivered and the delivery location (tons/acres),

2) the minimum acceptable quality,

3) fair price differentials between quality grades,

4) the timing of delivery or method of flow control,

5) approved production practices (weed control, use of pesticides),

6) the payment schedule,

7) the risk borne by each party, and risk sharing,

8) auxiliary services provided by the contractor,

9) conditions allowing adjustment of contract terms and means to mediate disputes,

10) a means to prevent leakage of contracted supply and fraud.

If a fair contract can be drafted, then both the grower and the contractor will benefit from continuity and long term relationships. Retention of growers is important because it can result in substantial savings for the contractor in terms of reduced transaction costs to recruit new growers. Since the proposed project would utilize the hay from nearly 180,000 acres and could involve 2,000 growers, transaction costs and grower retention are very important.

There are unique aspects of alfalfa biomass production. Unique conditions require unique contract specifications. With 180,000 acres of alfalfa being grown, harvests could occur from May 25 to September 1 or later, depending on contract terms and incentives as well as grower attitudes. Because the project is large in scale and because 60% of the crop must have storage, remote storage sites will be important. They will provide storage as well as quality testing. The remote storage sites are assumed to be spaced around the biomass shed within 5 miles of each grower. Two types of vehicles were identified as suitable for transportation of large round bales to the remote storage sites. The number of remote storage sites specified in Chapter 5 is large in order to reduce the costs of transportation from field to remote storage site. It is assumed that all hay can be brought in or through the remote storage sites within 15 days of harvest. Approximately 40% of all the production of alfalfa stems will be consumed during the growing season. Therefore, alfalfa processing must occur for 40% of the hay in this time period.

**Quantity delivered**

At issue is whether or not contracts should be based on acres of hay or tons of hay. If a contract is based on acres, such as canning contracts or sugar beets, it is often because there are no other market channels for these crops than through the contractor. In the case of corn for processing, contracts are made on the basis of bushels. This is partly due to the fact that there are readily available market channels for extra crop grown on farms and there are readily available market sources for the contractor in years when grower yields are too poor to fulfill the contract. The biomass energy facility will be designed to provide stems to fuel electric power production and leaves for co-product processing. The power plant and alfalfa processing facility will be designed with minimum and maximum capacities. If growers contract on the basis of tons and are unable to deliver, growers may be asked to compensate the power plant for the additional cost above alfagas (biomass fuel) needed to buy natural gas to fire the combustion turbine. Essentially, the growers would be contracting to deliver stems sufficient to provide so many BTU's. If they didn't, they may be responsible for the cost of a higher price substitute fuel (natural gas).

If growers were to contract their production from a given number of acres of alfalfa, there would be temptations for some to report low yields in years of high hay prices and divert some of their hay to the hay market. This is called "contract leakage".

The place to certify the amount delivered will be the remote storage site. Should there be different prices paid for hay delivered to remote storage sites - based on distance to the site? For contracted sugarbeet production, transportation allowances attempt to equalize trucking costs from remote storage to the central processing plant. Since title to the alfalfa changes at the remote storage site, the quantity and quality of hay for future payment is determined there. Because the grower co-op needs growers far and near to spread risk and attain the critical mass for plant economies, it can be argued that there should be no price differentials due to production location (within a set maximum boundary).

**Minimum quality acceptable**

Quality becomes an issue in several dimensions. One attribute that must be specified is acceptable moisture. If bales are too wet, microbial activity can cause them to heat, causing dry matter losses as well as the possibility of fire from spontaneous combustion. Perhaps any bale exceeding 18% should be rejected from storage at remote sites and sent directly for drying and fractionation. If alfalfa bales are too wet for safe storage, producers must suffer sharp discounts thereby discouraging this practice. Perhaps a continuous-weighing conveyor or a scale device built into the fork of a forklift could effectively detect wet bales based on their weight.

**Quality testing**

It is important that the contractor not suffer quality losses caused by growers sorting out poorer bales for delivery. Alfalfa will need to be tested at the regional storage site upon receipt. Near infrared reflectance spectroscopy (NIRS) is a rapid testing method used in the U.S. to test forages. The test can be performed within minutes after samples are prepared. Hay delivered to the biomass shed should be tested for moisture, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), % leaf fraction, and % weeds.

**Fair Price Differentials Between Quality Grades**

A great way to encourage unhappy growers and lose grower continuity is for the contractor to be imprecise in measuring quality and thus overpaying for poor quality. This also creates further incentives for quality leakage.

**Timing of Delivery or Flow Control**

Canning companies offer incentives for growers of peas and sweet corn to grow for them at times of the season when maximum yields are not possible in order to keep a consistent volume of product flowing to the processing facility. To encourage pea and sweet corn growers to produce for the non-optimum times, they must be compensated according to planting date. Similarly, in order to have flow control and some measure of risk balancing, the biomass contractor may wish to encourage some growers to use different cutting schedules so that the cutting times will be dispersed over the whole biomass shed. Flow control would be accomplished in an area by offering price incentives to time particular cuttings in order to smooth out the amount of hay heading into the remote storage sites during particular harvest windows.

**Approved Production Practices**

Producers will probably want an initial payment when their bales are graded and enter the remote storage site. The contractor will probably wish to make payments only as fast as sales of leaves and stems occur in aggregate for the biomass shed. Subsequent payments may be made over the next ten months as sales of leaves and stems occur.

**Risk Borne by Each Party, Risk Sharing**

Producers will generally accept the risk of rain damage and poor growing conditions. Once the hay is delivered at the remote site, the quality grade is established upon which the grower will be compensated. Weight and quality losses during storage would then be the responsibility of the cooperative or the joint venture.

**Auxiliary Services Provided by the Contractor**

Several possible services that the contractor (or other private contractors) could provide for growers include field pick-up of bales with specialized equipment and hauling to remote storage sites. Under such a scenario the grower may get nervous waiting for his bales to be moved in before they suffer damage due to rain while already baled. By supplying transport services from the field to remote storage, the contractor could effectively prevent "leakage" of contracted hay. The contractor will either provide or contract with trucking companies for hauling of hay on semi's from remote storage sites or from fields in a direct haul situation during harvest to the processing plant.

**Conditions Allowing Adjustment of Contract Terms, Dispute Resolution**

Pertinent to this issue are situations when a grower might wish to leave the co-op. A worthy mechanism utilized by others is that of requiring a grower to officially notify the co-op of his plan to leave three years before his obligations end.

If farmers differ with grain elevators on measured quality grades, they theoretically have avenues for a re-grade through state and federal agencies. Perhaps there will need to be a similar path for dispute resolution with hay.

**Means to Prevent Leakage of Contracted Supply and Fraud**

As stated previously, answers to this issue lie in crafting clear contracts and spending the money to measure quality precisely. Contract terms could specify tonnages with defined leaf and stem percentages with recourse against the grower to compensate for insufficient delivery. Penalties could be based on the additional expenses born for insufficient feedstock delivery.

Another important task of the contractor is monitoring performance. The contractor must ask whether or not contract terms provide sufficient incentives to keep the proper balance of quantity and quality needed for profitability.

## 9.3 Coop Development

**Key Components for Success**

USDA:RDA

Cooperative Development Program

- The Cooperative Development Program within USDA has available no cost technical assistance for the development of producer cooperatives for biomass energy production. Financial assistance for cooperatives to develop marketing strategies and for other cooperative related business functions has also been available through a competitive grant process, pending funding allocation. Further information on the Cooperative Development Program is available by contacting the Center for Alternative Plant and Animal Products, University of Minnesota.

# CHAPTER 10. ENVIRONMENTAL IMPACT

## 10.1 Energy Balance

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### Introduction

Does energy input into production, transport, and processing of alfalfa for fuel result in a net energy gain or loss? The answer to the question is one of utmost importance when biomass is proposed as a viable energy source. If indeed the biomass system consumes more energy than it produces, it may be more environmentally sound use fossil fuels directly. Evaluating energy inputs and outputs for a biomass system is not as easy as it might seem. First, it is difficult to determine what inputs should be included in the system and to get accurate values for those inputs. Depending on the inputs chosen and the values assigned to these inputs, an energy balance can be "adjusted" significantly. Secondly, with a biomass system, there are often co-products generated. These co-products cannot logically be evaluated on their gross energy because they are not converted to heat, but are used as a food or feed source. For example, the protein leaf meal generated in alfalfa conversion must be evaluated in terms of feed value, not gross energy content. A biomass energy balance should be viewed only as one of many guides in determining the effectiveness of using biomass as an energy source. Energy inputs and outputs used in the following evaluation are based on the best information available. All assumptions and references are given to assist readers in reaching an independant conclusion.

### Energy Analysis

Energy inputs into the dedicated feedstock supply system (DFSS) rotation (four years alfalfa, two years corn and one year soybeans) are compared to energy inputs in a conventional crop rotation (one year corn, one year soybeans). A comparison of energy inputs for these rotations aids an evaluation of the sustainability of those systems. The net energy balance (energy inputs : energy outputs) for the conversion of alfalfa feedstock to electricity and protein meal is also determined.

With any energy evaluation, the first task is to define energy input and energy output boundaries. For example, energy inputs of a tillage system might consider only fuel used per acre by the tractor pulling the implement. However, an energy analysis might also include the energy involved in manufacturing both the tractor and the implement; the energy involved in producing the steel for the tractor and implement; the energy involved in producing the equipment to produce the tractor and implement; and the energy used to mine the iron ore to produce the steel. An energy analysis might also take into account the human labor energy used to drive the tractor, or the energy needed to build the structure to store the tractor or implement. As can be seen, the boundary for energy inputs could be drawn in several places. Energy outputs are more defined. Energy output boundaries for an electric power plant typically include only the electricity produced at the plant. However, waste heat might be included if it were used for some purpose. In the case of alfalfa conversion, the 28% protein leaf meal production is also considered.

**Energy Analysis for Different Crop Rotations**

Energy inputs for crop rotations vary from year to year, depending on the crop. Therefore, crop rotations must be compared after a complete rotation. The DFSS rotation proposed is a seven year rotation (A-A-A-A-C-C-S) while a corn-soybean rotation (C-S) is a two year rotation. Energy comparisons after seven years would be impacted by which crop was grown first in the corn soybean rotation. In order to get an accurate energy comparison, a 14-year rotation was considered: two DFSS rotations vs seven corn-soybean rotations.

Energy inputs for the rotations include the direct fuel use in crop production; the manufacture, maintenance and repair of the farm equipment; the production, packaging and transport of fertilizer, insecticide, and herbicide; and the fuel used to transport the products to the feed mill or storage site (**Table 10.1-1**). In this analysis, energy inputs for field operations, transportation, fertilizer, herbicide, and insecticide usage are an average of the inputs considered in chapter 4. The average of fourteen year estimates of energy inputs indicate the DFSS rotation is significantly less energy intensive than the corn-soybean rotation, resulting in totals of 48.6 MBtu/acre/year and 70.9 MBtu/acre/year, respectively. These energy values are less than those that would be predicted if we used single crop values given by other researchers. Alfalfa production is estimated to consumes 4.7 MBtu/acre/year (Heichel 1980), corn production consumes 9.3 MBtu/acre/year (Pimentel 1980), and soybean production consumes 3.8 MBtu/acre/year (Scott, 1980). Summing these values for a 14 year rotation similar to our DFSS and CS rotations give 82.4 MBtu and 91.7 MBtu, respectively. Crop rotation effects and reduced tillage within the DFSS rotation are the main reasons why our energy inputs are less than those reported by others.

**Table 10.1-1** Estimated energy use in the DFSS and in a corn-soybean rotation based on a fourteen year rotation are presented.

## ENERGY INPUTS

| | DFSS Rotation (14 yrs*) | | CS Rotation (14yrs*) | |
|---|---|---|---|---|
| INPUTS | Quantity/a | MBtu/a | Quantity/a | MBtu/a |
| Labor | 21.3 hrs | -- | 18.3 hrs | -- |
| Machinery[1] | -- | 5.1 | -- | 5.7 |
| Diesel Fuel[2] | 73.7 gal | 10.2 | 81.7 gal | 11.3 |
| Fertilizer[3] | | | | |
| -nitrogen | 134 lbs | 4.2 | 716 lbs | 22.2 |
| -phosphorus | 630 lbs | 3.2 | 412 lbs | 2.1 |
| -potassium | 2160 lbs | 8.6 | 996 lbs | 4.0 |
| Seeds[4] | | | | |
| -alfalfa | 25 lbs | 2.8 | 0 lbs | 0 |
| -corn | 60 lbs | 2.7 | 105 lbs | 4.7 |
| -soybean | 150 lbs | 2.0 | 525 lbs | 7.1 |
| Herbicide[5] | 9.3 lbs | 1.4 | 8.1 | 1.2 |
| Insecticide[5] | 3.2 lbs | 0.5 | 0 lbs | 0 |
| Drying[6] | 428 bu | 6.3 | 798 bu | 11.1 |
| Transport[7] | 44.3 tons | 1.6 | 30.7 tons | 1.7 |
| Total (14 year rotation) | | 48.6 | | 70.9 |
| Average (per acre per year) | | 3.5 | | 5.3 |

* A 14 year rotation was used to insure equal years of corn and soybeans in the corn-soybean rotation. A seven year rotation would give either four years corn and three years soybeans or four years soybeans and three years corn. The energy balance is significantly different for these scenarios. Inputs quantities used are an average of what was used in chapter 3.

[1]Energy required to manufacture, maintain, and repair machinery is estimated at half of the diesal fuel requirement for field operations.

[2]One gallon diesel fuel = 138,800 Btu

[3]Production and transportation of nitrogen fertilizer requires 31,000 Btu/lb. Production and transportation of phosphorus fertilizer requires 5000 Btu/lb. Production and transportation of potassium fertilizer requires 4000 Btu/lb.

[4]Production of alfalfa seed requires 111,000 Btu/lb.Production of corn seed requires 44,717 Btu/lb. Production of soybean seed requires 13,650 Btu/lb. (Heichel,1980)

[5]Production, packaging and transportation of herbicide and insecticide require 150,00 Btu/lb of active ingredient (Pimentel[c], 1980)

[6]To dry 1 bu of corn requires 2000 Btu per lb of moisture removed. Drying from 25% to15% removes approximately 7.42 lbs water.

[7]To transport farm commodities (farm to market) requires 4700 Btu per ton per mile.(Pimental[b], 1980). Alfalfa transported 5 miles, corn and soybeans transported 12 miles.

Note: Spreadsheet utilization guide for energy balance calculations (Appendix 10.1).

Energy inputs for corn and soybeans are reduced when these crops are grown in the DFSS rotation. The first and second year of corn in the DFSS rotation used 6.4 MBtu/acre and 8.5 MBtu/acre, whereas, energy inputs for corn in the corn-soybean rotation are 9.6 MBtu/acre. This energy savings can be attributed to reduced nitrogen fertilizer use because of alfalfa nitrogen credits. Energy inputs for soybeans were approximately the same for both rotations.

Comparisons were made on the outputs from 14 years under each sample rotation. A typical DFSS rotation will produce an estimated 30 tons alfalfa (25.5 tons dry matter), 428 bushels corn, and 71 bushels soybeans. A typical corn-soybean rotation will produce an estimated 748 bushels of corn and 249 bushels of soybeans. Comparisons can be made using gross energy outputs for these two rotations. Gross energy values for alfalfa, corn, and soybeans have been given as 8116 Btu/lb dm , 8617 Btu/lb dm, and 8615 Btu/lb dm, respectively (Fluck, 1992). Using these values, the gross energy output for fourteen years of the DFSS rotation is 623 million Btu/acre versus 418 million btu/acre for the corn-soybean rotation. Estimated protein generated by the DFSS rotation is 12,789 lbs/acre vs 8897 lbs per acre with the corn-soybean rotation (alfalfa = 18% CP (dm), corn = 10% CP (dm), soybeans = 40% CP (dm); yields based on 15% moisture alfalfa, 15% moisture corn, 13% moisture soybeans). These comparisons indicate both an increased gross energy output and an increased crude protein output with the DFSS rotation. However, these crops are typically used for feed, not fuel. Before comparing the value of these rotations as animal feed, the nutritional aspects of these crop rotations should be evaluated.

**Energy Analysis for Alfalfa Conversion**

The second analysis compares the energy spent to produce, transport, and process alfalfa to the energy and co-product output (**Table 10.1-2**). Also considered, are energy inputs and outputs for a traditional electrical energy source, coal (**Table 10.1-3**). Energy input:output analysis is helpful in rating the efficiency of using alfalfa as an energy crop. Energy spent for production and transport of alfalfa to a storage facility, 285 Btu/lb, is estimated from our DFSS energy analysis. Energy spent for transporting the alfalfa from storage to the fractionation facility, 94 Btu/lb, is based on a 40 mile distance between the storage site and the fractionation facility. Energy values for drying and fractionating the alfalfa, 146 Btu/lb and 102 Btu/lb, are estimates from Northern States Power. These energy estimates are only for direct energy inputs. Indirect energy inputs for the manufacture, maintenance, and repair of all equipment and structures related to alfalfa conversion have not been considered.

**Table 10.1-2** Energy balance for alfalfa conversion to electricity using an integrated gasification combined cycle power production system.

**ENERGY BALANCE for ALFALFA**

| INPUT | Quantity per lb alfalfa[1] | Notes |
|---|---|---|
| Farm production and transport to storage[2] | 285 Btu | DFSS rotation estimates - alfalfa |
| Transport to conversion plant[2] | 94 Btu | 2.35 Btu/lb/mile, 40 mile average |
| Dry dry from 15% to 10% | 146 Btu | 3% of stems used for drying |
| Fractionate[2] | 102 Btu | 0.03 hph/lb, motor efficiency=75% |
| TOTAL ENERGY INPUTS | 627 Btu | |
| **OUTPUT** | | |
| Feed | 0.10 lbs crude protein | 0.45 lb leaves[1] -27% crude protein (dm) |
| Electricity | 1433 Btu | 0.55 lb stems[1] -6900 Btu/lb alfalfa (15% moisture) -IGCC conversion[3]: 9000 Btu/kWh =0.42 kWh/lb alfalfa (15% moisture) |

[1]Alfalfa at 15% moisture 55% leaf material and 45% stem material.
[2]Maintenance, manufacture and repairs not included.
[3]personnel communication NSP (IGCC-Integrated Gasification Combined Cycle)

**Table 10.1-2** indicates a ratio of energy input to energy output of **1:2.28**. An energy balance analysis for coal (**Table 10.1-3**) indicates a ratio of energy input to energy output of 1:4.38. Alfalfa conversion to electricity is less energy efficient than coal conversion to electricity based solely on production, transport, and processing costs. Alfalfa conversion to electricity also produces a high value leaf meal co-product. Past researchers have assigned an energy value to alfalfa leaf meal as the equivalent energy needed to produce a similar protein meal. Crude protein produced from one pound of alfalfa hay is 0.10 lbs. as represented by the alfalfa leaf meal fraction (0.85 dm x 0.45 leaf fraction x 0.27 C.P.). To produce this amount of crude protein from soybeans would require 477 Btu (Scott, 1980). This increases the energy balance (input:output ratio) for alfalfa to **1:3.04**.

**Table 10.1-3** Estimated energy balance for coal conversion to electricity using an integrated gasification combined cycle electric power production system.

**ENERGY BALANCE for COAL**

| **INPUTS** | **Quantity per lb coal** | **Notes** |
|---|---|---|
| Mining transport, breaking, sizing, washing, distribution[1] | 827 Btu | Cervinka(1980) =7.3% of high heat value |
| **OUTPUTS** | | |
| Electricity | 3625 Btu | 8500 Btu/lb coal (25% moisture) -IGCC conversion[2]: 8000 Btu/kWh =1.06kWh/lb coal |

[1]Manufacture, maintenance, and repair of equipment not included.
[2]personnel communication NSP (IGCC-Integrated Gasification Combined Cycle)

**Conclusions**

A primary concern when converting biomass to energy is the energy balance. Our energy analysis indicates the conversion of alfalfa to electricity results in a net energy increase. The ratio of energy input to energy output (1:3) is less than for coal conversion to electricity (1:4.4) however, this is not surprising, given that energy in coal represents biomass energy that over millions of years was concentrated to a form that need only be stripped out of the ground and loaded on trains. Biomass energy in alfalfa reflects solar energy sequestered in plant tissues in a period of less than a year. The lower energy density of biomass may well be compensated for by other environmental and economic considerations. The highly positive energy balance (1:3) indicates that alfalfa is a very energy efficient biomass energy crop. Our analysis indicates that the DFSS rotation generates more gross energy and more crude protein than a traditional corn-soybean rotation and does it with lower energy inputs.

# 10.2 Soil and Water

## SOIL AND WATER RESOURCE IMPACTS/BENEFITS

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Soil Conservation Service, USDA

The proposed biomass shed as defined includes the land area within a 50 mile radius of Granite Falls, Minnesota. The impacts on the soil and water resources of the area from adopting an alfalfa based rotation to supply biomass material for the power plant were evaluated by looking at present land use and soil erosion levels compared with projected soil erosion levels when those same acres are placed in an alfalfa based rotation.

Present land use in the biomass shed is illustrated in **Figure 10.2-1**. Approximately 83% of the total land area is currently devoted to the production of agricultural crops. A review of the soils on these cropland fields indicates that approximately 89% or in excess of 3.5 million acres of cropland would be suitable for production of alfalfa. Total available acreage is approximately ten times that needed to supply alfalfa to the plant.

**Figure 10.2-1** Current land use in the biomass shed.

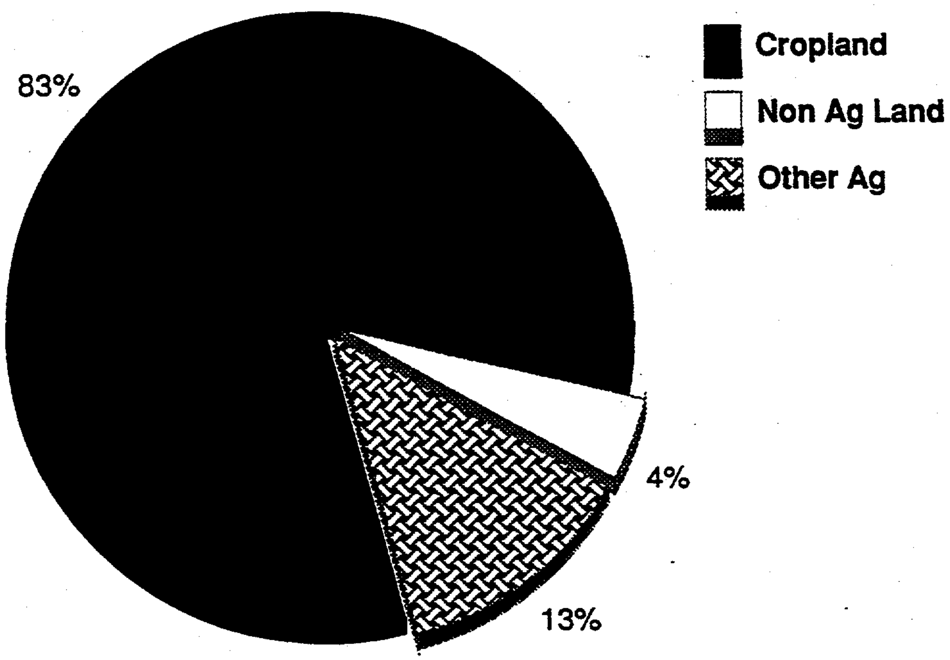
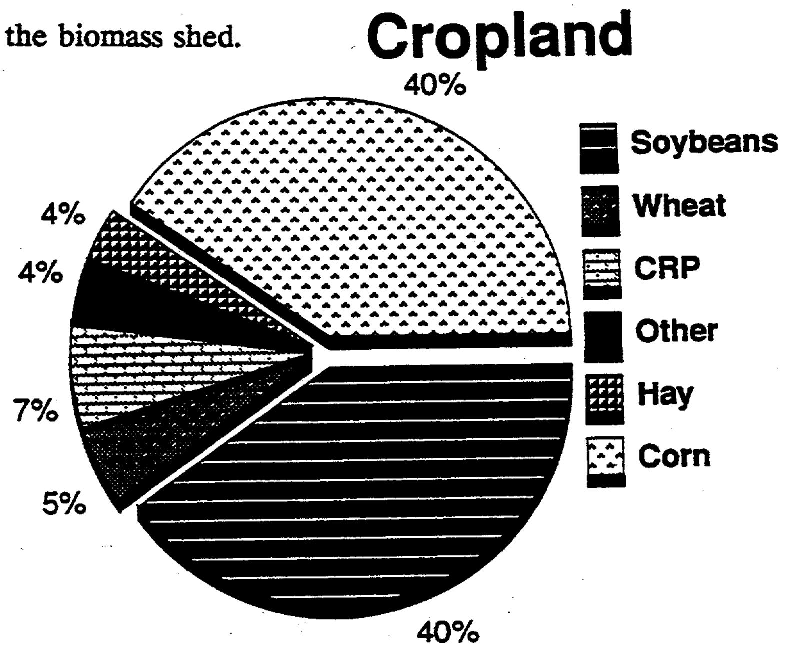


**Figure 10.2-2** identifies the extent of the major crops produced in the area. Currently approximately 80% of the cropland is used to produce corn and soybeans; 5% for the production of wheat; 3.5% for hay production (includes all species); 4.5% in other annual crops; and 7% enrolled in the Conservation Reserve Program (CRP). CRP contracts begin to expire in 1996. The majority of CRP acres will potentially be returned to annual crop production in 1997. Approximately 5% of the cropland is classified as highly erodible land thereby requiring implementation of a conservation compliance system for the producer to retain eligibility for USDA program benefits.

**Figure 10.2-2** Crops in the biomass shed.




Soil erosion problems on cropland in the area include both blowing soil from wind erosion and water erosion in the form of sheet and rill erosion and ephemeral gully and classic gully erosion. Soil erosion levels have been estimated for both wind erosion and sheet and rill water erosion. Rates of soil erosion are compared to a tolerable soil loss. Tolerable soil loss is defined as an acceptable erosion rate that will permit long term productivity of the soil resource.

County reliable data taken from the 1982 National Resources Inventory summarized for the area indicates that under present condition approximately 30% of the cropland has erosion rates at or below tolerable levels and 70% of the cropland is eroding at rates greater than tolerable levels. Adoption of the alfalfa based rotation on all cropland in the biomass shed would reduce soil erosion to tolerable erosion levels on 70% of the cropland, leaving 30% of the cropland with erosion rates reduced but still exceeding tolerable erosion levels.

The analysis of impacts from applying the alfalfa based rotation assumes that the present condition is a two year corn-soybean rotation using clean tillage practices. The alfalfa based rotation is a seven year corn-corn-soybean-alfalfa-alfalfa-alfalfa-alfalfa rotation also using clean tillage. The analysis shows that the alfalfa based rotation would reduce sheet and rill water erosion by 60% and wind erosion by 45%. Erosion reductions are illustrated in **Figures 10.2-3** and **10.2-4**.

Since about 10% of the total cropland in the biomass shed (depending on production radius) will be required for alfalfa production, the overall effect on the biomass shed in terms of reducing soil erosion will be limited. However, by focusing biomass production on fields with high erosion rates as well as on eroding fields with high sediment delivery rates to surface waters will mean greater environmental benefits may be achieved.

**Figure 10.2-3** Sheet or rill erosion on moderate and severe slopes shown as tons per acre of loss.

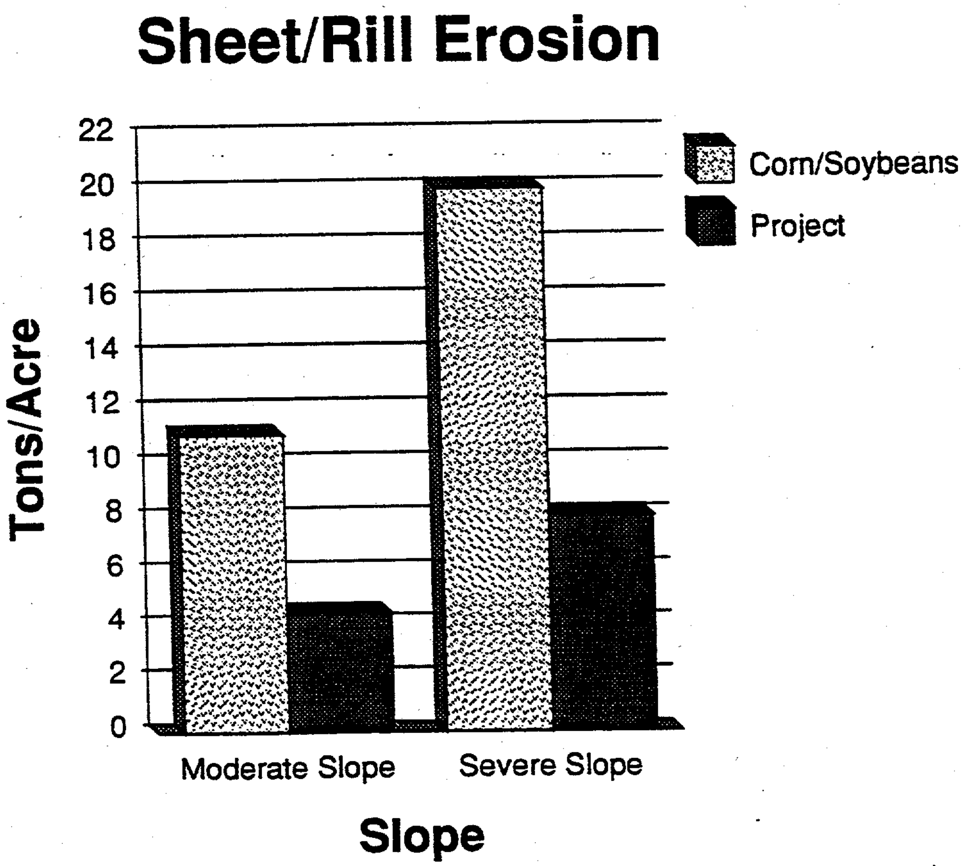
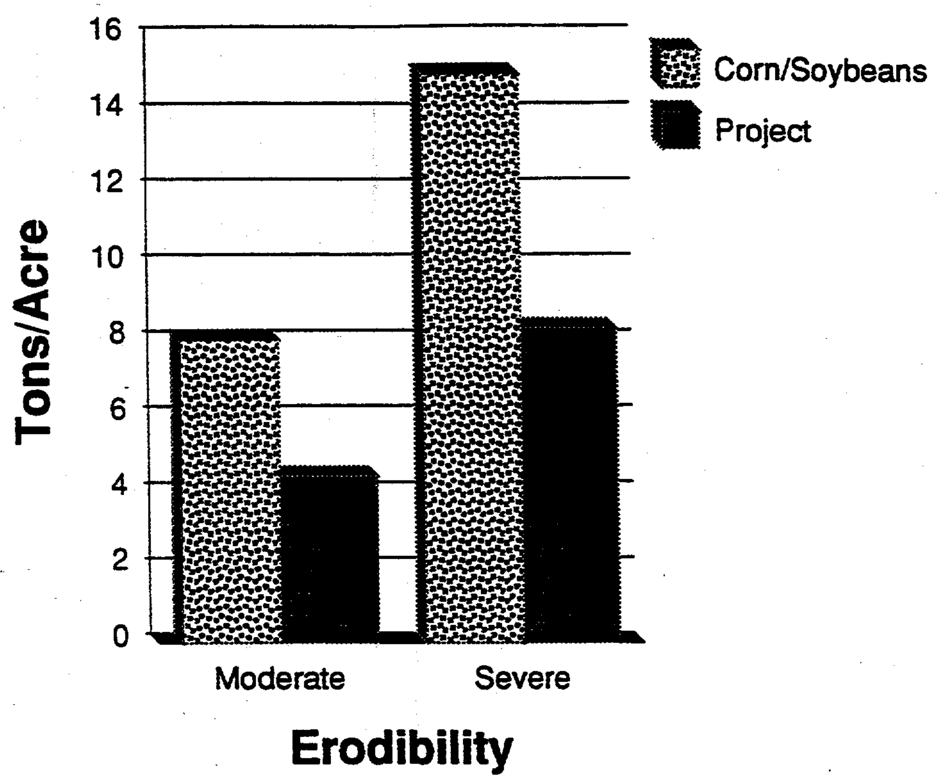


**Figure 10.2-4** Wind erosion loss (tons/acre) for moderate and severely erodable soils.




Crop rotations that include perennial plants such as alfalfa improve soil structure and build soil organic matter levels to improve the overall quality of the soil resource. Rotation effects typically improve the yield of the following crop.

Alfalfa and other perennial legumes obtain nitrogen from the atmosphere (nitrogen fixation) and add fixed nitrogen to the soil for succeeding crops to utilize. This activity will reduce the amount of commercial nitrogen that will need to be added to the rotation production system.

Alfalfa and other perennial legumes in the crop rotation reduce certain weed, insect, and disease populations and facilitate use of cultural controls for other pests that may occur. Thus, the need for and use of pesticides in the system will be reduced.

Reduced soil erosion, improved soil quality, lower nitrogen input and reduced pesticide use in the biomass shed will have a positive impact on the environment and the total resource base including soil, water, air, plants, animals and people.

## 10.3 Changes in Soil Structure

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Soil Science, University of Minnesota

Corn grain yields are 10 to 15% higher when following alfalfa compared to corn due to the "rotation effect". Although there is a benefit from the atmospheric N that is converted to available forms for the following corn crop, the "rotation effect" is independent of the response to soil N. There is also less pressure from insects, diseases, and weeds when rotations are followed. Although all of these factors contribute to the better crop performance when alfalfa is in the rotation, the soil influence is not to be undervalued.

Water and gas flows through soil are largely dependent on not only the total porosity, but also the pore size distribution, continuity, and tortuosity. The pore characteristics are influenced mostly by the soil particle size distribution. Soil particles can be bound together by cementing agents, causing them to act like larger particles. This phenomenon affects water and gas flow.

When alfalfa is introduced into a rotation, several changes in soil properties occur. Cementing agents (such as polysaccharides and gels) are introduced from direct alfalfa root exudates which also stimulate microbial activity. Together these influences reduce soil bulk density, increase pore space, and aeration, and provide macropores that provide for better water flow. The absence of tillage during the alfalfa years of the rotation also allows soil structure formation, increased soil organic matter, and enhanced physical and biological soil properties.

Most farmers generally recognize improved soil tilth when following alfalfa. The soil is well aggregated and the aggregates are very stable. It is hard to assign a dollar value to improved soil tilth. The benefits of the alfalfa in the rotation are greatest on the fine textured soils (developed in glacial till or lacustrine sediments). Alfalfa has the greatest impact on improving the internal soil drainage and aeration of these soils, which need tile drainage to effectively grow crops. In wet years enhanced internal drainage on soils previously in alfalfa can influence yields about 25%. On average the influence of good internal drainage on yields is about 15%. Alfalfa in a rotation increases the effectiveness of the tile.

# 10.4 Environmental Impacts of Biomass Production in the Upper Minnesota River Basin

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## Introduction

Non-point source monitoring studies conducted by the Minnesota Waste Control Commission, MWCC, (1990, 1991, 1994) have documented that during 1976-1992 the water quality of the Minnesota River has been worse than that of the Mississippi and St. Croix Rivers. The loading of total suspended solids in the lower Minnesota River was 22 times greater than that in the St. Croix River and 3.6 times greater than that in Mississippi river (MWCC, 1994). According to MWCC, these numbers translate to approximately 625,000 tons per year of total suspended solids (86 20-ton truckload per day) transported by the Minnesota River at Fort Snelling in the Twin Cities. Loading of total P from the Minnesota River was 5.5 times greater than from the St. Croix River and 1.5 times greater than from the Mississippi River (MWCC, 1994). During 1990-1992, 84% to 96% of the entire annual loading of chemical oxygen demand (COD), nitrate, total suspended solids, and total P to the lower Minnesota River was from diffuse sources upstream.

The poor water quality of the Minnesota River is one of the major water quality issues facing the state of Minnesota. The Minnesota Pollution Control Agency (MPCA) has estimated that a 40% reduction in head water pollutant loading will be necessary to achieve federally mandated water quality goals in the lower Minnesota River.

A recent study (Ginting et al., 1993) in West Central Minnesota has shown that although total P and sediment losses in spring runoff are higher from moldboard plowed tillage systems, systems that leave crop residues on the surface result in more soluble P in snow melt. After several major runoff events during the early growing season, sediment losses under the moldboard system surpass those of cropping systems that leave crop residues on the soil surface.

Estimates from this feasibility study have shown a great reduction in sediment losses when tillage is eliminated and soil cover provided with alfalfa production. This could translate to a substantial reduction in loading of biological oxygen demand, phosphorus, and sediment to the Minnesota River. The caveat is the unknown contribution of the soluble P leaching from alfalfa residues during the spring thaw period.

## Research Needed

Future research is necessary to quantify the effect of introducing alfalfa into a corn-soybean rotation on the transport of sediment, P, N, and carbonaceous material in surface runoff from watersheds under the climatic and soil conditions of West Central Minnesota. The impact on both individual storms and annual loading needs to be considered. The specific research objectives are:

1. To evaluate the effect of alfalfa introduction into a corn-soybean rotation on water quality of surface runoff at the subwatershed scale during fall, spring and summer months. This will quantify the effect on annual loading of runoff; sediment; total, bio-available, and soluble P; nitrate and carbonaceous material from the watershed.

2. To quantify processes affecting runoff water quality at the plot scale under natural precipitation.

3. To quantify and model processes affecting runoff water quality during the snow melt period.

4. To develop methods of upscaling plot runoff and water quality data to the watershed scale.

5. To assess the cost-benefit ratios of various management practices in improving the runoff water quality at the watershed scale.

## Models and Scaling:

Even though considerable research data might exist for a given problem in the literature, upscaling and extrapolating the data both in space and time is difficult. Models provide an excellent and inexpensive opportunity for such scaling.

For the sediment and nutrient transport in surface runoff, there is extensive literature at a plot level. However, there has been limited effort in upscaling this data to the watersheds. Procedures are needed to take data from the plot studies and apply them to large areas such as small and large watersheds, or to even subbasin scale. In addition, as most of the research covers a small time scale, methods are needed to extrapolate data to longer time periods.

A few of the well known functional models in the literature dealing with sediment and nutrient transport are GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) and AGNPS (Agricultural Non-point Source Pollution Model). Each of these models is applicable at a different scale. Application of GLEAMS is appropriate at a plot/field scale whereas that of AGNPS is more suitable for a watershed scale. However, little effort has been made to link these models.

A recent study conducted by the Soil Conservation Service (1993) used these models to assess the impact of land management in 10 watersheds along the Minnesota River. These models were used separately for a given purpose. For example, GLEAMS was used to estimate nutrient loading whereas AGNPS was used to predict sheet and rill soil erosion and sediment yield. The prediction from these two models were used in conjunction with TR-20 (Technical Release-20, SCS, 1991) Hydrologic Delivery model outputs to estimate losses of sediment and nutrients at both the field and watershed level. Although the assessment based on this approach has been useful in identifying broad alternatives for reducing the sediment and contaminant transport to the Minnesota River, no effort has been made to test and validate these upscaling procedures. In addition, the manure management alternatives were not considered in the approach. Since both the AGNPS and GLEAMS models either lack or include an over-simplified description of frozen soil conditions, there is a need to include or improve such a component in these models to make these models fully applicable to cold climate regions. Furthermore, both plot and small watershed level scale experiments proposed in this study provide a unique opportunity to test and possibly develop new upscaling procedures for extrapolating data. Although limited in time scale, this three year study will also be used to consider scaling and extrapolating issues with respect to time.

## 10.5 Wildlife

# Impact of Alfalfa Biomass Production on Wildlife Diversity and Abundance

Al Berner and Allison Leete
Minnesota Department of Natural Resources

### INTRODUCTION

The purpose of this report is to provide information on the impacts of suggested practices to be used in managing alfalfa for production of biomass on the abundance and diversity of wild birds and mammals. The biomass grown will be used to produce a high protein leaf meal and to provide 1,000 tons per day of fuel for a proposed gasification generation power plant in Granite Falls, Minnesota. These findings are based upon a literature review and interviews with wildlife experts.

### BACKGROUND

The nine major counties affected by this project are primarily in the Minnesota River watershed and lie on both sides of this major river drainage system. Historically, this area was characterized by flat to rolling topography with vast expanses of native prairie, grass-forb communities laden with wetlands. The majority of the wildlife species in these areas evolved with a dependence on these two major vegetation types.

Most wildlife species continued to cope or in some cases flourish with the advent of diversified agriculture. However, in the early 1960's with the shift to monotypic, production agriculture, which was accelerated by federal feed grain farm policies, abundance of most wildlife species changed dramatically (Berner 1988).

Most wildlife populations declined until the early 1970's, leveled off in the late 1970's and early 1980's, and began increasing with the establishment of permanent cover on Conservation Reserve Program (CRP) and Reinvest in Minnesota (RIM) acres. For example, pheasant populations, which generally mirrored the changes seen in most bird species dependent on undisturbed grasslands for reproduction, showed the following changes between 1955 and 1993 in the major 9 counties that will be affected by this project.

