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Economic feasibility of growing herbaceous biomass energy crops in Iowa

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Economic feasibility of growing herbaceous biomass energy crops in Iowa

by

Young-Woo Park

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ABSTRACT

Depletion of natural energy resources and environmental degradation caused by current energy resources (fossil fuels) have rekindled interest in energy availability and developing environmentally benign and renewable alternative energy resources. In addition, the reduced productive capacity of soil and environmental problems in rural areas caused by the loss of topsoil has created interest in ways to conserve soil.

These concerns have generated considerable attention on the production of herbaceous energy crops on marginal land as a possible solution to meeting future energy demands, addressing environmental concerns, and reducing soil erosion.

This research suggests that herbaceous energy crops, especially switchgrass, can be grown productively with minimal erosion, and produced at costs only somewhat higher than fossil fuels. They also have good soil conservation properties on the marginal land in Iowa.

CHAPTER 1

AN OVERVIEW OF THE ENERGY PROBLEM

Introduction

Over the past three decades, there has been growing public concern over environmental degradation and natural resource depletion as related to sustainable improvements in human well-being. Unprecedented sharp increases in oil prices in the 1970s, growing public awareness of environmental degradation, such as global warming, urban-industrial air pollution, and acidification of the environment, and world population growth, especially in current less industrialized countries, have all contributed to the public's concern on whether or not it will be possible to provide sustained economic well-being while ensuring that the quality of life remains unchanged for all generations (Smith, 1979, WCED, 1987).

In the face of such concerns, many studies have focused on energy resources, because energy is necessary for daily survival and has been an engine of economic growth. Energy is an essential input for many processes of economic production and provides 'essential services' for human well-being, such as heating, lighting, cooking, and transportation (WCED, 1987). Thus, availability of energy for an indefinite time period is crucial for all generations to come. However, today's primary energy resources, such as oil, coal, and natural gas, are non-renewable and nonrecycleable. In addition to exhaustability of the primary energy resources, there is growing consensus that most environmental problems of today are energy related ones, specifically combustion of fossil fuels (WCED, 1987; WRI, 1994).

Concerns over sustained availability of energy and environmental impacts of energy, specifically fossil fuels, and projected increase in energy demand, especially in the current developing countries due to both economic and population growth, have intensified development of alternative energy sources that are renewable and environmentally benign, such as biomass, solar, wind, and so on.

Population and Energy Demand

The world has experienced an enormous increase in the scale of energy demand. Above all, two factors are primarily responsible for this increase in energy demand: population growth and growth in per capita energy consumption (Schipper and Meyers, 1992). These two factors will be continuously responsible for future increase in the world energy demand, especially in the current less developed countries.

In 1994, the world population was around 5.3 billion (WRI, 1994) having more than doubled from an estimated 2.5 billion in 1950 (United Nations, 1992). During the same period, world total primary energy consumption increased about 4.5 times, changing from 75.68 quadrillion Btu in 1950 to 342.07 quadrillion Btu in 1990 (Schipper and Meyers, 1992; EIA, 1994).

In the 30 years from 1994, world population is expected to increase substantially in absolute terms although its rate of growth is expected to decline. According to the United Nations' prediction, the absolute amount of world population will grow by about 3.2 billion. This will bring the world's population to 8.5 billion in 2025 (United Nations, 1992) if there is no special intervention or unforeseen change from trends. The current average growth rate of global population is about 1.7 percent annually. This is projected to decline continuously and to be about 1.0 percent in 2025 (United Nations, 1992).

Most of this population growth will occur in today's less developed countries. At least 3.0 billion of the United Nations' predicted increase of 3.2 billion in world population between 1991 and 2025 is predicted to occur in present less developed countries (United Nations, 1992), that is, almost 94 percent of the total increase. Currently, 75 percent of the world population (4.3 billion) lives in present less developed countries in 1994, and 83 percent of the world population (7.1 billion) is projected to live in present less developed countries.