During the period of 1955-1964, pheasant densities varied from 84 to 214, and averaged 140 birds per square mile. With the conversion of Soil Bank's Conservation Reserve Acres, grassland (e.g., native hay, pastures) and wetland areas, and small grains to row crops, pheasant populations declined precipitously from 1965 to 1976, varying from 2 to 43, and averaging 15 birds per square mile. Since 1987, with the onset of cover establishment on CRP acres, pheasant densities have ranged from 25 to 104, and averaged 40 birds per square mile. Although there are few data available, one would suggest that small mammals that depend on undisturbed grasslands would have been affected similarly.

Bird species that require little cover or nest early (e.g., killdeer, horned larks) were either benefitted or not affected. Also, some species that utilize grasslands but are not dependent on them, such as white-tailed deer, have experienced notable increases. Deer populations in the fall have increased from less than one deer per square mile in the 1960's to over 3.8 deer per square mile since 1985.

To preserve the diversity of plants and animals in the face of intensive agriculture, state and federal natural resource agencies (e.g., Minnesota Department of Natural Resources, U.S. Fish and Wildlife Service) have attempted to protect key natural habitat components (e.g., grasslands, wetlands, riparian woodlands) through acquisition and easements (e.g., RIM). To date, these programs have affected over 92,150 acres or about 2.4% of the project area (**Table 10.5-1**).

In comparison, the CRP has retired almost 250,000 acres or 5.7% of the landscape within the biomass shed since 1985 (**Table 10.5-1**). And, another 4% of the land has been idled annually under the federal Acreage Reduction Program (ARP). The alfalfa biomass project, if operated at expected capacity, would impact about 3.5% of the 9-county area. The proposed project, therefore, would impact over 40% more land than state and federal agencies have been able to protect since 1952 and almost equal to the acres presently idled under ARP.

## FINDINGS

Alfalfa is one of the most attractive, herbaceous cover types to nesting birds in the Midwest. Only wetlands, other legumes, mixed hay, and undisturbed grasslands (e.g., CRP) equal or exceed the diversity and abundance of breeding bird species observed using alfalfa (Graber and Graber 1963, Sample 1989).

**Table 10.5-1** The number of acres acquired by the Minnesota Department of Natural Resources (Wildlife Areas) and U.S. Fish and Wildlife Service (Waterfowl Areas), placed under easements by the Minnesota Soil and Water Resources Board -Reinvest In Minnesota- (RIM), and leased under USDA's Conservation Reserve Program (CRP) in the primary nine counties affected by the proposed biomass project.

| County | Sq. Miles | Conservation Reserve Program | Wildlife Mgmt Areas | Waterfowl Production Areas | Reinvest In Minnesota |
|---|---|---|---|---|---|
| Chippewa | 582 | 8,525 | 10,770 (14)[a] | 0 (0) | 800 (22)[b] |
| Kandiyohi | 824 | 37,809 | 3,408 (16) | 11,899 (161) | 1,483 (55) |
| Lac Qui Parle | 773 | 37,944 | 20,130 (42) | 3,368 (41) | 271 (12) |
| Lincoln | 540 | 60,500 | 7,778 (59) | 0 (0) | 301 (14) |
| Lyon | 713 | 24,510 | 9,050 (43) | 0 (0) | 659 (21) |
| Redwood | 874 | 18,469 | 4,104 (18) | 0 (0) | 2,221 (58) |
| Renville | 980 | 5,659 | 865 (10) | 160 (1) | 3,465 (103) |
| Swift | 747 | 23,613 | 8,991 (15) | 7,220 (96) | 984 (33) |
| Yellow Medicine | 758 | 30,222 | 3,767 (28) | 640 (8) | 1,243 (29) |
| Totals | 6,791 | 247,251 | 68,893 (255) | 23,287 (307) | 11,427 (347) |
| Percent of Area | | 5.7 % | 1.6[c] % | 0.5 % | 0.3 % |

[a]The first number is acres; the number in parenthesis (parcels)
[b]Numbers include all acres presently under contract; including 10-year, 20-year, and perpetual easements
[c]Average and total include 24,252 acres of the Lac Qui Parle Wildlife Management Area (WMA) which is along both sides of Lac Qui Parle Lake. Without this major unit, the remaining WMAs represent only about 1% of the project area.

## Songbirds

At least 13 songbird species are known to commonly breed in alfalfa fields (**Table 10.5-2**). Approximately 60% of these species specifically require herbaceous cover for nesting (Janssen 1987, Johnsgard 1979).

The timing of mowing operations is critical to the nest success of most of these species (86%); see **Figure 10.5-1** (Roseberry and Klimstra 1970, Dolbeer 1976, Zimmerman 1982, Bollinger and Gavin 1989, Bollinger et al. 1990). Mowing causes high mortality of songbird eggs, nestlings and young fledglings (young birds with limited capability for flight), but not of the adults. Also, breeding densities of most songbird species are lower after mowing than before, indicating area desertion (Frawley and Best 1991). The number of species and individuals within a species that establish nests and fledge young increase, the later mowing occurs. From 25 May to 4 June, the average time for the first cutting of alfalfa, 9 out of the 14 species (64%) would have <10% successful nests fledged. By comparison, 11 out of the 14 species (79%) could have >40% successful nests fledged if mowing occurred after 25 June. Three out of the 14 species are late nesters. The majority of their nestlings fledge after July 1 (e.g., dickcissel). Alfalfa would not benefit these species due to heavy nest loss, and nestling and fledgling mortality from mowing operations. Only mowing after 15 July would benefit these species.

## Gamebirds

Five waterfowl species and two upland game species nest in alfalfa; see **Table 10.5-2** (Johnsgard 1979). These birds prefer to establish their ground nests amongst plants when visual obstruction is 100% at 10" or more in height and residual cover from the previous year exceeds 45% (Kantrud and Higgins 1992).

As with songbirds, the timing of mowing is critical for the nesting success of gamebirds (**Figure 10.5-2**). Mowing of alfalfa hay, with no residual cover, between 25 May and 4 June decreases potential gamebird production by >90%. By contrast, a mowing date of 25 June or later allows for approximately 30-50% of potential production (Warner and Etter 1989, Eberhardt and Rave unpubl. 1994).

Particularly during the last five days of incubation and first day of hatch, hens will not readily flush from their nests and mowing can kill them, as well as their eggs and precocial chicks; see **Figure 10.5-3** (Warner and Etter 1989).

**Table 10.5-2** The impact of mowing on wildlife species[a] that use alfalfa fields.

| SPECIES[a]<br>[a]Scientific names - Appendix 10.3 | Normal Mowing Date<br>5/25-6/4 | Late Mowing Date<br>6/25+ |
|---|---|---|
| **SONGBIRDS:** | | |
| Early nesters (April-May): | | |
| Brewer's blackbird | - | + |
| Horned lark | + | + |
| Killdeer | + | + |
| Meadowlarks (eastern & western) | + | + |
| Mid nesters (June): | | |
| Bobolink | - | + |
| Grasshopper sparrow | - | + |
| Red-winged blackbird | + | + |
| Savannah sparrow | - | + |
| Vesper sparrow | - | + |
| Late nesters (July- August): | | |
| Dickcissel | - | - |
| Common yellowthroat | - | - |
| Sedge wren | - | - |
| **GAMEBIRDS:** | | |
| Blue-winged teal | 0 | + |
| Mallard | - | + |
| Gadwall | 0 | + |
| Gray partridge | 0 | + |
| Northern pintail | - | + |
| Northern shoveler | 0 | + |
| Ring-necked pheasant | 0 | + |
| **MAMMALS:** | | |
| Badger | 0 | 0 |
| Coyote | 0 | 0 |
| Eastern cottontail | - | + |
| Eastern mole | 0 | 0 |
| House mouse | - | + |
| Meadow jumping mouse | - | - |
| Meadow vole | 0 | 0 |
| Northern grasshopper mouse | - | + |
| Plains pocket gopher | 0 | 0 |
| Prairie deermouse (rare) | - | + |
| Prairie vole | 0 | 0 |
| Red fox | 0 | 0 |
| Short-tailed shrew | 0 | 0 |
| 13-lined ground squirrel | + | - |
| Western harvest mouse | - | - |
| White-tailed deer | - | + |
| White-tailed jackrabbit | - | + |
| Woodchuck | 0 | 0 |
| **TOTALS:** | | |
| Advantageous (+) | 6 | 25 |
| Harmful (-) | 19 | 6 |
| Neutral (0) | 14 | 8 |

**Figure 10.5-1** The cumulative percent of the fledged nests by week for four representative species of songbirds that use alfalfa fields for nesting (Roseberry and Klimstra 1970, Dolbeer 1978, Zimmerman 1987, Bollinger and Gavin 1989). The dashed vertical line indicates the impact of mowing on recruitment from alfalfa fields during the week of 26 June - 2 July.

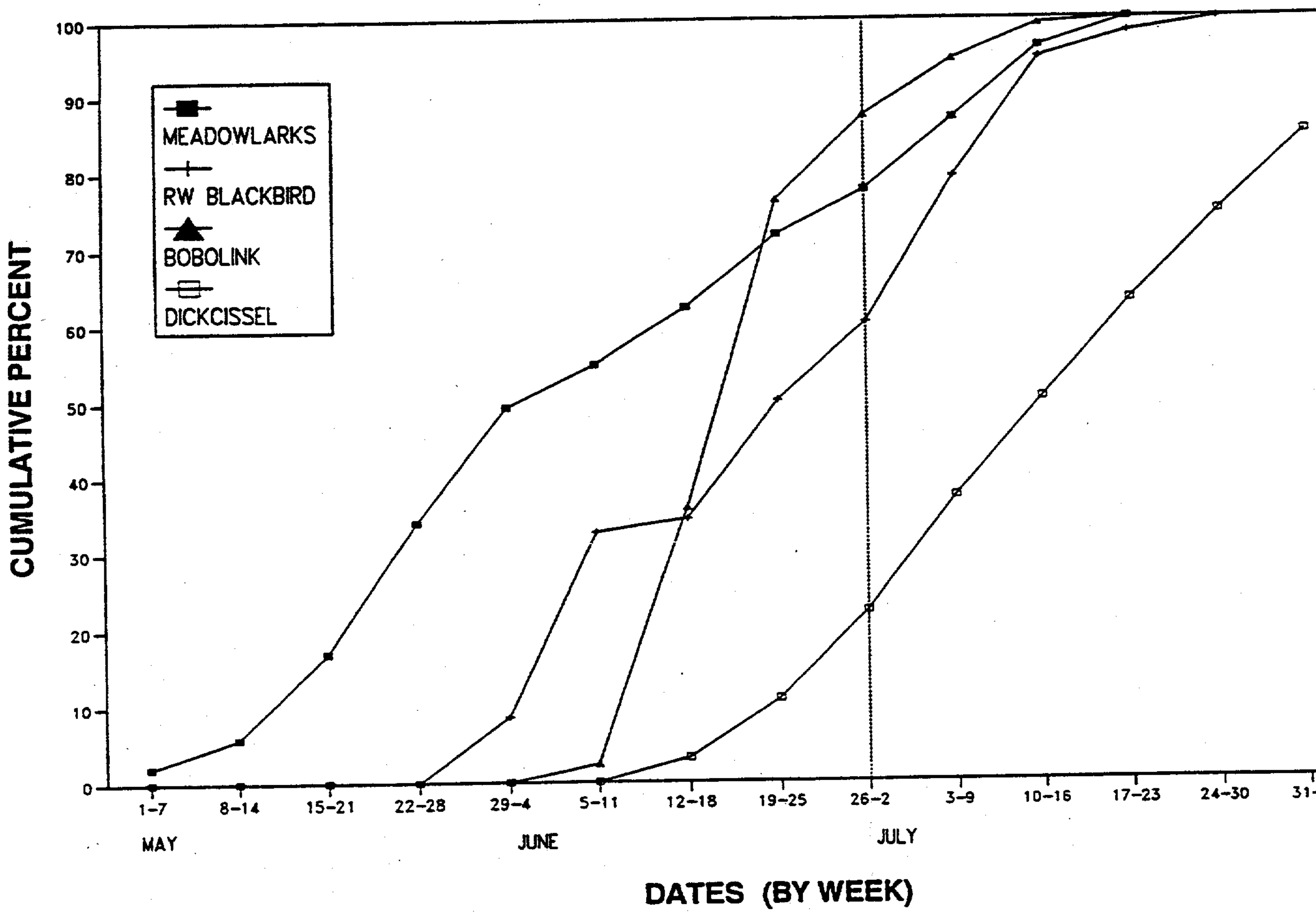


**Figure 10.5-2** The cumulative percent of hatched nests by week for three representative species of gamebirds that use alfalfa fields for nesting (Warner and Etter 1989, Eberhardt and Rave unpubl. 1994). The dashed vertical line indicates the impact of mowing on recruitment from alfalfa fields during the week of 26 June - 2 July.

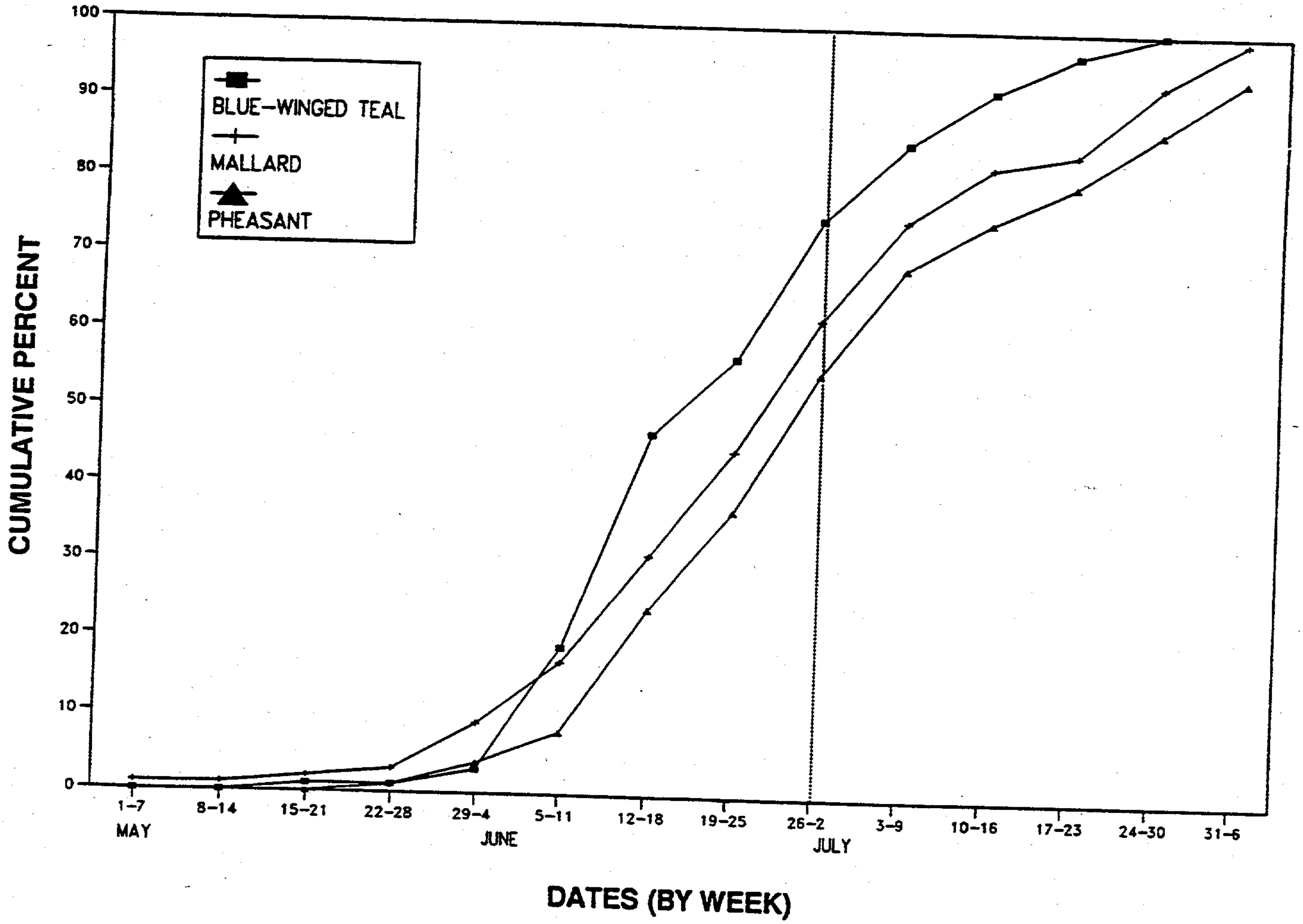
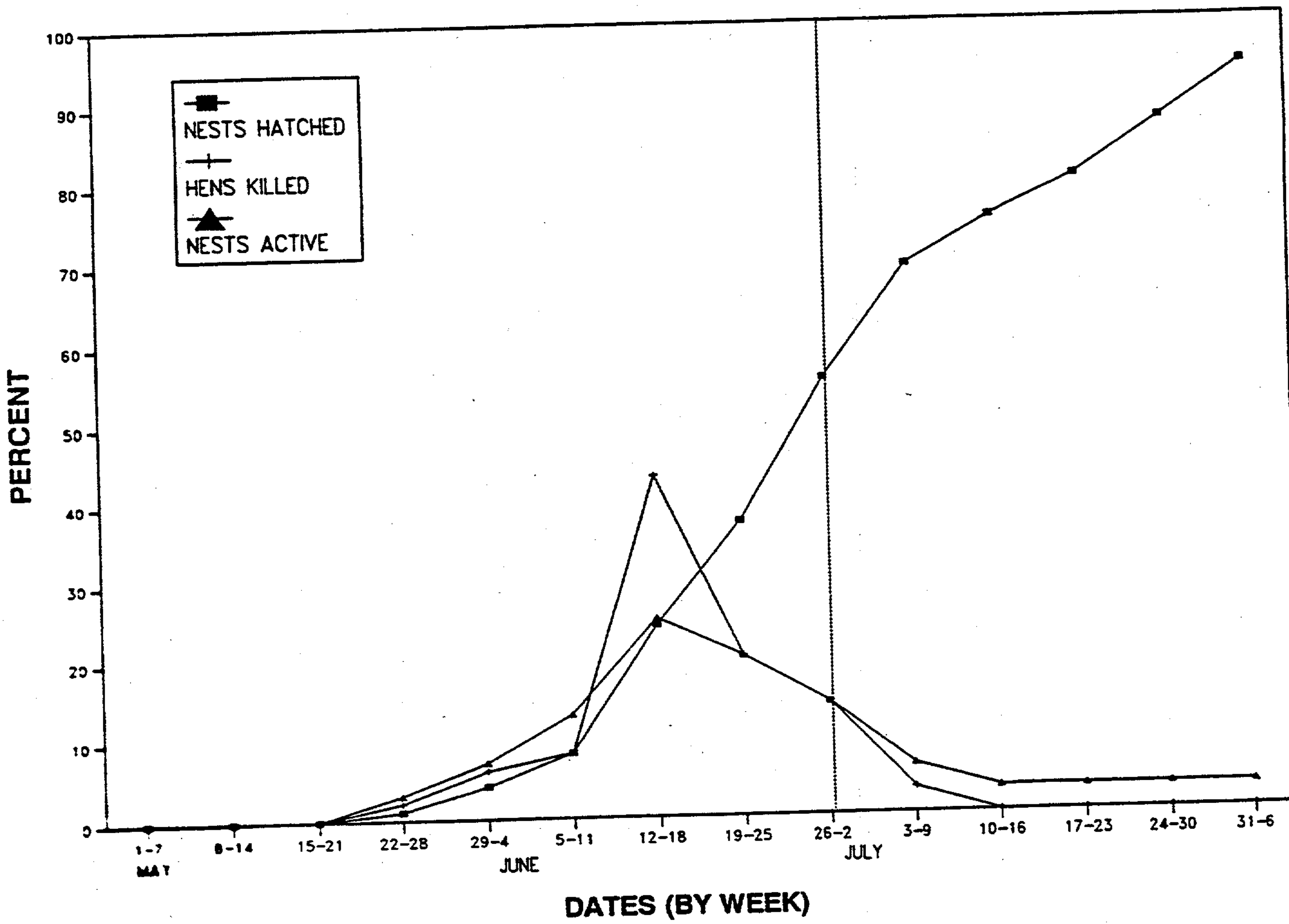


**Figure 10.5-3** The percent of hens killed by mowers, the percent of active nests, and cumulative percent of hatched nests by week for the ring-necked pheasant (Warner and Etter 1989). The dashed vertical line indicates the impact of mowing on hen mortality, nest destruction, and recruitment in alfalfa fields during the week of 26 June - 2 July.



## Spring Cover

The amount of residual cover available in the spring greatly affects when these species, particularly pheasants and mallards, establish nests, incubate, hatch young, and are most vulnerable to mowing mortalities (Martz 1967, Kirsch et al. 1978). If there is no residual cover over winter, sufficient growth must occur before nests are established. In the case of pheasants, hen mortality would be greatest (approximately 30% of the nesting hens) during the third week of June with an approximate 30% of potential production. In contrast, an excellent over winter residual cover would shift the nesting activity up to two weeks earlier than with no residual cover; see **Figures 10.5-4, 5 and 6** (Gates et al. 1970, Trautman 1982, Kantrud and Higgins 1992). In this case, by 25 June over 60% potential pheasant production (**Figure 10.5-6**) and <10% hen mortality (**Figure 10.5-5**) are expected. Also, residual cover provides roosting and escape cover for resident upland gamebirds (pheasants and partridge), thereby increasing their fall to spring survivorship.

**Figure 10.5-4** Potential impacts of the availability of residual nesting cover in alfalfa fields in spring on the temporal pattern of active ring-necked pheasant nests (Kirsch et al. 1978, Warner and Etter 1989). The dashed vertical line indicates the impact of mowing on hen mortality in alfalfa fields under three residual cover scenarios during the week of 26 June - 2 July.

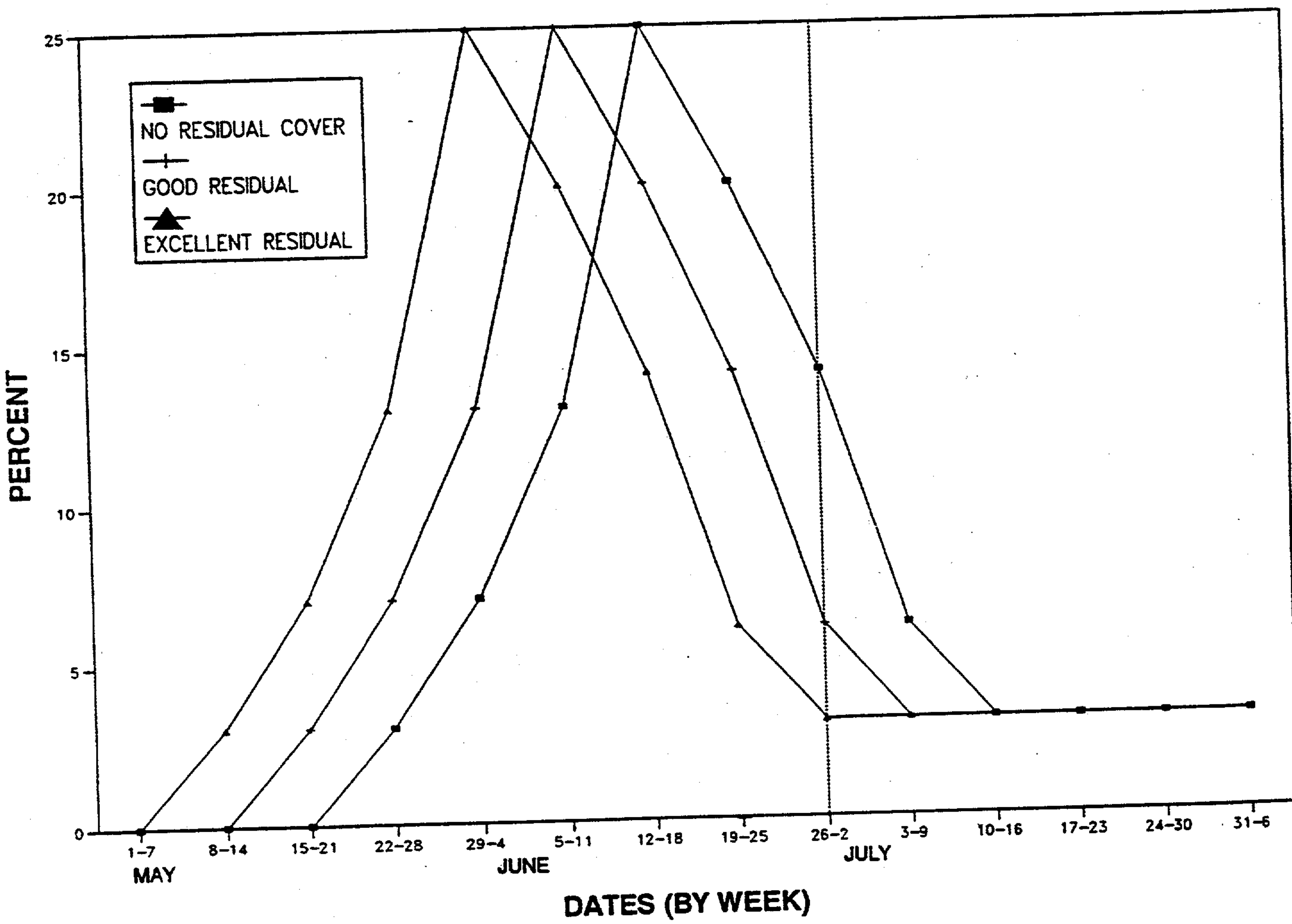


**Figure 10.5-5** Potential impacts of the availability of residual nesting cover in alfalfa fields in spring on the temporal pattern of active ring-necked pheasant hen mortality caused by mowing (Kirsch et al. 1978, Warner and Etter 1989). The dashed vertical line indicates the impact of mowing on nesting hens in alfalfa fields under three residual cover scenarios during the week of 26 June - 2 July.

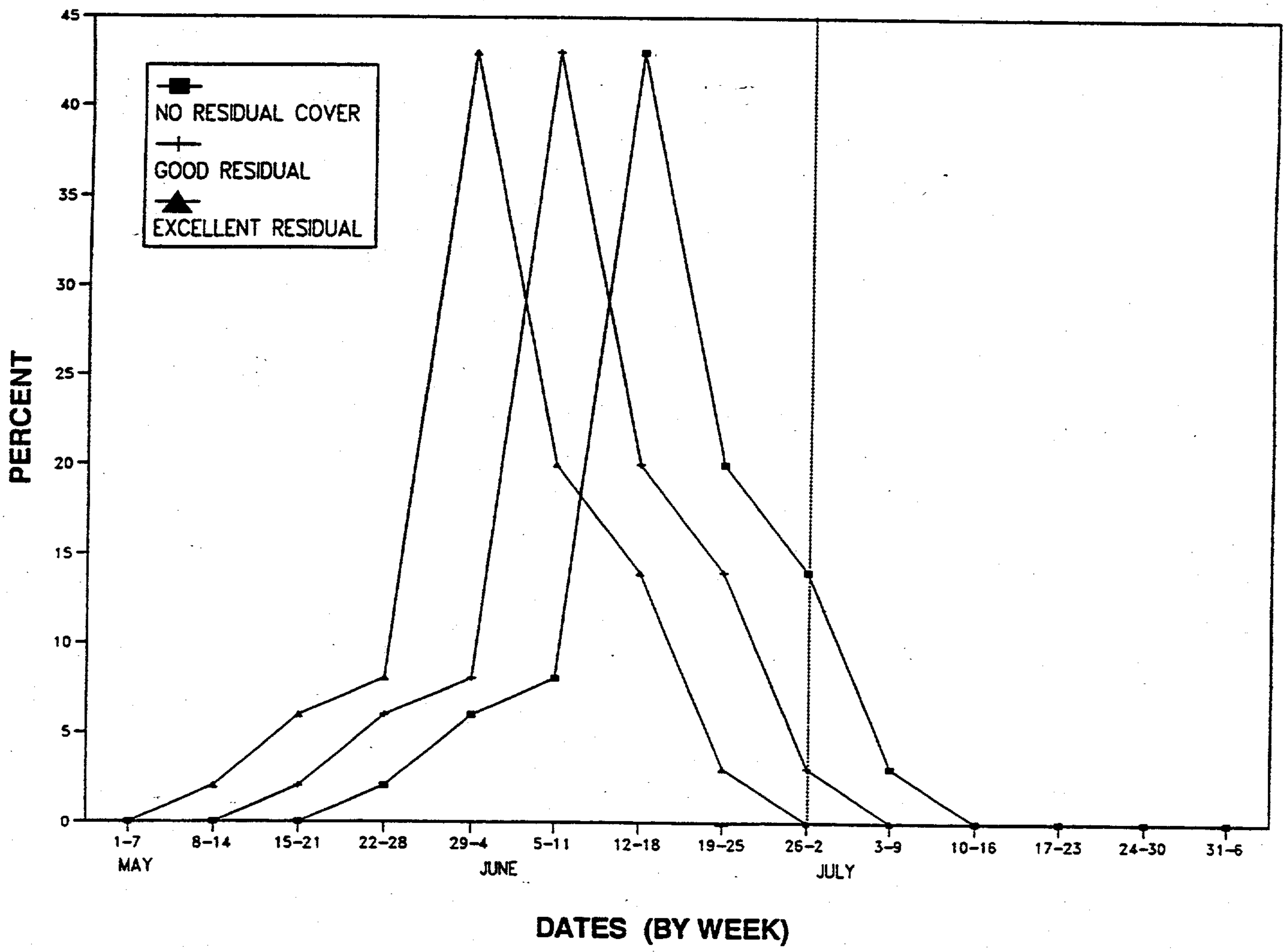
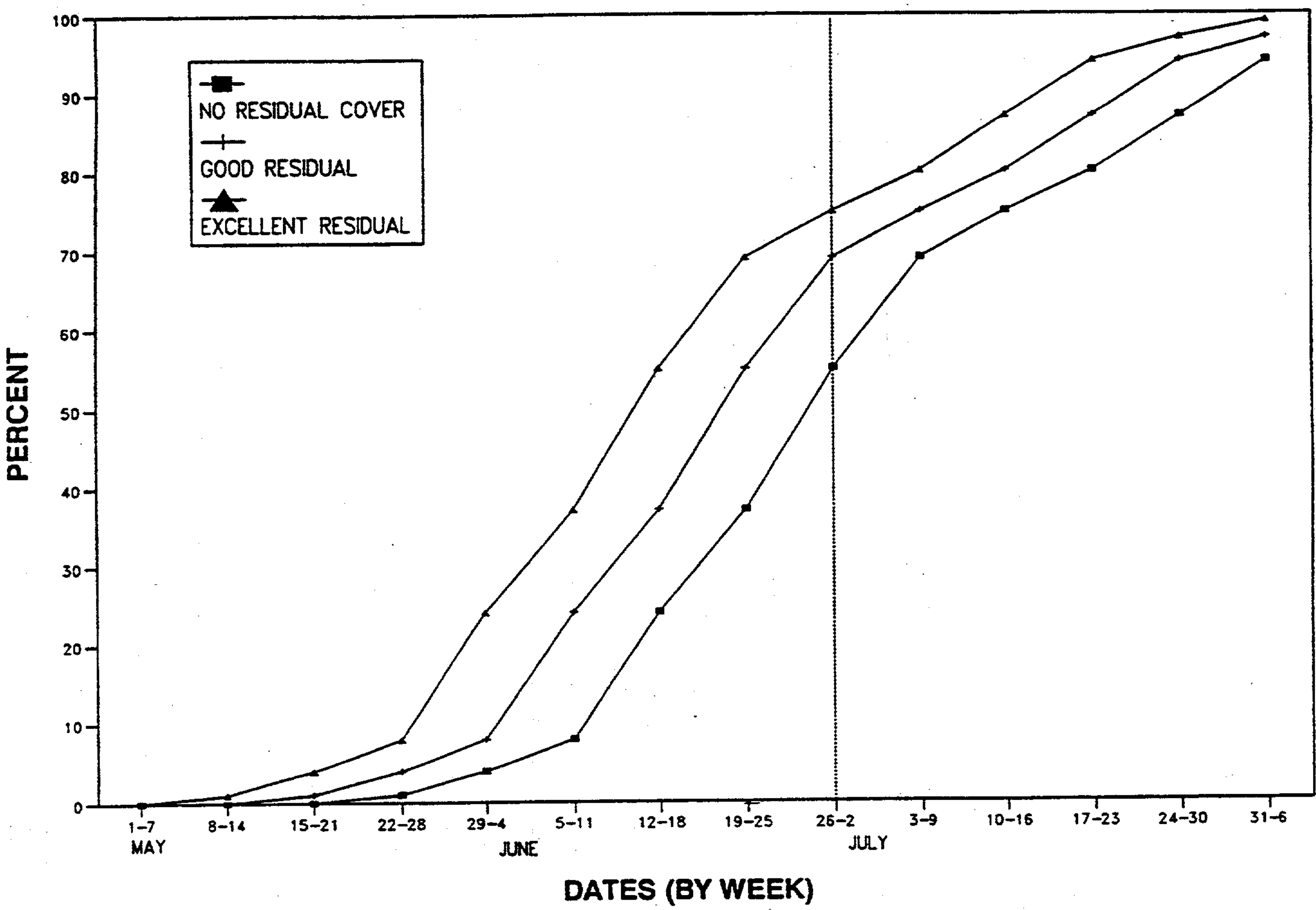


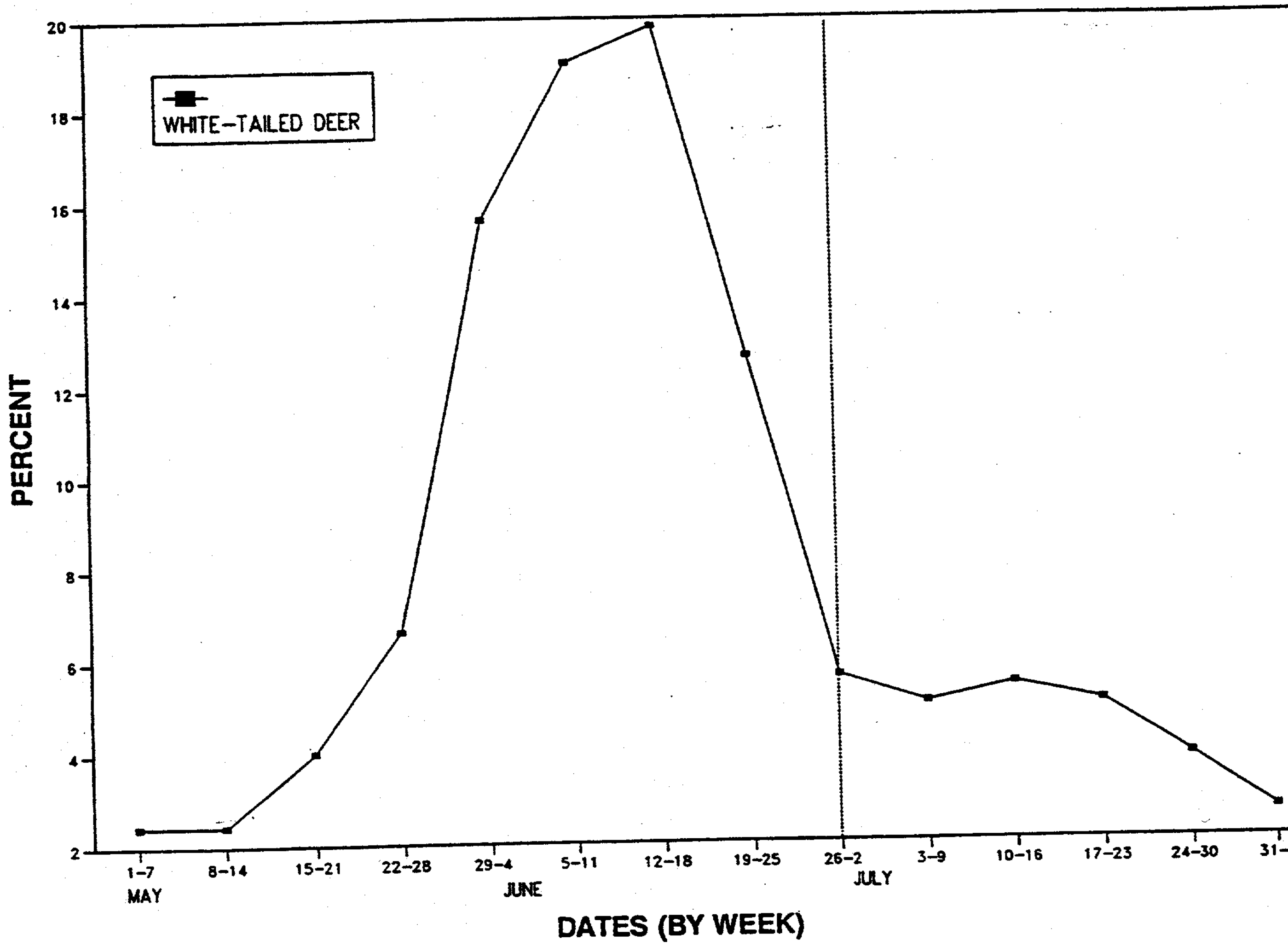
**Figure 10.5-6** Potential impacts of the availability of residual nesting cover in alfalfa fields in spring on the cumulative percent of successful ring-necked pheasant nests (Kirsch et al. 1978, Warner and Etter 1989). The dashed vertical line indicates the impact of mowing on recruitment from alfalfa fields under three residual cover scenarios during the week of 26 June - 2 July.



**Mammals**

Approximately 18 mammal species use alfalfa fields for feeding, hunting and/or denning; see **Table 10.5-2** (Jones Jr. and Birney 1988). Those breeding species that establish underground nests are less affected by mowing than are birds and mammals with nests and young at ground level. Mowing between 25 May and 4 June can negatively affect 9 of the 18 species while benefiting only one; see Table 10.3-2 (Birney per. comm. 1994, Frydendall per. comm. 1994). Young white-tailed deer, less than 8 days old (Schulz 1982) and white-tailed jackrabbit, less than 4 weeks old (Jackson 1961) are particularly vulnerable to mowing at this time (**Figure 10.5-7**). Because both deer and jackrabbit drop their young on the ground without establishing a nest, standing cover is required to protect their young from exposure.

**Figure 10.5-7** Percent of white-tailed deer fawns born by week in southern Minnesota. Dates were estimated using the relationship between fetus body length and expected parturition date, 1978-1983 (Minnesota Department of Natural Resources files). The dashed vertical line indicates the potential impact of mowing on fawn survival in alfalfa fields during the week of 26 June - 2 July.



Although later mowing benefits some rodent species, regular mowing keeps potential pest species (e.g., pocket gophers and meadow and prairie voles) at lower population levels by some den and tunnel destruction through compaction, as well as periodic removal of food and cover (particularly the accumulation of litter) by mowing. The periodic removal of cover, regardless of when it occurs, exposes the field residents to increased predation from both mammalian and avian predators (Birney per. comm. 1994, Frydendall per. comm. 1994).

**Landscape Effects**

The size, shape, and distribution of alfalfa fields affect the diversity, abundance, and success of nesting birds. Mammalian predation and nest parasitism by brown-headed cowbirds increase as field size decreases. To minimize the effects of predation, a minimal field width of 150 feet is recommended (Johnson and Temple 1990). In addition, cowbirds parasitize nests at a higher rate within 150 feet from the field's edge (Sample 1989; Johnson and Temple 1990). Therefore, to minimize the impact on parasitized species, a minimum field width of 600 feet and size of 8 acres are recommended.

If alfalfa grown for this project is managed in a manner favorable to nesting birds (mowing after 25 June and good residual cover in spring), then the expected density of 22.4 acres per square mile could significantly affect wildlife populations in the area (50 mile radius = 7,853 square miles and 176,000 acres of alfalfa). Even so, depending on the quality of the existing habitat and what cover types the alfalfa replaces, population changes still might vary from a notable decline to a substantial increase from existing levels. Using the ring-necked pheasant as an example, replacing very productive undisturbed grasslands, such as CRP, with traditionally managed alfalfa would be very negative to pheasant populations. While, replacing annual set-asides, such as ARP acres (Berner 1988) or row crops with late mowed alfalfa would be very positive (**Table 10.5-3**).