Comparison of energy consumption between industrialized countries and current less developed countries shows a close positive relationship between economic growth and energy consumption. Today (1991 data), industrialized countries, which account for only a quarter of the world's population (1.2 billion), consume about three-quarters of the world's commercial energy (222.3 quadrillion Btu). By source, industrialized countries consume about 72 percent of the oil, 84 percent of natural gas, and 60 percent of coal (WRI, 1994). Energy consumption in the United States was 81.14 quadrillion Btu in 1991. Of this, residential and commercial sectors accounted for 36.26%, the industrial sector accounted for 36.47%, and the transportation sector accounted for 27.26%. Energy consumption by source in each sector was as follows: coal (0.48%), natural gas (25.53%), petroleum (7.31%), and electricity (21.0%), respectively in residential and commercial sectors; coal (8.79%), natural gas (29.20%), petroleum (27.24%), and electricity (10.92%), respectively in the industrial sector; and petroleum (97.02%) in the transportation sector (EIA, 1993).

Per capita energy consumption shows striking differences between the developing and industrialized countries. Each person in the industrialized countries consumes about 10 times more commercial energy than a person in the developing countries. In 1991, world per capita commercial energy consumption stood at 5.6 million Btu. Per capita consumption in Africa was only 20 percent of the world average, 1.1 million Btu, while in Europe, it was 2.3 times the world average, 12.9 million Btu, and in the United States, which is the largest consumer of energy, it is 5.4 times of the world average, 30.3 million Btu (WRI, 1994).

Although the impact of population growth on energy consumption and on the environment will be influenced by any improvements in energy intensity, energy use patterns, and economic growth rates, the sheer growth in the number of global energy consumers, especially in present less developed countries, will place heavy pressure on energy resources and environment as it has in the past. If the present less developed countries follow the energy consumption pattern of the current developed countries as they pursue industrialization, demand for commercial energy resources, primarily fossil fuels, will increase drastically. Indeed, the percentage change in primary energy consumption in the current less developed countries over the past twenty years signals such a change (WRI, 1994).

According to the International Energy Agency's (IEA, 1994) projection on world energy demand between 1993 and 2010, world energy demand for commercial energy will continue growing, at an average annual rate of 2.1 percent. By 2010, the world will be consuming 48 percent more energy than it was in 1991. Energy consumption in the OECD is projected to increase by 28 percent between now and 2010, and oil demand is projected to increase up by 18 percent over 1991 while energy and oil demand in the present less developed countries is expected to grow more than 4 percent per annum and 3.8 percent per year on average, respectively, over the forecast period.

Gas consumption is also expected to rise continuously over the forecast period, growing at an average 2.1 percent per annum in the OECD (over half of this growth occurring in the power sector), while in the non-OECD it grows at an average annual rate of 5.6 percent. World coal demand is expected to grow at 2.1 percent per annum. The current less developed countries coal demand is expected to grow at 3.8 percent per year with China accounting for over half of the incremental demand (IEA, 1994).

Electricity is expected to be the most rapidly growing form of final energy. In many countries (including Europe and Japan), the growth of electricity will keep pace with or exceed GDP growth. Demand growth in electricity is particularly striking in the present less developed countries where per capita consumption will double on average by 2010 (IEA, 1994).

According to Energy Information Administration's forecast (EIA, 1994), which forecasts the world energy prices under the various assumptions for GDP growth rates worldwide and oil production of OPEC and non-OPEC countries, the world oil price ranges from just over $20 a barrel to $35 a barrel in 1992 dollars in 2010. Other forecasts have world oil prices in the $27-$30 range in 2010 (EIA, 1994).

Environmental Effects of Energy Use

Up to the early 1970s, the dominant concerns about energy centered on the benefit side of the energy consumption, such as industrialization and economic growth, and so naturally focused on the availability of energy resources. These kinds of problems still remain the principal concern today in many regions of the world, especially in the developing countries, where the issue is energy for economic production and growth (Schipper and Meyers, 1992). However, growing public awareness of environmental degradation has led the local and world community to look afresh at the environmental consequences of human activities, especially energy related to environmental problems. Human activities and burning fossil fuels are believed to be the primary causes of the environmental problems today, such as global warming, urban industrial air pollution, and acidification of the environment (WCED, 1987).

Environmental consequences associated with various types of energy production and consumption include problems of urban air quality arising from emissions of particulates, sulpher dioxide (SO_2) and nitrous oxides (NO_x), water and soil contamination and acid deposition, and emissions of greenhouse gases, carbon dioxide (CO_2).