**Table 10.5-3** Impact of cover type replacement by alfalfa on wildlife values.

**Impact of Cover Type Replacement with Alfalfa**

| | Alfalfa | |
|---|---|---|
| | Normal Mowing | Late Mowing |
| Current Land Use | 5/25-6/40 | 6/25+ |
| **Row crop** | - | ++ |
| Small grain | - | + |
| CRP | -- | |
| Annual set-aside | 0 | ++ |

where: 0 = no dramatic change
+ = beneficial
- = harmful

**Impacts of Suggested Mowing -**

- **Schedules**

Taking into consideration yield (tons/acre), leaf to stem ratio, leaf retention, and stand longevity, agronomists have suggested the following mowing schedules:

| Option | Mowing Schedule Dates | | | |
|---|---|---|---|---|
| **1.** | **25 June** | **1 Sept.** | | |
| 2. | 4 June | 14 July | 1 Sept. | |
| 3. | 24 May | 25 June | 4 Aug. | 1 Sept. |

Of these three, only option 1 has the potential of a significant positive impact on wildlife populations. The lateness of mowing, potential for renesting in July and August (not possible in any of the other options) and the potential for adequate residual cover in spring, make this option the most attractive for wildlife. Options 2 and 3 would have mostly negative impacts on the wildlife species using the alfalfa fields.

In an attempt to optimize the positive impacts of biomass alfalfa on wildlife diversity and abundance, while taking alfalfa quality production needs into consideration, one would suggest two additional mowing schedule options:

| Option | Mowing Schedule Dates | | |
|---|---|---|---|
| **A.** | **25 June** | **25 Aug.** | |
| B. | 25 June | 25 July | 1 Sept. |

Impacts of option A are very similar to those observed under option 1, while option B impacts are intermediate to options 1 and 2.

- **Patterns**

Typically, alfalfa fields are mowed in an inward, spiraling pattern (**Figure 10.5-8**). This pattern of mowing creates an ever- decreasing area of cover into which young gamebird broods (< 1 week old) are gradually herded and then usually killed by the mower. With new types of mowing equipment (e.g., swathers), this deadly pattern of mowing does not have to occur. If possible, fields should be mowed from one side to the other (**Figure 10.5-9a**) or from the middle outward in both directions (**Figure 10.5-9b**). The latter two mowing patterns should minimize mortality of young chicks by mowers.

**Figure 10.5-8** Typical pattern used in the mowing of alfalfa fields.

**Typical Mowing Pattern**

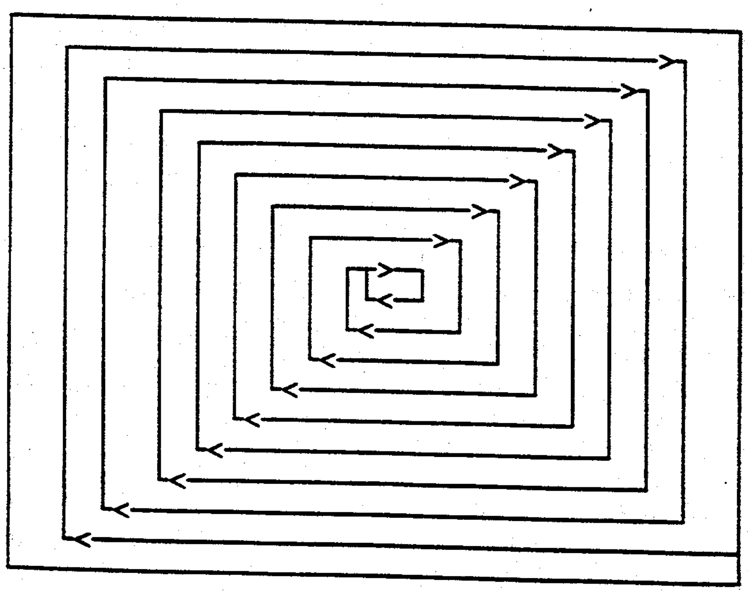
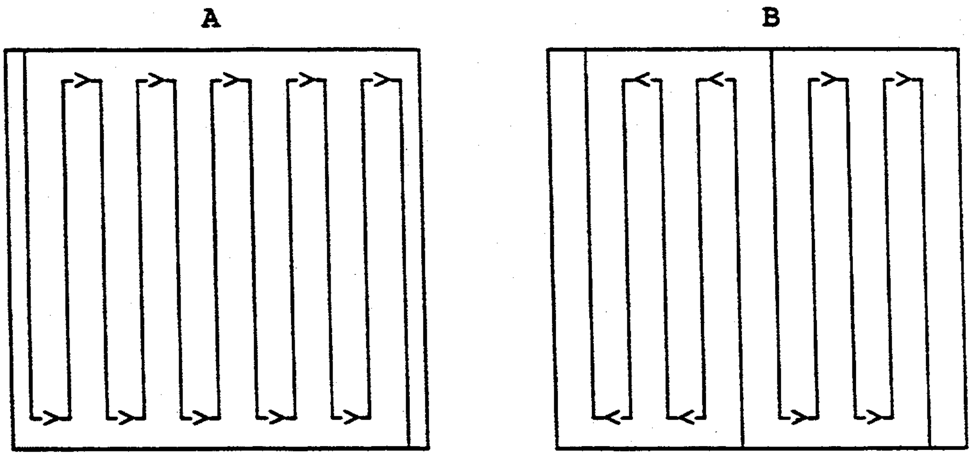


**Figure 10.5-9a+b** Two recommended mowing patterns to reduce killing young - less than one week old - gamebirds in alfalfa fields (Olsen and Leatham 1980).

**RECOMMENDED MOWING PATTERNS**




**Changing from an inward, spiraling mowing pattern to one that goes from one side to other or from the middle outward in both directions reduces the number of young (less than 1 week old) gamebirds killed by mowers.**

## SUMMARY

Establishing about 176,000 acres of alfalfa (22.4 acres per square mile in the 7,853 square mile biomass shed around Granite Falls) to produce electricity and a high protein feed, will have a significant impact on the abundance and diversity of wildlife in the area. The magnitude and direction (+ or -) of these impacts will depend on the following factors: mowing schedule, availability of overwinter residual cover, cover type replacement, size and shape of fields, distribution of fields, and mowing patterns.

**A two-cut schedule with late June and late August mowing dates will have very significant positive impacts on both wildlife abundance and diversity.** Mowing schedules similar to those used in conventional forage production, however, will have significant negative impacts on wildlife. Mowing schedules that result in 1) the development of good residual cover for winter (this aids earlier nest establishment), and 2) later first cut mowing in the spring will greatly increase the potential nest success of most species utilizing alfalfa.

Assuming favorable mowing schedules, replacing row crops or annual set-asides (ARP acres) with alfalfa, will result in favorable wildlife impacts. If these alfalfa acres replace CRP, however, reduced wildlife benefits will be expected. Late June and late August mowing will produce a neutral to slight reduction (less than 20%), while early June, mid-July and late August mowing results in a substantial reduction (greater than 30%).

Fields eight acres or larger and 600 feet or more in width produce the best wildlife population results. Long, narrow fields are less productive due to increased nest predation and parasitism.

Assuming adequate availability of other critical wildlife habitat components (e.g., winter cover, wetlands), an even distribution of fields will produce favorable results. A distribution pattern that complements existing habitat components will promote even greater wildlife abundance and diversity.

# CHAPTER 11. POLICY ISSUES

## 11.1 The 1995 Farm Bill

Steven Taff
Agricultural and Applied Economics, University of Minnesota

### Incentives and Policy

We are interested in agricultural policies affecting this project, at least to the extent to that particular policies may affect the market position of the proposed alfalfa biomass rotation of (AAAACCS) versus any competing rotations, particularly corn-soybeans (CS). The alfalfa biomass rotation gains whenever policies in aggregate act to raise its relative profits, either by raising its relative price or by lowering its relative production costs. The rotation loses whenever policies in aggregate lower their relative profits. It is useful to examine the major elements of current U.S. agricultural policy to learn how they may affect the relative position of the alfalfa rotation. We discuss in particular the workings of the present crop subsidy programs and how their expected alterations could either help or harm the alfalfa biomass rotation. Much of this section is speculative, so it will be kept short. What we identified in Section 3.2 (regional biomass supply curve) will help us decide which of the policy-affect project parameters are so critical that they merit further elaboration. We expect that the whole project will succeed or fail mostly on its own merits.

In the second section, we speculate on the relative position of the alfalfa rotation in the current conservation compliance provisions of the farm program. Does even a single year of beans on highly erodible land mean that the sequence does not meet conservation goals? What will expected state-level pollution controls stemming from the new Clean Water Act do to corn-bean rotations in the project area? Will alfalfa rotations be eligible for the "green payments" now touted for the next farm bill?

Changing the rules under which agricultural producers operate changes the prices and costs they face. Different price-cost regimes might lead to different management choices. The changes might be direct, as in a tax on certain pesticides or a supplemental cash payment on certain crops, or indirect, as in the soil erosion liability shift discussed in the section on supply-curve shifters or in the imposition of size constrains on farming operations.

Any rule change that increases the net returns from the alfalfa biomass rotation versus the corn-bean rotation will lead to relatively more hay being offered to the processing cooperative.

Of the myriad legal possibilities, we focus here on a handful of rule changes that appear to be politically possible as well. In doing so, we offer no predictions about and no recommendations toward the writing of the next federal farm bill. We do explore, however, the ramifications of certain farm bill proposals on the financial structure of the hay power system. We look at changes in: (1) set-aside requirements, (2) feed grain subsidies, (3) water pollution control laws, and (4) the conservation reserve program. This brief list illustrates the diversity of policy instruments that could affect the financial viability of the hay power system.

(1) Permit hay production on set-aside lands: Under current federal farm policy, producers who wish to receive price subsidies for feed grains such as corn must set aside (not plant) a designated portion of their cropland each year. This forced land idling, which is best thought of as a tax on the federal subsidies, can range from zero (as in 1994) to 20% (as in 1987 and 1988) of a producer's crop base. On annual set-aside land, no income-producing crop is permitted under current rules. In recent years, Congress has added an additional 10-25% "flex" acres provision. On this land, the farmer can grow a feed grain, but with no subsidy paid over and above what the farmer receives in the market.

If both annual set-aside and flex acres could be planted to hay, the amount of hay produced would increase dramatically because any payment for hay from idled land in excess of production costs would be financially beneficial. Land charges are already being borne, so any income-producing crop would improve the farmer's financial situation. Of course, in years in which the set-aside rate is zero, hay production would have to "compete" more directly with regular, subsidized corn production.

Because alfalfa is most efficiently grown in a multi year system, annual set-aside rules would have to be changed to permit a saleable crop to be grown on the same idled acres each year for a period of at least four years. Such a change presumes that there will be at least this number of acres each year in required set aside. A possible rule variant might be to permit alfalfa land to be designated as set-aside only in those years in which idling is required. No "multiyear contract" would be needed. All the producer would need do, essentially, is to demonstrate to the government that the required number of acres are not being planted to corn. One of the purposes of the set-aside requirement is to reduce the production of the designated crop -- corn, in our case -- put onto the market. This provision increases the market price of corn, which in turn reduces the size of the associated subsidy and, hence, the size of the federal budget outlay.

Permitting noncommodity crops such as alfalfa on set aside land will lead to increased production and decreased market prices for hay, both within and outside the biomass shed. This may have a dampening effect upon producer income to the extent that hay growers sell into the open market as well as into the biomass market.

(2) Reduce corn subsidies: Eligible feed grain producers receive a deficiency payment (the difference between a mandated target price and the market price) for each bushel of corn they legally produce. Farmers can grow corn only the number of acres assigned to their crop "base", less any required set-aside. In the study area, deficiency payments were $.20 per bushel of yield potential on planted corn acres. Absent this subsidy, the average biomass:corn-soy net returns ratio improves considerably in favor of biomass, as discussed in section 3.2, above.

Clearly, the presence of this subsidy for corn is a "barrier" to the adoption of the biomass rotation on a wider scale. Its demise would reduce the net returns of the corn-soybean rotation relative to the biomass rotation. However, elimination of corn subsidies would also reduce the absolute net returns of the biomass rotation itself, for two years in that rotation are corn. Thus, abolition of the subsidy improves the position of alfalfa relative to corn, but diminishes the ability of the producer to earn the income necessary to support the initial investment needed to switch to the biomass rotation.

The chances that the long-running price support and subsidy programs will be soon replaced are unknown. Typical of this time in the farm bill cycle, numerous proposals have been put forward to reduce or redirect farm subsidy spending. The farm bill itself will not be updated until late 1995 at the earliest. We think it prudent at this point to analyze the financial merits of the hay power system in a conservative, skeptical manner. That means assessing relative crop returns with current subsidies. If the biomass rotation is economically favorable for some farms under current policy regimes, it can't help but work for more farms under a regime of zero corn subsidy, if that situation ever comes to pass.

(3) Increase soil erosion damage liability: Many policies that influence farmers' management decisions come, not from the farm bill, but from legislation focused on other related topics. One such example is the Clean Water Act, slated for reauthorization in late 1994. Most observers expect special attention this time to nonpoint sources of pollution, such as erosion from farm fields. A recent major study of the Minnesota River, which drains most of the biomass shed, suggests that soil erosion over vast areas accounts for a substantial share of the pollution in that river.

Cleaning up nonpoint pollution could be an expensive process, if anyone is forced to pay the bill. It is likely that Congress will provide less than sufficient money to states to match the clean-up requirements expected to be imposed. Minnesota is also likely to under-fund the cleanups in agricultural areas to meet the new requirements. We judge that a new round of regulations dealing with soil erosion and livestock waste management are a plausible consequence of this mismatch of goals and resources. The cost of any new farm regulations are necessarily borne by the landowners, much as the fruits of farm subsidy programs are harvested by the same individuals.

All this leads to a situation in which the relative costs of complying with the new regulations becomes important. Which rotation will be the more expensive to maintain under the new rules? If the biomass rotation proves the less costly, then it gains relative to the corn-soybean rotation.

## 11.2 Conservation Reserve Program (CRP)

There are about 2,000,000 acres of Minnesota farmland enrolled in the federally funded Conservation Research Program. The CRP program has several objectives including: reducing soil erosion, producing long-term agricultural productivity, improving water and environmental quality, and reducing surplus commodities. Over a quarter of a million acres are in the biomass shed. With the contracts for most of these acres expiring between 1996 and 1998, the future use of the land is uncertain.

The 10-year contracts under which these lands are kept out of production begin to expire in 1996. Will these lands be especially suited for the hay power project? Should they be specially targeted for forage production?

Nearly 80% the CRP land in the project area is in Land Capability Classes II or III. Land in these classes can support conventional cropping under appropriate conservation management practices. The CRP lands are not, in general, highly erodible or environmentally sensitive. Their return to corn/soybean production will not pose any significant ecological risk, if the farm operator uses some care in his tillage methods.

If these lands are to be specially targeted to the biomass energy project, such focusing would have to be justified on the basic of special ownership or land cover characteristics, not because the lands would need to be protected from erosion more than others. The fact that the CRP lands are currently not cropped means that their owners might be more open to the suggestion of participating in the biomass rotation.

### Converting CRP Lands to Biomass Production - Technical Issues

Currently land in the CRP program represents an important resource for alfalfa biomass production. From a survey we have learned that the amount of alfalfa remaining in CRP land after six or eight years is minimal. Perennial grasses and weeds predominate in stands that were once alfalfa-brome mixtures. Therefore, strategies for establishing alfalfa in former CRP lands are essential. These would include evaluation of minimum tillage methods as well as weed control measures needed to establish vigorous alfalfa stands on land with heavy mulch.

# 11.3 Crop Insurance

## Production Risk Management (Crop Insurance)

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Businesses insure parts or all of their operations from adverse fiscal effects caused by predictable events occurring with uncertain timing. In the present project, producers' price risk is expected to be managed by the contract with the coop: prices will be known and certain. Producers will still have to contend with production risk. What happens when yields don't meet expectations? What circumstances or events cause yields to suffer?

In this feasibility study we have characterized production risks as events or circumstances that harm yield of the growing or living crop. Among the possibilities are drought, excessive moisture, disease, insect infestations, winter kill, and hail. Alfalfa yields can also suffer losses in dry matter and quality caused by rainfall or hail after cutting, but before baling. Farmers also suffer losses due to quality in their alfalfa crop due to tactical decisions to delay harvest. Ironically, the main reason farmers may delay harvest and precipitate quality losses is their desire to avoid the possibility of imminent rain. Of all the types of losses mentioned, none of the various insurance programs are designed to protect the grower from the losses in dry matter and quality that can occur at harvest. The insurance industry and federal government are attempting to reduce a farmer's risk in alfalfa production with respect to the levels of dry matter yield affected primarily by vagaries in moisture patterns.

We generally assume that the producer, not the coop, will be subject to production risk on the producer's land. This need not be the case. For example, the coop could guarantee a fixed payment per acre, whatever the yield, as long as the farmer follows management guidelines specified by the coop.

Even if insurance is shown to be useful for the producer, it may not be a good buy. We will examine current crop insurance programs policies here and identify gaps in current insurance availability.

The crop insurance policies available in part or all of the project area are: (1) hail insurance, (2) federal multiple peril crop insurance (MPCI), and (3) the pilot forage group risk plan (GRP).

Hail insurance is widely sold by private companies. It covers crop damage from a severe storm, but few other risks. This coverage, which is not subsidized or sponsored by the federal government, is presumed to be actuarially sound.

The MPCI covers a wide range of weather risks for crop farmers and forage growers. Subsidized in part by the federal government, it is offered largely through private agents. Corn and soybean coverage is available to all parts of the project area, but the forage policy is sold only in Kandiyohi, McLeod, Meeker, and Swift Counties. Farmers can cover themselves within a specified range of yield and market price possibilities. Actual farm yields, measured against yield histories for the same farm, are the basis of loss calculations. Policies are widely sold for corn and beans, but are relatively rare for forages, given their high premium levels and perceived poor payoff.

The relatively low MPCI participation by forage producers led to the creation (starting in 1994 crop year) of the forage GRP. Counties within the pilot forage GRP and biomass feasibility study are McLeod and Meeker. This policy is touted as administratively simple and financially prudent for some producers. Forage GRP policies offer farmers the opportunity to peg a combination of market price and yield levels to insure against, much as MPCI. Its distinguishing feature is the calculation of loss: all yields are measured by county averages, not by individual participants. The GRP is said to be best suited for high performance operations whose yield histories tend to move in concert with county averages.

As of this writing, Congress is considering a major overhaul of the federal crop insurance programs, in response to the spotty participation of farmers who experienced yield losses during 1993's floods. It is uncertain how a new program might affect growers in the project area. We are fairly certain, however, that the present narrower coverage for forage crops versus corn and soybeans will continue. This implies that the forage enterprises of farmers participating in the project will be relatively more exposed to weather risks than will be their corn and soybean enterprises. A producers' cooperative may wish to explore self-insurance, special group coverage, or other risk-management options for its member growers.

# CHAPTER 12. CONCLUSIONS

## 12.1 Technical and Economic Feasibility

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Biomass energy production systems must provide viable economic returns for producers of biomass (farmers) and produce electrical power at a price that is competitive with future fossil fuel systems. Because all biomass fuels are less energy dense than coal, the biomass crop must provide other sources of revenue for producers and for utilities.

Biomass energy crops are similar to other agricultural crops. High yielding biomass energy crops require high inputs of water and nutrients, just like other high input agricultural crops. Multiple use crops that provide food or fiber, and energy integrate traditional agricultural production and processing with "new generation" energy production and processing. Agriculture dependent electricty production must be integrated with agricultural processing to be sustainable.

The integration of agricultural production and energy production benefits both agriculture and energy production systems. Efficiency is the goal, not maximum production. This is not a new idea; it has been successfully implemented in the paper industry and by the production of ethanol and co-products from corn. Single use crops for energy production based on maximizing biomass yield ignore the efficiencies that may be gained from integrating these systems.

Alfalfa, an herbaceous perennial legume, is an ideal biomass energy crop to integrate agricultural and energy systems. First, alfalfa can be grown in rotation with row crops such as corn and soybeans providing substantial environmental benefits as a part of a traditional rotation. Second, growing alfalfa is not new to farmers in the proposed biomass shed. Third, alfalfa can be separated into <u>two</u> high value feedstocks: alfalfa stems and alfalfa leaves. Alfalfa stems (over 8000 BTU/pound dry) can be gasified to produce electricity and alfalfa leaves (about 30% crude protein) can be processed into value-added alfalfa. The two revenue streams, one for electricity and one for leaf meal products, makes the alfalfa biomass system feasible and economical and results in a very efficient use of feedstock resource.

The feasibility of growing alfalfa in the proposed biomass shed is excellent based on present production knowledge by farmers and the wealth of research data available in the management and production of alfalfa. Seed of present varieties is available and needed acreage could be brought into production within a two to four years. Farm equipment already exists for production and harvesting of alfalfa. Equipment for separating leaves and stems is available by modifying existing equipment being used in the alfalfa dehydration industry.

Alfalfa forage has been used an animal feed for centuries and continues to be an important animal feed today. Alfalfa leaf meal will be used as a protein supplement. Alfalfa leaf protein will compete in the marketplace with other protein sources. However, since alfalfa in a biomass rotation replaces other protein meal sources (corn and soybeans), there will be only a minor influence on total feed protein production.

Alfalfa leaves may also be processed into many other valuable products. Other alfalfa leaf products currently being produced at some level include: alfalfa leaf pigments (xanthophylls), liquid protein products for human and animal consumption, fragrances for shampoos and cosmetics, and natural biological molecules for pharmaceuticals. Once the alfalfa biomass system is in operation further investigation of these and other alternative products will proceed, potentially making alfalfa leaves an even more valuable co-product.

Presently, the economic feasibility of the alfalfa biomass business venture is viable under a 3 or 4 cut alfalfa production system using existing alfalfa varieties. Cutting alfalfa three or four times results in maximum leaf and stem tonnage production thus resulting in the highest amount of revenue. This production information is based on data obtained with present varieties. A program to select for tall, large diameter and solid stems with higher lignin content has been underway for several years in the USDA-ARS alfalfa breeding program at St. Paul. Some seed of alfalfa biomass types will be available for testing in 1995. These alfalfas could move alfalfa production to a 2 cut system and increase the efficiency of the system by 25% in the near term. It is the opinion of alfalfa breeders that varieties with all the desired traits could be accomplished within a period of six years.

Four years of alfalfa inserted into a 7-year corn/soybean rotation based on production costs and value of alfalfa stems and leaves is economically viable. Economic advantages of the rotation may be directly attributed to the inclusion of a perennial legume in the rotation. Reduced input costs, compared to contentional rotations and increased yields for other crops in the rotation result in increased profit for producers. The system improves agricultural sustainability by reducing chemical inputs and reducing soil erosion.

# SUSTAINABLE BIOMASS ENERGY PRODUCTION

## APPENDIX

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## VOLUME 1 - Appendix

**(Appendix numbers correspond to the chapter in Volume 1 where the topic is covered)**

APPENDIX 1.0

# SUSTAINABLE BIOMASS ELECTRICITY PRODUCTION FOCUS GROUP STUDY

## FINAL REPORT

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# INTRODUCTION

## RESEARCH CONTEXT

In 1993 Northern States Power Company (NSP) and the University of Minnesota, most notably the Center for Alternative Plant and Animal Products (CAPAP) began a study of economic development through biomass systems integration. The major objective of the study was to determine the feasibility of a biomass gasification electrical generation facility in Granite Falls, Minnesota that would be fueled with a Dedicated Feedstock Supply System (DFSS) — alfalfa stems. A unique characteristic of alfalfa stems as a DFSS is the high value of its co-product, alfalfa leaves — a high protein feed supplement that is especially suitable for ruminant animals.

The major purpose for this research study was to obtain the perceptions and attitudes of farmers within the proposes biomass shed about including sufficient alfalfa in their crop rotations to provide the DFSS for the proposed generator.

The Center for Education in Agriculture and Extension (CEAE) was selected to conduct focus group interviews with selected farmers in five locations — within an approximate 50 radius around Granite Falls. This radius was deemed sufficient in acreage and number of farmers to supply the alfalfa necessary to fuel the plant.

At the conclusion of the focus group interview a "Participation Survey" of the participants was conducted. The purposes of the survey were to: determine respondent's probable intention to participate in the plan; the acreage that would likely be designated; and to determine concerns or areas where lack of knowledge exist, before a decision about participation could be made.

This report does not seek to persuade CAPAP personnel, NSP professionals, farmers, or others to a particular point of view. Instead, it seeks to respectfully listen, to gain understanding and knowledge about the perceptions and insights of area farmers have about producing alfalfa for biomass energy and animal feed.

## LOCATION AND PARTICIPANT SELECTION

Five locations within a fifty-mile radius of Granite Falls, Minnesota, were selected to represent identifiable, major, farm enterprises within the proposed biomass shed. Thus, Willmar participants represented dairy farmers, Appleton participants represented farmers that irrigate, Canby represented farmers with large acreages in Conservation Reserve Program (CRP), Marshall represented farmers that plant large acreages of corn and soybeans, and the Olivia focus group participants represented farmers that grow sugarbeets

Names of farmers, that fit each respective group, were obtained from lists obtained from County Extension Educators, agriculture commodity groups, and other farmer organizations and cooperatives. Following a screening procedure, forty farmers, all men, were invited to participate in the five focus group interviews. Thirty-nine of those invited participated in the interviews. Generally, participants were experienced, operating farmers, with average to larger than average farming operations.

Interviews were conducted between April 4-6, 1994 in the five towns previously identified.

At the outset of each focus group a 10-minute overview of the feasibility study was presented (Appendix A). Topics included: defining the DFSS, organizational possibilities, project scope and scale, probable transportation and quality scenarios, assumed rotational benefits, and general project expectations.

At the conclusion of each focus group interview, participants were asked to complete a brief "Participation Survey." The purposes of the survey were to: determine respondent's probable intention to participate in the plan; the acreage that would likely be designated; and to determine areas of concern or lack of knowledge before a decision about participation could be made.

## ASSUMPTIONS

This focus group project, like all research projects, is subject to assumptions that create limitations. An assumption in this project is that the questioning route devised by the researchers and others was sufficient both in depth and breadth to provide responses to assist CAPAP and NSP to better determine the feasibility of a biomass gasification electrical generation facility in Granite Falls fueled with alfalfa.

Another assumption of this project is that the participants represented the broad range of farmers, including both men and women, within the biomass shed.

For some participants the outline of the project presented before the focus group interview was their introduction to the feasibility study, for others it added to existing knowledge. Therefore, this report is limited in that participants did not have equal prior knowledge of the project and therefore may not have had equal opportunity to formulate responses to the questions.

These assumptions and limitations not withstanding, this report gives the reader insight into the perceptions of, and concerns about, the proposed project, as verbalized by farmers within the area.

Representative participant quotes are used throughout the report to support the common concerns identified across focus groups. These quotes represent the perspective of the participants and have much to offer in understanding the feelings they hold about the topic.

The results of this report are not organized according to the focus group questions. Instead, the report is organized around major themes that evolved from the discussions. Effort has been made to present these themes as distinct and separate, yet considerable overlap exists. Themes are presented in order of relatedness to one another and not in order of importance.

# RESULTS

## ALFALFA — GOOD TO GROW, NOT TO HARVEST AND MARKET.

Farmers participating in all five focus groups expressed a strong interest in finding a way to include alfalfa into their current crop rotations. Desirable reasons that participants stated included: erosion control benefits; soil fertility and tilth improvement; and pest control benefits. A major theme from all the focus groups conducted for this project is the idea that alfalfa is a good crop — a desirable and valuable crop in the rotation.

> **I always raised alfalfa. We got away from it in the last year or so because we got out of cattle and it kind of bothers me not to have alfalfa into the rotation. So it would be a real positive to allow non-cattle or non-dairy producers to have alfalfa in the rotation.**
>
> -Marshall Participant-

> **[Alfalfa is a] renewal resource, environmentally friendly, I think.**
>
> -Olivia Participant-

> **The environmental aspects of this project are very important based on the location of the project at the Minnesota River basin.**
>
> -Appleton Participant-

Contrasting with the belief that alfalfa is a good and desirable crop to grow, there is a belief that alfalfa is not a "good" crop to harvest and market. Timeliness of harvest, the necessity for specialty equipment, weather problems, the bulkiness of hay, together with limited market opportunities and uncertain prices were among the factors cited that have contributed to the limited amount of alfalfa presently grown.

Participants believe year-to-year weather variations make alfalfa a risky crop to harvest. For many participants, the negative factors of harvesting and marketing out weighed the favorable factors of growing alfalfa — factors that were often cited as reasons not to include it as a crop.

> **It's really a high stress crop. I mean you have to cut it at exactly the right time; you have to harvest it exactly at the right time, usually at night. You have to let it dry out and then the night air comes back on. So I think the reason it's not a big cash crop in this area is because of our high humidity and higher rainfalls.**
>
> -Marshall Participant-

> **There is no real market for it except the sale at the auction barn and the whim of the market. Like this year, I've heard guys pay $120 per ton for alfalfa and then the next year they'll pay $20 for the same quality hay. Well, you can't stay in business with that type of fluctuation.**
>
> -Marshall Participant-

> **Well, everybody knows that there's only so much market for so much good quality. Are you the person that's going to take that risk or not?**
>
> -Canby Participant-

## STEMS OR LEAVES — WHICH ONE DRIVES THE PLAN?

Participants were perplexed by the relationship between the comparative value of alfalfa leaves and stems as outlined in the currently proposed plan. They questioned the logic of basing the feasibility of the plan around stems when that portion sells for only $20.00 per ton compared to the projected sale price of processed leaves at $125.00 or more per ton.

Since the leaves appear to be the more valuable portion of the plant, they reasoned it seems more practical to grow alfalfa cultivars that have a greater percentage of leaves and not concentrate on growing alfalfa cultivars that contain a higher lignin content in the stems. Since leaves are more valuable than stems, and probably since farmers traditionally place more emphasis on management for leaf quality than they do for stem quality, they questioned the rationale of only two cuttings as a practice to obtain higher per acre lignin production. They asked, "Wouldn't it make more economic sense to take four cuttings instead of two?"

> **I guess I've got a problem with this where you're going to raise hay for the stems and it's the less profitable part. We're going to want types of hay for the stem part and it's less profitable than the leaves? The leaves are going to be the best part, I just don't quite understand what we're going after here.**
>
> -Marshall Participant-

> **If 90% of your money is coming from these leaves, why wouldn't you plant a high producing leafy alfalfa that you're going to get four cuttings from? You're only getting 10% from by-products.**
>
> -Canby Participant-

## QUALITY — HOW IS IT MEASURED?

Farmer participants were concerned with quality issues. They have experienced harvest problems with alfalfa in the past. They were concerned with probable quality dockages caused by rain, storage, or other harvesting problems.

Additional quality issues were articulated in a myriad of questions. Among questions raised were the following: complex management concerns; acceptable varieties, particularly those that retain leaves better than others; desirable stage of growth; acceptable ratios of leaves to stems; bale size and shape; planting rates; and transportation.

> **This is the big question in my mind when you start talking about 15% moisture hay. What are your dockage's going to be and this and that? All hay isn't equal.**
>
> -Willmar Participant-

**That would be just like MCP [Minnesota Corn Processors Association], you don't haul moldy corn, you don't haul light corn. There's a certain standard set up by farmers and that would be the same thing. You would have to be paid for the quality you bring in. You couldn't pay the guy that left his leaves on the same as the guy that came in with just stems.**

-Canby Participant-

## TECHNICAL CONCERNS — SEPARATION, ASH, CONTRACTS, AND MORE.

Focus group participants listed many questions they would like answered or researched before committing to participation in an alfalfa biomass energy production program. Among the questions and concerns were those that dealt with: complex management and risk; assurance of long-term contracts; acceptable cultivars; desirable stage of growth for harvest; acceptable ratio of leaves to stems; bale size and type; storage; moisture content within bales; leaf-stem separation and processing; and ash use, disposal and handling costs; and costs of transportation on the farm to a receiving site.

**All of us know that weather has a bigger impact on alfalfa than it does on any other crop as far as harvesting it and that could be a risk. If the farmer has to assume it all, then he cuts down his 100 acres on June 15 and it all gets rained on two or three times and it's not worth anything. Then that's a fairly big risk on the farmer's part.**

-Willmar Participant-

**There's going to have to be something built into the contract there cause they're [NSP] going to have to live with a contract to assure the [electrical] supply, but they can't use their over-supply to kill off or to lower price [of alfalfa].**

-Marshall Participant-

**Maybe we should start with market first. What can we get for the material? Then, you decide whether it's going to be the contract [with NSP] or if people want to make their organization [form a co-op] to supply the market. Get some concrete numbers on your**

**market then things will take care of themselves. If there's a place to sell it and make some money, you'll get the stuff.**

-Marshall Participant-

## ONE BUYER — ONE PRODUCT.

Participants were skeptical about partnering with NSP in a biomass purchasing plan. Why is NSP interested in alfalfa? Participants had a consistent belief that they could be put into a subordinate position and that NSP could take advantage of them. They believed that they were playing on an uneven field and that NSP had all the players necessary to win! They were curious about the financial commitment and motivation to the project of NSP. They wanted assurances that they could be even partners in the plan.

**What is NSP's tax advantage for doing this and everything else?**

-Canby Participant-

**If NSP all of a sudden says to this co-op [us], "We don't want your hay," What are you [farmers] going to do with it? ... So they have to have some risk involved in this thing or, you're [farmers] going to get stuck holding the bag.**

-Appleton Participant-

Too, participants were concerned that they would be producing a product for which there would be only one buyer — NSP. This made them feel uncomfortable and vulnerable.

**Bob brought up the biggest thing — right now you only got one market!**

-Appleton Participant-

Farmers were also concerned the leaf meal product, upon which much of the economic feasibility of the plan is based, is an untested, unresearched, product that does not have an established market. This brought up concerns of market development, protein product competition, and possible depression of corn and soybean prices.

> **Yeah, are we going to set some other market off here. If we're going to bring 100,000 acres of leaves [leaf meal] on the market, we got to sell them. They weren't sold the year before and I have no idea what kind of quantity or tons or percentage or, whatever, but is there a market for that?**
>
> -Canby Participant-

Participants also expressed a collective anxiety about the possible agricultural market disruption if several more alfalfa gasification plants were established.

**PARTICIPATION — FARMS AND FARMERS.**

There was a lack of consensus about what kind of farmers would most likely be interested in participating in alfalfa production to generate biomass energy. Several farmers felt alfalfa is a crop that could work for all types of farm operations. Others thought that farmers with large acreage would be willing to participate, although the exact meaning of the term "large farms" was unclear during the interviews.

Dairy focus group participants thought few dairy farmers would be interested in participating primarily because they tend to have limited acreage and the local supply of good quality alfalfa hay to purchase for feed is scarce so dairy farmers need to produce their own high quality alfalfa hay. Non-dairy producers pointed out that dairy farmers tend to already own equipment necessary to produce alfalfa and consequently thought dairy farmers would be likely candidates to produce for the biomass energy project.

> **There's a niche for every farmer and it can work for everybody.**
>
> -Canby Participant-

I don't think it necessarily will be the dairy farmers probably doing most of their growing. I think it's going to be grain farmers that are going to be growing it. They have the acres; we don't.

-Willmar Participant-

If you could go out and say that the co-op is going to help you purchase your machinery and there's a real minimal investment up front. If it's $10.00 an acre just so he's made a commitment to come there and sign a grower agreement and get some of these other agencies involved in financing it, I don't think you're going to have a problem selling [procuring] acres.

-Appleton Participant-

He's [dairy farmers in general] already got the equipment. He's got to go through the exercise anyway [harvesting] so, in a way, it might fit into his program to add another 25 to 50% to his crop. Then he could keep the best up on his farm and maybe give the rest to the power plant.

-Marshall Participant-

A big one [farm operation], because you're going to have so much equipment on this hay and hay shed that you're not going to mess around with 50 to 100 acres. No way!

-Marshall Participant-

That's going to be the risk takers and those guys are the ones that will be well enough capitalized, well enough educated to say, "Well, let's take a chance." I think it will be the large grain farmers and you only need 500 of them and you draw that big circle and that isn't going to be hard to find [farmer participants].

-Marshall Participant-

You're talking about the younger guy that's got the energy.

-Marshall Participant-

I think one important factor that nobody brought up would be four years coming out of a rotation as we're sitting right now in our operation. It would be tough to come up with any number of acres that you could pull out of your current rotation, a three year rotation, that you could pull out for four years and put into a different crop.

-Olivia Participant-

**I would think the area that has a lot of CRP [Crop Reserve Program] right now/. I would think that it would be more feasible in an area like that than in an area around here where there's very little CRP.**

-Olivia Participant-

**I think this would appear to guys that are getting closer to retirement and saying, "I'd like to slow down a little bit, I wouldn't like to work quite so hard." They could put some of their acres in this, but that's also the point when they're not, maybe, as open to invest in new businesses at that time either and if this would call for an investment in the cooperative to do that it could be detracting from that.**

-Olivia Participant-

## CO-OPS — MODELS THAT WORK & RELATIONSHIP TO NSP.

Participants expressed belief that they were playing on an uneven field and that NSP had "all the players necessary to win." They were curious about NSP's financial commitment, motivation and involvement in the study as well as in a possible demonstration facility.

**You take the sweet corn people. I mean, sweetcorn's got to come [be harvested] when the company says, not when the grower wants it. I mean, maybe it will and maybe it won't have to be but it might have to be. You might have to give up that control too.**

-Olivia Participant-

**Right or wrong, I want to throw one out here. Why don't NSP just go ahead and build this plant and contract with farmers to haul [produce] it?**

-Olivia Participant-

**[The Co-op should] contract the acres, set up facilities to own the leaf processing end of it all the way through, and sell off [to NSP] the stems.**

-Olivia Participant-

Although some participants expressed negative feelings toward the establishment of a cooperative to supply alfalfa stems to NSP and to market the leaf meal product, most participants believed a co-op would be a valuable business organization and should be part of the plan. Not only did they approve of the Co-op — NSP relationship, they offered concrete suggestions about the organization of it. Most of the suggestions were in the form of comparisons with existing, successful co-ops. "Pay-to-play," and "farmer-oriented" were key concepts of a successful co-op that were voiced by participants.

> **Patterning it on the MCP is an excellent idea, but because of the fact that MCP is working as a farmer-owned co-op and doesn't really have a large entity like Northern States Power involved, whereas this operation would. So you need some kind of firm commitment [from NSP] that are means of tying them down.**
>
> -Canby Participant-

> **Basically, what you need is a whole new cooperative formed. Just like the sugar beet cooperative. You want to invest in that [cooperative], if you want to invest in this plan you buy so many shares.**
>
> -Willmar Participant-

> **What I'm saying is if there are some benefits in it for NSP, I think they should shoulder some of the costs of building, or at least putting some of the equity into the cooperative. I don't know if they've put money into a cooperative or not, it would probably be a whole different ball game then, but I don't know if the farmer wants to take on the whole responsibility of funding this thing, because if for some reason, it doesn't work, then what? The farmer's already got enough hanging on his head. He sure doesn't need anymore. At least that's my feelings.**
>
> -Appleton Participant-

> **The ideal would be to sell to them under a contract. That way if it goes bust then we don't lose all the money. Well, on the other hand, if it's profitable, it never hurt anyone to own shares in MCP [Minnesota Corn Producers].**
>
> -Marshall Participant-

**Well, I was just wondering is NSP looking for the farmer to finance this plant to process this hay? You know, it sounds like you're looking for another co-op. If you're looking for a co-op, that means farmer owned investment, farmer investment. Or is NSP going to put up the processing plant, and we just sell to them under contract?**

-Marshall Participant-

**If Northern States Power is going to be this involved to the extent that I believe they are with this, I believe a joint ownership of the operation with them, combining a lot of their managerial skills can be available [helpful] to us.**

-Canby Participant-

## COMMUNITY — BENEFITS AND DISADVANTAGES.

Overall, farmers thought the plan as described would have positive benefits to the communities in the region, especially in the town of Granite Falls. Producers noted that when farm income is steady local businesses benefit, resulting in stronger communities. They also felt it was better to keep dollars spent on energy at home, rather than buying coal from other regions of the country. "It's hard to see a lot of drawbacks" was the consensus.

When participants were asked about any possible negative impacts on communities, few were cited. Participants thought the area immediately surrounding the power facility would be most affected by increased traffic. However, they noted "there are already lots of trucks on the road" and didn't see the increased traffic as a major problem. Some participants wondered if there would be increased dust and air pollution resulting from the change from coal to alfalfa biomass.

**It's hard to see a lot of drawbacks.**

-Willmar Participant-

**I think it kind of starts back out on the farm. When the farmer's makes money, everyone makes money and everybody has a good time. Really, it does. I mean Main Street, your car dealers, your grocery stores. You go places. You do things. Dollars get spent.**

-Olivia Participant-

**Keeps the money at home. You have dealers who are selling equipment. You got seed dealers. What it is doing is keeping the money in the local area.**

-Willmar Participant-

## SURVEY RESULTS

At the conclusion of each focus group interview participants were asked to complete a brief "Participation Survey". The purposes of the survey were to: determine respondent's probable intention to participate in the plan; the acreage that would likely be designated; and to determine areas of concern or lack of knowledge before a decision about participation could be made.