The pre-industrial concentration of carbon dioxide (CO_2) was 280 parts of carbon dioxide per million parts of air by volume. This concentration reached 356 in 1992 and is expected to double to 560, if the present trend continues, between the middle and the end of the next century (WCED, 1987; WRI, 1994). Doubling of CO_2 could raise surface temperature globally between 1.5° C and 4.5° C on average, with perhaps a two to three times greater warming at the poles. This would lead to a sea level rise of 25-140 centimeters. A rise in the upper part of this range would inundate low-lying coastal cities and agricultural areas, and many countries could expect their economic, social, and political structures to be severely disrupted. It would also slow the 'atmospheric heat-engine', which is driven by the differences between equatorial and polar temperatures, thus influencing rainfall regimes. Experts believe that crop and forest boundaries will move to higher latitudes; the effects of warmer oceans on marine ecosystems or fisheries and food chains are also virtually unknown (WCED, 1987).

Concerns about global climate change from the effect of atmospheric concentration of greenhouse gases is potentially the most important emerging environmental problem relating to energy. The most significant of the greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tropospheric ozone (O_3) and chlorofluorocarbons (CFCs). At present, it is estimated that CO_2 contributes about 50 percent to the anthropogenic greenhouse effect, with methane and CFCs each contributing about 15 percent and N_2O about 9 percent (OECD, 1992). Fossil fuel burning accounts for about 75 percent of global anthropogenic CO_2 released, the remainder coming mainly from deforestation and oxidation of exposed soil (WRI, 1994).

In the case of methane, although most emissions are due to the anaerobic decomposition of organic matter, fuel consumption and distribution systems, principally of natural gas, may account for 10 to 30 percent of total emissions. Methane is also released during the mining of coal (OECD, 1992).

Energy Availability

The question of availability of energy resources to meet growing energy needs in the world economy for an indefinite time period is important but uncertain because, after all, a complete answer to this question depends on many factors, such as population growth, economic growth, and the availability of certain future technologies. However, some studies provide crude estimates of energy resource availability. If we look at the future availability of fossil fuels, which accounted for about 87 percent of world commercial energy consumption in 1992 (EIA, 1994), the future is not bright. According to the World Resources Institute's (WRI) report, given current energy consumption rate and technologies, proven reserves alone could supply oil needs for 45 years, natural gas for 52 years, and coal for 209 years (WRI, 1994). On the other hand, even with only the current technology, nuclear energy could provide more than 8000 years at the current consumption rate (Nordhaus, 1974). With renewable energy resources like biomass, solar, and wind, there is virtually unlimited energy available (Johansson, et al., 1993). These renewable energy resources have not been utilized because they have not been competitive in price compared to fossil fuels although they are currently technologically feasible.

Alternatives to Nonrenewable Energy

Given the essentiality of energy to human well- being and economic growth, energy related environmental problems, and the dissipative nature of energy consumption, many researchers have concentrated on the development of alternative energy sources that are available for an indefinite time period, dependable, safe, and environmentally sound.

Some of the alternative energy sources, such as nuclear power and hydroelectric power, have already made a significant contribution in many countries as commercial energy sources while others, such as geothermal, wind, solar-thermal, photovoltaic, wood, and biomass, are still at either the research and development stage or making minimal contribution as commercial energy sources.

Of the alternative energy resources, biomass, which utilizes the photosynthetic capability of plants to capture and store solar energy, has gained support in many countries, especially in less developed countries. Biomass resources include wood-products industry wastes, crop residues, municipal solids, sewage, animal wastes, harvesting of standing biomass, biomass-energy plantations, and other forms of plant-derived energy (Coal and Skerrett, 1995; Scurlock and Hall, 1990). Biomass currently accounts for about 15% of world primary energy consumption and 38% of energy use in developing countries.

Unlike other alternative energy sources which have been used primarily for generating electricity, biomass can be used for many purposes. It can be used to generate electricity either by using direct burning or co-firing with coal. It also can be fermented to a liquid fuel such as ethanol (Lynd et al., 1991). Unlike solar energy, the technology for collecting biomass energy is technically mature and widely understood and practiced. Unlike either wind, geothermal, or solar energy, biomass energy comes in an easily storable form and is thus available when needed (Brown, 1994).

Utilization of biomass for energy can lessen potential national security problems associated with overdependence on geographically concentrated energy sources such as oil, since biomass can be grown in many parts of the world. Establishing biomass production on deforested or marginal lands could also help restore such lands to productive use (Hall, et al., 1993; OECD, 1984). For industrialized countries, where high agricultural productivity has led to large government farm subsidies, bioenergy crops could provide an attractive alternative that might help eliminate subsidies (OECD, 1984).

Biomass production and use is believed to be environmentally benign if it is grown in a sustainable fashion. It would make no contribution to atmospheric CO_2 since carbon released during combustion of the biomass for energy would be photosynthesized by new plant growth.

Thus, net reductions in CO_2 emission would occur to the extent that biomass replaces fossil fuels (Hall et al., 1993).

Despite renewability and environmentally sustainability compared to fossil fuels, biomass has not been widely accepted as a primary energy source because of its disadvantages in price and end use. Thus, current and future substitutability of alternative energy sources for fossil fuels will primarily depend on price and end use.

Today, renewables are not price competitive with fossil fuels. However, it is expected that renewables will be able to compete pricewise with fossil fuels as demand for energy increases and depletion of fossil fuels intensifies. In addition, the price competitiveness of renewables to fossil fuels will improve if environmental damage costs, which are not currently reflected in the market price of fossil fuels, are accounted in the fossil fuels prices. Thus, the expected increase in future energy demand and exhaustion of fossil fuels, along with growing environmental concern, may make renewable energy sources become competitive with fossil fuels.

This dissertation will consider biomass, specifically energy crops, as an alternative energy source for fossil fuels because of its renewability, readiness with current technology, environmental benefits, and capability to meet various end uses.

Problem Statement

To evaluate the substitutability of biomass for fossil fuels, the following questions should be considered: first, given the potential that fossil fuels may be physically and economically exhausted, what are the possibilities for biomass to become a significant alternative to these energy sources; second, what are the costs of producing biomass and how do they relate to the cost of coal and natural gas; third, what are the potential environmental impacts of biomass production and use.

Objectives

The objectives of this dissertation are, first, to provide a background survey of the literature on renewable energy, primarily biomass, second, to develop projected cost of production estimates for a variety of biomass crops and cropping systems using agronomic data from experiments conducted in Iowa, price data available from historical statistics, and information on technology and best management practices available from extension and other research sources, and third, to compare these alternative systems with one another and to DOE guidelines on biomass fuels. Comparison will be in terms of cost, feasibility, compatibility, and environmental impacts.

Plan of the Dissertation

The plan of this dissertation is as follows. Chapter II reviews the literature on renewable energy resources. The primary focus is on biomass. This includes state of technology, availability, cost, current and future use, and the environmental impacts of renewables. In this chapter, the potential for biomass as a fuel is reviewed

Chapter III presents the conceptual model and assumptions used for estimating production costs. This model is partial equilibrium in nature since it deals only with a production cost analysis of biomass energy crops. Furthermore, the model is primarily static and considers current costs and technology. Chapter IV deals with physical aspects of biomass production and a description of the agronomic experiments used in this dissertation. This chapter describes species and cropping systems used in the agronomic experiments. It also includes a brief explanation of the characteristics of each species used in the agronomic experiments. Production processes and yields for each cropping system are presented as well. Chapter V presents estimated costs of producing perennial grasses as biomass for energy use. Chapter VI presents estimated costs of producing annual crops, various rotations and combined biomass systems. Chapter VII discusses the production costs of intercrop systems. In Chapter VIII, alternative biomass production systems are compared with each other by using the cost estimates presented in Chapters V, VI, and VII. Production costs of energy crops are also compared with other energy resources (woody crops) and studies done by others.

Chapter IX discusses the environmental impacts of biomass production. Chapter X summarizes findings of this dissertation and makes conclusions based on the findings.

CHAPTER 2

LITERATURE REVIEW

Depletion of primary energy resources (fossil fuels) and environmental degradation caused by fossil fuel production and consumption have been a primary concern for developing sustainable and environmentally benign alternative energy resources which can be substituted for fossil fuels, especially oil and coal. Of many alternative energy resources, biomass seems one of the most interesting because it is in principle renewable and to a large extent the techniques for converting it to energy are known (OECD, 1984).