Surveys were distributed to the 39 individuals that attended the focus group interviews. Thirty-seven surveys were completed and returned for a return rate of 94.9%.

Table 1

Number of participants and surveys returned

| Location | Number | Surveys | Percent |
|---|---|---|---|
| Appleton | 7 | 5 | 71.4 |
| Canby | 8 | 8 | 100.0 |
| Marshall | 8 | 8 | 100.0 |
| Olivia | 8 | 8 | 100.0 |
| Willmar | 8 | 8 | 100.0 |
| Totals | 39 | 37 | 94.9 |

Of the 37 responses, 19 (51.4%) indicated they would participate in plan. Seven of the 19 (36.8%) stated they would participate with less than 80 acres, nine of 19 (47.4%) with 81 to 120 acres, none of the 19 (0.0%) with 121 to 160 acres, and three of the 19 (15.8%) with 161 or more acres.

Respondents from the Willmar focus group (Dairy) had the highest rate of probable participation. Of that group, six (75.0%), indicated they would participate in the plan if an opportunity was given. This response is interesting in that it is in sharp contrast to their statements about probable low dairy farmer participation.

Reasons respondents gave for not participating in the plan fit into three broad categories: technical issues and questions; assurances about long-term commitment from NSP; and the lack of basic information upon which to make a decision.

Table 2

Acreage allocation participants indicated they would likely be willing to commit to alfalfa leaf meal/biomass production.

| Location | <80 | 81 - 120 | 121 - 160 | >160 | Total |
|---|---|---|---|---|---|
| Appleton | 1 | 3 | 0 | 0 | 4 |
| Canby | 1 | 2 | 0 | 0 | 3 |
| Marshall | 1 | 1 | 0 | 1 | 3 |
| Olivia | 1 | 1 | 0 | 1 | 3 |
| Willmar | 3 | 2 | 0 | 1 | 6 |
| Totals | 7 | 9 | 0 | 3 | 19 |

# SUMMARY

Farmers would require a clear, concise plan before making a decision about including alfalfa for a DFSS. This is in spite of the fact they generally believe the plan could benefit themselves and the community-at-large.

In all the focus groups conducted for this project, the idea that alfalfa is a "good" crop was unanimous. Yet, this perception of "good" was continually tempered with the farmers' perception of financial risk. Participants clearly understood the many benefits of including a perennial legume in their crop rotations.

Farmers perceive change as being risky. The level of perceived risk, together with the perception of enhanced rewards (i.e. -- more money, less work) are major factors upon which farmers make decisions. Given the perception that change is risky, farmers must have assurances that the rewards for changing their crop rotations to include some or more alfalfa will be substantially greater than they presently receive with their present crop rotations. If farmers perceive the rewards to be less than, equal to, or even slightly more than, they receive from their present crop rotations, they will not participate in a plan to produce alfalfa for a DFSS. They will change their cropping rotations and participate in DFSS only when they believe the potential rewards for participation are substantially greater than they receive from their present crop rotations.

## RESEARCH PROCEDURES

The study was conducted using the following procedures.

1. With input from the appropriate representatives of the CAPAP and College of Agriculture (COA) faculty, the final questioning route was refined and finalized.
2. With consultation from the appropriate representatives of the CAPAP and COA, a design for sampling was established and exact locations were identified. Five locations were selected—representative of the agriculture diversity within an approximate 50 mile radius of Granite Falls—in which to conduct focus group interviews. The locations selected were Appleton, Canby, Marshall, Olivia, and Willmar.
3. Using guidelines established by the primary researcher, the CAPAP reserved locations for each of the focus group interviews.
4. Using a pro-forma established by the primary researcher, the CAPAP invited eight individuals to each of the five focus group locations for the interview.
5. Each focus group interview lasted approximately 1 and 1/2 hours and was audio taped. The same questioning route was used at each location.
6. From a "1099" information form, CAPAP was responsible for paying $30.00 to each focus group participant.
7. The audio tapes were transcribed by CAPAP and the transcripts analyzed for key themes. This report represents the result of analysis of those transcripts.

## Invitation Protocol

Telephone Screening

Name ________________________________

Date ____________________

Address ____________________________

Phone ______________________

Hello, my name is ______________ and I'm calling from the University of Minnesota. We want to get the opinion of farmers in Southwestern Minnesota o a project we are working on. This will take less than minutes. May I proceed?

1 Is this the head of the household?

() Yes [CONTINUE]

() No [May I please speak to the head of the household?]

2. Does the majority of your income come from farming sources?

() Yes [CONTINUE]

() No [TERMINATE]

2. Do you make the crop or livestock decisions on your farm?

() Yes [CONTINUE]

() No [TERMINATE]

3. Do you farm 400 or more acres?

() Yes [CONTINUE]

() No [TERMINATE]

5. Are you between the ages of 30 and 50?

() Yes [CONTINUE]

() No [TERMINATE]

[IF "YES" TO ALL QUALIFYING QUESTIONS, CONTINUE]
We are asking people like you to join us for a discussion about a cropping rotation we are working on. We want your opinion. You will be given $30.00 for your time and travel expenses and a free meal will be provided before or after the meeting. The discussion will be (time) (date) (place) and will last about one and one-half hours. Would you be able to participate in the meeting?

( ) YES [If YES] I will be sending you a letter confirming this information. Thank you very much for your cooperation.

( ) NO [If NO] Thank you for your time. You are welcome to attend a general information meeting on this project that will be held April 11 at 2:00 PM in the Montevideo Courthouse Assembly Room.

## SAMPLE LETTER OF CONFIRMATION

Dear

Thank you for accepting our invitation to participate in the discussion group in the (time) (date) (place). Because our time together is limited, we will begin promptly.

As you know, the purpose of our meeting is to discuss various aspects of alfalfa production. Topics to be covered will include, but not be limited to:

1.

2.

3.

Your insights and opinions are very important.

We are looking forward to meeting with you. If you have any questions, please do not hesitate to call me. My number is ___________.

At x:00 p. m., prior to the meeting, dinner (lunch) will be provided. You will be given $30.00 to help with the cost of your transportation and for your contribution of time.

Sincerely,

Earl W. Bracewell, Primary Researcher

## Sample Letter Of Thank-you

Dear

Thank you for giving your time and thoughts to the discussion of the University of Minnesota CAPAP for Alternative Plant and Animal Products sponsored focus group that discussed various aspects of alfalfa production.

There were many excellent suggestions and comments. Your suggestions will undoubtedly help the agricultural industry of Minnesota.

I enjoyed getting to meet with you. Our meetings were very useful as we strive to better serve the agricultural community of Minnesota.

Best wishes in the future.

Sincerely

Earl W. Bracewell, Primary Researcher

## OVERVIEW OF THE BIOMASS ENERGY FEASIBILITY STUDY

The US Department of Energy predicts that renewable biomass energy crops will provide a significant portion of future fuel needs in America. To make electricity from biomass it could be burned, making steam that would drive a steam turbine which in turn produces electricity. A newer, more efficient way to convert biomass to electricity is through a process called gasification. Plant matter (biomass) placed in a chamber under pressure and at a high temperature (over 1500 degrees F) is converted to gases, with the conversion rate of over 95%. These gases, primarily methane and hydrogen, are combusted to drive a combustion turbine and produce electricity at a higher efficiency rather than can be achieved in steam turbine system.

A proposal funded by DOE to conduct a cooperative, cost-shared study to determine the feasibility of establishing a biomass fueled electric is underway in Minnesota. The MN project is studying the feasibility of raising and using alfalfa as the sources of biomass fuel. Partners in this venture include Northern States Power, the University of Minnesota, the Institute of Gas Technology, Tampella Power Corporation, and Westinghouse Electric Corporation.

The study focuses on examining ~~the possibility~~ of fueling the power plant in Granite Falls with gasified alfalfa stems and selling the leaf as a supplemental animal feed. The plant currently runs on coal, and there is sufficient space to put the machinery into the existing facility.

These organizations are conducting a 9 month feasibility study. In September we will present a report to DOE with recommendations on whether to go ahead with a demonstration project in Granite Falls or not. We are involved with a number of research projects to assess the feasibility of this idea, but farmer input is also critically important.

### BIOMASS PRODUCTION

Why Alfalfa? There are several environmental and economic reasons. Alfalfa in the rotation has potential environmental benefits including reduced soil erosion and decreased pesticide and fertilizer use, and has wildlife benefits. Alfalfa, in order to gain the high lignin content necessary for fuel-quality stems, only 2-3 cuttings per year would be taken. The first harvest would be delayed until after June 15 to allow the pheasant and duck eggs time to hatch prior to the first cutting, potentially resulting in more wildlife in the region.

Minnesota farmers currently produce about 7 million tons of alfalfa per year, the fourth largest production in the country. However, alfalfa covers less than 6% of Minnesota's total crop land. Alfalfa is a crop compatible with the current corn and soybean rotation prevalent in the area, and in the past has been grown extensively in the region. It is easily established, and yields crops during the first year - estimated at around 2 tons/acre during the first year, and 4 tons in subsequent years. It also provides a high energy content necessary for gasification. There are several reasons corn isn't considered a viable option, some more easily overcome than others: corn has higher moisture content than alfalfa and would have to be dried, has a lower lignin content, and is tough to get to be a uniform size (necessary for gasification. Alfalfa is 40-50% leaf, which means there is a second, profitable market. One of the key areas being researched in this study is the market potential for a high protein animal feed.

One of the bigger reasons for not using corn has to do with the 30% cover requirement enforced by the SCS and other agencies, and for other environmental reasons. The Minnesota River has been identified as the most polluted river in the state. Right or wrong, much of the blame for the pollution is being placed on non-point sources and agriculture has been identified as the major source of this pollution. Alfalfa has the potential to reduce some of the adverse environmental impacts of farming. The other reason alfalfa holds potential is because machinery is readily available and would not need to be developed or modified to raise alfalfa for fuel.

PROPOSED BIOMASS SHED

The proposed biomass shed is within a 50-mile radius of Granite Falls. Current production in this area includes about 2.8, 2.6, million acres of corn, soybean, and 340,000 acres in alfalfa. Average farm size in the shed is 580 acres. The shed currently produces nearly 4 times more alfalfa biomass than would be required for a 1,000 ton/day biomass energy production facility. Alfalfa yield levels in SW MN average 4.5 tons/acre/year.

Current thinking is to harvest and store as the large round bales. This would likely require a combination of on-farm and off-farm storage, either at a collective site or at the NSP facility.

Pre-feasibility study economic analysis based on current economic conditions in SW MN and using a value for the alfalfa of $60/ton to the grower. This figure is derived by taking a 40% leaf figure, and valuing the leaves at $125/ton. The stems are estimated to be worth $17/ton (a competitive cost with coal which averages about $17-20/ton).

The projected average annual return per acres over a 7-year biomass rotation (4 years alfalfa, two years corn, one year soybeans) is $63.10 without government payment. Average annual return including government corn payments is estimated at $76.73.

This analysis indicates that the biomass rotation would be more profitable for the farmer than the conventional corn-soybean rotation with or without government programs payments. Future reductions in government program payments, as are likely, would further increase the profit spread for the biomass producer over the conventional rotation.

Economic benefits of the biomass rotation are directly attributed to the inclusion of a perennial legume in the rotation. Reduced input costs of the biomass rotation compared to the conventional rotation combined with minor yield increases for corn and beans in the biomass rotation result in increased profits for the grower.

The benefits of including alfalfa in a rotation are well documented. However, increases in total alfalfa production have been limited because of the problems associated with shipping alfalfa long distances to reach markets and a declining dairy market for average quality hay.

## ALFALFA COOPERATIVE

A proposed farmer-owned alfalfa cooperative (AC) is one example of a potential business arrangement that will be examined in this feasibility study. The AC could contract with growers to produce alfalfa. The AC could possibly separate the alfalfa into stem and leaf fractions at a facility integrated with the power plant. The reason for separating at NSP is because the leaves could be heat treated to decrease the protein digestibility in the rumen of cows and bi-pass proteins have a higher economic value than soybeans, for example. The power plant has waste heat that could be used to treat the leaves. There is, of course, a danger of over-heating the leaves and ruining them but research is being done on this right now at the U of M.

Densified alfalfa stem fraction could be sold under a long-term guaranteed purchase agreement to NSP as a uniform high quality biomass fuel (about $17-20/ton) The alfalfa leaf fraction is sold as a relatively low-cost ($125/ton or more), high protein, high energy feed supplement.

The ability to separate a value-added leaf meal product from the stem fuel should help make alfalfa biomass fuel competitive with other alternative fuels. Quality issues are important -NSP needs a high quality stem portion to run the plant, farmers will need high quality leaf to sell. Both can agronomically be accomplished. Separation techniques are being evaluated by the ag engineers working on the project.

The storage issues of this quantity of alfalfa are important to determining whether or not to go ahead with a demonstration project. What it comes down to is this is a tremendous amount of material. On-farm covered storage sheds with a crushed gravel base, with a maximum storage height of 12 feet are estimated to cost $3/square foot. Tarps cost around 20 cents/square foot, but a 10% loss can be expected.

ADDITIONAL RESEARCH NEEDS

- Separation machinery
- Storage facility and transportation options
- Evaluation of leaf feed quality
- Value of Ash as Fertilizer
- Increase energy content of stems
- Farmer Cooperative possibilities
- Energy audit to compare current system with proposed system
- Impacts on communities
- Further economic evaluation including markets, cooperative

## KEY QUESTIONS

1. What parts of the proposed plan do **you** like best?

2. What parts of the proposed plan do **you** like least?

3. What factor or factors of the plan would be the most persuasive to help **you** in your decision **to participate** in a plan like this?

   Probe - **not to participate**

4. Some farmers adopt new ideas very quickly. How do you describe those farmers and do you think they would participate in this plan?

   Probe - Are there any factors in the plan that would persuade that kind of farmer **not to participate** in this program if it were available?

5. Some farmers are slower to adopt new ideas. How do you describe those farmers and do you think they would participate in this plan?

   Probe - Are there any factors in the plan that would persuade that kind of farmer to **participate** in this program if it were available?

6. Overall, what do you think are the main factors that will determine whether or not farmers would participate in a plan like this?

7. What, if any, do think would be the benefits to a plan like we've described?

   Probes-
   - improved farm income
   - environmental – wildlife, reduced pesticides & fertilizers, reduced erosion
   - social
   - alternative crop
   - increased employment
   - community development
   - revitalization of rural areas

8. What, if any, do think would be the undesirable consequences to a plan like we've described?

Probes- more traffic

another co-op

social

less time off in summer

9. If you were the manager of an organization like we've described, how would you convince farmers to participate?

Probes -- educational materials?

who, or what agency should be the deliverer?

guaranteed hay price, profit?

social benefits?

environmental benefits?

10. If you were the manager of an organization like we've described, how would you convince the "community-at-large" that this plan is a good plan?

Probes -- price?

educational materials?

who, or what agency should be the deliverer?

social benefits?

environmental benefits?

community development

revitalization of rural areas

11. "Participation Survey"

## PARTICIPATION SURVEY

Suppose that you, beginning in the 1995 cropping season, could participate in a plan similar to the one we've been discussing. Based on what you know and understand today, please complete the following questionnaire. **(Place an x in only one of the participation boxes below.)**

- ☐ I would not participate in the plan.
- ☐ I would participate in the plan with the following acreage of alfalfa. **(Place an x in only one of the acreage boxes below.)**
  - ☐ less than 80 acres
  - ☐ 81 to 120 acres
  - ☐ 121 to 160 acres
  - ☐ 161 or more acres
- ☐ I would not participate in the plan as I now understand it. Before I would participate I would have to have the following assurances or would have to have greater understanding of the following parts of the plan. **(Please be specific, use back side if necessary.)**

1.

2.

3.

**THANK YOU FOR YOUR TIME AND COOPERATION**

## RESEARCHERS

### Earl W. Bracewell

Earl W. Bracewell, Ph.D., Focus Group Consultant, has conducted several qualitative research studies, most notably those requiring ethnographic methodology and focus group interview skills. Bracewell is currently a member of the faculty of the University of Minnesota in the Department of Vocational and Technical Education and Associate in the Centre for Education in Agriculture and Extension. Prior to his present appointment, he was a faculty member of the University of Alaska, Cooperative Extension Service. Additionally he served in a long-term, agricultural and business development position in Papua New Guinea.

### Helène Murray

Helen Murray, Ph.D., is Coordinator, Minnesota Institute for Sustainable Agriculture, and Adjunct Assistant Professor, Department of Agronomy and Plant Genetics at the University of Minnesota. Murray has taken a lead role in interdisciplinary research and education projects aimed at understanding whole farming systems and designing complementary research and educational programs. She was formerly Sustainable Agriculture Coordinator for a joint Oregon State University and Washington State University program and additionally served in the Peace Corps in Nepal.

# APPENDIX 1.1

## Local Biomass Project Meetings

Jan. 10, 1994 - Granite Falls - County Agents and Interested Local Groups

Jan. 14, 1994 - Montevideo - Planning Session

Jan. 31, 1994 - Montevideo - County Commissioners

Jan. 31, 1994 - Montevideo - Extension Educators

Jan. 31, 1994 - Granite Falls - G.F. Chamber of Commerce

Mar. 14, 1994 - Extension Educators and Interested Local Groups

Apr. 04, 1994 - Willmar - Focus Group

Apr. 05, 1994 - Appleton - Focus Group

Apr. 05, 1994 - Canby - Focus Group

Apr. 06, 1994 - Marshall - Focus Group

Apr. 06, 1994 - Olivia - Focus Group

Apr. 11, 1994 - Extension Educators and Interested Local Groups

Apr. 28, 1994 - Granite Falls - G.F. Kiwannas Club Meeting

May 16, 1994 - Granite Falls - Economic Development Group

June 09, 1994 - Granite Falls - Luncheon Meeting with DOE, EPRI, NSP and U of MN

June 09, 1994 - Granite Falls - Public Meeting with DOE, EPRI, NSP and U of MN

July 18, 1994 - Granite Falls - Extension Educators and Interested Local Groups

Aug. 08, 1994 - Granite Falls - Extension Educators and Interested Local Groups

Sep. 08, 1994 - Granite Falls - Extension Educators and Interested Local Groups

# APPENDIX 1.2

**Summary of comments from meeting with District County Commissioners**
**Chippewa County Courthouse on January 31, 1994**

* Concern expressed about seed cost and availability.
* Storage areas will be needed at both farms and at the power facility
* Cooperative to manage production and sales a good idea
* Will this compete with the existing dairy feed market?
* Will there be new jobs at the NSP plant?
* Who makes the decision to go from a feasibility study to a demonstration project?
* How does alfalfa compare with coal in terms of BTU values?
* Why can't corn be utilized instead of alfalfa?

**Summary of comments from meeting with County Extension Educators**
**Chippewa County Courthouse on January 31, 1994**

* Concerns about cost of equipment. How long of a commitment will growers need in order to want to recoup expenses? One agent says a minimum of 3 years.

* How long will the rotation be?

* Is the 15% moisture in bales do-able? Where will the bales be stored?

* What type of arrangement will there be between NSP and growers?

* Alfalfa adds some stability to farmers in terms of market options

* What happens when growers can irrigate? (changes the quality of alfalfa, may be of higher value than using it as a DFFS)

* SCS may want to consider planting several 1 acre blocks as trial sites

* Concerns expressed because of previous problems with new projects in the region, i.e., Jerusalem artichokes, wind power problems (in terms of economic development, an out of state firm was awarded the contract)

* May want to look at conducting focus groups in a variety of areas of the region, e.g., dairy groups, irrigated areas, CRP areas, etc.)

**Summary of comments from meeting with**
**Granite Falls Chamber of Commerce on January 31, 1994**

* One farmer says that as alfalfa matures it ends up with aphid problems and leaves fall off

* How many more diseases will we have with more alfalfa planted?

* How far away will we need to go to sell the alfalfa leaf meal

* Will it compete with distillery grains?

* Energy issues are tough. For example ethanol is renewable but is getting a "bad rap"

* How are you planning to pay farmers?

* What is the length of the potential demonstration project?

* If you can use alfalfa why can't you use corn and soybean residues? (corn has higher moisture content, low lignin content, and is tough to get to be a uniform size; soybeans have higher lignin values but lower yields)

* What is EPA's role in this project? Are they a thorn or ally?

* Will need considerable research on what to do with the alfalfa meal

* How long before we see an inflated price on coal?

* How long will it be before the plant breeders come up with a specific cultivar that is well suited to this type of goal (high lignin, high quality fuel)

* Is there potential for a farmer-owned cooperative?

* How many BTUs are there in alfalfa versus coal? (6,000 for alfalfa, 8,000 for coal)

* What about the impacts on wildlife when alfalfa is planted? What about the impacts on farms if wildlife increases? For example, will we see increased pocket gophers resulting in huge problems for farmers?

* Would sweet clover fit into this program? (no, a one year crop with slow recovery after one cutting)

* Are there problems getting the alfalfa to 15% moisture?

* The Integrated Farm Management program is in place. Could possibly seed mixtures of oats and alfalfa, then harvest and sell the oats while alfalfa is getting established

* Seedbed preparation questions asked. Concern about how to do this, there is a critical need for more information. Farmers will need to modify their equipment for seeding alfalfa and will need to adjust their rotational patterns, fertilizer rates, etc.

* Potassium tends to be limiting in alfalfa plantings.

* Alfalfa lower pesticide and fertilizer use, resulting in increased earthworm activity which helps improve drainage

* Pocket gopher problems likely to be high if planting CRP land to alfalfa

* How does the corn co-operative schedule their arrivals and deliveries?

* How much of the alfalfa leaf drops off as the plant matures?

## APPENDIX 1.3

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#(Attended Granite Falls Biomass Project Public Meeting)
*(Attended 1st Ag Advisory Council Meeting, June 9, 1994 Granite Falls)

# APPENDIX 3

Appendix A: DESCRIPTION OF SOIL ASSOCIATIONS

(source: Soil Associations of Minnesota of Minnesota Soil Survey Staff of the U.S. Department of Agriculture, Soil Conservation Service and University of Minnesota Agricultural Experiment Station. October 1983 4-R-38340).

B3 BEARDEN-MCINTOSH-COLVIN

The soils in this association are on very gently sloping to nearly level ground moraines with a covering of calcareous silty lacustrine material. This association is in western Minnesota. The landscape consists of broad low lying areas of Colvin soils between the Bearden and McIntosh soils on rises. Native vegetation was prairie. Bearden and Colvin formed in thick deposits of silty lacustrine sediments. McIntosh formed in thinner silty sediments. Bearden and McIntosh are somewhat poorly drained. Colvin is poorly drained. Bearden and Colvin have surface layers of silty clay loam. McIntosh has a surface layer of silt loam that is underlain by loam glacial till. All of the soils are calcareous. Minor soils in the association are Hamerly, Winger, and Perella.

B7 BURR-DUPAGE

The soils in this association are nearly level and are on a narrow Glacial Lake Plain in southwestern Minnesota. They formed in calcareous silty lacustrine deposits and loamy alluvial deposits from streams that cross the lake bed. The landscape is a broad flat, with a few low knolls of glacial till. Native vegetation was prairie. Burr is poorly drained, and has a high content of gypsum. It has a thick surface layer of silty clay loam and silty clay. DuPage is moderately well drained. It has a loam surface layer. Both soils are occasionally flooded. McIntosh Variant, which is also common in this association, is not flooded. Minor soils are Arvilla, Egeland, Oldham, and Ves soils.

C2 SINAI-FULDA-HATTIE

The soils in this association are on nearly level to sloping ground moraines in west-central Minnesota. Some of the moraines are covered with a thin layer of clayey lacustrine sediments. Sinai is on plane or slightly convex areas and gentle side slopes. Fulda is on broad flats or in swales. Hattie is on convex knolls and sideslopes. Native vegetation was prairie. Sinai is moderately well or well drained md Fulda is poorly drained. Both soils formed in lacustrine sediments and have silty clay surface soil and subsoil. Hattie is well or moderately well drained, and calcareous. It formed in glacial till and has a clay surface layer and subsoil. Minor soils are Dovray, Hegne, and Tonka.

C3 SPICER-VES-TARA

The soils in this association are on nearly level to undulating lake plains in western Minnesota. The landscape consists of a broad nearly level lake basin of silty lacustrine sediments with numerous islands of loamy glacial till, and islands of till covered with lacustrine sediments. Native vegetation was prairie. Spicer is calcareous and poorly drained. It formed in the laclistrine sediments and has a silty clay loam surface soil and silt loam subsoil. Ves is well drained md formed on islands of glacial till. It has a loam surface soil and subsoil. Tara is moderately well drained and formed on silt covered islands of glacial till. It has a silt loam surface soil and subsoil. Minor soils are Canisteop Colvin, Doland, McIntosh, Nomania, Okoboji, Storden, and Webster.

D2 BARNES-FLOM-BUSE

The soils in this association are on steep to nearly level moraines in western Minnesota. They formed in calcareous, loamy glacial till. Barnes is on irregular convex side slopes and knolls while Buse is on steep end moraines. Flom soils are in shallow drainageways and on wet flats. Native vegetation was prairie. Barnesis well drained. It has a loam surface soil and subsoil. Flom is poorly drained. The surface soil is silty clay loam a nd the subsoilis clay loam. Buse is well drained and calcareous. It has a loam surface soil and subsoil. Minor soils are Fulda, Langhei, Oak Lake, Parnell, Poinsett, quam, Singaas, and Vallers.

D3 WADENILL-SUNBURG-KORONIS

The soils in this association are on undulating to moderately steep ground moraines in central Minnesota. They formed in calcareous loam glacial till. Wadenill and Sunburg formed under prairie vegetation. Koranis formed in an area transitional between prairie and forest. All of the soils are well drained aid are on knolls and sideslopes. Wadenill has a fine sandy loam surface soil and subsoil. Sunburg has a calcareous loam surface layer over a fine sandy loam subsoil. Koronis has a loam surface layer and fine sandy loam subsoil. Minor Soils are Canisteo, Delft, Glencoe, Marcellon, and Palms.

D4 CANISTEO-VES-NORMANIA

The soils of this association are on nearly level to undulating ground moraines in southwestern Minnesota. They formed in calcareous shaly, loamy glacial till. Canisteo are on broad flats and rims of depressions, Ves on low knolls and convex side slopes, and Normania on slight rises and the concave part of lower side slopes. Native vegetation was prairie. Canisteo is poorly drained, and calcareous. The surface soil and subsoil are clay loam. Ves is well drained and Nomania is moderately well drained. Both Ves and Nomania have loam a surface layer and subsoil. Minor soils are Glencoe, Harps, Okoboji, Seaforth, Spicer, Storden, and Webster.

## D5 FORMAN-AASTAD-FLOM

The soils in this association are on undulating to nearly level moraines and till plains in southwestern Minnesota. They formed in loamy glacial till. Forman is on convex parts of the landscape and adjacent to steep side slopes along the deep drainageways. Aastad is on the plane and slightly convex areas. Flom is in shallow drainageways. Native vegetation was prairie. Forman is well drained, Aastad is moderately well drained and Flom is poorly drained. All three soils have a clay loam surface soil and a firm clay loam subsoil. Minor soils are Buse, Darnen, Hamerly, Quam, and Vallers.

## D6 CANISTEO-NICOLLET-OKOBOJI

The soils in this association are on nearly level to gently undulating ground moraines in southwestern Minnesota. The ground moraine is covered with a layer of silty and clayey lacustrine sediments in Kandiyohi, Meeker, and northern Renville counties. Canisteo soils are on broad flats and on rims of depressions, Nicollet on low rises, and Okoboji in depressions. Native vegetation was prairie. Canisteo is poorly drained, and calcareous and Nicollet is moderately well or somewhat poorly drained. Commonly Canisteo and Nicollet have a clay loam surface layer and subsoil where the ground moraine is covered with lacustrine sediments. The surface and subsoil layers are silty clay loam. Okoboji is very poorly drained. The surface soil is silty clay loam and the subsoil is silty clay. Minor soils are Brawnton, Clarion, Crippin, Glencoe, Guckeen, Marna, Palms, Webster, and Storden.

## Hl KRANZBURG-VIENNA-HIDEWC)OD

The soils in this association are on gently sloping to nearly level loess covered ground moraines in southwestern Minnesota. They formed in a covering of loess over calcareous loamy glacial till. Kranzburg and Vienna are on ridgetops and side slopes. Hidewood is in drainageways. Native vegetation was prairie. Kranzburg has a silty clay loam surface soil and subsoil. Vienna has silty clay loam surface soil formed in loess and glacial till and a clay loam subsoil formed in glacial till. Both Kranzburg and Vienna are well drained. Hidewood is somewhat poorly drained. They have a silty clay loam surface soil and subsoil. Minor soils are Brookings, Buse, Darnei, and LismDre.

## I2 ARVESON-MARYSLAND-SVERDRUP

The soils in this association are on nearly level to undulating glacial outwash plains and glacial lake beaches in west-central Minnesota. They formed in loamy water-deposited sediments. Arveson and Marysland are on broad flat areas and in swales. Sverdrup is on low rises and convex ridges. Native vegetation was prairie. Arveson and Marysland are poorly to very poorly drained, and calcareous. Both soils are moderately deep to sandy sediments. Arveson soils have a clay loam surface soil and a loam or sandy loam subsoil over a loamy sand or fine sand substratum. Marysland soils have loam surface and subsurface layers and a sand subsoil. Sverdrup is well drained and has a sandy loam surface soil, and sandy loam or loamy sand subsoil that is underlain by sand. Minor soils in the association are Clontarf, FossLun, Maddock, Renshaw, and Swenoda.

I4 BISCAY-ESTHERVILLE-HAWICK

The soils in this association are on nearly level to sloping outwash plains, valley trains, and river terraces in south-central Minnesota. Biscay formed in a moderately thick covering of loamy sediments. Estherville formed in a thin covering of loamy sediments. Hawick formed in very thin loamy sediments or sandy materials.

J1 COLAND-STORDEN-SWANLAKE

The soils in this association are on nearly level bottomlands and steep side slopes in the Upper Minnesota River Valley. Coland formed in alluvium. Storden and Swanlake formed in calcareous loamy glacial till. Coland soils are on bottcmlands, Storden on west and south facing sideslopes and Swanlake on north and east facing sideslopes. Coland aid Storden soils formed under prairie vegetation and Swanlake soils formed under woodland. Coland is poorly drained and has a thick silty clay loam surface layer over a sandy loam subsoil. Sta-den and Swanlake are well drained and have a loam surface layers and underlying material. Minor soils are Calco, Comfrey, Copaston, Dorchester, DuPage, Lester, Millington, Nishna, Terril, andwadena.

**Appendix B**

Table B.1 The detailed soil data used in simulations

**Chippewa County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.21 | 0.18 | 0.17 | 15.0 | 21.0 | 60.0 | 10.86 | 0.335 | Colvin-Spicer |
| 0.22 | 0.19 | 0.17 | 14.0 | 31.0 | 60.0 | 11.24 | 0.144 | Tara s.l. |
| 0.21 | 0.17 | 0.15 | 15.0 | 24.0 | 60.0 | 10.08 | 0.072 | Canisteo s.c.l. |
| 0.21 | 0.19 | 0.19 | 19.0 | 36.0 | 60.0 | 11.78 | 0.118 | Spicer |
| 0.26 | 0.20 | 0.16 | 7.0 | 18.0 | 60.0 | 10.74 | 0.180 | Doland_swan |
| 0.20 | 0.19 | 0.17 | 27.0 | 38.0 | 60.0 | 11.23 | 0.053 | Waubay s.l. |
| 0.20 | 0.18 | 0.19 | 8.0 | 17.0 | 60.0 | 11.39 | 0.046 | Glyndon |
| 0.21 | 0.18 | 0.18 | 10.0 | 18.0 | 60.0 | 11.10 | 0.052 | Ves l. |

**Kandiyohi County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.19 | 0.20 | 0.17 | 30.0 | 36.0 | 60.0 | 10.98 | 0.052 | Delft |
| 0.21 | 0.16 | 0.15 | 10.0 | 24.0 | 60.0 | 9.74 | 0.109 | Wadenill |
| 0.17 | 0.17 | 0.15 | 7.0 | 20.0 | 60.0 | 9.40 | 0.113 | Sunburg |
| 0.21 | 0.17 | 0.17 | 22.0 | 30.0 | 60.0 | 11.08 | 0.218 | Canisteo |
| 0.16 | 0.11 | 0.03 | 12.0 | 18.0 | 60.0 | 3.84 | 0.122 | Estherville |
| 0.20 | 0.18 | 0.18 | 16.0 | 32.0 | 60.0 | 11.12 | 0.133 | Harps |
| 0.21 | 0.18 | 0.18 | 10.0 | 20.0 | 60.0 | 11.10 | 0.068 | Ves |
| 0.21 | 0.18 | 0.03 | 18.0 | 28.0 | 60.0 | 6.54 | 0.176 | Biscay-Palms |

**Lac Qui Parle County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.19 | 0.17 | 0.17 | 10.0 | 25.0 | 60.0 | 10.40 | 0.238 | Ves l. |
| 0.21 | 0.18 | 0.17 | 12.0 | 34.0 | 60.0 | 10.90 | 0.058 | Waubay s.l. |
| 0.22 | 0.22 | 0.19 | 10.0 | 55.0 | 60.0 | 13.05 | 0.062 | Calco |
| 0.16 | 0.17 | 0.17 | 14.0 | 23.0 | 60.0 | 10.34 | 0.067 | Normania |
| 0.20 | 0.18 | 0.18 | 16.0 | 38.0 | 60.0 | 11.12 | 0.208 | Harps-Glencoe |
| 0.21 | 0.21 | 0.18 | 7.0 | 20.0 | 60.0 | 11.40 | 0.067 | Esmond |
| 0.20 | 0.16 | 0.14 | 9.0 | 45.0 | 60.0 | 9.66 | 0.078 | Burr-Calco |
| 0.21 | 0.17 | 0.16 | 10.0 | 21.0 | 60.0 | 10.21 | 0.049 | Barnes |
| 0.20 | 0.17 | 0.18 | 15.0 | 30.0 | 60.0 | 10.95 | 0.049 | Vallers |
| 0.20 | 0.17 | 0.18 | 17.0 | 50.0 | 60.0 | 10.81 | 0.042 | Webster |
| 0.20 | 0.17 | 0.19 | 16.0 | 25.0 | 60.0 | 11.38 | 0.042 | Perella |
| 0.21 | 0.18 | 0.18 | 9.0 | 55.0 | 60.0 | 11.07 | 0.040 | Lamoure |

whc1, whc2 and whc3 = crop available soil water holding capacity of soil layer 1, 2 and 3, respectively.
d1, d2, and d3 = depths of soil layer 1, 2 and 3, respectively.
tl_whc = crop available soil water holding capacity of total soil profile.
area = soil area of fraction of total county area.

**Lincoln County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.20 | 0.18 | 0.17 | 12.0 | 24.0 | 54.0 | 10.68 | 0.423 | Barnes |
| 0.23 | 0.20 | 0.17 | 13.0 | 21.0 | 54.0 | 11.22 | 0.177 | Flom |
| 0.20 | 0.18 | 0.17 | 8.0 | 27.0 | 57.0 | 10.63 | 0.078 | Forman |
| 0.22 | 0.20 | 0.17 | 16.0 | 42.0 | 60.0 | 11.78 | 0.054 | Oaklake |
| 0.22 | 0.17 | 0.17 | 12.0 | 48.0 | 54.0 | 10.80 | 0.063 | Vallers |
| 0.19 | 0.17 | 0.17 | 9.0 | 45.0 | 60.0 | 10.38 | 0.054 | Buse |
| 0.25 | 0.18 | 0.18 | 24.0 | 54.0 | 60.0 | 12.48 | 0.045 | Parnell |
| 0.21 | 0.19 | 0.17 | 6.0 | 17.0 | 39.0 | 10.66 | 0.049 | Singsaas |
| 0.22 | 0.19 | 0.17 | 13.0 | 29.0 | 54.0 | 11.17 | 0.057 | Svea |

**Lyon County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.18 | 0.17 | 0.15 | 12.0 | 19.0 | 68.0 | 9.50 | 0.053 | Aastad |
| 0.19 | 0.17 | 0.16 | 11.0 | 16.0 | 60.0 | 9.98 | 0.180 | Barnes |
| 0.21 | 0.17 | 0.16 | 20.0 | 39.0 | 60.0 | 10.79 | 0.095 | Flom |
| 0.20 | 0.17 | 0.15 | 22.0 | 31.0 | 60.0 | 10.28 | 0.178 | Canisyeo |
| 0.20 | 0.17 | 0.17 | 42.0 | 47.0 | 60.0 | 11.46 | 0.048 | Glencoe |
| 0.18 | 0.17 | 0.16 | 11.0 | 19.0 | 60.0 | 9.90 | 0.134 | Formans |
| 0.21 | 0.18 | 0.18 | 11.0 | 21.0 | 60.0 | 11.13 | 0.164 | Ves |
| 0.21 | 0.18 | 0.18 | 14.0 | 30.0 | 60.0 | 11.22 | 0.045 | Colvin |
| 0.21 | 0.18 | 0.14 | 25.0 | 38.0 | 60.0 | 10.67 | 0.046 | Lamoure |
| 0.21 | 0.18 | 0.16 | 15.0 | 24.0 | 60.0 | 10.53 | 0.057 | Seaforth |

**Red Wood County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.20 | 0.17 | 0.15 | 18.0 | 29.0 | 60.0 | 10.12 | 0.323 | Canisteo |
| 0.20 | 0.17 | 0.18 | 19.0 | 33.0 | 60.0 | 11.04 | 0.115 | Webster |
| 0.20 | 0.17 | 0.17 | 26.0 | 33.0 | 60.0 | 10.98 | 0.047 | Glencoe |
| 0.22 | 0.19 | 0.19 | 8.0 | 48.0 | 60.0 | 11.64 | 0.100 | Okoboji |
| 0.21 | 0.18 | 0.18 | 10.0 | 25.0 | 60.0 | 11.10 | 0.268 | Ves |
| 0.21 | 0.18 | 0.18 | 12.0 | 30.0 | 60.0 | 11.16 | 0.047 | Seaforth |
| 0.22 | 0.18 | 0.18 | 17.0 | 28.0 | 60.0 | 11.48 | 0.100 | Normania |

whc1, whc2 and whc3 = crop available soil water holding capacity of soil layer 1, 2 and 3, respectively.
d1, d2, and d3 = depths of soil layer 1, 2 and 3, respectively.
tl_whc = crop available soil water holding capacity of total soil profile.
area = soil area of fraction of total county area.

**Renvill County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.20 | 0.18 | 0.18 | 13.0 | 30.0 | 60.0 | 11.06 | 0.159 | Harps |
| 0.20 | 0.17 | 0.18 | 16.0 | 32.0 | 60.0 | 10.96 | 0.098 | Webster |
| 0.23 | 0.23 | 0.16 | 9.0 | 36.0 | 60.0 | 12.12 | 0.057 | Winger-Quam |
| 0.19 | 0.17 | 0.16 | 16.0 | 35.0 | 60.0 | 10.27 | 0.119 | Nicollet |
| 0.22 | 0.19 | 0.19 | 8.0 | 28.0 | 60.0 | 11.64 | 0.104 | Okoboji |
| 0.21 | 0.18 | 0.18 | 8.0 | 37.0 | 60.0 | 11.04 | 0.052 | Seaforth |
| 0.21 | 0.18 | 0.18 | 13.0 | 25.0 | 60.0 | 11.19 | 0.100 | Clarion-Swanlake |
| 0.21 | 0.18 | 0.18 | 9.0 | 22.0 | 60.0 | 11.07 | 0.105 | Ves |
| 0.20 | 0.17 | 0.15 | 20.0 | 38.0 | 60.0 | 10.36 | 0.205 | Canisteo-Glencoe |

**Swift County**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name |
|---|---|---|---|---|---|---|---|---|
| 0.16 | 0.16 | 0.16 | 10.0 | 20.0 | 60.0 | 9.60 | 0.221 | Barnes |
| 0.20 | 0.20 | 0.20 | 6.0 | 12.0 | 60.0 | 12.00 | 0.136 | Colvin |
| 0.16 | 0.16 | 0.16 | 8.0 | 32.0 | 60.0 | 9.60 | 0.093 | Hamerly |
| 0.16 | 0.16 | 0.03 | 12.0 | 27.0 | 60.0 | 5.31 | 0.079 | Marysland |
| 0.20 | 0.17 | 0.17 | 11.0 | 20.0 | 54.0 | 10.53 | 0.084 | Vallers-Winger |
| 0.16 | 0.14 | 0.05 | 12.0 | 17.0 | 60.0 | 4.77 | 0.054 | Arveson |
| 0.20 | 0.20 | 0.20 | 9.0 | 18.0 | 60.0 | 12.00 | 0.053 | Beazden |
| 0.16 | 0.16 | 0.16 | 16.0 | 20.0 | 60.0 | 9.60 | 0.048 | Svea |
| 0.20 | 0.17 | 0.20 | 24.0 | 40.0 | 60.0 | 11.52 | 0.095 | Parnell |
| 0.21 | 0.20 | 0.16 | 13.0 | 24.0 | 60.0 | 10.69 | 0.034 | Tara |
| 0.16 | 0.16 | 0.04 | 13.0 | 33.0 | 60.0 | 6.36 | 0.030 | Mayer |
| 0.16 | 0.16 | 0.16 | 7.0 | 20.0 | 60.0 | 9.60 | 0.073 | Buse |

**Yellow Medicine County,**

| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name | |
|---|---|---|---|---|---|---|---|---|---|
| whc1 | whc2 | whc3 | d1 | d2 | d3 | tl_whc | area | soil name | |
| 0.21 | 0.17 | 0.16 | 8.0 | 23.0 | 60.0 | -15.40 | 11.24 | 0.100 | Barnes |
| 0.21 | 0.18 | 0.18 | 9.0 | 21.0 | 60.0 | -15.32 | 10.08 | 0.443 | Ves |
| 0.23 | 0.15 | 0.15 | 36.0 | 45.0 | 60.0 | -15.47 | 11.78 | 0.026 | Du Page |
| 0.18 | 0.17 | 0.16 | 7.0 | 17.0 | 60.0 | -15.27 | 10.74 | 0.105 | Forman |
| 0.20 | 0.17 | 0.15 | 20.0 | 31.0 | 60.0 | -16.02 | 11.23 | 0.240 | Canisteo |
| 0.21 | 0.19 | 0.19 | 13.0 | 38.0 | 60.0 | -16.59 | 11.39 | 0.059 | Spicer |
| 0.14 | 0.04 | 0.04 | 16.0 | 37.0 | 60.0 | -16.18 | 11.10 | 0.027 | Arvilla |

whc1, whc2 and whc3 = crop available soil water holding capacity of soil layer 1, 2 and 3, respectively.
d1, d2, and d3 = depths of soil layer 1, 2 and 3, respectively.
tl_whc = crop available soil water holding capacity of total soil profile.
area = soil area of fraction of total county area.

**Appendix B**

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level.

**Chippewa County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.34 | 122.00 | 98.16 | 63.62 | 128.57 | 105.45 | 90.49 | 0.00 | -2.40 | -52.08 | 96.31 | 112.04 | -15.73 | Colvin-Spicer |
| 0.14 | 124.68 | 98.16 | 65.38 | 128.74 | 109.00 | 94.00 | 0.00 | -3.96 | -50.32 | 98.06 | 113.46 | -15.40 | Tara s.l. |
| 0.07 | 122.00 | 97.11 | 63.20 | 122.01 | 102.76 | 86.74 | 0.00 | -3.00 | -52.19 | 94.14 | 109.46 | -15.32 | Canisteo s.c.l. |
| 0.12 | 128.35 | 98.16 | 63.92 | 128.75 | 109.31 | 94.00 | 0.00 | -4.33 | -50.61 | 98.79 | 114.25 | -15.47 | Spicer |
| 0.18 | 122.09 | 98.16 | 64.56 | 128.74 | 108.11 | 93.53 | 0.00 | -2.80 | -48.59 | 97.53 | 112.80 | -15.27 | Doland_swan |
| 0.05 | 122.00 | 98.16 | 62.05 | 128.74 | 108.11 | 91.97 | 0.00 | -4.80 | -53.65 | 96.59 | 112.61 | -16.02 | Waubay s.l. |
| 0.05 | 122.00 | 97.11 | 60.77 | 128.74 | 108.11 | 90.91 | 0.00 | -6.15 | -54.39 | 95.89 | 112.48 | -16.59 | Glyndon |
| 0.05 | 122.00 | 98.07 | 62.45 | 128.70 | 106.80 | 90.40 | 0.00 | -4.43 | -53.25 | 96.05 | 112.22 | -16.18 | Ves l. |
| **W.M.** | **123.15** | **98.03** | **63.78** | **128.20** | **107.03** | **91.78** | **0.00** | **-3.37** | **-51.28** | **96.90** | **112.51** | **-15.62** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.34 | 38.64 | 34.50 | 29.27 | 38.64 | 34.50 | 29.46 | 0.00 | 0.00 | 0.00 | 35.47 | 35.94 | -0.47 | Colvin-Spicer |
| 0.14 | 40.16 | 35.01 | 29.46 | 40.16 | 35.62 | 30.73 | 0.00 | 0.00 | 0.00 | 35.85 | 36.32 | -0.47 | Tara s.l. |
| 0.07 | 38.09 | 33.42 | 28.31 | 38.09 | 34.13 | 29.46 | 0.00 | 0.00 | 0.00 | 34.78 | 35.28 | -0.51 | Canisteo s.c.l. |
| 0.12 | 40.37 | 35.01 | 29.46 | 40.37 | 36.00 | 30.92 | 0.00 | 0.00 | 0.00 | 36.03 | 36.52 | -0.48 | Spicer |
| 0.18 | 39.36 | 34.80 | 29.46 | 39.36 | 34.80 | 30.09 | 0.00 | 0.00 | 0.00 | 35.67 | 36.14 | -0.46 | Doland_swan |
| 0.05 | 39.37 | 34.90 | 29.46 | 39.37 | 34.90 | 29.81 | 0.00 | 0.00 | 0.00 | 35.64 | 36.12 | -0.48 | Waubay s.l. |
| 0.05 | 39.19 | 34.50 | 29.46 | 39.19 | 34.50 | 29.57 | 0.00 | 0.00 | 0.00 | 35.61 | 36.09 | -0.48 | Glyndon |
| 0.05 | 39.19 | 34.50 | 29.34 | 39.19 | 34.50 | 29.46 | 0.00 | 0.00 | 0.00 | 35.53 | 36.01 | -0.48 | Ves l. |
| **W.M.** | **39.25** | **34.63** | **29.31** | **39.25** | **34.89** | **29.95** | **0.00** | **0.00** | **0.00** | **35.60** | **36.07** | **-0.48** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Kandiyohi County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 123.72 | 102.88 | 73.33 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | -18.19 | 102.57 | 107.27 | -4.70 | Delft |
| 0.11 | 113.74 | 100.68 | 70.02 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | -23.42 | 99.47 | 105.28 | -5.81 | Wadenill |
| 0.11 | 109.76 | 95.47 | 65.70 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | -28.33 | 96.14 | 103.12 | -6.98 | Sunburg |
| 0.22 | 125.47 | 105.50 | 74.63 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | -13.07 | 104.23 | 107.92 | -3.68 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | -6.76 | 64.58 | 65.71 | -1.13 | Estherville |
| 0.13 | 124.73 | 104.52 | 74.32 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | -17.02 | 103.34 | 107.67 | -4.33 | Harps |
| 0.07 | 125.65 | 104.25 | 74.05 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | -17.30 | 103.34 | 107.71 | -4.37 | Ves |
| 0.18 | 109.76 | 85.01 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | -18.51 | 90.89 | 94.63 | -3.73 | Biscay-Palms |
| **W.M.** | **114.66** | **93.78** | **66.21** | **116.92** | **95.63** | **72.00** | **0.00** | **0.00** | **-17.07** | **94.41** | **98.55** | **-4.14** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 38.66 | 34.35 | 27.19 | 38.66 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 34.88 | 35.36 | -0.48 | Delft |
| 0.11 | 37.95 | 34.02 | 27.19 | 37.95 | 34.13 | 28.32 | 0.00 | 0.00 | 0.00 | 34.21 | 34.69 | -0.47 | Wadenill |
| 0.11 | 37.81 | 33.79 | 27.19 | 37.81 | 34.02 | 27.63 | 0.00 | 0.00 | 0.00 | 33.58 | 34.09 | -0.51 | Sunburg |
| 0.22 | 39.19 | 34.35 | 27.28 | 39.19 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 35.13 | 35.58 | -0.45 | Canisteo |
| 0.12 | 28.87 | 22.77 | 15.67 | 28.87 | 22.77 | 15.67 | 0.00 | 0.00 | 0.00 | 23.21 | 23.28 | -0.07 | Estherville |
| 0.13 | 39.26 | 34.35 | 27.19 | 39.26 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 35.02 | 35.49 | -0.47 | Harps |
| 0.07 | 39.27 | 34.35 | 27.19 | 39.27 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 35.02 | 35.48 | -0.46 | Ves |
| 0.18 | 35.27 | 30.37 | 23.79 | 35.27 | 30.49 | 25.51 | 0.00 | 0.00 | 0.00 | 31.55 | 31.84 | -0.28 | Biscay-Palms |
| **W.M.** | **36.58** | **31.83** | **24.96** | **36.58** | **31.94** | **25.95** | **0.00** | **0.00** | **0.00** | **32.42** | **32.80** | **-0.38** | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Lac Qui Parle County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 110.07 | 79.92 | 46.15 | 125.90 | 107.81 | 85.01 | 0.00 | -24.53 | -61.73 | 81.58 | 108.29 | -26.71 | Ves l. |
| 0.06 | 110.32 | 85.01 | 50.86 | 128.64 | 109.79 | 85.01 | 0.00 | -24.77 | -61.80 | 85.72 | 111.49 | -25.77 | Waubay s.l. |
| 0.06 | 119.87 | 89.93 | 62.59 | 132.34 | 113.40 | 89.93 | 0.00 | -13.25 | -50.08 | 94.87 | 116.20 | -21.34 | Calco |
| 0.07 | 110.07 | 78.43 | 45.75 | 124.58 | 106.61 | 84.00 | 0.00 | -25.44 | -61.53 | 80.85 | 107.64 | -26.79 | Normania |
| 0.21 | 112.55 | 85.01 | 50.35 | 129.46 | 109.79 | 85.01 | 0.00 | -25.67 | -62.31 | 86.00 | 111.87 | -25.87 | Harps-Glencoe |
| 0.07 | 113.43 | 85.01 | 53.25 | 129.58 | 110.76 | 85.01 | 0.00 | -24.58 | -59.42 | 88.26 | 113.19 | -24.93 | Esmond |
| 0.08 | 110.07 | 78.19 | 45.56 | 121.47 | 102.97 | 80.39 | 0.00 | -25.36 | -56.47 | 79.29 | 105.06 | -25.76 | Burr-Calco |
| 0.05 | 110.07 | 81.11 | 48.72 | 126.75 | 109.02 | 85.01 | 0.00 | -22.15 | -60.30 | 82.56 | 108.51 | -25.95 | Barnes |
| 0.05 | 110.97 | 84.91 | 49.37 | 129.10 | 109.79 | 85.01 | 0.00 | -24.87 | -63.30 | 85.16 | 111.23 | -26.07 | Vallers |
| 0.04 | 110.07 | 84.73 | 50.14 | 128.89 | 109.79 | 85.01 | 0.00 | -24.00 | -62.53 | 84.89 | 110.89 | -26.00 | Webster |
| 0.04 | 112.58 | 85.01 | 51.76 | 130.05 | 110.28 | 85.01 | 0.00 | -25.18 | -62.02 | 86.77 | 112.56 | -25.79 | Perella |
| 0.04 | 112.67 | 85.01 | 49.71 | 129.62 | 110.03 | 85.01 | 0.00 | -25.83 | -62.96 | 85.69 | 111.74 | -26.05 | Lamoure |
| **W.M.** | **111.68** | **82.92** | **49.55** | **127.66** | **108.85** | **84.89** | **0.00** | **-24.17** | **-60.66** | **84.53** | **110.32** | **-25.80** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 38.52 | 34.88 | 29.05 | 38.52 | 35.06 | 29.19 | 0.00 | 0.00 | 0.00 | 35.09 | 35.48 | -0.38 | Ves l. |
| 0.06 | 40.01 | 35.60 | 29.05 | 40.01 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.86 | 36.21 | -0.35 | Waubay s.l. |
| 0.06 | 40.55 | 36.03 | 29.05 | 40.55 | 36.22 | 29.19 | 0.00 | 0.00 | 0.00 | 37.00 | 37.33 | -0.33 | Calco |
| 0.07 | 38.52 | 34.69 | 28.99 | 38.52 | 34.88 | 29.05 | 0.00 | 0.00 | 0.00 | 34.95 | 35.34 | -0.39 | Normania |
| 0.21 | 40.55 | 35.63 | 29.05 | 40.55 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.93 | 36.30 | -0.37 | Harps-Glencoe |
| 0.07 | 40.55 | 35.85 | 29.05 | 40.55 | 35.89 | 29.19 | 0.00 | 0.00 | 0.00 | 36.25 | 36.60 | -0.34 | Esmond |
| 0.08 | 38.52 | 34.29 | 27.67 | 38.52 | 34.45 | 28.76 | 0.00 | 0.00 | 0.00 | 34.33 | 34.71 | -0.38 | Burr-Calco |
| 0.05 | 38.52 | 34.88 | 29.05 | 38.52 | 35.23 | 29.19 | 0.00 | 0.00 | 0.00 | 35.19 | 35.55 | -0.36 | Barnes |
| 0.05 | 40.04 | 35.28 | 29.05 | 40.04 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.79 | 36.16 | -0.37 | Vallers |
| 0.04 | 39.90 | 35.23 | 29.05 | 39.90 | 35.56 | 29.19 | 0.00 | 0.00 | 0.00 | 35.72 | 36.09 | -0.37 | Webster |
| 0.04 | 40.55 | 35.85 | 29.05 | 40.55 | 35.89 | 29.19 | 0.00 | 0.00 | 0.00 | 36.08 | 36.44 | -0.37 | Perella |
| 0.04 | 40.44 | 35.64 | 29.05 | 40.44 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.88 | 36.25 | -0.37 | Lamoure |
| **W.M.** | **39.58** | **35.26** | **28.93** | **39.58** | **35.47** | **29.15** | **0.00** | **0.00** | **0.00** | **35.58** | **35.94** | | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Lincoln County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 122.20 | 83.75 | 44.72 | 127.60 | 95.99 | 73.06 | 0.00 | -1.69 | -43.98 | 86.02 | 102.24 | -16.22 | Barnes |
| 0.18 | 122.81 | 88.07 | 46.72 | 129.23 | 101.24 | 74.84 | 0.00 | 0.00 | -44.54 | 89.95 | 105.40 | -15.45 | Flom |
| 0.08 | 121.19 | 82.81 | 44.66 | 126.33 | 95.99 | 73.06 | 0.00 | -2.33 | -44.48 | 85.36 | 101.71 | -16.35 | Forman |
| 0.05 | 122.81 | 89.24 | 46.87 | 129.23 | 101.24 | 75.44 | 0.00 | 0.00 | -47.62 | 90.54 | 105.98 | -15.43 | Oaklake |
| 0.06 | 122.81 | 85.40 | 45.57 | 129.23 | 96.78 | 73.06 | 0.00 | 0.00 | -43.60 | 87.41 | 103.47 | -16.06 | Vallers |
| 0.05 | 119.58 | 79.80 | 43.83 | 122.81 | 94.59 | 73.06 | 0.00 | -4.07 | -44.87 | 83.87 | 100.20 | -16.33 | Buse |
| 0.05 | 122.81 | 92.77 | 52.39 | 133.89 | 101.24 | 79.26 | 0.00 | 0.00 | -45.07 | 94.40 | 107.40 | -13.00 | Parnell |
| 0.05 | 122.54 | 85.07 | 44.98 | 129.23 | 95.99 | 73.06 | 0.00 | -0.89 | -43.72 | 86.51 | 102.97 | -16.45 | Singsaas |
| 0.06 | 122.81 | 87.37 | 45.95 | 129.23 | 101.16 | 73.06 | 0.00 | 0.00 | -43.32 | 89.04 | 104.88 | -15.84 | Svea |
| **W.M.** | **122.24** | **85.31** | **45.62** | **128.18** | **97.71** | **73.78** | **0.00** | **-1.16** | **-44.33** | **87.45** | **103.34** | **-15.89** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 38.84 | 32.84 | 26.37 | 38.84 | 32.84 | 26.37 | 0.00 | 0.00 | 0.00 | 33.71 | 33.71 | 0.00 | Barnes |
| 0.18 | 38.84 | 33.53 | 27.70 | 38.84 | 33.53 | 27.70 | 0.00 | 0.00 | 0.00 | 34.69 | 34.69 | 0.00 | Flom |
| 0.08 | 38.84 | 32.77 | 26.12 | 38.84 | 32.77 | 26.12 | 0.00 | 0.00 | 0.00 | 33.55 | 33.55 | 0.00 | Forman |
| 0.05 | 38.84 | 33.65 | 27.73 | 38.84 | 33.65 | 27.73 | 0.00 | 0.00 | 0.00 | 34.90 | 34.90 | 0.00 | Oaklake |
| 0.06 | 38.84 | 33.51 | 26.74 | 38.84 | 33.51 | 26.74 | 0.00 | 0.00 | 0.00 | 34.07 | 34.07 | 0.00 | Vallers |
| 0.05 | 38.84 | 32.56 | 25.86 | 38.84 | 32.56 | 25.86 | 0.00 | 0.00 | 0.00 | 33.08 | 33.08 | 0.00 | Buse |
| 0.05 | 40.29 | 33.65 | 28.68 | 40.29 | 33.65 | 28.68 | 0.00 | 0.00 | 0.00 | 35.35 | 35.35 | 0.00 | Parnell |
| 0.05 | 38.84 | 33.26 | 26.53 | 38.84 | 33.26 | 26.53 | 0.00 | 0.00 | 0.00 | 33.91 | 33.91 | 0.00 | Singsaas |
| 0.06 | 38.84 | 33.51 | 27.26 | 38.84 | 33.51 | 27.26 | 0.00 | 0.00 | 0.00 | 34.50 | 34.50 | 0.00 | Svea |
| **W.M.** | **38.91** | **33.12** | **26.82** | **38.91** | **33.12** | **26.82** | **0.00** | **0.00** | **0.00** | **34.05** | **34.05** | **0.00** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Lyon County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 122.10 | 87.57 | 40.69 | 127.89 | 100.36 | 84.77 | 0.00 | -5.78 | -50.45 | 88.30 | 106.80 | -18.50 | Aastad |
| 0.18 | 123.38 | 87.95 | 41.54 | 127.89 | 101.33 | 87.57 | 0.00 | -8.15 | -50.18 | 90.46 | 109.37 | -18.90 | Barnes |
| 0.10 | 127.89 | 91.87 | 47.01 | 130.29 | 110.11 | 92.28 | 0.00 | -4.07 | -49.60 | 94.72 | 113.38 | -18.65 | Flom |
| 0.18 | 124.32 | 91.24 | 44.12 | 127.89 | 105.38 | 91.15 | 0.00 | -6.75 | -49.92 | 92.64 | 111.55 | -18.91 | Canisyeo |
| 0.05 | 126.51 | 91.08 | 47.24 | 130.66 | 110.11 | 92.28 | 0.00 | -3.09 | -49.58 | 95.68 | 114.53 | -18.85 | Glencoe |
| 0.13 | 121.98 | 87.57 | 40.82 | 127.89 | 100.36 | 86.09 | 0.00 | -7.31 | -50.33 | 89.65 | 108.61 | -18.96 | Formans |
| 0.16 | 126.77 | 91.50 | 47.54 | 130.66 | 110.11 | 92.28 | 0.00 | -5.58 | -49.50 | 95.04 | 113.88 | -18.84 | Ves |
| 0.05 | 127.89 | 91.88 | 48.15 | 130.66 | 110.11 | 92.28 | 0.00 | -4.75 | -49.47 | 95.63 | 114.20 | -18.58 | Colvin |
| 0.05 | 127.89 | 92.04 | 46.70 | 128.89 | 110.11 | 92.28 | 0.00 | -3.88 | -49.63 | 94.46 | 113.10 | -18.64 | Lamoure |
| 0.06 | 127.24 | 91.87 | 46.33 | 127.89 | 107.85 | 91.15 | 0.00 | -6.66 | -49.67 | 93.90 | 112.54 | -18.63 | Seaforth |
| **W.M.** | **125.06** | **90.16** | **44.44** | **128.87** | **105.73** | **89.94** | **0.00** | **-6.18** | **-49.89** | **92.65** | **111.46** | **-18.81** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 38.91 | 33.96 | 28.65 | 38.91 | 33.96 | 28.65 | 0.00 | 0.00 | 0.00 | 34.40 | 34.39 | 0.01 | Aastad |
| 0.18 | 38.91 | 34.18 | 28.65 | 38.91 | 34.18 | 28.65 | 0.00 | 0.00 | 0.00 | 35.25 | 35.23 | 0.02 | Barnes |
| 0.10 | 39.90 | 35.59 | 30.07 | 39.90 | 35.59 | 30.07 | 0.00 | 0.00 | 0.00 | 36.49 | 36.49 | 0.00 | Flom |
| 0.18 | 38.91 | 34.91 | 29.81 | 38.91 | 34.91 | 29.81 | 0.00 | 0.00 | 0.00 | 36.01 | 36.01 | 0.00 | Canisyeo |
| 0.05 | 39.90 | 35.74 | 30.07 | 39.90 | 35.74 | 30.07 | 0.00 | 0.00 | 0.00 | 36.75 | 36.75 | 0.00 | Glencoe |
| 0.13 | 38.91 | 34.18 | 28.65 | 38.91 | 34.18 | 28.65 | 0.00 | 0.00 | 0.00 | 34.99 | 34.97 | 0.02 | Formans |
| 0.16 | 39.90 | 35.59 | 30.07 | 39.90 | 35.59 | 30.07 | 0.00 | 0.00 | 0.00 | 36.57 | 36.57 | 0.00 | Ves |
| 0.05 | 39.90 | 35.74 | 30.07 | 39.90 | 35.74 | 30.07 | 0.00 | 0.00 | 0.00 | 36.66 | 36.66 | 0.00 | Colvin |
| 0.05 | 39.82 | 35.59 | 30.07 | 39.82 | 35.59 | 30.07 | 0.00 | 0.00 | 0.00 | 36.45 | 36.45 | 0.00 | Lamoure |
| 0.06 | 39.50 | 35.41 | 30.07 | 39.50 | 35.41 | 30.07 | 0.00 | 0.00 | 0.00 | 36.29 | 36.29 | 0.00 | Seaforth |
| **W.M.** | **39.33** | **34.94** | **29.51** | **39.33** | **34.94** | **29.51** | **0.00** | **0.00** | **0.00** | **35.89** | **35.88** | **0.01** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued).

**Redwood County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.32 | 122.68 | 93.42 | 52.95 | 132.61 | 112.99 | 92.34 | 0.00 | -11.22 | -55.46 | 94.67 | 115.52 | -20.85 | Canisteo |
| 0.12 | 128.58 | 96.84 | 53.02 | 133.41 | 116.76 | 93.42 | 0.00 | -14.30 | -58.04 | 97.01 | 118.12 | -21.10 | Webster |
| 0.05 | 128.05 | 96.20 | 53.01 | 133.41 | 116.76 | 93.42 | 0.00 | -14.16 | -57.49 | 96.87 | 118.00 | -21.14 | Glencoe |
| 0.10 | 133.41 | 97.73 | 52.98 | 133.76 | 116.76 | 95.46 | 0.00 | -13.16 | -60.79 | 98.99 | 120.17 | -21.18 | Okoboji |
| 0.27 | 129.64 | 97.73 | 52.80 | 133.41 | 116.76 | 93.42 | 0.00 | -14.97 | -57.94 | 97.35 | 118.37 | -21.03 | Ves |
| 0.05 | 130.52 | 97.73 | 53.57 | 133.41 | 116.76 | 93.42 | 0.00 | -14.58 | -58.08 | 97.71 | 118.64 | -20.93 | Seaforth |
| 0.10 | 133.41 | 97.73 | 54.89 | 135.27 | 116.76 | 97.58 | 0.00 | -13.45 | -60.55 | 99.33 | 120.11 | -20.78 | Normania |
| **W.M.** | **127.99** | **96.16** | **53.15** | **133.37** | **115.54** | **93.69** | **0.00** | **-13.30** | **-57.68** | **96.80** | **117.77** | **-20.97** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.32 | 41.92 | 36.55 | 30.70 | 41.92 | 36.56 | 30.70 | 0.00 | 0.00 | 0.00 | 37.04 | 37.14 | -0.10 | Canisteo |
| 0.12 | 42.57 | 37.02 | 30.78 | 42.57 | 37.02 | 30.78 | 0.00 | 0.00 | 0.00 | 37.69 | 37.80 | -0.10 | Webster |
| 0.05 | 42.57 | 36.84 | 30.78 | 42.57 | 36.84 | 30.78 | 0.00 | 0.00 | 0.00 | 37.71 | 37.81 | -0.10 | Glencoe |
| 0.10 | 42.73 | 37.38 | 30.78 | 42.73 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 38.05 | 38.13 | -0.08 | Okoboji |
| 0.27 | 42.57 | 37.38 | 30.78 | 42.57 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 37.74 | 37.84 | -0.10 | Ves |
| 0.05 | 42.57 | 37.38 | 30.78 | 42.57 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 37.81 | 37.91 | -0.10 | Seaforth |
| 0.10 | 42.73 | 37.38 | 30.78 | 42.73 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 38.10 | 38.17 | -0.07 | Normania |
| **W.M.** | **42.39** | **37.04** | **30.76** | **42.39** | **37.05** | **30.76** | **0.00** | **0.00** | **0.00** | **37.58** | **37.67** | **-0.10** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Renville County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.16 | 130.67 | 102.68 | 69.00 | 130.30 | 112.94 | 96.21 | 0.00 | 0.00 | -45.47 | 103.29 | 116.17 | -12.88 | Harps |
| 0.10 | 130.67 | 102.36 | 69.65 | 130.30 | 112.94 | 95.70 | 0.00 | 0.00 | -45.30 | 103.09 | 115.97 | -12.88 | Webster |
| 0.06 | 135.54 | 105.73 | 73.95 | 132.59 | 115.07 | 97.79 | 0.00 | 0.00 | -44.26 | 108.17 | 118.55 | -10.38 | Winger-Quam |
| 0.12 | 126.39 | 98.72 | 67.53 | 130.30 | 111.02 | 89.92 | 0.00 | 0.00 | -47.36 | 100.21 | 114.21 | -14.00 | Nicollet |
| 0.10 | 131.35 | 105.60 | 70.89 | 132.59 | 112.94 | 97.79 | 0.00 | 0.00 | -43.07 | 105.60 | 117.48 | -11.87 | Okoboji |
| 0.05 | 130.27 | 102.58 | 68.69 | 130.30 | 112.94 | 96.62 | 0.00 | 0.00 | -45.73 | 103.19 | 116.17 | -12.97 | Seaforth |
| 0.10 | 130.67 | 104.54 | 70.63 | 131.28 | 112.94 | 96.15 | 0.00 | 0.00 | -43.80 | 104.39 | 116.63 | -12.24 | Clarion-Swanlake |
| 0.11 | 130.67 | 103.06 | 69.08 | 130.30 | 112.94 | 96.55 | 0.00 | 0.00 | -45.34 | 103.46 | 116.27 | -12.81 | Ves |
| 0.20 | 127.77 | 100.75 | 69.82 | 130.30 | 111.20 | 92.27 | 0.00 | 0.00 | -43.75 | 101.72 | 114.96 | -13.24 | Canisteo-Glencoe |
| **W.M.** | **129.77** | **102.38** | **69.62** | **130.64** | **112.36** | **94.81** | **0.00** | **0.00** | **-44.79** | **103.12** | **115.88** | **-12.76** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.16 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.81 | 37.21 | -0.40 | Harps |
| 0.10 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.78 | 37.17 | -0.39 | Webster |
| 0.06 | 41.75 | 35.92 | 29.92 | 41.75 | 36.03 | 29.96 | 0.00 | 0.00 | 0.00 | 37.39 | 37.73 | -0.33 | Winger-Quam |
| 0.12 | 41.75 | 35.65 | 29.92 | 41.75 | 35.75 | 29.96 | 0.00 | 0.00 | 0.00 | 36.37 | 36.78 | -0.41 | Nicollet |
| 0.10 | 41.75 | 35.92 | 29.92 | 41.75 | 36.03 | 29.96 | 0.00 | 0.00 | 0.00 | 37.09 | 37.47 | -0.38 | Okoboji |
| 0.05 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.80 | 37.20 | -0.40 | Seaforth |
| 0.10 | 41.75 | 35.92 | 29.92 | 41.75 | 35.96 | 29.96 | 0.00 | 0.00 | 0.00 | 36.93 | 37.31 | -0.38 | Clarion-Swanlake |
| 0.11 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.82 | 37.22 | -0.40 | Ves |
| 0.20 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.56 | 36.96 | -0.39 | Canisteo-Glencoe |
| **W.M.** | **41.71** | **35.75** | **29.89** | **41.71** | **35.89** | **29.93** | **0.00** | **0.00** | **0.00** | **36.74** | **37.13** | **-0.39** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Swift County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.22 | 125.58 | 95.03 | 55.91 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -36.12 | 94.59 | 104.24 | -9.65 | Barnes |
| 0.14 | 139.01 | 102.20 | 63.44 | 139.01 | 108.27 | 87.09 | 0.00 | 0.00 | -44.95 | 104.11 | 113.11 | -9.00 | Colvin |
| 0.09 | 125.58 | 95.03 | 55.91 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -36.12 | 94.59 | 104.24 | -9.65 | Hamerly |
| 0.08 | 108.41 | 77.38 | 48.98 | 108.41 | 77.38 | 61.62 | 0.00 | 0.00 | -12.52 | 77.78 | 81.65 | -3.87 | Marysland |
| 0.08 | 135.26 | 100.36 | 61.96 | 135.26 | 106.44 | 82.21 | 0.00 | 0.00 | -39.11 | 100.87 | 109.98 | -9.11 | Vallers-Winger |
| 0.05 | 100.20 | 63.08 | 41.23 | 100.20 | 70.62 | 54.72 | 0.00 | 0.00 | -11.22 | 71.54 | 74.55 | -3.00 | Arveson |
| 0.05 | 139.01 | 102.20 | 63.44 | 139.01 | 108.27 | 87.09 | 0.00 | 0.00 | -44.95 | 104.11 | 113.11 | -9.00 | Beazden |
| 0.05 | 125.58 | 95.03 | 55.91 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -36.12 | 94.59 | 104.24 | -9.65 | Svea |
| 0.10 | 139.01 | 102.20 | 63.44 | 139.01 | 106.78 | 87.09 | 0.00 | 0.00 | -40.01 | 103.26 | 112.09 | -8.83 | Parnell |
| 0.03 | 137.16 | 102.12 | 65.08 | 137.16 | 106.44 | 86.36 | 0.00 | 0.00 | -37.48 | 102.34 | 110.67 | -8.33 | Tara |
| 0.03 | 108.41 | 79.32 | 51.64 | 108.41 | 83.75 | 68.79 | 0.00 | 0.00 | -17.99 | 82.42 | 88.38 | -5.95 | Mayer |
| 0.07 | 125.58 | 95.03 | 55.91 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -36.12 | 94.59 | 104.24 | -9.65 | Buse |
| **W.M.** | **127.36** | **94.16** | **57.40** | **129.34** | **97.32** | **78.97** | **0.00** | **0.00** | **-34.70** | **95.07** | **103.50** | **-8.43** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.22 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Barnes |
| 0.14 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.28 | 36.79 | -0.51 | Colvin |
| 0.09 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Hamerly |
| 0.08 | 35.18 | 25.66 | 20.89 | 35.18 | 25.66 | 21.66 | 0.00 | 0.00 | 0.00 | 27.64 | 27.83 | -0.18 | Marysland |
| 0.08 | 41.37 | 35.48 | 28.54 | 41.37 | 35.48 | 28.80 | 0.00 | 0.00 | 0.00 | 35.78 | 36.30 | -0.52 | Vallers-Winger |
| 0.05 | 33.66 | 22.88 | 19.20 | 33.66 | 23.10 | 19.20 | 0.00 | 0.00 | 0.00 | 25.48 | 25.62 | -0.14 | Arveson |
| 0.05 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.28 | 36.79 | -0.51 | Beazden |
| 0.05 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Svea |
| 0.10 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.23 | 36.74 | -0.51 | Parnell |
| 0.03 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.07 | 36.56 | -0.49 | Tara |
| 0.03 | 35.77 | 28.44 | 23.45 | 35.77 | 28.44 | 24.42 | 0.00 | 0.00 | 0.00 | 29.51 | 29.78 | -0.27 | Mayer |
| 0.07 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Buse |
| **W.M.** | **38.88** | **32.79** | **26.40** | **38.88** | **33.19** | **27.51** | **0.00** | **0.00** | **0.00** | **33.81** | **34.28** | **-0.46** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

W.M. = county area weighted mean

Table B.2 Simulated corn and soybean yield and yield loss in **fixed cutting** schedule for each soil at various probability level (continued)

**Yellow Medicine County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 122.88 | 96.26 | 56.31 | 132.16 | 106.85 | 88.98 | 0.00 | -9.28 | -41.88 | 93.16 | 111.62 | -18.46 | Barnes |
| 0.44 | 125.59 | 97.78 | 57.09 | 133.03 | 108.43 | 90.08 | 0.00 | -12.90 | -42.73 | 96.13 | 114.16 | -18.02 | Ves |
| 0.03 | 125.59 | 105.28 | 60.51 | 137.96 | 111.36 | 90.08 | 0.00 | -3.18 | -47.32 | 101.16 | 116.97 | -15.81 | Du Page |
| 0.11 | 120.67 | 91.75 | 53.14 | 126.68 | 103.29 | 88.98 | 0.00 | -5.37 | -41.66 | 90.50 | 109.32 | -18.82 | Forman |
| 0.24 | 124.04 | 96.88 | 56.49 | 132.00 | 107.47 | 88.98 | 0.00 | -8.98 | -41.90 | 94.21 | 112.12 | -17.91 | Canisteo |
| 0.06 | 125.59 | 100.02 | 57.90 | 137.96 | 111.36 | 90.08 | 0.00 | -10.15 | -44.27 | 98.40 | 115.81 | -17.41 | Spicer |
| 0.03 | 97.49 | 51.54 | 27.24 | 97.49 | 61.19 | 30.44 | 0.00 | 0.00 | -12.28 | 61.42 | 65.47 | -4.05 | Arvilla |
| **W.M.** | **123.67** | **95.86** | **55.78** | **131.49** | **106.48** | **87.98** | **0.00** | **-10.04** | **-41.72** | **94.11** | **111.76** | **-17.65** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 40.54 | 36.20 | 30.03 | 40.54 | 36.20 | 30.03 | 0.00 | 0.00 | 0.00 | 36.50 | 36.50 | 0.00 | Barnes |
| 0.44 | 40.54 | 36.35 | 30.03 | 40.54 | 36.35 | 30.03 | 0.00 | 0.00 | 0.00 | 37.47 | 37.45 | 0.01 | Ves |
| 0.03 | 42.20 | 36.35 | 30.26 | 42.20 | 36.35 | 30.26 | 0.00 | 0.00 | 0.00 | 38.11 | 38.09 | 0.02 | Du Page |
| 0.11 | 40.45 | 35.68 | 30.03 | 40.45 | 35.68 | 30.03 | 0.00 | 0.00 | 0.00 | 35.83 | 35.83 | 0.00 | Forman |
| 0.24 | 40.54 | 36.20 | 30.03 | 40.54 | 36.20 | 30.03 | 0.00 | 0.00 | 0.00 | 36.70 | 36.70 | 0.00 | Canisteo |
| 0.06 | 41.12 | 36.35 | 30.26 | 41.12 | 36.35 | 30.26 | 0.00 | 0.00 | 0.00 | 37.91 | 37.89 | 0.02 | Spicer |
| 0.03 | 30.15 | 22.48 | 13.51 | 30.15 | 22.48 | 13.51 | 0.00 | 0.00 | 0.00 | 22.81 | 22.85 | -0.04 | Arvilla |
| **W.M.** | **40.33** | **35.85** | **29.60** | **40.33** | **35.85** | **29.60** | **0.00** | **0.00** | **0.00** | **36.66** | **36.65** | **0.01** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean

**Appendix B**

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level.