With regard to energy related problems, three main policy areas are very much current issues: more efficient use of energy (energy savings), development of energy production (on a competitive level) from domestic sources, and substitution of other energy resources for fossil fuels (OECD, 1984). The first policy is a demand-side related issue and the last two policies are supply-side related issues. Biomass offers a way for the agricultural and forestry sectors to help achieve these last two goals. Biomass is an example of a national resource for which conversion equipment can be manufactured in the individual country to a large extent. Moreover, biomass can be substituted for fossil fuels in very many areas: heating for buildings, vehicle fuel, generating electricity, or a raw material in the chemical industry because biomass can be converted into modern energy carriers such as gaseous and liquid fuels and electricity. The prospects are good that these energy carriers can be produced from biomass at competitive costs under a wide range of circumstances. Moreover, large-scale utilization for energy can provide a basis for rural development and employment (Hall et al., 1993).

Biomass is any organic matter available on a renewable basis for convention to energy. Residues from agricultural crops, herbaceous and woody energy crops, commercial wood and logging residues, animal wastes, and the organic portion of municipal solid waste are all biomass (Brower et al., 1993; Hall et al., 1993). Biomass production using forests and herbaceous energy crops are ultimately a solar technology that utilizes the photosynthetic capability of plants to capture and store solar energy (Edmonds and Reilly, 1985). These raw materials (called feedstocks) are used to produce biofuels, which may be solid, liquid, or gas (Brower et al., 1993).

Energy production from biomass, whether it be electrical or thermal energy through direct combustion, or production of liquid and gaseous fuels, is obtained by utilizing organic residues and wastes or by producing crops specifically for energy purposes. Direct combustion, which is the burning of biomass in a steam boiler and running the steam through a turbine, just like a conventional coal-fired power plant (Brower et al., 1993), is at present the most important means of using biomass in many developed countries. It provides between 2 and 4% of total energy consumption in the United States (equivalent 3.2 Quadrillion BTUs), 10% in Austria, and 9% in Sweden (OECD, 1984; Hall et al., 1993). Biomass currently accounts for about 15% of world primary energy use and 38% of energy use in developing countries (Hall et al., 1993). Worldwide, biomass energy is six times as much as that derived from hydro and nuclear energy combined (Hall, 1982).

According to a study released in 1980 by the Office of Technology Assessment of the United States of Congress, up to 17 Quadrillion BTUs of biomass energy could be produced in the United States annually. In comparison, the total energy consumption in the United States in 1992 was 82 Quadrillion BTUs (EIA, 1994). A recent study by the Union of Concerned Scientists estimated that, throughout the Midwest in the United States, 400 trillion Btu per year are generated from biomass, which corresponds to 2% of the region's primary energy consumption (Brower et al., 1993). The same study also estimated that 18 million (MM) dry tons of waste (predominantly crop residues) and 4 MM dry tons of energy crops (assumed to be switchgrass) would be annually available in Iowa for between $40 and $50 per dry ton (Brower et al., 1993). According to an Iowa Department of Natural Resource's projection, 69 trillion British Thermal Units (BTUs) of ethanol from corn and 15 billion kilowatt hours(kWh) (equivalent to 179 trillion BTUs) of electricity from dedicated energy crops of switchgrass could be produced in Iowa (Brown, 1994).

Besides its potential to meet future energy demands, if biomass is grown sustainably, its production and use creates no net buildup of carbon dioxide (CO_2) in the atmosphere, because the CO_2 released during combustion is offset by the CO_2 extracted from the atmosphere during photosynthesis (Hall et al., 1993). The Department of Energy (DOE) and Oak Ridge National Laboratory (ORNL) researchers indicate that, for every 1 megagram(Mg) of carbon produced by woody biomass, an estimated 3 Mg of carbon dioxide is sequestered. The DOE, ORNL, and the National Audubon Society all indicate the potential for no net increase of carbon dioxide with biomass growth and production from woody and herbaceous perennials as compared to a net increase in carbon dioxide with the use of fossil fuels or the use of annual crops for biofuels (Colletti, 1994).