**Chippewa County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.34 | 123.93 | 101.05 | 72.82 | 128.57 | 105.45 | 90.49 | 0.00 | 0.00 | -28.91 | 103.17 | 112.04 | -8.86 | Colvin-Spicer |
| 0.14 | 126.92 | 102.76 | 76.76 | 128.74 | 109.00 | 94.00 | 0.00 | 0.00 | -27.55 | 105.05 | 113.46 | -8.40 | Tara s.l. |
| 0.07 | 122.00 | 99.41 | 70.69 | 122.01 | 102.76 | 86.74 | 0.00 | 0.00 | -29.37 | 100.64 | 109.46 | -8.82 | Canisteo s.c.l. |
| 0.12 | 128.74 | 102.76 | 76.93 | 128.75 | 109.31 | 94.00 | 0.00 | 0.00 | -27.87 | 105.80 | 114.25 | -8.45 | Spicer |
| 0.18 | 126.07 | 102.76 | 75.55 | 128.74 | 108.11 | 93.53 | 0.00 | 0.00 | -28.80 | 104.46 | 112.80 | -8.34 | Doland_swan |
| 0.05 | 125.35 | 100.81 | 73.76 | 128.74 | 108.11 | 91.97 | 0.00 | 0.00 | -28.92 | 103.53 | 112.61 | -9.08 | Waubay s.l. |
| 0.05 | 126.33 | 101.15 | 71.44 | 128.74 | 108.11 | 90.91 | 0.00 | 0.00 | -30.48 | 102.85 | 112.48 | -9.63 | Glyndon |
| 0.05 | 125.41 | 101.56 | 71.78 | 128.70 | 106.80 | 90.40 | 0.00 | 0.00 | -29.47 | 102.98 | 112.22 | -9.24 | Ves l. |
| **W.M.** | **125.44** | **101.71** | **74.14** | **128.20** | **107.03** | **91.78** | **0.00** | **0.00** | **-28.71** | **103.80** | **112.51** | **-8.72** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.34 | 38.64 | 34.50 | 29.27 | 38.64 | 34.50 | 29.46 | 0.00 | 0.00 | 0.00 | 35.47 | 35.94 | -0.47 | Colvin-Spicer |
| 0.14 | 40.16 | 35.01 | 29.46 | 40.16 | 35.62 | 30.73 | 0.00 | 0.00 | 0.00 | 35.85 | 36.32 | -0.47 | Tara s.l. |
| 0.07 | 38.09 | 33.42 | 28.31 | 38.09 | 34.13 | 29.46 | 0.00 | 0.00 | 0.00 | 34.78 | 35.28 | -0.51 | Canisteo s.c.l. |
| 0.12 | 40.37 | 35.01 | 29.46 | 40.37 | 36.00 | 30.92 | 0.00 | 0.00 | 0.00 | 36.03 | 36.52 | -0.48 | Spicer |
| 0.18 | 39.36 | 34.80 | 29.46 | 39.36 | 34.80 | 30.09 | 0.00 | 0.00 | 0.00 | 35.67 | 36.14 | -0.46 | Doland_swan |
| 0.05 | 39.37 | 34.90 | 29.46 | 39.37 | 34.90 | 29.81 | 0.00 | 0.00 | 0.00 | 35.64 | 36.12 | -0.48 | Waubay s.l. |
| 0.05 | 39.19 | 34.50 | 29.46 | 39.19 | 34.50 | 29.57 | 0.00 | 0.00 | 0.00 | 35.61 | 36.09 | -0.48 | Glyndon |
| 0.05 | 39.19 | 34.50 | 29.34 | 39.19 | 34.50 | 29.46 | 0.00 | 0.00 | 0.00 | 35.53 | 36.01 | -0.48 | Ves l. |
| **W.M.** | **39.25** | **34.63** | **29.31** | **39.25** | **34.89** | **29.95** | **0.00** | **0.00** | **0.00** | **35.60** | **36.07** | **-0.48** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Kandiyohi County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 124.13 | 105.50 | 74.63 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | -14.80 | 104.85 | 107.27 | -2.42 | Delft |
| 0.11 | 122.25 | 100.68 | 73.27 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | -20.03 | 102.35 | 105.28 | -2.92 | Wadenill |
| 0.11 | 116.69 | 95.78 | 68.58 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | -24.94 | 99.35 | 103.12 | -3.77 | Sunburg |
| 0.22 | 125.47 | 105.50 | 74.63 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | -9.68 | 106.07 | 107.92 | -1.85 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | -1.94 | 65.04 | 65.71 | -0.66 | Estherville |
| 0.13 | 124.73 | 105.50 | 74.63 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | -13.62 | 105.45 | 107.67 | -2.22 | Harps |
| 0.07 | 125.65 | 105.50 | 74.63 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | -13.91 | 105.48 | 107.71 | -2.23 | Ves |
| 0.18 | 114.00 | 87.44 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | -7.39 | 92.76 | 94.63 | -1.87 | Biscay-Palms |
| **W.M.** | **117.14** | **94.59** | **67.04** | **116.92** | **95.63** | **72.00** | **0.00** | **0.00** | **-12.18** | **96.42** | **98.55** | **-2.13** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 38.66 | 34.35 | 27.19 | 38.66 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 34.88 | 35.36 | -0.48 | Delft |
| 0.11 | 37.95 | 34.02 | 27.19 | 37.95 | 34.13 | 28.32 | 0.00 | 0.00 | 0.00 | 34.21 | 34.69 | -0.47 | Wadenill |
| 0.11 | 37.81 | 33.79 | 27.19 | 37.81 | 34.02 | 27.63 | 0.00 | 0.00 | 0.00 | 33.58 | 34.09 | -0.51 | Sunburg |
| 0.22 | 39.19 | 34.35 | 27.28 | 39.19 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 35.13 | 35.58 | -0.45 | Canisteo |
| 0.12 | 28.87 | 22.77 | 15.67 | 28.87 | 22.77 | 15.67 | 0.00 | 0.00 | 0.00 | 23.21 | 23.28 | -0.07 | Estherville |
| 0.13 | 39.26 | 34.35 | 27.19 | 39.26 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 35.02 | 35.49 | -0.47 | Harps |
| 0.07 | 39.27 | 34.35 | 27.19 | 39.27 | 34.47 | 28.32 | 0.00 | 0.00 | 0.00 | 35.02 | 35.48 | -0.46 | Ves |
| 0.18 | 35.27 | 30.37 | 23.79 | 35.27 | 30.49 | 25.51 | 0.00 | 0.00 | 0.00 | 31.55 | 31.84 | -0.28 | Biscay-Palms |
| **W.M.** | **36.58** | **31.83** | **24.96** | **36.58** | **31.94** | **25.95** | **0.00** | **0.00** | **0.00** | **32.42** | **32.80** | **-0.38** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Lac Qui Parle County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 119.36 | 89.93 | 64.93 | 125.90 | 107.81 | 85.01 | 0.00 | -7.81 | -42.88 | 93.73 | 108.29 | -14.56 | Ves l. |
| 0.06 | 124.87 | 95.40 | 71.70 | 128.64 | 109.79 | 85.01 | 2.53 | -3.63 | -43.06 | 98.45 | 111.49 | -13.04 | Waubay s.l. |
| 0.06 | 137.39 | 107.35 | 78.08 | 132.34 | 113.40 | 89.93 | 0.00 | 0.00 | -39.71 | 106.86 | 116.20 | -9.34 | Calco |
| 0.07 | 118.20 | 89.93 | 63.86 | 124.58 | 106.61 | 84.00 | 0.00 | -8.58 | -42.75 | 92.90 | 107.64 | -14.74 | Normania |
| 0.21 | 125.62 | 96.57 | 71.50 | 129.46 | 109.79 | 85.01 | 3.21 | -4.14 | -43.67 | 98.75 | 111.87 | -13.12 | Harps-Glencoe |
| 0.07 | 128.67 | 99.72 | 75.23 | 129.58 | 110.76 | 85.01 | 5.61 | -1.87 | -41.69 | 101.15 | 113.19 | -12.04 | Esmond |
| 0.08 | 119.03 | 87.81 | 59.64 | 121.47 | 102.97 | 80.39 | 0.00 | -10.00 | -42.30 | 90.55 | 105.06 | -14.51 | Burr-Calco |
| 0.05 | 121.09 | 89.93 | 66.17 | 126.75 | 109.02 | 85.01 | 0.00 | -5.25 | -42.85 | 94.62 | 108.51 | -13.89 | Barnes |
| 0.05 | 124.67 | 94.98 | 69.77 | 129.10 | 109.79 | 85.01 | 2.20 | -4.60 | -43.33 | 97.88 | 111.23 | -13.35 | Vallers |
| 0.04 | 123.93 | 94.00 | 70.34 | 128.89 | 109.79 | 85.01 | 1.28 | -4.00 | -42.62 | 97.52 | 110.89 | -13.36 | Webster |
| 0.04 | 126.93 | 97.61 | 70.77 | 130.05 | 110.28 | 85.01 | 4.70 | -4.13 | -43.67 | 99.56 | 112.56 | -12.99 | Perella |
| 0.04 | 124.55 | 95.66 | 70.79 | 129.62 | 110.03 | 85.01 | 2.91 | -4.78 | -43.94 | 98.38 | 111.74 | -13.36 | Lamoure |
| **W.M.** | **123.68** | **94.17** | **68.71** | **127.66** | **108.85** | **84.89** | **1.66** | **-5.43** | **-42.81** | **96.89** | **110.32** | **-13.43** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 38.52 | 34.88 | 29.05 | 38.52 | 35.06 | 29.19 | 0.00 | 0.00 | 0.00 | 35.09 | 35.48 | -0.38 | Ves l. |
| 0.06 | 40.01 | 35.60 | 29.05 | 40.01 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.86 | 36.21 | -0.35 | Waubay s.l. |
| 0.06 | 40.55 | 36.03 | 29.05 | 40.55 | 36.22 | 29.19 | 0.00 | 0.00 | 0.00 | 37.00 | 37.33 | -0.33 | Calco |
| 0.07 | 38.52 | 34.69 | 28.99 | 38.52 | 34.88 | 29.05 | 0.00 | 0.00 | 0.00 | 34.95 | 35.34 | -0.39 | Normania |
| 0.21 | 40.55 | 35.63 | 29.05 | 40.55 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.93 | 36.30 | -0.37 | Harps-Glencoe |
| 0.07 | 40.55 | 35.85 | 29.05 | 40.55 | 35.89 | 29.19 | 0.00 | 0.00 | 0.00 | 36.25 | 36.60 | -0.34 | Esmond |
| 0.08 | 38.52 | 34.29 | 27.67 | 38.52 | 34.45 | 28.76 | 0.00 | 0.00 | 0.00 | 34.33 | 34.71 | -0.38 | Burr-Calco |
| 0.05 | 38.52 | 34.88 | 29.05 | 38.52 | 35.23 | 29.19 | 0.00 | 0.00 | 0.00 | 35.19 | 35.55 | -0.36 | Barnes |
| 0.05 | 40.04 | 35.28 | 29.05 | 40.04 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.79 | 36.16 | -0.37 | Vallers |
| 0.04 | 39.90 | 35.23 | 29.05 | 39.90 | 35.56 | 29.19 | 0.00 | 0.00 | 0.00 | 35.72 | 36.09 | -0.37 | Webster |
| 0.04 | 40.55 | 35.85 | 29.05 | 40.55 | 35.89 | 29.19 | 0.00 | 0.00 | 0.00 | 36.08 | 36.44 | -0.37 | Perella |
| 0.04 | 40.44 | 35.64 | 29.05 | 40.44 | 35.85 | 29.19 | 0.00 | 0.00 | 0.00 | 35.88 | 36.25 | -0.37 | Lamoure |
| **W.M.** | **39.58** | **35.26** | **28.93** | **39.58** | **35.47** | **29.15** | **0.00** | **0.00** | **0.00** | **35.58** | **35.94** | **-0.37** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Lincoln County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 127.60 | 85.34 | 59.26 | 127.60 | 95.99 | 73.06 | 0.00 | 0.00 | -33.39 | 93.59 | 102.24 | -8.65 | Barnes |
| 0.18 | 129.23 | 92.26 | 61.95 | 129.23 | 101.24 | 74.84 | 0.00 | 0.00 | -32.57 | 97.08 | 105.40 | -8.32 | Flom |
| 0.08 | 126.33 | 85.34 | 58.22 | 126.33 | 95.99 | 73.06 | 0.00 | 0.00 | -32.67 | 92.90 | 101.71 | -8.81 | Forman |
| 0.05 | 129.23 | 92.77 | 61.19 | 129.23 | 101.24 | 75.44 | 0.00 | 0.00 | -30.61 | 97.38 | 105.98 | -8.60 | Oaklake |
| 0.06 | 129.23 | 88.31 | 60.76 | 129.23 | 96.78 | 73.06 | 0.00 | 0.00 | -33.70 | 95.05 | 103.47 | -8.42 | Vallers |
| 0.05 | 122.09 | 85.33 | 57.55 | 122.81 | 94.59 | 73.06 | 0.00 | 0.00 | -34.17 | 91.31 | 100.20 | -8.89 | Buse |
| 0.05 | 129.23 | 92.77 | 63.69 | 133.89 | 101.24 | 79.26 | 0.00 | 0.00 | -24.34 | 100.17 | 107.40 | -7.24 | Parnell |
| 0.05 | 129.23 | 87.18 | 58.59 | 129.23 | 95.99 | 73.06 | 0.00 | 0.00 | -34.49 | 94.18 | 102.97 | -8.78 | Singsaas |
| 0.06 | 129.23 | 92.26 | 61.19 | 129.23 | 101.16 | 73.06 | 0.00 | 0.00 | -33.35 | 96.44 | 104.88 | -8.44 | Svea |
| **W.M.** | **127.93** | **87.97** | **60.04** | **128.18** | **97.71** | **73.78** | **0.00** | **0.00** | **-32.75** | **94.81** | **103.34** | **-8.53** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.42 | 38.84 | 32.84 | 26.37 | 38.84 | 32.84 | 26.37 | 0.00 | 0.00 | 0.00 | 33.71 | 33.71 | 0.00 | Barnes |
| 0.18 | 38.84 | 33.53 | 27.70 | 38.84 | 33.53 | 27.70 | 0.00 | 0.00 | 0.00 | 34.69 | 34.69 | 0.00 | Flom |
| 0.08 | 38.84 | 32.77 | 26.12 | 38.84 | 32.77 | 26.12 | 0.00 | 0.00 | 0.00 | 33.55 | 33.55 | 0.00 | Forman |
| 0.05 | 38.84 | 33.65 | 27.73 | 38.84 | 33.65 | 27.73 | 0.00 | 0.00 | 0.00 | 34.90 | 34.90 | 0.00 | Oaklake |
| 0.06 | 38.84 | 33.51 | 26.74 | 38.84 | 33.51 | 26.74 | 0.00 | 0.00 | 0.00 | 34.07 | 34.07 | 0.00 | Vallers |
| 0.05 | 38.84 | 32.56 | 25.86 | 38.84 | 32.56 | 25.86 | 0.00 | 0.00 | 0.00 | 33.08 | 33.08 | 0.00 | Buse |
| 0.05 | 40.29 | 33.65 | 28.68 | 40.29 | 33.65 | 28.68 | 0.00 | 0.00 | 0.00 | 35.35 | 35.35 | 0.00 | Parnell |
| 0.05 | 38.84 | 33.26 | 26.53 | 38.84 | 33.26 | 26.53 | 0.00 | 0.00 | 0.00 | 33.91 | 33.91 | 0.00 | Singsaas |
| 0.06 | 38.84 | 33.51 | 27.26 | 38.84 | 33.51 | 27.26 | 0.00 | 0.00 | 0.00 | 34.50 | 34.50 | 0.00 | Svea |
| **W.M.** | **38.91** | **33.12** | **26.82** | **38.91** | **33.12** | **26.82** | **0.00** | **0.00** | **0.00** | **34.05** | **34.05** | **0.00** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Lyon County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 122.10 | 95.22 | 50.25 | 127.89 | 100.36 | 84.77 | 0.00 | 0.00 | -40.90 | 97.03 | 106.80 | -9.77 | Aastad |
| 0.18 | 124.32 | 99.68 | 50.67 | 127.89 | 101.33 | 87.57 | 0.00 | 0.00 | -40.48 | 100.08 | 109.37 | -9.29 | Barnes |
| 0.10 | 130.29 | 103.75 | 54.97 | 130.29 | 110.11 | 92.28 | 0.00 | 0.00 | -39.75 | 105.04 | 113.38 | -8.33 | Flom |
| 0.18 | 126.51 | 100.36 | 52.08 | 127.89 | 105.38 | 91.15 | 0.00 | 0.00 | -40.16 | 102.58 | 111.55 | -8.98 | Canisyeo |
| 0.05 | 136.74 | 105.17 | 55.20 | 130.66 | 110.11 | 92.28 | 0.00 | 0.00 | -39.61 | 105.95 | 114.53 | -8.58 | Glencoe |
| 0.13 | 124.32 | 98.15 | 50.45 | 127.89 | 100.36 | 86.09 | 0.00 | 0.00 | -40.69 | 99.01 | 108.61 | -9.60 | Formans |
| 0.16 | 134.28 | 105.13 | 55.49 | 130.66 | 110.11 | 92.28 | 0.00 | 0.00 | -39.59 | 105.43 | 113.88 | -8.45 | Ves |
| 0.05 | 135.33 | 106.15 | 56.10 | 130.66 | 110.11 | 92.28 | 0.00 | 0.00 | -39.55 | 105.93 | 114.20 | -8.27 | Colvin |
| 0.05 | 128.89 | 103.74 | 54.65 | 128.89 | 110.11 | 92.28 | 0.00 | 0.00 | -39.80 | 104.66 | 113.10 | -8.45 | Lamoure |
| 0.06 | 127.89 | 103.38 | 54.28 | 127.89 | 107.85 | 91.15 | 0.00 | 0.00 | -39.87 | 104.02 | 112.54 | -8.52 | Seaforth |
| **W.M.** | **128.30** | **101.59** | **52.92** | **128.87** | **105.73** | **89.94** | **0.00** | **0.00** | **-40.11** | **102.55** | **111.46** | **-8.91** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 38.91 | 33.96 | 28.65 | 38.91 | 33.96 | 28.65 | 0.00 | 0.00 | 0.00 | 34.40 | 34.39 | 0.01 | Aastad |
| 0.18 | 38.91 | 34.18 | 28.65 | 38.91 | 34.18 | 28.65 | 0.00 | 0.00 | 0.00 | 35.25 | 35.23 | 0.02 | Barnes |
| 0.10 | 39.90 | 35.59 | 30.07 | 39.90 | 35.59 | 30.07 | 0.00 | 0.00 | 0.00 | 36.49 | 36.49 | 0.00 | Flom |
| 0.18 | 38.91 | 34.91 | 29.81 | 38.91 | 34.91 | 29.81 | 0.00 | 0.00 | 0.00 | 36.01 | 36.01 | 0.00 | Canisyeo |
| 0.05 | 39.90 | 35.74 | 30.07 | 39.90 | 35.74 | 30.07 | 0.00 | 0.00 | 0.00 | 36.75 | 36.75 | 0.00 | Glencoe |
| 0.13 | 38.91 | 34.18 | 28.65 | 38.91 | 34.18 | 28.65 | 0.00 | 0.00 | 0.00 | 34.99 | 34.97 | 0.02 | Formans |
| 0.16 | 39.90 | 35.59 | 30.07 | 39.90 | 35.59 | 30.07 | 0.00 | 0.00 | 0.00 | 36.57 | 36.57 | 0.00 | Ves |
| 0.05 | 39.90 | 35.74 | 30.07 | 39.90 | 35.74 | 30.07 | 0.00 | 0.00 | 0.00 | 36.66 | 36.66 | 0.00 | Colvin |
| 0.05 | 39.82 | 35.59 | 30.07 | 39.82 | 35.59 | 30.07 | 0.00 | 0.00 | 0.00 | 36.45 | 36.45 | 0.00 | Lamoure |
| 0.06 | 39.50 | 35.41 | 30.07 | 39.50 | 35.41 | 30.07 | 0.00 | 0.00 | 0.00 | 36.29 | 36.29 | 0.00 | Seaforth |
| **W.M.** | **39.33** | **34.94** | **29.51** | **39.33** | **34.94** | **29.51** | **0.00** | **0.00** | **0.00** | **35.89** | **35.88** | **0.01** | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Redwood County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.32 | 132.61 | 104.09 | 66.05 | 132.61 | 112.99 | 92.34 | 0.00 | 0.00 | -36.09 | 103.33 | 115.52 | -12.19 | Canisteo |
| 0.12 | 133.41 | 104.09 | 66.12 | 133.41 | 116.76 | 93.42 | 0.00 | 0.00 | -34.45 | 105.75 | 118.12 | -12.36 | Webster |
| 0.05 | 133.41 | 104.09 | 66.11 | 133.41 | 116.76 | 93.42 | 0.00 | 0.00 | -34.56 | 105.60 | 118.00 | -12.41 | Glencoe |
| 0.10 | 138.12 | 104.82 | 66.08 | 133.76 | 116.76 | 95.46 | 0.00 | 0.00 | -36.64 | 107.55 | 120.17 | -12.61 | Okoboji |
| 0.27 | 133.41 | 104.09 | 65.90 | 133.41 | 116.76 | 93.42 | 0.00 | 0.00 | -34.01 | 106.05 | 118.37 | -12.32 | Ves |
| 0.05 | 133.73 | 104.09 | 66.67 | 133.41 | 116.76 | 93.42 | 0.00 | 0.00 | -33.15 | 106.45 | 118.64 | -12.19 | Seaforth |
| 0.10 | 136.68 | 104.80 | 67.99 | 135.27 | 116.76 | 97.58 | 0.00 | 0.00 | -34.73 | 107.92 | 120.11 | -12.18 | Normania |
| **W.M.** | **133.96** | **104.23** | **66.25** | **133.37** | **115.54** | **93.69** | **0.00** | **0.00** | **-35.05** | **105.47** | **117.77** | **-12.30** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.32 | 41.92 | 36.55 | 30.70 | 41.92 | 36.56 | 30.70 | 0.00 | 0.00 | 0.00 | 37.04 | 37.14 | -0.10 | Canisteo |
| 0.12 | 42.57 | 37.02 | 30.78 | 42.57 | 37.02 | 30.78 | 0.00 | 0.00 | 0.00 | 37.69 | 37.80 | -0.10 | Webster |
| 0.05 | 42.57 | 36.84 | 30.78 | 42.57 | 36.84 | 30.78 | 0.00 | 0.00 | 0.00 | 37.71 | 37.81 | -0.10 | Glencoe |
| 0.10 | 42.73 | 37.38 | 30.78 | 42.73 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 38.05 | 38.13 | -0.08 | Okoboji |
| 0.27 | 42.57 | 37.38 | 30.78 | 42.57 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 37.74 | 37.84 | -0.10 | Ves |
| 0.05 | 42.57 | 37.38 | 30.78 | 42.57 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 37.81 | 37.91 | -0.10 | Seaforth |
| 0.10 | 42.73 | 37.38 | 30.78 | 42.73 | 37.38 | 30.78 | 0.00 | 0.00 | 0.00 | 38.10 | 38.17 | -0.07 | Normania |
| **W.M.** | **42.39** | **37.04** | **30.76** | **42.39** | **37.05** | **30.76** | **0.00** | **0.00** | **0.00** | **37.58** | **37.67** | **-0.10** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Renville County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.16 | 137.25 | 105.73 | 74.47 | 130.30 | 112.94 | 96.21 | 0.00 | 0.00 | -38.44 | 108.72 | 116.17 | -7.45 | Harps |
| 0.10 | 137.25 | 105.08 | 74.47 | 130.30 | 112.94 | 95.70 | 0.00 | 0.00 | -38.27 | 108.59 | 115.97 | -7.38 | Webster |
| 0.06 | 137.25 | 110.10 | 82.39 | 132.59 | 115.07 | 97.79 | 0.00 | 0.00 | -30.25 | 112.31 | 118.55 | -6.24 | Winger-Quam |
| 0.12 | 130.67 | 101.55 | 74.47 | 130.30 | 111.02 | 89.92 | 0.00 | 0.00 | -39.54 | 106.41 | 114.21 | -7.80 | Nicollet |
| 0.10 | 137.25 | 107.51 | 75.63 | 132.59 | 112.94 | 97.79 | 0.00 | 0.00 | -36.04 | 110.39 | 117.48 | -7.09 | Okoboji |
| 0.05 | 137.25 | 105.54 | 74.47 | 130.30 | 112.94 | 96.62 | 0.00 | 0.00 | -38.70 | 108.72 | 116.17 | -7.45 | Seaforth |
| 0.10 | 137.25 | 105.73 | 74.68 | 131.28 | 112.94 | 96.15 | 0.00 | 0.00 | -36.77 | 109.48 | 116.63 | -7.15 | Clarion-Swanlake |
| 0.11 | 137.25 | 105.73 | 74.47 | 130.30 | 112.94 | 96.55 | 0.00 | 0.00 | -38.31 | 108.89 | 116.27 | -7.38 | Ves |
| 0.20 | 131.61 | 104.33 | 74.47 | 130.30 | 111.20 | 92.27 | 0.00 | 0.00 | -36.72 | 107.60 | 114.96 | -7.36 | Canisteo-Glencoe |
| **W.M.** | **135.17** | **105.20** | **74.98** | **130.64** | **112.36** | **94.81** | **0.00** | **0.00** | **-37.28** | **108.56** | **115.88** | **-7.32** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.16 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.81 | 37.21 | -0.40 | Harps |
| 0.10 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.78 | 37.17 | -0.39 | Webster |
| 0.06 | 41.75 | 35.92 | 29.92 | 41.75 | 36.03 | 29.96 | 0.00 | 0.00 | 0.00 | 37.39 | 37.73 | -0.33 | Winger-Quam |
| 0.12 | 41.75 | 35.65 | 29.92 | 41.75 | 35.75 | 29.96 | 0.00 | 0.00 | 0.00 | 36.37 | 36.78 | -0.41 | Nicollet |
| 0.10 | 41.75 | 35.92 | 29.92 | 41.75 | 36.03 | 29.96 | 0.00 | 0.00 | 0.00 | 37.09 | 37.47 | -0.38 | Okoboji |
| 0.05 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.80 | 37.20 | -0.40 | Seaforth |
| 0.10 | 41.75 | 35.92 | 29.92 | 41.75 | 35.96 | 29.96 | 0.00 | 0.00 | 0.00 | 36.93 | 37.31 | -0.38 | Clarion-Swanlake |
| 0.11 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.82 | 37.22 | -0.40 | Ves |
| 0.20 | 41.75 | 35.75 | 29.92 | 41.75 | 35.92 | 29.96 | 0.00 | 0.00 | 0.00 | 36.56 | 36.96 | -0.39 | Canisteo-Glencoe |
| **W.M.** | **41.71** | **35.75** | **29.89** | **41.71** | **35.89** | **29.93** | **0.00** | **0.00** | **0.00** | **36.74** | **37.13** | **-0.39** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Swift County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.22 | 130.12 | 95.66 | 64.79 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -25.06 | 98.62 | 104.24 | -5.62 | Barnes |
| 0.14 | 139.01 | 104.10 | 66.50 | 139.01 | 108.27 | 87.09 | 0.00 | 0.00 | -46.86 | 106.90 | 113.11 | -6.21 | Colvin |
| 0.09 | 130.12 | 95.66 | 64.79 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -25.06 | 98.62 | 104.24 | -5.62 | Hamerly |
| 0.08 | 108.41 | 77.38 | 54.03 | 108.41 | 77.38 | 61.62 | 0.00 | 0.00 | -8.17 | 79.05 | 81.65 | -2.60 | Marysland |
| 0.08 | 135.26 | 102.12 | 65.51 | 135.26 | 106.44 | 82.21 | 0.00 | 0.00 | -32.85 | 104.26 | 109.98 | -5.72 | Vallers-Winger |
| 0.05 | 100.20 | 64.85 | 49.42 | 100.20 | 70.62 | 54.72 | 0.00 | 0.00 | -6.92 | 72.82 | 74.55 | -1.73 | Arveson |
| 0.05 | 139.01 | 104.10 | 66.50 | 139.01 | 108.27 | 87.09 | 0.00 | 0.00 | -46.86 | 106.90 | 113.11 | -6.21 | Beazden |
| 0.05 | 130.12 | 95.66 | 64.79 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -25.06 | 98.62 | 104.24 | -5.62 | Svea |
| 0.10 | 139.01 | 103.46 | 66.50 | 139.01 | 106.78 | 87.09 | 0.00 | 0.00 | -42.43 | 106.23 | 112.09 | -5.86 | Parnell |
| 0.03 | 137.16 | 102.12 | 66.50 | 137.16 | 106.44 | 86.36 | 0.00 | 0.00 | -36.19 | 105.34 | 110.67 | -5.33 | Tara |
| 0.03 | 108.41 | 79.32 | 55.91 | 108.41 | 83.75 | 68.79 | 0.00 | 0.00 | -18.00 | 84.33 | 88.38 | -4.04 | Mayer |
| 0.07 | 130.12 | 95.66 | 64.79 | 130.12 | 95.90 | 79.32 | 0.00 | 0.00 | -25.06 | 98.62 | 104.24 | -5.62 | Buse |
| **W.M.** | **129.34** | **95.16** | **63.45** | **129.34** | **97.32** | **78.97** | **0.00** | **0.00** | **-29.34** | **98.24** | **103.50** | **-5.26** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.22 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Barnes |
| 0.14 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.28 | 36.79 | -0.51 | Colvin |
| 0.09 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Hamerly |
| 0.08 | 35.18 | 25.66 | 20.89 | 35.18 | 25.66 | 21.66 | 0.00 | 0.00 | 0.00 | 27.64 | 27.83 | -0.18 | Marysland |
| 0.08 | 41.37 | 35.48 | 28.54 | 41.37 | 35.48 | 28.80 | 0.00 | 0.00 | 0.00 | 35.78 | 36.30 | -0.52 | Vallers-Winger |
| 0.05 | 33.66 | 22.88 | 19.20 | 33.66 | 23.10 | 19.20 | 0.00 | 0.00 | 0.00 | 25.48 | 25.62 | -0.14 | Arveson |
| 0.05 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.28 | 36.79 | -0.51 | Beazden |
| 0.05 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Svea |
| 0.10 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.23 | 36.74 | -0.51 | Parnell |
| 0.03 | 41.37 | 35.48 | 28.80 | 41.37 | 35.48 | 28.92 | 0.00 | 0.00 | 0.00 | 36.07 | 36.56 | -0.49 | Tara |
| 0.03 | 35.77 | 28.44 | 23.45 | 35.77 | 28.44 | 24.42 | 0.00 | 0.00 | 0.00 | 29.51 | 29.78 | -0.27 | Mayer |
| 0.07 | 38.10 | 33.13 | 26.34 | 38.10 | 34.03 | 28.54 | 0.00 | 0.00 | 0.00 | 34.11 | 34.63 | -0.53 | Buse |
| **W.M.** | **38.88** | **32.79** | **26.40** | **38.88** | **33.19** | **27.51** | **0.00** | **0.00** | **0.00** | **33.81** | **34.28** | **-0.46** | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.3 Simulated corn and soybean yield and yield loss in **floating cutting** schedule for each soil at various probability level (continued)

**Yellow Medicine County**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 125.59 | 105.20 | 63.02 | 132.16 | 106.85 | 88.98 | 0.00 | 0.00 | -29.71 | 103.24 | 111.62 | -8.38 | Barnes |
| 0.44 | 133.03 | 107.43 | 64.80 | 133.03 | 108.43 | 90.08 | 0.00 | 0.00 | -27.73 | 106.66 | 114.16 | -7.50 | Ves |
| 0.03 | 140.32 | 108.31 | 72.94 | 137.96 | 111.36 | 90.08 | 0.00 | 0.00 | -24.09 | 110.64 | 116.97 | -6.33 | Du Page |
| 0.11 | 125.52 | 98.85 | 59.64 | 126.68 | 103.29 | 88.98 | 0.00 | 0.00 | -31.25 | 100.18 | 109.32 | -9.14 | Forman |
| 0.24 | 125.59 | 105.28 | 65.80 | 132.00 | 107.47 | 88.98 | 0.00 | 0.00 | -31.25 | 100.18 | 109.32 | -9.14 | Forman |
| 0.06 | 137.27 | 107.43 | 67.06 | 137.96 | 111.36 | 90.08 | 0.00 | 0.00 | -28.51 | 104.16 | 112.12 | -7.97 | Canisteo |
| 0.03 | 97.49 | 51.78 | 30.44 | 97.49 | 61.19 | 30.44 | 0.00 | 0.00 | -23.82 | 108.68 | 115.81 | -7.13 | Spicer |
| **W.M.** | **129.19** | **104.31** | **63.74** | **131.49** | **106.48** | **87.98** | **0.00** | **0.00** | **-27.62** | **104.08** | **111.76** | **-7.68** | |

| Area | Soybean Yield(new) 10% | 50% | 90% | Soybean Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 40.54 | 36.20 | 30.03 | 40.54 | 36.20 | 30.03 | 0.00 | 0.00 | 0.00 | 36.50 | 36.50 | 0.00 | Barnes |
| 0.44 | 40.54 | 36.35 | 30.03 | 40.54 | 36.35 | 30.03 | 0.00 | 0.00 | 0.00 | 37.47 | 37.45 | 0.01 | Ves |
| 0.03 | 42.20 | 36.35 | 30.26 | 42.20 | 36.35 | 30.26 | 0.00 | 0.00 | 0.00 | 38.11 | 38.09 | 0.02 | Du Page |
| 0.11 | 40.45 | 35.68 | 30.03 | 40.45 | 35.68 | 30.03 | 0.00 | 0.00 | 0.00 | 35.83 | 35.83 | 0.00 | Forman |
| 0.24 | 40.54 | 36.20 | 30.03 | 40.54 | 36.20 | 30.03 | 0.00 | 0.00 | 0.00 | 36.70 | 36.70 | 0.00 | Canisteo |
| 0.06 | 41.12 | 36.35 | 30.26 | 41.12 | 36.35 | 30.26 | 0.00 | 0.00 | 0.00 | 37.91 | 37.89 | 0.02 | Spicer |
| 0.03 | 30.15 | 22.48 | 13.51 | 30.15 | 22.48 | 13.51 | 0.00 | 0.00 | 0.00 | 22.81 | 22.85 | -0.04 | Arvilla |
| **W.M.** | **40.33** | **35.85** | **29.60** | **40.33** | **35.85** | **29.60** | **0.00** | **0.00** | **0.00** | **36.66** | **36.65** | **0.01** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

**Appendix B**

Table B.4 Simulated Lac Qui Parle county's corn yield and yield loss in different cutting schedules for each soil at various probability level.

**Fixed Cutting (June 20 and Aug 31)**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 110.07 | 79.91 | 45.97 | 125.90 | 107.81 | 85.01 | 0.00 | -24.47 | -61.84 | 81.65 | 108.29 | -26.63 | Ves l. |
| 0.06 | 112.17 | 85.01 | 50.68 | 128.64 | 109.79 | 85.01 | 0.00 | -25.17 | -61.99 | 85.78 | 111.49 | -25.71 | Waubay s.l. |
| 0.06 | 119.70 | 90.25 | 60.18 | 132.34 | 113.40 | 89.93 | 0.00 | -13.19 | -52.48 | 94.75 | 116.20 | -21.45 | Calco |
| 0.07 | 110.07 | 78.42 | 45.81 | 124.58 | 106.61 | 84.00 | 0.00 | -25.35 | -61.41 | 80.93 | 107.64 | -26.71 | Normania |
| 0.21 | 112.31 | 85.01 | 50.17 | 129.46 | 109.79 | 85.01 | 0.00 | -25.24 | -62.50 | 86.01 | 111.87 | -25.86 | Harps-Glencoe |
| 0.07 | 113.38 | 85.01 | 53.05 | 129.58 | 110.76 | 85.01 | 0.00 | -25.12 | -59.62 | 88.24 | 113.19 | -24.95 | Esmond |
| 0.08 | 110.07 | 78.08 | 45.37 | 121.47 | 102.97 | 80.39 | 0.00 | -25.29 | -56.56 | 79.36 | 105.06 | -25.69 | Burr-Calco |
| 0.05 | 110.07 | 81.11 | 48.54 | 126.75 | 109.02 | 85.01 | 0.00 | -22.09 | -60.48 | 82.64 | 108.51 | -25.87 | Barnes |
| 0.05 | 112.30 | 84.72 | 49.19 | 129.10 | 109.79 | 85.01 | 0.00 | -25.24 | -63.48 | 85.20 | 111.23 | -26.03 | Vallers |
| 0.04 | 110.86 | 85.01 | 49.95 | 128.89 | 109.79 | 85.01 | 0.00 | -24.40 | -62.71 | 84.95 | 110.89 | -25.94 | Webster |
| 0.04 | 112.34 | 85.01 | 51.15 | 130.05 | 110.28 | 85.01 | 0.00 | -25.24 | -62.63 | 86.75 | 112.56 | -25.81 | Perella |
| 0.04 | 113.21 | 84.72 | 49.52 | 129.62 | 110.03 | 85.01 | 0.00 | -25.50 | -63.14 | 85.71 | 111.74 | -26.03 | Lamoure |
| **W.M.** | **111.84** | **82.92** | **49.23** | **127.66** | **108.85** | **84.89** | **0.00** | **-24.13** | **-60.95** | **84.56** | **110.32** | **-25.76** | |

**Fixed cuttings with killing alfalfa after 1st cut on June 20**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 131.19 | 98.27 | 75.99 | 125.90 | 107.81 | 85.01 | 15.14 | 0.00 | -40.54 | 100.24 | 108.29 | -8.04 | Ves l. |
| 0.06 | 131.64 | 99.72 | 78.08 | 128.64 | 109.79 | 85.01 | 11.20 | 0.00 | -43.06 | 103.67 | 111.49 | -7.82 | Waubay s.l. |
| 0.06 | 144.05 | 109.79 | 78.08 | 132.34 | 113.40 | 89.93 | 0.00 | 0.00 | -39.71 | 109.84 | 116.20 | -6.36 | Calco |
| 0.07 | 131.19 | 96.61 | 75.22 | 124.58 | 106.61 | 84.00 | 14.21 | 0.00 | -40.24 | 99.61 | 107.64 | -8.03 | Normania |
| 0.21 | 131.64 | 99.72 | 78.08 | 129.46 | 109.79 | 85.01 | 10.14 | 0.00 | -43.67 | 103.88 | 111.87 | -7.99 | Harps-Glencoe |
| 0.07 | 131.64 | 102.40 | 78.08 | 129.58 | 110.76 | 85.01 | 5.63 | 0.00 | -41.69 | 105.66 | 113.19 | -7.53 | Esmond |
| 0.08 | 131.19 | 91.57 | 75.38 | 121.47 | 102.97 | 80.39 | 11.37 | 0.00 | -36.79 | 97.95 | 105.06 | -7.10 | Burr-Calco |
| 0.05 | 131.19 | 98.34 | 78.08 | 126.75 | 109.02 | 85.01 | 16.85 | 0.00 | -39.58 | 100.95 | 108.51 | -7.56 | Barnes |
| 0.05 | 131.19 | 99.72 | 78.08 | 129.10 | 109.79 | 85.01 | 11.85 | 0.00 | -43.33 | 103.25 | 111.23 | -7.98 | Vallers |
| 0.04 | 131.42 | 99.72 | 78.08 | 128.89 | 109.79 | 85.01 | 12.45 | 0.00 | -42.62 | 103.02 | 110.89 | -7.87 | Webster |
| 0.04 | 131.64 | 99.74 | 78.08 | 130.05 | 110.28 | 85.01 | 8.19 | 0.00 | -43.67 | 104.46 | 112.56 | -8.10 | Perella |
| 0.04 | 131.19 | 99.72 | 78.08 | 129.62 | 110.03 | 85.01 | 11.17 | 0.00 | -43.94 | 103.61 | 111.74 | -8.13 | Lamoure |
| **W.M.** | **132.16** | **99.27** | **77.18** | **127.66** | **108.85** | **84.89** | **11.30** | **0.00** | **-41.49** | **102.55** | **110.32** | **-7.78** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.4 Simulated Lac Qui Parle county's corn yield and yield loss in different cutting schedules for each soil at various probability level (continued).

**Floating Cutting**

| | Corn Yield(new) | | | Corn Yield(old) | | | Diff. Yield | | | Average Yield, Bu/A | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 10% | 50% | 90% | 10% | 50% | 90% | 10% | 50% | 90% | AvYnw | AvYod | AvDif | soil name |
| 0.24 | 119.36 | 89.93 | 64.93 | 125.90 | 107.81 | 85.01 | 0.00 | -7.81 | -42.88 | 93.73 | 108.29 | -14.56 | Ves l. |
| 0.06 | 124.87 | 95.40 | 71.70 | 128.64 | 109.79 | 85.01 | 2.53 | -3.63 | -43.06 | 98.45 | 111.49 | -13.04 | Waubay s.l. |
| 0.06 | 137.39 | 107.35 | 78.08 | 132.34 | 113.40 | 89.93 | 0.00 | 0.00 | -39.71 | 106.86 | 116.20 | -9.34 | Calco |
| 0.07 | 118.20 | 89.93 | 63.86 | 124.58 | 106.61 | 84.00 | 0.00 | -8.58 | -42.75 | 92.90 | 107.64 | -14.74 | Normania |
| 0.21 | 125.62 | 96.57 | 71.50 | 129.46 | 109.79 | 85.01 | 3.21 | -4.14 | -43.67 | 98.75 | 111.87 | -13.12 | Harps-Glencoe |
| 0.07 | 128.67 | 99.72 | 75.23 | 129.58 | 110.76 | 85.01 | 5.61 | -1.87 | -41.69 | 101.15 | 113.19 | -12.04 | Esmond |
| 0.08 | 119.03 | 87.81 | 59.64 | 121.47 | 102.97 | 80.39 | 0.00 | -10.00 | -42.30 | 90.55 | 105.06 | -14.51 | Burr-Calco |
| 0.05 | 121.09 | 89.93 | 66.17 | 126.75 | 109.02 | 85.01 | 0.00 | -5.25 | -42.85 | 94.62 | 108.51 | -13.89 | Barnes |
| 0.05 | 124.67 | 94.98 | 69.77 | 129.10 | 109.79 | 85.01 | 2.20 | -4.60 | -43.33 | 97.88 | 111.23 | -13.35 | Vallers |
| 0.04 | 123.93 | 94.00 | 70.34 | 128.89 | 109.79 | 85.01 | 1.28 | -4.00 | -42.62 | 97.52 | 110.89 | -13.36 | Webster |
| 0.04 | 126.93 | 97.61 | 70.77 | 130.05 | 110.28 | 85.01 | 4.70 | -4.13 | -43.67 | 99.56 | 112.56 | -12.99 | Perella |
| 0.04 | 124.55 | 95.66 | 70.79 | 129.62 | 110.03 | 85.01 | 2.91 | -4.78 | -43.94 | 98.38 | 111.74 | -13.36 | Lamoure |
| **W.M.** | **123.68** | **94.17** | **68.71** | **127.66** | **108.85** | **84.89** | **1.66** | **-5.43** | **-42.81** | **96.89** | **110.32** | **-13.43** | |

**Floating cuttings with killing alfalfa after 1st cut**

| | Corn Yield(new) | | | Corn Yield(old) | | | Diff. Yield | | | Average Yield, Bu/A | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | 10% | 50% | 90% | 10% | 50% | 90% | 10% | 50% | 90% | AvYnw | AvYod | AvDif | soil name |
| 0.24 | 131.19 | 102.97 | 78.08 | 125.90 | 107.81 | 85.01 | 15.14 | 0.00 | -40.54 | 104.02 | 108.29 | -4.27 | Ves l. |
| 0.06 | 131.64 | 105.54 | 78.08 | 128.64 | 109.79 | 85.01 | 11.20 | 0.00 | -43.06 | 107.22 | 111.49 | -4.27 | Waubay s.l. |
| 0.06 | 144.05 | 110.28 | 78.08 | 132.34 | 113.40 | 89.93 | 0.00 | 0.00 | -39.71 | 111.86 | 116.20 | -4.34 | Calco |
| 0.07 | 131.19 | 102.44 | 77.81 | 124.58 | 106.61 | 84.00 | 14.21 | 0.00 | -40.24 | 103.37 | 107.64 | -4.27 | Normania |
| 0.21 | 131.64 | 105.91 | 78.08 | 129.46 | 109.79 | 85.01 | 10.14 | 0.00 | -43.67 | 107.47 | 111.87 | -4.40 | Harps-Glencoe |
| 0.07 | 131.64 | 106.75 | 78.08 | 129.58 | 110.76 | 85.01 | 5.63 | 0.00 | -41.69 | 108.93 | 113.19 | -4.26 | Esmond |
| 0.08 | 131.19 | 102.27 | 77.25 | 121.47 | 102.97 | 80.39 | 11.37 | 0.00 | -36.79 | 101.32 | 105.06 | -3.73 | Burr-Calco |
| 0.05 | 131.19 | 103.61 | 78.08 | 126.75 | 109.02 | 85.01 | 16.85 | 0.00 | -39.58 | 104.50 | 108.51 | -4.01 | Barnes |
| 0.05 | 131.64 | 105.04 | 78.08 | 129.10 | 109.79 | 85.01 | 11.85 | 0.00 | -43.33 | 106.87 | 111.23 | -4.36 | Vallers |
| 0.04 | 131.64 | 104.17 | 78.08 | 128.89 | 109.79 | 85.01 | 12.45 | 0.00 | -42.62 | 106.60 | 110.89 | -4.29 | Webster |
| 0.04 | 131.64 | 105.91 | 78.08 | 130.05 | 110.28 | 85.01 | 8.19 | 0.00 | -43.67 | 108.03 | 112.56 | -4.53 | Perella |
| 0.04 | 131.64 | 105.76 | 78.08 | 129.62 | 110.03 | 85.01 | 11.17 | 0.00 | -43.94 | 107.24 | 111.74 | -4.49 | Lamoure |
| **W.M.** | **132.21** | **104.77** | **78.00** | **127.66** | **108.85** | **84.89** | **11.30** | **0.00** | **-41.49** | **106.05** | **110.32** | **-4.27** | |

* Corn and Soybean yield in Bu/Ac. ** Probability

Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.

AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.

AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.

W.M. = county area weighted mean.

Table B.4 Simulated Lac Qui Parle county's corn yield and yield loss in different cutting schedules for each soil at various probability level (continued).

**Floating cuttings with killing alfalfa after 2nd cut**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.24 | 131.19 | 101.32 | 78.08 | 125.90 | 107.81 | 85.01 | 15.14 | 0.00 | -40.54 | 102.55 | 108.29 | -5.74 | Ves l. |
| 0.06 | 131.64 | 105.54 | 78.08 | 128.64 | 109.79 | 85.01 | 11.20 | 0.00 | -43.06 | 106.20 | 111.49 | -5.29 | Waubay s.l. |
| 0.06 | 144.05 | 110.28 | 78.08 | 132.34 | 113.40 | 89.93 | 0.00 | 0.00 | -39.71 | 111.50 | 116.20 | -4.70 | Calco |
| 0.07 | 131.19 | 100.46 | 77.81 | 124.58 | 106.61 | 84.00 | 14.21 | 0.00 | -40.24 | 101.87 | 107.64 | -5.77 | Normania |
| 0.21 | 131.64 | 105.91 | 78.08 | 129.46 | 109.79 | 85.01 | 10.14 | 0.00 | -43.67 | 106.41 | 111.87 | -5.46 | Harps-Glencoe |
| 0.07 | 131.64 | 106.75 | 78.08 | 129.58 | 110.76 | 85.01 | 5.63 | 0.00 | -41.69 | 108.20 | 113.19 | -4.99 | Esmond |
| 0.08 | 131.19 | 99.29 | 77.25 | 121.47 | 102.97 | 80.39 | 11.37 | 0.00 | -36.79 | 99.91 | 105.06 | -5.15 | Burr-Calco |
| 0.05 | 131.19 | 102.97 | 78.08 | 126.75 | 109.02 | 85.01 | 16.85 | 0.00 | -39.58 | 103.27 | 108.51 | -5.24 | Barnes |
| 0.05 | 131.64 | 105.04 | 78.08 | 129.10 | 109.79 | 85.01 | 11.85 | 0.00 | -43.33 | 105.76 | 111.23 | -5.47 | Vallers |
| 0.04 | 131.64 | 103.57 | 78.08 | 128.89 | 109.79 | 85.01 | 12.45 | 0.00 | -42.62 | 105.51 | 110.89 | -5.38 | Webster |
| 0.04 | 131.64 | 105.91 | 78.08 | 130.05 | 110.28 | 85.01 | 8.19 | 0.00 | -43.67 | 107.01 | 112.56 | -5.55 | Perella |
| 0.04 | 131.64 | 105.54 | 78.08 | 129.62 | 110.03 | 85.01 | 11.17 | 0.00 | -43.94 | 106.16 | 111.74 | -5.58 | Lamoure |
| **W.M.** | **132.21** | **103.94** | **78.00** | **127.66** | **108.85** | **84.89** | **11.30** | **0.00** | **-41.49** | **104.90** | **110.32** | **-5.43** | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

**Appendix B**

Table B.5 Simulated Kandiyohi county's corn yield and yield loss in different cutting schedules for each soil at various probability level.

**Fixed Cutting**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 123.72 | 102.92 | 73.48 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | -18.14 | 102.61 | 107.27 | -4.66 | Delft |
| 0.11 | 113.74 | 100.68 | 70.17 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | -23.37 | 99.51 | 105.28 | -5.77 | Wadenill |
| 0.11 | 109.76 | 95.47 | 65.85 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | -28.28 | 96.18 | 103.12 | -6.94 | Sunburg |
| 0.22 | 125.47 | 105.50 | 74.63 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | -13.02 | 104.29 | 107.92 | -3.63 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | -6.81 | 64.57 | 65.71 | -1.13 | Estherville |
| 0.13 | 124.73 | 104.54 | 74.47 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | -16.96 | 103.40 | 107.67 | -4.27 | Harps |
| 0.07 | 125.65 | 104.22 | 74.20 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | -17.25 | 103.39 | 107.71 | -4.32 | Ves |
| 0.18 | 109.76 | 85.01 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | -18.19 | 90.93 | 94.63 | -3.70 | Biscay-Palms |
| **W.M.** | **114.66** | **93.78** | **66.28** | **116.92** | **95.63** | **72.00** | **0.00** | **0.00** | **-16.99** | **94.45** | **98.55** | **-4.10** | |

**Fixed cuttings with killing alfalfa after 1st cut on June 20**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 124.13 | 105.56 | 74.63 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | 0.00 | 106.37 | 107.27 | -0.91 | Delft |
| 0.11 | 122.34 | 105.21 | 74.63 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | 0.00 | 104.42 | 105.28 | -0.86 | Wadenill |
| 0.11 | 119.73 | 104.42 | 74.63 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | -0.73 | 102.02 | 103.12 | -1.09 | Sunburg |
| 0.22 | 125.47 | 105.56 | 76.78 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | 0.00 | 107.24 | 107.92 | -0.68 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | 0.00 | 65.46 | 65.71 | -0.24 | Estherville |
| 0.13 | 124.73 | 105.56 | 74.63 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | 0.00 | 106.88 | 107.67 | -0.79 | Harps |
| 0.07 | 125.65 | 105.56 | 74.63 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | 0.00 | 106.94 | 107.71 | -0.78 | Ves |
| 0.18 | 114.00 | 90.15 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | 0.00 | 94.16 | 94.63 | -0.47 | Biscay-Palms |
| **W.M.** | **117.49** | **96.57** | **68.34** | **116.92** | **95.63** | **72.00** | **0.00** | **0.00** | **-0.08** | **97.87** | **98.55** | **-0.68** | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.5 Simulated Kandiyohi county's corn yield and yield loss in different cutting schedules for each soil at various probability level (continued).

**Floating Cutting**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield,Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 124.13 | 105.50 | 74.63 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | -14.80 | 104.85 | 107.27 | -2.42 | Delft |
| 0.11 | 122.25 | 100.68 | 73.27 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | -20.03 | 102.35 | 105.28 | -2.92 | Wadenill |
| 0.11 | 116.69 | 95.78 | 68.58 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | -24.94 | 99.35 | 103.12 | -3.77 | Sunburg |
| 0.22 | 125.47 | 105.50 | 74.63 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | -9.68 | 106.07 | 107.92 | -1.85 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | -1.94 | 65.04 | 65.71 | -0.66 | Estherville |
| 0.13 | 124.73 | 105.50 | 74.63 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | -13.62 | 105.45 | 107.67 | -2.22 | Harps |
| 0.07 | 125.65 | 105.50 | 74.63 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | -13.91 | 105.48 | 107.71 | -2.23 | Ves |
| 0.18 | 114.00 | 87.44 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | -7.39 | 92.76 | 94.63 | -1.87 | Biscay-Palms |
| **W.M.** | **117.14** | **94.59** | **67.04** | **116.92** | **95.63** | **72.00** | **0.00** | **0.00** | **-12.18** | **96.42** | **98.55** | **-2.13** | |

**Floating cuttings with killing alfalfa after 1st cut**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield,Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 124.13 | 105.56 | 77.56 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | 0.00 | 106.84 | 107.27 | -0.43 | Delft |
| 0.11 | 122.34 | 105.21 | 77.56 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | 0.00 | 104.97 | 105.28 | -0.31 | Wadenill |
| 0.11 | 119.73 | 104.42 | 75.49 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | 0.00 | 102.66 | 103.12 | -0.46 | Sunburg |
| 0.22 | 125.47 | 105.56 | 77.56 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | 0.00 | 107.57 | 107.92 | -0.35 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | 0.00 | 65.46 | 65.71 | -0.24 | Estherville |
| 0.13 | 124.73 | 105.56 | 77.56 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | 0.00 | 107.29 | 107.67 | -0.38 | Harps |
| 0.07 | 125.65 | 105.56 | 77.56 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | 0.00 | 107.35 | 107.71 | -0.36 | Ves |
| 0.18 | 114.00 | 90.15 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | 0.00 | 94.16 | 94.63 | -0.47 | Biscay-Palms |
| **W.M.** | **117.49** | **96.57** | **69.66** | **116.92** | **95.63** | **72.00** | **0.00** | **0.00** | **0.00** | **98.18** | **98.55** | **-0.37** | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

Table B.5 Simulated Kandiyohi county's corn yield and yield loss in different cutting schedules for each soil at various probability level (continued).

**Floating cuttings with killing alfalfa after 2nd cut**

| Area | Corn Yield(new) 10% | 50% | 90% | Corn Yield(old) 10% | 50% | 90% | Diff. Yield 10% | 50% | 90% | Average Yield, Bu/A AvYnw | AvYod | AvDif | soil name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | 124.13 | 105.56 | 77.56 | 123.72 | 105.50 | 79.99 | 0.00 | 0.00 | 0.00 | 106.70 | 107.27 | -0.57 | Delft |
| 0.11 | 122.34 | 104.16 | 75.47 | 121.70 | 102.81 | 78.68 | 0.00 | 0.00 | -1.40 | 104.72 | 105.28 | -0.55 | Wadenill |
| 0.11 | 119.73 | 99.34 | 74.63 | 119.73 | 97.66 | 75.49 | 0.00 | 0.00 | -4.95 | 102.10 | 103.12 | -1.02 | Sunburg |
| 0.22 | 125.47 | 105.56 | 77.56 | 124.13 | 105.50 | 82.45 | 0.00 | 0.00 | 0.00 | 107.43 | 107.92 | -0.49 | Canisteo |
| 0.12 | 95.26 | 63.24 | 33.07 | 95.26 | 64.15 | 33.07 | 0.00 | 0.00 | 0.00 | 65.46 | 65.71 | -0.24 | Estherville |
| 0.13 | 124.73 | 105.56 | 77.56 | 124.13 | 105.50 | 80.62 | 0.00 | 0.00 | 0.00 | 107.15 | 107.67 | -0.52 | Harps |
| 0.07 | 125.65 | 105.56 | 77.56 | 124.13 | 105.56 | 80.24 | 0.00 | 0.00 | 0.00 | 107.21 | 107.71 | -0.50 | Ves |
| 0.18 | 114.00 | 90.15 | 68.84 | 114.00 | 90.15 | 71.29 | 0.00 | 0.00 | 0.00 | 94.16 | 94.63 | -0.47 | Biscay-Palms |
| W.M. | 117.49 | 95.88 | 69.34 | 116.92 | 95.63 | 72.00 | 0.00 | 0.00 | -0.71 | 98.02 | 98.55 | -0.53 | |

* Corn and Soybean yield in Bu/Ac. ** Probability
Yield(new)= Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
Yield(old)= Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvYnw = Simulated average corn/soybean yield when alfalfa is introduced into corn-soybean rotation.
AvYod = Simulated average corn/soybean yield based on the current corn-soybean rotation.
AvDif = Simulated average difference in corn/soybean yield between with and without alfalfa.
W.M. = county area weighted mean.

## APPENDIX CHAPTER 4

### 4.2 Guide to using "PRODUCTION" spreadsheet

A spreadsheet entitled "Production" was developed (Microsoft EXCEL 4.0) to determine the cost of production for both the DFSS rotation and the corn-soybean rotation. Several assumptions are made which, several of which may significantly affect the total cost estimates. The following guide will help define the inputs used and will hopefully be of assistance for anyone attempting to use the spreadsheet to generate new cost estimates.

To assist in locating user inputs, all inputs are printed in normal type and followed by a "?" while outputs are in bold type followed by "=". The first section of inputs deals with expected yields from crops and the payments received for the produce.

| | |
|---|---|
| SOIL AREA? | Input the soil area as defined by ????. This input does not affect any outcomes and is only used as a reference for the user. |
| CASH RENT? | Input amount of cash paid for rent of farmland. |
| CER? | Input the crop equivalent rating for the area in question. Average CER for the Granite falls area is between 62 and 65. This number is used to estimate alfalfa, corn and soybean yields. |
| LEAF PRICE ($/T)? | Input the estimated value of leaves per ton - paid to the producer upon delivery. |
| STEM PRICE ($/T)? | Input the estimated value of stems per ton - paid to the producer upon delivery. |
| CORN ($/BU)? | Input the payment to the producer per bushel of corn. |
| SOYBEANS ($/BU)? | Input the payment to the producer per bushel of soybeans |
| Deficiency Payment | Input the government payment per bushel for corn. |
| cutting schedule (2,3 or 4)? | Input the number of times alfalfa will be cut in establishment years. (2,3 or 4) |
| % leaves in 2 (3 and 4) cut system? | Input the estimated leaf percentage in |

From this information yield goals are estimated. From these yield goals, fertilizer use and gross revenue is estimated.

The following two sections look for current market rates for many production inputs. All but one are self explanatory and will not be described in detail. The only one that may be difficult to understand is the final input "OVERHEAD ($/acre)?". This input is defined as the overhead cost per acre on the farm. Such things as phone, electricity, office space, and office equipment are included in this number. Estimates for this number, along with many others can be found in publications from the Southwest Farm Management data.

The next section, "FIELD OPERATION COSTS", asks for estimated costs per acre for machinery, labor hours per acre for for different field operations, and fuel costs per acre. Tractor and machine costs listed are for overhead and direct costs, **they do not include labor.** Inputs for this section were gathered from a recent University of

Minnesota Extension Service publication entitled "Minnesota farm machinery economic cost estimates for 1994" (Fuller, Lazarus, Carrigan).

The following section entitled "FIELD OPERATIONS PER YEAR (DFSS ROTATION)" lists the individual years of the rotation and the available field operations. Field operations are selected by the user by designating in the crop column the number of times a certain field operation will be preformed in a given year. For example, if the user has determined that the first alfalfa year need one pass from a disk chisel, a "1" should be placed in the first column and in the row designated "DISK CHISEL 16'". If in the fourth year of the rotation, the first corn year, two passes with a field cultivator are needed a "2" should be input in the fourth column and the row designated "FIELD CULTIVATOR 18'". The items in the table in printed in bold type are predetermined by yield goal or number of cuttings (alfalfa).

From the inputs given a series of costs and revenues are generated. Costs are broken down in several categories to simplify the task of removing unwanted inputs from the total costs. The following is a description of the costs and revenues listed.

| | |
|---|---|
| FIELD OPERATION TTL= | Gives the calculated direct and indirect costs of the field operations (Note: this number does not reflect labor costs) |
| SUB TOTAL= | Gives the calculated cost per acre for fertilizer, herbicide, seed, drying and twine. |
| STORAGE= | Gives the calculated per acre cost of storage . |
| TRANSPORTATION= | Gives the calculated per acre cost of transportation . |
| LABOR= | Gives the calculated per acre cost for labor. |
| RENT= | Gives the price per acre for rent |
| DIRECT CASH EXPENSE= | Gives the sum of per acre costs for the previous five listed costs. |
| OVERHEAD= | Gives the estimated overhead charge per acre |
| TOTAL EXPENDITURES (/a)= | Gives the sum of all per acre costs involved in producing the given commodity |
| Expenditures (/ton or /bu)= | Gives the calculated per ton costs or per bushel costs for the given commodity |
| $/ton or $/bu (no trans)= | Gives the calculated per ton or per bushel costs without transportation costs. |
| GROSS REVENUE (/a)= | Gives the calculated value of the commodity produced per acre. |
| NET RETURN (/a)= | Gives the GROSS REVENUE minus TOTAL EXPENDITURES |

The next section of the spreadsheet entitled "FIELD OPERATIONS PER YEAR (Traditional Rotation)" is identical to the previous section except inputs and outputs are for a corn-soybean rotation.

The final page of the spreadsheet deals with energy use for the crop rotations. User inputs for this page are described in the appendix for chapter 8.

## ON FARM PRODUCTION COSTS

8/27/94

| | |
|---|---|
| SOIL AREA #? | 7 |
| CASH RENT(/ACRE)? | $70.25 |
| CER? | 85 |
| LEAF PRICE ($/T)? | $115.10 |
| STEM PRICE ($/TON)? | $30.00 |
| CORN ($/BU)? | $2.23 |
| SOYBEANS ($/BU)? | $6.01 |
| Support Payment ($/BU)? | $0.20 |
| cutting schedule (2,3 or 4)? | 3 |
| % leaves per 2 cut schedule? | 0.44 |
| % leaves per 3 cut schedule? | 0.47 |
| % leaves per 4 cut schedule? | 0.50 |

COMPARE AVE. NET REVENUE / YR

| | |
|---|---|
| $25.47 | DFSS ROTATION |
| $20.34 | CS ROTATION |

| DFSS ROTATION | Yield goal | TONS LEAF | TONS STEM | SALE $/UNIT | GOV SUPPORT |
|---|---|---|---|---|---|
| ALFALFA | 1.97 | 0.92 | 1.04 | $70.00 | |
| ALFALFA | 4.37 | 2.05 | 2.32 | $70.00 | |
| ALFALFA | 4.37 | 2.05 | 2.32 | $70.00 | |
| ALFALFA | 4.37 | 2.05 | 2.32 | $70.00 | |
| CORN | 107 | | | $2.23 | $21.38 |
| CORN | 107 | | | $2.23 | $21.38 |
| SOYBEANS | 36 | | | $6.01 | |

### CORN SOYBEAN ROTATION

| | yield (bu) | sale ($/bu) | gov support |
|---|---|---|---|
| CORN | 107 | $2.23 | $21.38 |
| SOYBEANS | 36 | $6.01 | |

### COST OF FIELD INPUTS

| | | |
|---|---|---|
| (Urea) N ($/LB)? | $0.22 | |
| (Anhydrous) N ($/LB)? | $0.12 | |
| P ($/LB)? | $0.22 | |
| K ($/LB)? | $0.09 | |
| 2-4-DB ($/a)? | $3.00 | |
| Benefin/Eptam ($/a)? | $19.00 | |
| ALFALFA-Dicamba ($/a)? | $4.57 | |
| SOYBEANS-Pursuit ($/a)? | $18.84 | |
| CORN HERBICIDE ($/a)? | $25.10 | |
| CORN INSECTICIDE ($/a)? | $13.44 | |
| ALF INSECTICIDE ($/a)? | $5.68 | |
| ALFALFA SEED ($/a)? | $54.60 | |
| CORN SEED ($/a)? | $24.20 | |
| SOYBEAN SEED ($/a)? | $13.08 | |
| GRAIN DRYING ($/BU)? | $0.09 | |
| STORAGE ($/BU? | $0.09 | Six month storage (SWFBM- 0.015/bu/mo) |
| ALF. HAULING ($/ton)? | $3.93 | from transport spreadsheet (5 miles, labor, fuel, equip.) |
| GRAIN HAUL ($/bu)? | $0.14 | approximately $4.50/ton (12 miles, labor, fuel, equip.) |
| TWINE ($/ton)? | $1.40 | |
| LABOR ($/hr)? | $11.00 | |
| FUEL ($/gal)? | $1.00 | |
| OVERHEAD ($/a)? | $8.00 | |

## FIELD OPERATION COSTS

scmidt production

| OPERATION | MACHINE Tractor ($) | Machine ($) | LABOR (hrs/ac) | OTHER | DIRECT & OVERHEAD TOTAL ($) | FUEL (g/acre) |
|---|---|---|---|---|---|---|
| M-BOARD PLOW 5-16? | $5.18 | $4.36 | 0.33 | 0 | $9.54 | 1.72 |
| M-BOARD PLOW 6-16? | $5.68 | $4.10 | 0.27 | 0 | $9.78 | 1.71 |
| DISK CHISEL 16? | $3.78 | $2.64 | 0.11 | 0 | $6.42 | 1.42 |
| FIELD CULTIVATOR 18? | $1.73 | $0.79 | 0.11 | 0 | $2.52 | 0.57 |
| FINISH TDM. DISK 21? | $2.13 | $2.44 | 0.09 | 0 | $4.57 | 0.69 |
| TDM DISK 16? | $1.94 | $2.05 | 0.12 | 0 | $3.99 | 0.64 |
| SPGTOOTH DRAG 48? | $0.39 | $1.39 | 0.04 | 0 | $1.78 | 0.13 |
| FERT. SPREADER 40? | $0.39 | $1.69 | 0.06 | 0 | $2.08 | 0.13 |
| ANHYDROUS APPL. 30? | $1.92 | $4.69 | 0.11 | 0 | $6.61 | 0.67 |
| PRESSWHEEL DRILL 20? | $2.48 | $4.99 | 0.167 | 0 | $7.47 | 0.75 |
| ROWPLANTER 6-30? | $1.33 | $3.74 | 0.218 | 0 | $5.07 | 0.45 |
| BOOM SPRAYER 50? | $0.36 | $0.35 | 0.06 | 0 | $0.71 | 0.12 |
| BOOM SPRAYER 30? | $0.46 | $0.54 | 0.1 | 0 | $1.00 | 0.14 |
| CULTIVATOR 6-30? | $1.21 | $0.78 | 0.13 | 0 | $1.99 | 0.41 |
| MOWER/COND.? | $1.61 | $3.73 | 0.252 | 0 | $5.34 | 0.49 |
| SWATHER/COND. 15? | $0.00 | $12.47 | 0.172 | 0 | $12.47 | 0.48 |
| HAY RAKE 9? | $2.01 | $0.92 | 0.286 | 0 | $2.93 | 0.61 |
| ROUND BALER? | $2.01 | $4.18 | 0.238 | 0 | $6.19 | 0.69 |
| COMBINE GRAIN HD MED.? | $11.27 | $1.31 | 0.279 | 0 | $12.58 | 1.25 |
| GRAIN SWATHER 18? | $0.00 | $6.99 | 0.114 | 0 | $6.99 | 0.32 |
| CORN COMBINE 6-30? | $16.16 | $4.28 | 0.338 | 0 | $20.44 | 1.83 |

## FIELD OPERATIONS PER YEAR (DFSS Rotation)

scmidt production

| | ALFALFA | ALFALFA | ALFALFA | ALFALFA | CORN | CORN | SOYBEANS |
|---|---|---|---|---|---|---|---|
| M-BOARD PLOW 5-16"? | | | | | 1 | 1 | |
| M-BOARD PLOW 6-16"? | | | | | | | |
| DISK CHISEL 16'? | 1 | | | | | | 1 |
| FIELD CULTIVATOR 18'? | 2 | | | | 2 | 2 | 1 |
| FINISH TDM. DISK 21'? | | | | | | | |
| TDM DISK 16'? | | | | | | | 1 |
| SPGTOOTH DRAG 48'? | 1 | | | | | | |
| FERT. SPREADER 40'? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| ANHYDROUS APPL. 30'? | | | | | | | |
| PRESSWHEEL DRILL 20'? | 1 | | | | | | |
| ROWPLANTER 6-30"? | | | | | 1 | 1 | 1 |
| BOOM SPRAYER 50'? | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| BOOM SPRAYER 30'? | | | | | | | |
| CULTIVATOR 6-30"? | | | | | 1 | 1 | 2 |
| MOWER/COND.? | | | | | | | |
| SWATHER/COND. 15'? | 2 | 3 | 3 | 3 | | | |
| HAY RAKE 9'? | 1 | 1 | 1 | 1 | | | |
| ROUND BALER? | 2 | 3 | 3 | 3 | | | |
| COMBINE GRAIN HD MED.? | | | | | | | 1 |
| GRAIN SWATHER 18'? | | | | | | | |
| CORN COMBINE 6-30"? | | | | | 1 | 1 | |
| FIELD OPERATION TTL= | $64.46 | $61.70 | $61.70 | $61.70 | $44.87 | $44.87 | $37.35 |
| N LBS/ACRE= | 0 | 0 | 0 | 0 | 0 | 67 | 0 |
| P LBS/ACRE= | 24 | 52 | 52 | 52 | 59 | 59 | 16 |
| K LBS/ACRE= | 98 | 219 | 219 | 219 | 142 | 142 | 41 |
| 2-4-DB? | 1 | | | | | | |
| Benefin/Eptam? | 1 | | | | | | |
| ALFALFA -Dicamba? | | | | 1 | | | |
| SOYBEANS - Pursuit? | | | | | | | 1 |
| CORN - Dicamba? | | | | | 1 | 1 | |
| CORN INS - Lorsban? | | | | | | 1 | |
| ALFALFA INS - Lorsban? | 1 | 1 | 1 | | | | |
| FUNG. 1 (pts/acre)? | | | | | | | |
| ALFALFA SEED? | 1 | | | | | | |
| CORN SEED? | | | | | 1 | 1 | |
| SOYBEAN SEED? | | | | | | | 1 |
| GRAIN DRYING? | | | | | 1 | 1 | |
| STORAGE (% of yield)? | | | | | 0.5 | 0.5 | 0.5 |
| TRANSPORTATION? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TWINE? | 1 | 1 | 1 | 1 | | | |
| SUB TOTAL= | $99.08 | $43.01 | $43.01 | $41.90 | $84.65 | $112.86 | $39.16 |
| STORAGE= | $0.00 | $0.00 | $0.00 | $0.00 | $4.81 | $4.81 | $1.60 |
| TRANSPORTATION= | $7.73 | $17.18 | $17.18 | $17.18 | $14.96 | $14.96 | $4.98 |
| LABOR= | $20.05 | $18.00 | $18.00 | $18.00 | $14.92 | $14.92 | $13.39 |
| RENT= | $70.25 | $70.25 | $70.25 | $70.25 | $70.25 | $70.25 | $70.25 |
| DIRECT CASH EXPENSE= | $197.11 | $148.44 | $148.44 | $147.33 | $189.59 | $217.80 | $129.38 |
| OVERHEAD= | $8.00 | $8.00 | $8.00 | $8.00 | $8.00 | $8.00 | $8.00 |
| TOTAL EXPENDITURES (/=a) | $269.57 | $218.14 | $218.14 | $217.03 | $242.46 | $270.67 | $174.73 |
| Expenses /ton (/bu)= | $137.04 | $49.90 | $49.90 | $49.65 | $2.27 | $2.53 | $4.91 |
| $/ton or $/bu (no trans.)= | $133.11 | $45.97 | $45.97 | $45.72 | $2.13 | $2.39 | $4.77 |
| GROSS REVENUE (/a)= | $137.69 | $305.98 | $305.98 | $305.98 | $259.72 | $259.72 | $213.91 |
| NET RETURN (/a)= | ($131.88) | $87.85 | $87.85 | $88.96 | $17.27 | ($10.94) | $39.18 |

## FIELD OPERATIONS PER YEAR (Traditional Rotation)

scmidt production

| | CORN | BEANS | |
|---|---|---|---|
| M-BOARD PLOW 5-16? | | 1 | |
| M-BOARD PLOW 6-16? | | | |
| DISK CHISEL 16'? | 1 | | |
| FIELD CULTIVATOR 18'? | 2 | 2 | |
| FINISH TDM. DISK 21'? | | | |
| TDM DISK 16'? | | | |
| SPGTOOTH DRAG 48'? | | | |
| FERT. SPREADER 40'? | | 1 | |
| ANHYDROUS APPL. 30'? | 1 | | |
| PRESSWHEEL DRILL 20'? | | | |
| ROWPLANTER 6-30? | 1 | 1 | |
| BOOM SPRAYER 50'? | 1 | 1 | |
| BOOM SPRAYER 30'? | | | |
| CULTIVATOR 6-30? | 1 | 2 | |
| MOWER/COND.? | | | |
| SWATHER/COND. 15'? | | | |
| HAY RAKE 9'? | | | |
| ROUND BALER? | | | |
| COMBINE GRAIN HD MED.? | | 1 | |
| GRAIN SWATHER 18'? | | | |
| CORN COMBINE 6-30? | 1 | | |
| FIELD OPERATION TTL= | $46.28 | $39.00 | |
| N LBS/ACRE= | 102 | 0 | |
| P LBS/ACRE= | 59 | 16 | |
| K LBS/ACRE= | 142 | 41 | |
| 2-4-DB? | | | |
| Benefin/Eptam? | | | |
| ALFALFA -Dicamba? | | | |
| SOYBEANS - Pursuit? | | 1 | |
| CORN - Dicamba? | 1 | | |
| CORN INS - Lorsban? | | | |
| ALFALFA INS - Lorsban? | | | |
| FUNG. 1 (pts/acre)? | | | |
| ALFALFA SEED? | | | |
| CORN SEED? | 1 | | |
| SOYBEAN SEED? | | 1 | |
| GRAIN DRYING? | 1 | | |
| STORAGE (% of yield)? | 0.5 | 0.5 | |
| TRANSPORTATION? | 1 | 1 | |
| TWINE? | | | |
| SUB TOTAL= | $96.90 | $39.16 | |
| STORAGE= | $4.81 | $1.60 | |
| TRANSPORTATION= | $14.96 | $4.98 | |
| LABOR= | $13.05 | $15.70 | |
| RENT= | $70.25 | $70.25 | |
| DIRECT CASH EXPENSE= | $199.97 | $131.69 | |
| OVERHEAD= | $8.00 | $8.00 | |
| TOTAL EXPENDITURES (/=a) | $254.25 | $178.69 | |
| Expenses /ton (/bu)= | $2.38 | $5.02 | |
| $/ton or $/bu (no trans.)= | $2.24 | $4.88 | |
| GROSS REVENUE (/a)= | $259.72 | $213.91 | |
| NET RETURN (/a)= | $5.47 | $35.22 | $20.34 |

## ENERGY USAGE

scmidt production

| | |
|---|---|
| Btu / gal diesel? | 138800 |
| Herbicide production (btu/lb)? | 150000 |
| Insecticide production (btu/lb)? | 150000 |
| Nitrogen production (Btu/lb-N)? | 31000 |
| Phosphorus production (Btu/lb-P)? | 5000 |
| Potash Production (Btu/lb-K)? | 4000 |
| Alfalfa Seed Production (Btu/lb)? | 111000 |
| Corn Seed Production (Btu/lb)? | 44700 |
| Soybean Seed Production (Btu/lb)? | 13560 |

| | 7 yr total DFSS Quantity/A | 7 yr total C/S Quantity/a | 7yr DFSS BTU | 7yr C/S BTU | 14yr DFSS BTU | 14yr CORN BTU |
|---|---|---|---|---|---|---|
| Direct Fuel Input (g/acre) | 36.87 | 40.85 | 5,117,556 | 5,669,286 | 1.02E+07 | 1.13E+07 |
| INDIRECT ENERGY INPUTS | | | | | | |
| man. and main. | 18.44 | 20.42 | 2,558,778 | 2,834,643 | 5.12E+06 | 5.67E+06 |
| N -lbs/a (31,000 btu/lb) | 67 | 358 | 2,081,774 | 11,083,708 | 4.16E+06 | 2.22E+07 |
| P -lbs/a (5000 btu's/lb) | 315 | 262 | 1,572,808 | 1,309,033 | 3.15E+06 | 2.62E+06 |
| K-lbs/a (4000 btu's/lb) | 1080 | 642 | 4,318,617 | 2,568,169 | 8.64E+06 | 5.14E+06 |
| 2,4-DB lb/a (0.4 lbs AI/a) | 0.40 | 0.00 | 60,000 | 0 | 1.20E+05 | 0.00E+00 |
| BENEFIN lb/a (0.75 lbs AI/a) | 1.50 | 0.00 | 225,000 | 0 | 4.50E+05 | 0.00E+00 |
| DICAMBA lb/a (0.5 lbs AI/a) | 0.50 | 0.00 | 75,000 | 0 | 1.50E+05 | 0.00E+00 |
| PURSUIT lb/a (0.05 lbs AI/a) | 0.05 | 0.18 | 7,500 | 26,250 | 1.50E+04 | 5.25E+04 |
| CORN DICAMBA lb/a (1.1 lbs AI/a) | 2.20 | 3.85 | 330,000 | 577,500 | 6.60E+05 | 1.16E+06 |
| TOTAL | | | | | | |
| CRN-LORSBAN (0.075 lb AI/a) | 0.08 | 0.00 | 11,250 | 0 | 2.25E+04 | 0.00E+00 |
| ALF-LORSBAN (0.5 lb AI/a) | 1.50 | 0.00 | 225,000 | 0 | 4.50E+05 | 0.00E+00 |
| FUNG. 1 (0.5 lb AI/a) | 0.00 | 0.00 | 0 | 0 | 0.00E+00 | 0.00E+00 |
| ALFALFA SEED (lbs) | 12.5 | 0.0 | 1,387,500 | 0 | 2.78E+06 | 0.00E+00 |
| CORN SEED (lbs) | 30.0 | 52.5 | 1,341,000 | 2,346,750 | 2.68E+06 | 4.69E+06 |
| SOYBEAN SEED (lbs/a) | 75.0 | 262.5 | 1,017,000 | 3,559,500 | 2.03E+06 | 7.12E+06 |
| GRAIN DRY(bu) (14840 btu/bu) | 214 | 374 | 3,172,279 | 5,551,487 | 6.34E+06 | 1.11E+07 |
| RANSPORT. (ton) (4700 Btu/lb/mi | 22.15 | 14.27 | 776,712 | 805,050 | 1.55E+06 | 1.61E+06 |
| | | | 2.43E+07 | 3.63E+07 | 4.86E+07 | 7.27E+07 |
| | | Btu/yr/a= | 3.47E+06 | 5.19E+06 | 3.47E+06 | 5.19E+06 |

YIELD (14 YR)

| | DFSS | CS | |
|---|---|---|---|
| Alfalfa (15% moisture) | 30 | 0 | tons |
| Corn (15% moisture) | 428 | 748 | bushel |
| Soybeans (15% moisture) | 71 | 249 | bushel |

GROSS ENERGY OUTPUT (14 YR)

| | | | |
|---|---|---|---|
| Alfalfa(8116 BTU/lb) | 4.16E+08 | 0.00E+00 | Btu |
| Corn (8616 BTU/lb) | 1.75E+08 | 3.07E+08 | Btu |
| Beans (8616 BTU/lb) | 3.18E+07 | 1.11E+08 | Btu |
| TOTAL | 6.23E+08 | 4.18E+08 | Btu |
| Btu OUT / Btu IN | 12.84 | 5.75 | |

PROTEIN PRODUCED (14 YR)

| | | | |
|---|---|---|---|
| Alfalfa (18% dm) | 9230 | 0 | lbs |
| Corn (10% dm) | 2035 | 3561 | lbs |
| Soybeans (42% dm) | 1525 | 5337 | lbs |
| TOTAL | 12789 | 8898 | lbs |

**Appendix 5.2 Guide to using "LOGISTICS" spreadsheet.**

A spreadsheet entitled "LOGISTICS" was developed (Microsoft EXCEL 4.0) to assist in analyzing the economics of alfalfa transportation and storage. As outlined in the text, several assumptions must be made. The following is a guide to using the spreadsheet. As a point of reference, all line items in bold type are calculated values while all items in normal type are user inputs.

The first two sections of the worksheet "PLANT NEEDS AND DEMOGRAPHICS" and"STORAGE AND TRANSPORTATION INPUTS" are where the initial assumptions are made. The following briefly describes the inputs needed.

## PLANT NEEDS AND DEMOGRAPHICS

| | |
|---|---|
| Tons stems/day needed? | Input the amount of stems per day needed for conversion on a dry matter basis |
| % ave moisture? | Input the average moisture content of the baled alfalfa (at the time of baling). (Assume constant moisture content throughout storage.) |
| %stems? | Input that percent of the alfalfa which will be going to the gassifier |
| d.m. storage loss- roof? | estimated amount of dry matter loss with bales stored under a roof (average over the period stored) |
| plastic? | estimated amount of dry matter loss when bales are stored with plastic (average over the period stored) |
| no cover? | estimated amount of dry matter loss when bales are stored with no cover (average over the period stored) |
| days/yr operating? | Input the number of days the gassifier will be operating |
| ave tons/acre? | Input the predicted average yield per acre of alfalfa (at the percent moisture content input above) |
| biomass shed rad (ml)? | Input the assumed bioshed radius |
| % of bioshed tillable? | Input the estimated amount of the bioshed that is usable farmland. |

## STORAGE &TRANSPORTATION

| | |
|---|---|
| bale density? | Input the estimated density of the baled alfalfa (at harvest) |
| % direct hauled? | Input the percent of alfalfa that will be transported directly to the plant i.e. not requiring any storage after final alfalfa cutting. |
| % stored on farm? | Input the predicted amount of alfalfa that will be stored on producer's farms. |
| regional radius (ml)? | Input the desired furthest distance growers will be from a regional storage area (as the crow flies). This furthest distance is also the average distance that must be traveled (over the road) by producers in this radius. |

| | |
|---|---|
| alfalfa acres/farm? | Input the expected average number of acres in alfalfa for all cooperating producers. |
| bale length? | Input the specified round bale length |
| bale diameter? | Input the specified bale diameter.(Note: Specific bale length and width are needed to optimize bale transportation) |

From these initial inputs a variety of numbers are calculated. Most notably, the number or regional storage sites required to give the average radius per site; the tons per year of alfalfa needed to be grown as a function of storage method; the acres per year planted in alfalfa needed to grow this amount of alfalfa and the percent of acreage in the bioshed that must be in alfalfa acres to produce the given amount of alfalfa. This summary section also notes the number of growers needed, the tons of alfalfa hauled direct and the tons of alfalfa stored.

The next section of inputs deals with transportation. The costs calculated in this section take into consideration alfalfa dry matter loss in storage and the tons of alfalfa hauled direct.

## TRANSPORTATION (STORAGE TO PLANT)

| | |
|---|---|
| Days/wk hauling? | Input how many days trucks will be operating |
| days/wk burning? | Input the days per week that the gassifier will be using stem material. |
| average speed (mph)? | Input the average speed trucks will be traveling from the storage site to the fractionating facility. |
| hours per day on road | Input the number of operating hours for the truck |
| load time (bales/min) | Input the number of minutes to load the truck at the storage site |
| unload time (bales /min) | Input the number of minutes to unload the truck at the fractionating plant. |
| truck width | Input the width of the stacked bales (not used in calculations - critical factor is the number of bales hauled per load) |
| truck length | Input the length of load (not used in calculations - critical factor is the number of bales hauled per load) |
| truck height | Input the height of the stacked bales (not used in calculations - **critical factor is the number of bales hauled per load)** |
| bales/load | Input the estimated number of bales hauled per load |
| cost/mile | Input the cost per round trip mile. Include labor, maintenance fuel, and purchase. |

"TRANSPORTATION COSTS SUMMARY" lists several aspects of transportation that result from the inputs given. The final output line "Direct and stored trans cost" give the cost of transportation when the given percentages of alfalfa are hauled direct and stored.

The next section involves calculating storage costs. Inputs needed relate to different types of storage methods - and the storage area needed for each method. Also needed are costs for various inputs. Two methods of storing hay under a rood are analyzed. The first is when bales are stored on end, the second, when bales are stored on their side in a pyramid. Two plastic cover scenarios are also analysed: with tarp life of one year and tarp life of three years.

**ROOFED STORAGE (on end)**

| | |
|---|---|
| # bales high? | Input the number of bales stacked on end |
| Building cost / ft2? | Input building costs per square foot (cost of building only -land preparation costs are listed elsewhere. |

**ROOFED STORAGE (on side)**

| | |
|---|---|
| # bales in pyramid? | Input the number of bales in the pyramid - for example, if a stack had three bales on the bottom, two bales on the second row and one bale on top the number input would be "6".. |
| # bales in bottom row? | Input the number of bales on the bottom row |
| # rows high? | Input the number of # of rows of bales (For example, a 3,2,1 pyramid has three rows. |

**PLASTIC TARPS**

| | |
|---|---|
| # bales in pyramid? | Input the number of bales in the pyramid (For example a 4-3-2-1 pyramid input "10". |
| # bales in bottom row? | Input the number of bales on the bottom row.(For the previous example input "4"). |
| 1 yr life tarp cost (/bale)? | Input the cost of the plastic tarp - tarp with a one year life include all clamps, springs, stakes, (also include landfill costs for tarp disposal). |
| 3 yr life tarp cost (/bale)? | Estimate of the cost of plastic tarp if it can be reused for three years (this cost must also include the extra cost for storing these tarps). |
| labor for tarp (min/bale)? | Estimate of time needed to cover and uncover bales |

## ADDITIONAL INFORMATION

| | |
|---|---|
| labor cost ($/hr)? | Input the cost of labor - include all benefits |
| land value (/acre/yr)? | Input land rental rate |
| additional land needed? | Input the percent increase in land that is needed at the storage site for driveways, buffer strips, parking, etc.. |
| land preparation cost ($/acre)? | Input the cost of preparing the site for storage. This price involves land leveling, removing topsoil, and hauling in and leveling gravel base. |
| Loader?: | Input the purchase price of a loader - for unloading and loading bales at the remote site. |
| equip-testing, weighing, etc? | Input the cost of additional equipment needed at each site. This cost includes office equipment, bale testing equipment, weigh scales, computers, bar coding equipment, etc. |
| DIRTI? | Depreciation, interest, repairs, taxes, and insurance on all capital expenditures. |

Outputs given from this set of input include estimated total costs of storage as a function of storage method and a breakdown of these costs. Also included are estimated costs per storage site.