In recent years, many studies have focused on the production of forests and herbaceous energy crops for biomass energy production (Chabbert et al., 1985; Cost et al., 1985; Cherney et al., 1990; Parish, Wolf, and Daniels, 1993; Turhollow, 1991). Forage or herbaceous energy crops, which include annual crops and perennial grasses, have been recognized as having great potential for production of energy because they are available in all parts of the nation and production technologies are known. Since herbaceous crops have been produced for animal feed, many farmers may already have most of the equipment needed to produce herbaceous energy crops. Therefore, farmers may be far more receptive to the idea of cultivating it for energy than they would be to the idea of cultivating trees (Brower et al., 1993; Sperling, 1990).

Of herbaceous energy crops, perennial grasses have been recognized as having great potential for dedicated energy crops, although their yields are lower than annual crops such as sorghum or corn, because they have excellent erosion control properties and can be grown productively on rolling lands and marginal lands that are generally unsuitable for tillage of row crops. Without creating an erosion hazard, all of the harvestable materials can be removed because the herbage sod remains in the field even after harvest, thereby protecting the soil from wind and water erosion (Linden et al., 1984; Sperling, 1990).

Cherney et al. (1990) found, in their study of potential biomass crops on marginal lands, that average sweet sorghum yields were 16.5 Mg dry matter/ha over 1985-1988, which was far higher yield than the most productive perennial grass (switchgrass, average of 10.9 Mg dry matter/ha). However, this was achieved with higher input usage and soil erosion.

Various studies have found that, of perennial grasses, switchgrass is one of the most promising biomass energy crops from an agronomic standpoint (Brower et al., 1993; Bransby, Sladden, and Kee, 1990; Cherney et al., 1990). Switchgrass is attractive because it is a perennial grass native to the plains of North America, and it is deep-rooted, very persistent, and less affected by drought than other perennial energy crops. Unlike sorghum and other annual crops, once established, switchgrass will hold the soil and limit erosion. It is also less sensitive to soil conditions than tree crops (Brower et al., 1993; Cherney et al., 1990).

Switchgrass has high yields among the perennial grasses. Cherney et al. (1990) show that switchgrass has superior yield (average of 10.9 Mg dry matter/ha with one cut per year over two years, 1988 and 1989) to other perennial species studied (alfalfa, reed canarygrass, tall fescue, birdsfoot trefoil, and big bluestem). Switchgrass yielded as much as 16 Mg dry matter/ha from two cuttings in a season. Another study found that switchgrass had the highest yields (8.16 Mg dry matter/ha) of the perennials studied (johnsongrass, bermudagrass, sericea lespedeza, and tall fescue) on marginal land in Alabama (Bransby, Sladden, Kee, 1990). In general, studies show that switchgrass has the potential to produce acceptable yields on a variety of good and marginal lands and through a wide geographic range (Turhollow, Cushman, and Johnston, 1990).

The long-term prospects for biomass as an energy source depends on its ability to compete with conventional energy. The cost of biomass production is one important indicator of the economic performance of energy plantations. In addition, the environmental impacts of biomass production must be considered.

Energy Cost of Growing Biomass

If biomass energy is to be used as a fossil fuel substitute, the energy provided should be greater than the fossil fuel energy needed to produce it. Energy is needed to establish plantings, to produce fertilizers and herbicides, and to harvest and transport the crop to an energy conversion facility. Although these energy inputs generally increase as the intensity of plantation management increases, so does the biomass yield. Furthermore, in the United States, agriculture is one of the top three energy consuming industries, accounting for 3% of the national energy budget (OECD, 1988). Thus, the relationship between energy output and input is key to understanding the energy implications of intensive management.

Recent estimates of the energy costs of plantation biomass (herbaceous crops) grown under United States conditions have been made by analysts at the Oak Ridge National Laboratory (ORNL). With near-term expected biomass yields (net of harvesting and storage losses) in the range 9 to 13 dry tons per hectare per year, net energy yields have been estimated to be in the range of 10 to 12 times the energy inputs for these crops (Table 2.1). With projected higher future yields, these ratios would be somewhat higher (Turhollow and Perlack, 1991).

Economic Costs of Growing Biomass

Many studies have estimated the production costs of growing biomass energy crops. The target range for biomass production costs established by the Department of Energy (DOE) is between $2.35 and $2.50 per million BTUs (Colletti, 1993). One study suggested that yields must be in the range of 13 to 40 Mg dry matter per hectare in the Midwest and Lake states and Southeast, with annuals and thick-stemmed perennial species at the higher end of the range and the thin-stemmed perennials (e.g., switchgrass) at the lower end of the range, to meet the goal of producing herbaceous energy crops at a cost of $1.90 to $2.85 per gigajoules(GJ) (or $2.00 to $3.00 per million British thermometer units (MM BTUs); 1 gigajoules = 9.487 x 10^5 BTUs) (Turhollow, Cushman, and Johnston, 1990; WRI, 1994).