The following section of the worksheet deals with equipment needs. As it turns out, the number of sets of equipment needed dictates the optimum number of storage sites. The equipment needed is a function of the peak rate at which alfalfa will be brought to storage. If indeed bales are to be stored under plastic or under a roof, it is critical that these bales are unloaded and stored in a timely manner. If bales are to be stored outside the rapid rate of bale stacking is not needed, thus reducing equipment needs.

## CALCULATING EQUIPMENT NEEDS

| | |
|---|---|
| hauling equipment? | Input the cost of to transport alfalfa from the field to the storage site. This number includes direct and overhead costs, i.e., cost of purchase, maintenance and fuel. but no labor. |
| Ave # of bales per load? | Input the average number of bales on a load coming from the field |
| average mph? | Input the average miles per hour for transportation from the field to the storage site. (Include field travel, gravel road travel and highway travel) |
| loading time min/bale? | Input the anticipated time to pick up and load a bale at the production site. Typically the bales will be in the field. |
| % 1st cutting? | Input the amount of alfalfa that will be coming in during the peak harvest season |

| | |
|---|---|
| # days allowed to store? | Input the number of days that are included in the peak season (For example if the peak season is estimated at 33% of total alfalfa production for the year will be done in 15 days: % first cutting will be '33' and # days to store will be '15'). |
| Storage site hours/day? | Input the hours of operation the storage site will be operating during peak season |
| Processing time/bale? | Input the estimated number of minutes it will take to process one bale of alfalfa. (This processing time includes bale testing, weighing, unloading and stacking). |

These inputs are used to calculate the sets of equipment needed, the number of equipment per site (for the given amount of sites), and the costs to transport alfalfa from the production site to the storage site.

The final page of the worksheet is a summary page. All information given has been calculated on prior pages. The only input needed is the price paid to producers for their alfalfa. This is needed to determine the true cost of alfalfa as it enters the fractionation facility. This "Paid to producer" input could be a preselected value or a the cost of producing alfalfa as determined by the alfalfa production spreadsheet.

As stated previously, there are many assumptions made in this worksheet. Many of which could dramatically effect the final cost of alfalfa at the fractionation facility.

# ALFALFA STORAGE AND TRANSPORTATION WORKSHEET

**PLANT NEEDS AND DEMOGRAPHICS** 8/25/94

| | | |
|---|---|---|
| tons stems/dy needed? | 992 | dry |
| % ave. moisture? | 15 | |
| **tons stems needed=** | **1167** | at moisture average moisture content specified |
| % stem? | 55 | |
| **tons hay needed=** | **2122** | |
| d.m. store loss roof (%)? | 2 | |
| plastic (%)? | 5 | |
| no cover (%)? | 10 | |
| days/yr operating? | 300 | |
| ave. tons/acre? | 4 | at 15% moisture |
| biomass shed rad (mi)? | 40 | |
| % of bioshed tillable? | 80 | |

**STORAGE TRANSPORTATION INPUTS**

| | | | | |
|---|---|---|---|---|
| bale density lb/ft3? | 10 | | | |
| % direct hauled? | 40 | | | |
| % stored on farm? | 0 | **region** | **region** | |
| **% stored regional=** | **60** | **sides (miles)** | **sq miles** | **# regions** |
| region radius (mi)? | 4.0 | **8.0** | **64** | **78.54** |
| alfalfa acres/farm? | 200 | | | |
| bale length? | 4.00 | | | |
| bale diameter? | 6.00 | | | |
| **bale volume =** | **113.10** | **cubic feet/bale** | | |
| **bale wt. (lbs)=** | **1131** | **before loss** | | |

**SUMMARY INFORMATION**

| | no cover | plastic | roof | no loss | |
|---|---|---|---|---|---|
| **tons/year=** | **679,016** | **656,680** | **644,372** | **636,578** | |
| **acres needed=** | **178,688** | **172,811** | **169,572** | **167,520** | |
| **bales/year=** | **1,200,765** | **1,161,266** | **1,139,501** | **1,125,717** | |
| **% acres in bioshed=** | **6.94** | **6.71** | **6.59** | **6.51** | **(acres in alfalfa)** |

**STORAGE STATISTICS**

**DIRECT HAUL**

| | no cover | plastic | roofed |
|---|---|---|---|
| **# of growers=** | **893** | **864** | **848** |
| **acres direct haul=** | **67,008** | **67,008** | **67,008** |
| **tons direct haul=** | **254,631** | **254,631** | **254,631** |

**TOTAL TO STORAGE**

| | no cover | plastic | roof |
|---|---|---|---|
| **acres stored=** | **111,680** | **105,802** | **102,564** |
| **tons stored=** | **424,385** | **402,049** | **389,741** |

**PER REGION TOTALS**

**DIRECT HAULED AND STORED**

| | NO COVER | PLASTIC | ROOFED |
|---|---|---|---|
| acres of alfalfa direct= | 853 | 853 | 853 |
| acres of alf. to storage= | 1,422 | 1,347 | 1,306 |
| tons direct= | 3,242 | 3,242 | 3,242 |
| tons stored= | 5,403 | 5,119 | 4,962 |

**STORAGE PER REGION**

**% on farm = 0.00 % at site= 100.00**

| | NO COVER | PLASTIC | ROOFED |
|---|---|---|---|
| on farm acres= | 0 | 0 | 0 |
| on farm tons= | 0 | 0 | 0 |
| at site acres= | 1,422 | 1,347 | 1,306 |
| at site tons= | 5,403 | 5,119 | 4,962 |

# TRANSPORTATION (STORAGE TO PLANT)

| | | |
|---|---|---|
| Days/week hauling? | 6 | |
| days/week burning? | 7 | |
| average speed (mph)? | 40 | |
| hours/day on road? | 16 | |
| ad time (minutes/bale)? | 0.50 | 15.0 minutes per load |
| ad time (minutes/bale)? | 0.33 | 9.9 minutes per load |
| truck width (ft)? | 9 | not used in calculations but should match bales per load |
| truck length (ft)? | 48 | not used in calculations |
| truck height (ft)? | 9 | not used in calculations |
| bales /load? | 30 | |
| cost per mile? | $1.50 | cost per loaded mile - overhead and direct includes labor |
| **cu ft per load=** | **3,393** | bale volume |

**TRANSPORTATION COSTS SUMMARY**

| | NO COVER | PLASTIC | ROOF | DIRECT HAUL |
|---|---|---|---|---|
| (includes store loss) tons/truck = | 15.3 | 16.1 | 16.6 | 17.0 |
| tons per day needed to haul= | 2476 | 2476 | 2476 | 2476 |
| trucks per day = | 162.14 | 153.61 | 148.90 | 145.93 |
| time per load (hrs) = | 2.42 | 2.42 | 2.42 | 2.42 |
| # loads/truck/day = | 6.63 | 6.63 | 6.63 | 6.63 |
| #trucks needed = | 24.47 | 23.18 | 22.48 | 22.03 |
| miles/truck/day = | 530.02 | 530.02 | 530.02 | 530.02 |
| miles/yr/truck= | 136,291 | 136,291 | 136,291 | 136,291 |
| transport cost= | $2,501,591 | $2,369,929 | $2,297,380 | $2,251,432 |
| trans cost *(%) method= | $1,500,955 | $1,421,957 | $1,378,428 | $900,573 |
| Direct and stored trans cost= | $2,401,528 | $2,322,530 | $2,279,001 | $2,251,432 |

# Remote Storage Costs

| | | | |
|---|---|---|---|
| **ROOFED** | **Bales on end** | | |
| | #bales high? | 5 | |
| | **stack height (ft)=** | **20** | bales on end |
| | **storage loss building (%)=** | **2.0** | |
| | building cost /ft2? | $5.50 | |
| **ROOFED** | **Bales stored their side (pyramid)** | | |
| | # bales in pyramid? | 46 | |
| | # bales in bottom row? | 13 | |
| | # rows high? | 4 | |
| | **aprox. stack height (ft)=** | **22** | |
| | **storage loss (%)=** | **2.0** | |
| **PLASTIC** | | | |
| | # bales / pyramid? | 10 | |
| | #bales on bottom row? | 4 | |
| | **storage loss plastic (%)=** | **5.0** | |
| | 1 year life tarp cost (/bale)? | $3.50 | new tarp each year includes landfill cost |
| | 3 year life -tarp cost (/bale)? | $1.25 | tarp every 3 years includes landfill cost |
| | labor for tarp (min/bale)? | 1.50 | (4 hours/144 bales—includes removal) |
| **NO COVER** | | | |
| | # bales/pyramid? | 1 | |
| | # bales on bottom row? | 1 | |
| | **storage loss outside (%)=** | **10.0** | |

**ADDITIONAL NEEDS FOR ALL STORAGE AREAS (PER SITE)**

| | | |
|---|---|---|
| labor cost (/hr) | $11.00 | |
| land value(/acre/year) | $100.00 | land cost |
| **labor/bale?** | **$0.55** | stacking (includes weigh, test, unload, stack) |
| additional land needed /site(%)? | 10 | NO COVER (for driveways, etc.) |
| additional land needed /site(%)? | 100 | PLASTIC (for driveways, etc.) |
| additional land needed /site(%)? | 100 | ROOF (for driveways, etc.) |
| land preparation ($/acre)? | $20,000.00 | (remove topsoil replace with gravel) |
| loader? | $70,000 | per set (purchase price) |
| equip—testing, weighing, etc? | $100,000 | per set (purchase price) |
| DIRTI (%)? | 15.00 | depreciation, interest, repair, taxes, insurance |

DATA FOR ALL SITES

| | NO COVER | 1 YR PLASTIC | 3 YR PLASTIC | On End ROOF | On Side ROOF |
|---|---|---|---|---|---|
| tons to store= | 424,385 | 402,049 | 402,049 | 389,741 | 389,741 |
| #bales to store= | 750,477 | 710,979 | 710,979 | 689,214 | 689,214 |
| acres for storage= | 620 | 157 | 157 | 114 | 107 |
| total land area= | 682 | 313 | 313 | 228 | 215 |

STORAGE COSTS

| | | | | | |
|---|---|---|---|---|---|
| building costs/yr= | $0 | $2,488,425 | $888,723 | $4,093,931 | $3,856,602 |
| cost of land/yr= | $68,225 | $31,338 | $31,338 | $22,784 | $21,463 |
| land preparation cost= | $2,046,757 | $940,137 | $940,137 | $683,518 | $643,894 |
| equipment cost/ yr= | $2,105,091 | $2,035,845 | $2,035,845 | $2,002,764 | $2,002,764 |
| labor/yr (all bales)= | $660,421 | $958,045 | $958,045 | $626,726 | $626,726 |
| TOTAL COST/YR= | $4,880,494 | $6,453,789 | $4,854,087 | $7,429,722 | $7,151,448 |
| cost per bale= | $4.06 | $5.56 | $4.18 | $6.52 | $6.28 |
| cost per ton= | $7.19 | $9.83 | $7.39 | $11.31 | $11.10 |

SUMMARY PER STORAGE SITE

| | NO COVER | 1 YR PLASTIC | 3 YR PLASTIC | On End ROOF | On Side ROOF |
|---|---|---|---|---|---|
| tons / site= | 5403 | 5119 | 5119 | 4962 | 4962 |
| total acres / site= | 8.69 | 3.99 | 3.99 | 2.90 | 2.73 |
| bales / site= | 9555 | 9052 | 9052 | 8775 | 8775 |
| haul days / site= | 2.29 | 2.29 | 2.29 | 2.29 | 2.29 |

# EQUIPMENT / TIME STUDY

## EQUIPMENT NEEDS - ON FARM AND AT STORAGE SITE

| | | |
|---|---|---|
| **farm labor ($/hr)=** | **$11.00** | |
| hauling equipment ($/mi)? | $1.00 | per loaded mile-direct and overhead--no labor costs |
| Ave # bales per load? | 10 | |
| average mph? | 15 | |
| loading time minutes/bale? | 2.0 | |
| % per 1st cutting? | 33 | |
| # days allowed to store? | 15 | |
| storage site hours/day? | 16 | |
| processing time/bale (min)? | 3.0 | per set of equipment |

## BALE UNLOADING TIME (PEAK)

| | NO COVER | PLASTIC | ROOF |
|---|---|---|---|
| bales per hour= | 1651.05 | 1596.74 | 1566.81 |
| bales per minute= | 27.52 | 26.61 | 26.11 |
| bales/hr/site= | 21.02 | 20.33 | 19.95 |

## EQUIPMENT NEEDS

| | | | |
|---|---|---|---|
| equipment needed (total)= | 82.55 | 79.84 | 78.34 |
| equipment / site= | 1.05 | 1.02 | 1.00 |
| min equipment needed= | 83 | 80 | 79 |

## TRANSPORTATION COSTS - FARM TO STORAGE (assume all bales go through storage)

| | NO COVER | PLASTIC | ROOF |
|---|---|---|---|
| Total tons hauled= | 679,016 | 656,680 | 644,372 |
| total # bales= | 1,200,765 | 1,161,266 | 1,139,501 |
| Total miles= | 960,612 | 929,013 | 911,601 |
| Load and unload= | 100,064 | 96,772 | 94,958 |
| total hrs on road= | 64,041 | 61,934 | 60,773 |
| LABOR COST TO HAUL= | $1,805,150 | $1,745,770 | $1,713,051 |
| HAUL EQUIPMENT COST= | $480,306 | $464,506 | $455,801 |
| TOTAL COST= | $2,285,456 | $2,210,277 | $2,168,851 |
| Cost per bale= | $1.90 | $1.90 | $1.90 |
| Cost per ton= | $3.37 | $3.37 | $3.37 |

# Summary of Farm Transport, Storage and Plant Transport.

## BASIC INFORMATION

| | | |
|---|---|---|
| Bioshed radius= | 40 | |
| Haul radius= | 4.0 | |
| Percent stems= | 55 | |
| Tons of stems/day= | 1167 | |
| Total tons per day= | 2122 | |
| Total tons to plant= | 636,578 | |
| Tons leaves generated | 286,460 | (assumes dry matter losses are the same in leaf and stem) |
| Number of sites= | 79 | (number of sites to get desired average haul distance for producers) |

## TOTALS PER YEAR

| | NO COVER | 1 year use PLASTIC | 3 year use PLASTIC | ROOF (END) | ROOF (SIDE) |
|---|---|---|---|---|---|
| Tons alfalfa per year | 679,016 | 656,680 | 656,680 | 644,372 | 644,372 |
| Number of bales | 1,200,765 | 1,161,266 | 1,161,266 | 1,139,501 | 1,139,501 |
| Acres in bioshed | 178,688 | 172,811 | 172,811 | 169,572 | 169,572 |
| % acres in bioshed | 6.9% | 6.7% | 6.7% | 6.6% | 6.6% |
| Equipment needed (Optimum # sites) | 83 | 80 | 80 | 79 | 79 |

## STORAGE PER REGION

| | | | | | |
|---|---|---|---|---|---|
| Tons / site= | 5403 | 5119 | 5119 | 4962 | 4962 |
| No. bales / site= | 9555 | 9052 | 9052 | 8775 | 8775 |
| storage acres / site= | 7.9 | 2.0 | 2.0 | 1.5 | 1.4 |
| Total acres / site= | 8.7 | 4.0 | 4.0 | 2.9 | 2.7 |
| Haul days / site= | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |

## COST BREAKDOWN

| | | | | | |
|---|---|---|---|---|---|
| Transport to storage | $2,285,456 | $2,210,277 | $2,210,277 | $2,168,851 | $2,168,851 |
| Storage | $4,880,494 | $6,453,789 | $4,854,087 | $7,429,722 | $7,151,448 |
| Transport to plant | $2,401,528 | $2,322,530 | $2,322,530 | $2,279,001 | $2,279,001 |
| TOTAL | $9,567,478 | $10,986,596 | $9,386,894 | $11,877,574 | $11,599,300 |
| After loss cost/ton | $15.03 | $17.26 | $14.75 | $18.66 | $18.22 |

## TOTAL COSTS: PRODUCTION, TRANSPORTATION AND STORAGE

| | | *cost transport to stora* | *price allowed-production* |
|---|---|---|---|
| Paid to producer | $60.00 | *$3.37* | *$56.63* |

| | | | | | |
|---|---|---|---|---|---|
| Payout to producers= | $40,740,963 | $39,400,799 | $39,400,799 | $38,662,342 | $38,662,342 |
| Payout for store/trans= | $7,282,021 | $8,776,319 | $7,176,618 | $9,708,723 | $9,430,449 |
| TOTAL COSTS= | $48,022,984 | $48,177,119 | $46,577,417 | $48,371,065 | $48,092,791 |
| Cost per ton at plant= | $75.44 | $75.68 | $73.17 | $75.99 | $75.55 |

# APPENDIX 9

The following graphs should be understood by growers and the contractor so that the two parties can enter into agreements with equal information.

Graph 9.2-1, also presented as 4.2-5, is particularly useful for producers to help them realize that the quality of their land and the cutting system that they are using affect the price per ton of alfalfa that makes the DFSS rotation equal C-S. A grower should know the inherent quality of his land and a contractor should understand the quality ranges of land on which he seeks to contract alfalfa and the yields he is likely to produce.

Graph 9.2-2 is useful for producers and contractors to help them understand the combinations of component prices of leaves and stems in a 3-cut system that are necessary in order to reach $60 and $70/T.

Graph 9.2-3 shows how a $60/T. price of hay represents different prices for the leaf and stem components depending upon the harvest schedules utilized. This graph reflects how changes in leaf-stem ratios due to alternative cutting schedules affect leaf and stem component prices.

Graph 9.2-4 shows the combined effects of the two previous graphs and the interactions between per ton hay prices and cutting schedules and how leaf and stem prices are affected. It is interesting to see the intersection of lines where stem price is $33/T. and leaf price is $100/T. The lines intersecting tell us that this combination of component prices occurs on a two cut system at $60/T. and on a four cut system at $70/T. If contractors and farmers are not aware of these dynamics in the type of contract they develop, they will soon wish to part company.

Graph 9.2-5 can help join ventures running fractionation realize the payments they will have to make for alfalfa leaves when they are paying $30 for stems for alfalfa produced by different cutting schedules on land of various CER's.

**Figure 9.2-1** Breakeven price for alfalfa (in a DFSS rotation) with traditional corn-soybean returns under three different cutting schedules and for land with various productivities (CER).

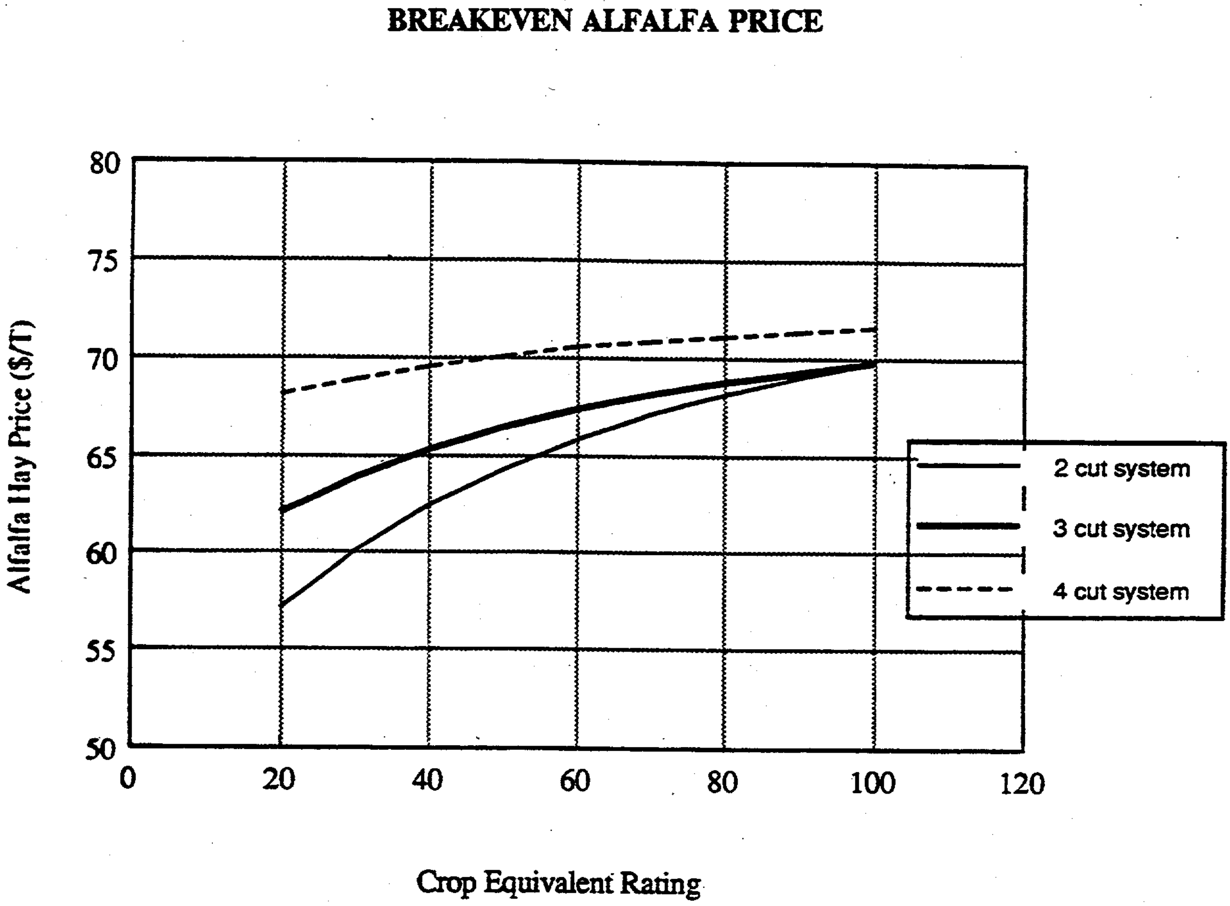


**Figure 9.2-2** Leaf and stem prices needed yield $60 or $70 per ton (aggregate) under a three-cut harvest schedule.

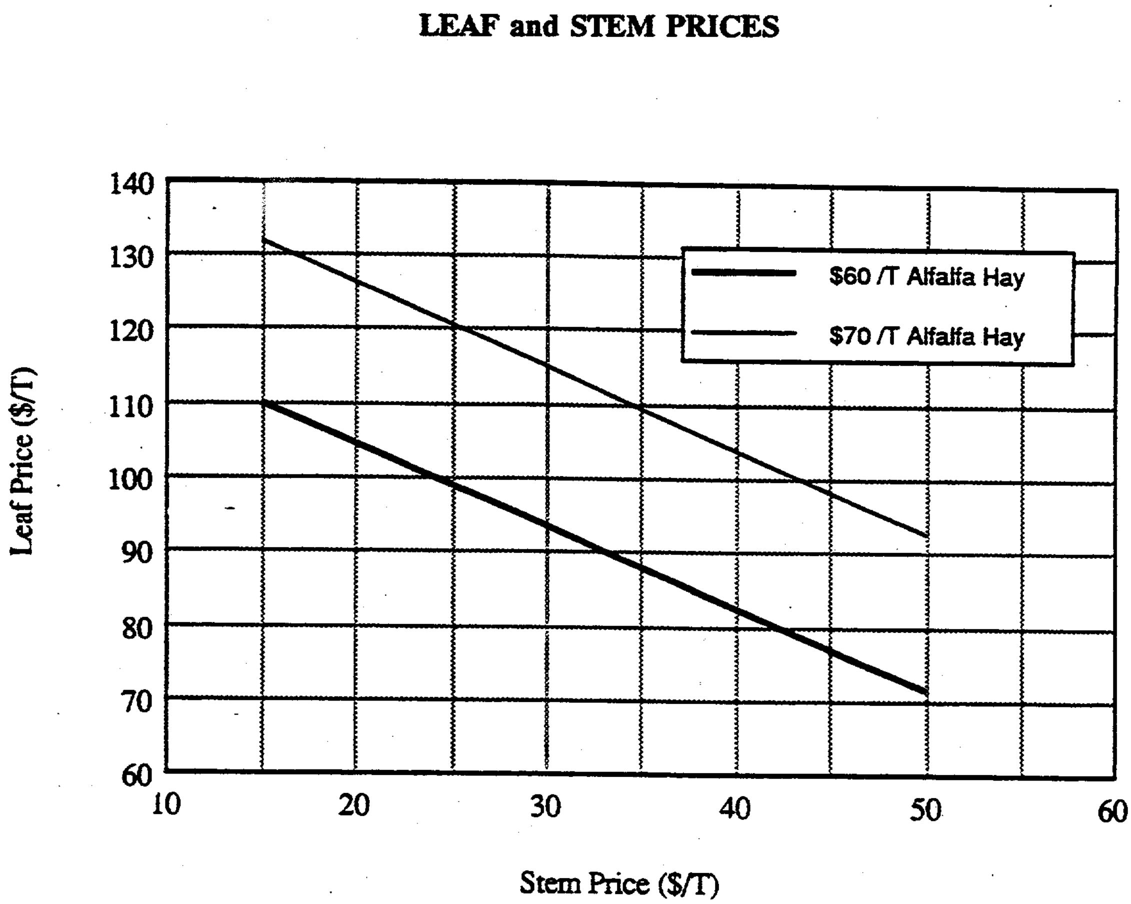


**Figure 9.2-3** Leaf and stem prices needed to yield $60 per ton (aggregate) under a two-, three-, or four-cut harvest schedule.

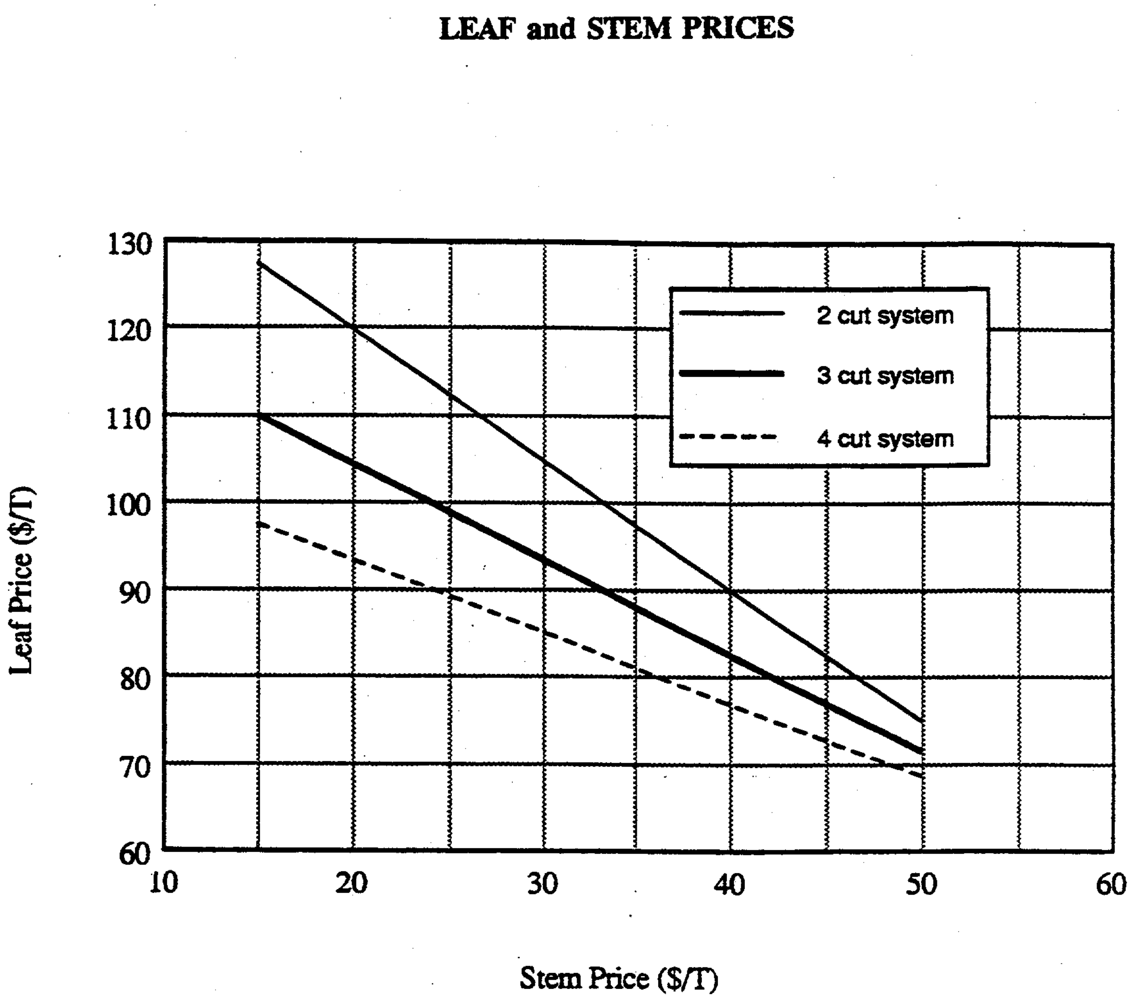


**Figure 9.2-4** Leaf and stem prices needed to yield $60 or $70 per ton (aggregate) under a two-, three-, or four-cut harvest schedule.

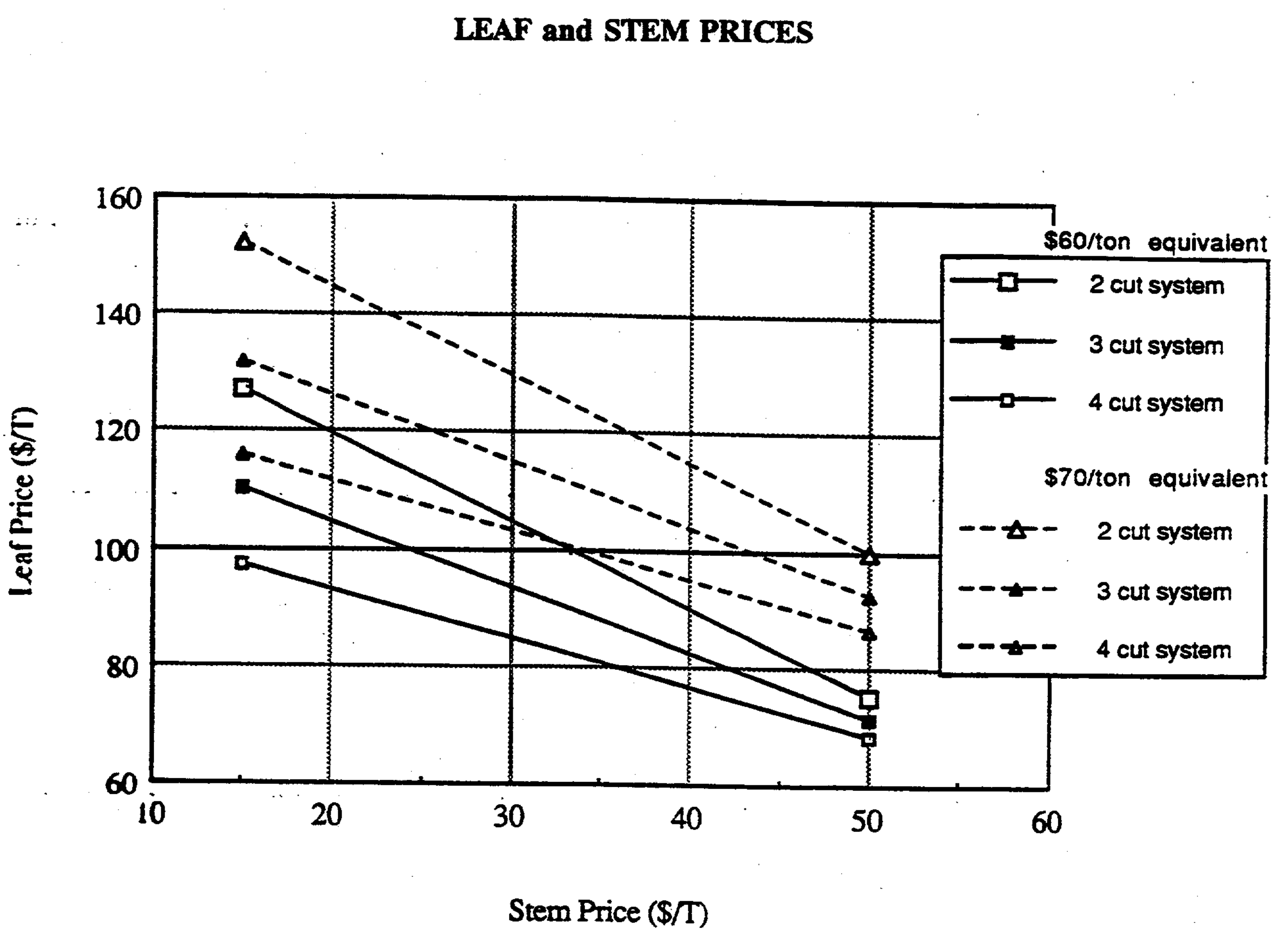
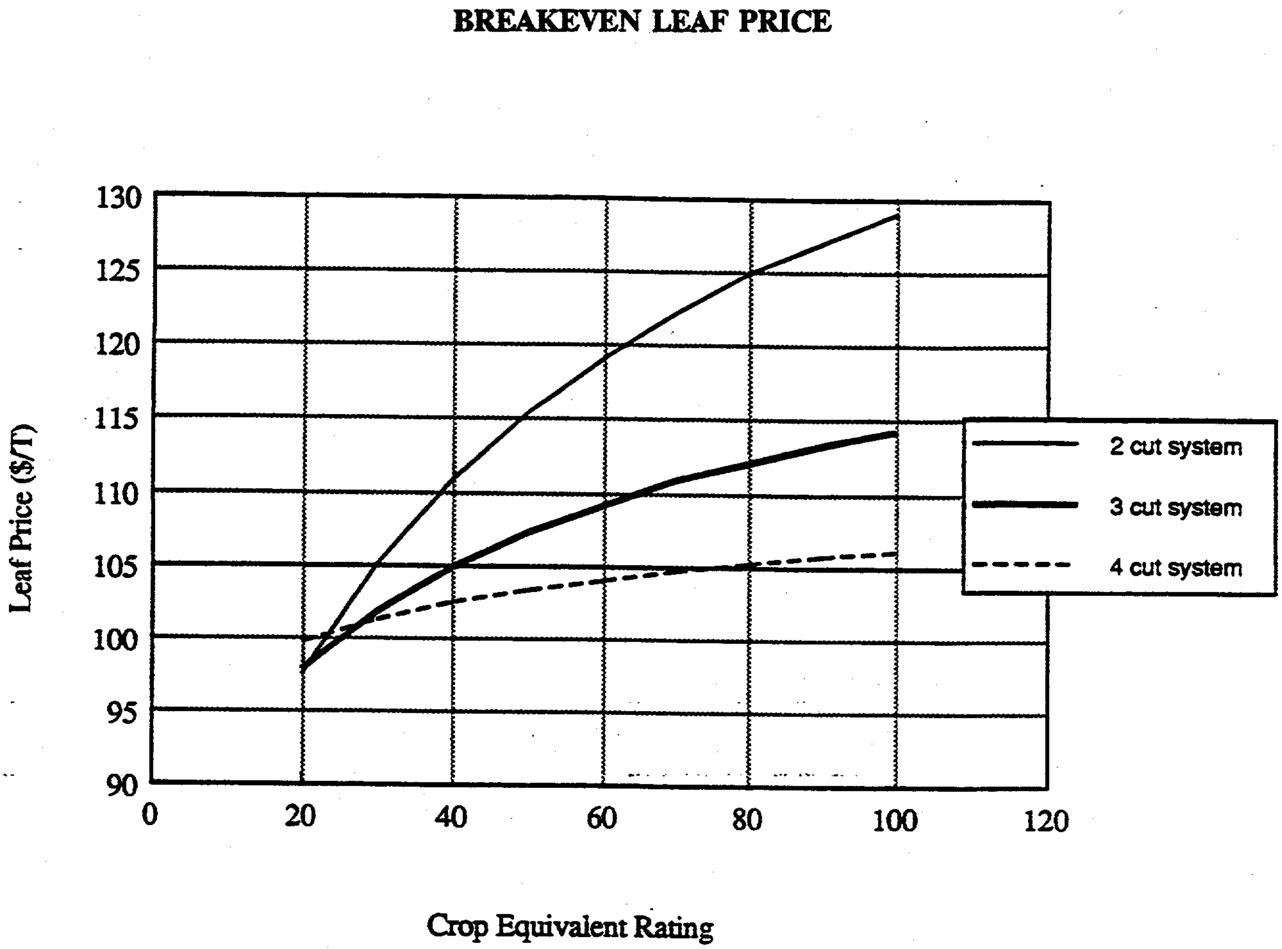


**Figure 9.2-5** Breakeven leaf price needed if stem value is set at $30 per ton (under three different harvest schedules).



**APPENDIX 10.1 Guide to using "PRODUCTION" spreadsheet for energy balance.**

A spreadsheet entitled "Production" was used to determine the cost of production for both the DFSS rotation and the corn-soybean rotation. The guide to using the spreadsheet can be found in appendix 4.2. The final page of the spreadsheet calculates the energy used in the various rotations. Energy use is a function of field operations and fertilizer and chemical inputs. Field operations are determined by crop rotation, chemical inputs are determined by both crop rotation and yield goal. Because of this dependency on yield goal, the energy balance varies between soil types. In real life, energy inputs also depend on individual equipment and soil types. The fuel used for field operations is an average theoretical fuel use. Therefore, the energy inputs given are merely attempts at estimating true energy inputs.

The section of the spreadsheet "PRODUCT" entitled "Energy Usage" requires user inputs. The inputs used for this analysis are documented in Chapter 10.1. The user is allowed to input values for the energy needed for production of fertilizer, herbicides, insecticides and seeds. The values for these numbers vary quite widely in published literature. Because of this the user is given these input options.

Energy inputs are calculated in both gallons of diesel fuel and Btu. Totals are given as an average per year, and 7 and 14 year totals. Also listed as outputs are the lbs or bushels of crop output, the gross energy of the output and the protein produced by the output.

**Appendix 10.3** Common and scientific names of the bird and mammal species known to use alfalfa fields as an important habitat component.

**BIRDS**

| | |
|---|---|
| Blue-winged teal | *Anas discors* |
| Bobolink | *Dolichonyx oryzivorus* |
| Brewer's blackbird | *Euphagus cyanocephalus* |
| Brown-headed cowbird | *Molothrus ater* |
| Mallard | *Anas platyrhynchos* |
| Common yellowthroat | *Geothlypis trichas* |
| Dickcissel | *Spiza americana* |
| Eastern meadowlark | *Sturnella magna* |
| Gadwall | *Anas strepera* |
| Grasshopper sparrow | *Ammodramus savanarum* |
| Gray partridge | *Perdix perdix* |
| Horned lark | *Eremophila alpestris* |
| Killdeer | *Charadrius vociferus* |
| Lark bunting | *Calamospiza melanocorys* |
| Northern pintail | *Anas acuta* |
| Northern shoveler | *Anas clypeata* |
| Red-winged blackbird | *Agelaius phoenicus* |
| Ring-necked pheasant | *Phasianus colchicus* |
| Savannah sparrow | *Passerculus sandwichensis* |
| Sedge wren | *Cistothorus platensis* |
| Vesper sparrow | *Pooecetes gramineus* |
| Western meadowlark | *Sturnella neglecta* |

**MAMMALS**

| | |
|---|---|
| Badger | *Taxidea taxus* |
| Coyote | *Canis latrans* |
| Eastern Cottontail | *Sylvilagus floridanus* |
| Eastern mole | *Scalopus aquaticus* |
| Meadow jumping mouse | *Zapus hudsonius* |
| Meadow vole | *Microtus pennsylvanicus* |
| Northern grasshopper mouse | *Onychomys leucogaster* |
| Plains pocket gopher | *Geomys bursarius* |
| Prairie deer mouse | *Peromyscus maniculatus* |
| Prairie pocket mouse | *Perognathus flavescens* |
| Prairie vole | *Microtus ochrogaster* |
| Red fox | *Vulpes vulpes* |
| Short-tailed shrew | *Blarina brevicauda* |
| 13-lined ground squirrel | *Spermophilus tridecemlineatus* |
| Western harvest mouse | *Reithrodontomys megalotis* |
| White-tailed deer | *Odocoileus virginianus* |
| White-tailed jackrabbit | *Lepus townsendii* |
| Woodchuck | *Marmota monax* |

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