Cost estimates for prospective United States sites made by an analyst at the Oak Ridge National Laboratory (ORNL) are presented in Table 2.2. These estimates are for acreage that might be established in the midwest or southeast, for a Short Rotation Woody Crop (SRWC) and for three herbaceous energy crops. The estimates consider yields and production

Table 2.1 Energy balances for biomass production on plantations

	Sorghum		Switchgrass	
	1990	2010	1990	2010
	gigajoules per hectare			
Energy input				
Establishment	1.29	1.29	0.39	0.39
Fertilizers	8.87	12.69	5.26	7.38
Herbicides	1.82	1.82	-	-
Equipment	-	-	-	-
Harvesting	3.72	8.24	5.47	8.41
Hauling[1]	3.81	6.90	2.79	3.60
Total	19.51	30.94	13.91	19.79
Energy output[2]	232.75	528.50	157.50	252.00
Net Energy Ratio[3]	10.9	16.1	10.3	11.7

Source: Turhollow and Perlack, 1991 Emissions of CO2 from energy crop production, Biomass and Bioenergy. 1:129-135.

[1] The energy required to transport the biomass 40 kilometers to a biomass processing plant.

[2] Yields net of harvesting and storage losses for present (future) production technology are assumed to be 13.3 (30.2) tons per hectare per year for sorghum (heating value of 17.5 gigajoules per ton), and 9.0 (14.4) tons per hectare per year for switchgrass (heating value of 17.5 megajoules per ton).

[3] The net energy ratio = (energy output - energy input)/energy input.

technology as at present and those projected to be achievable in 20 years if research and development goals are met. According to these estimates, herbaceous energy crop production costs can be produced at the target price range suggested by Turhollow et al. (1990) in the year 2010.

Brower et al. (1993) estimated the production costs of growing biomass energy crops at representative sites in Minnesota and Nebraska. Table 2.3 presents the production costs of growing two biomass energy crops, woody crops (hybrid poplar) in Minnesota and switchgrass in Nebraska. According to these estimates, hybrid poplar can be produced at $50.98/ton of dry matter in Minnesota and switchgrass can be produced at $49.33/ton of dry matter in Nebraska.

Table 2.2 Estimated current and projected productivity and production costs for biomass grown on dedicated plantations in the United States

Region and Species	Annual yields dry tons per hectare per year				Production costs \$/gigajoule of net biomass[1]	
	1990		2010		1990	2010
	Gross[2]	Net[3]	Gross[2]	Net[3]		
Midwest						
Hybrid poplar	13.5	10.5	20.0	16.5	3.48	2.50
Switchgrass	13.0	9.0	20.0	14.4	3.86	2.73
Sorghum	22.4	18.3	35.0	29.3	2.73	1.87
Southeast						
Energy cane	22.6	18.5	35.0	29.3	2.97	1.86
Switchgrass	13.0	9.0	22.0	15.9	3.52	2.19

Source: Turhollow, A. F. 1991. Economics of Dedicated Energy Crop Production, ORNL

[1] Assumed heating values are 19.8 gigajoules/dry ton for hybrid poplar and 17.5 gigajoules/dry ton for the other herbaceous crops.

[2] This is the standing yield at the time of harvest.

[3] This is the yield net of the losses in harvesting and storage.

Table 2.3 Production costs of energy crops (for typical sites in the Midwest)

Cost component	Hybrid poplar Minnesota	Switchgrass Nebraska
Establishment (\$/acre)		
Herbicides	6.91	0.26
Fertilizer/Liming	3.31	2.36
Machinery	2.64	1.27
Planting	5.01	4.65
Maintenance (\$/acre)		
Pesticides	11.84	0.00
Fertilizer	5.52	39.90
Land rent and taxes	75.48	57.50
Managerial	16.57	16.57
Harvesting (\$/acre)	128.63	45.98
Total (\$/acre)	**255.92**	**168.48**
Gross yield (tons/acre)	7.00	5.00
Net yield (tons/acre)	5.95	4.25
Total production and Harvesting cost (\$/ton)	**43.01**	**39.64**
Transportation and Baling (\$/ton)	7.97	9.69
Total (\$/ton)	**50.98**	**49.33**

Source: Brower et al. 1993. Powering the Midwest: Renewable Electricity for the Economy and the Environment. Cambridge, MA: the Union of Concerned Scientists.

Although these estimates are based on two selected sites in the Midwest, they can be used as a benchmark for production costs in other regions in the Midwest if we keep in mind the differences in land costs in different regions. Other than land costs, other costs involved in biomass energy crop production should be similar to ones shown in Table 2.3.

A recent study of selected warm-cool season annual and perennial herbaceous species on marginal land (low productivity) in Alabama estimated the production costs of growing biomass energy crops as shown in Table 2.4 (Bransby, Sladden, and Kee, 1990). The costs calculated are in-field production costs and exclude land, transportation from the field to a conversion facility, and storage costs. Harvest costs are assumed to be constant on a per hectare basis.

Of the perennials, switchgrass had the highest yield (8.16 Mg/ha). Sweet sorghum had the highest yield of all annual and perennial grasses. The production costs between sweet sorghum and switchgrass are not much different ($41.5/Mg for sweet sorghum and $42.2/Mg for switchgrass).

Table 2.4 Production cost per hectare and per Mg for biomass species based on average yields obtained in 1988 and 1989

Species	Mean yield (Mg/ha)	Production cost ($/ha)	Production cost ($/Mg)
Sweet sorghum	11.03	458	41.5
Corn	8.49	419	49.4
Johnsongrass	5.92	323	54.6
Switchgrass	8.16	344	42.2
Bermudagrass	6.60	334	50.6
Sericea lespedeza	7.08	262	37.0
Rye	3.64	331	90.9
Tall fescue	7.23	322	44.5

Source: Brabsby, D. I., Sladden, S. E., Kee, D. D., 1990. Selection and Improvement Of Herbaceous Energy Crops for the Southeastern USA, ORNL.

Environmental Impacts of Biomass

Soil loss tolerance (the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely) varies almost from field to field, according to topography, climate, soil type and, not least, according to the use to which the land is put. Soil erosion is associated with many forms of intensive agriculture, and there is a danger that the removal of crop residues will hasten the destabilization of the soil. As soils deteriorate, their ability to retain water is also affected, they become more susceptible to erosion and drought, and need increased irrigation (OECD, 1988) because crop residues serve a range of functions. Principally, they maintain the organic content and humus of the soil and provide surface protection. This means that they: "control water and wind erosion, act as a storehouse of nutrients, stabilize the soil structure and improve its texture, reduce bulk density, enhance infiltration and moisture retention, increase action exchange capacity, and provide energy for micro-organism activity, an essential factor in soil fertility" (Posselius and Stout, 1981).

Under current economic practices in the United States, the estimated average annual erosion loss of soil ranges from 18.1 Mg/ha (Lee, 1984) to 20 Mg/ha (Larson, 1979). This rate is about twice the estimated tolerances, which is 11 Mg/ha/year (D'Souza, Hogue, and Bohae, 1989). It has been estimated that in the western region of the corn belt in the United States, complete residual removal could cause a 10% decrease in crop yields and soil degradation (Morris, 1980). Another study indicates that from 1.8% to 3.8% reduction of the soil's organic matter content can reduce corn yields by 25% (Johnson, 1994). Soil erosion rates for corn in Iowa are approaching 27 metric tons per hectare (Malanson, 1994) and a loss of 1 inch of topsoil reduces corn yields by 3-6 bushels per acre (Johnson, 1994).

The microorganism activity associated with the decay of organic products provides storage for soil nitrogen, and prevents leaching during autumn and winter. Agricultural crop residues contain 40% of the nitrogen (N), 10% of the phosphorus (P), and 80% of the potassium (K) applied in fertilizer(Larson 1979). One megagram (Mg) of agricultural soil may contain about 4 Kg of N, 1 Kg of P, 20 Kg of K, and 10 Kg of calcium. At an average annual erosion rate of 18 Mg/ha, the average loss of nutrients per hectare of cropland would be total of 72 Kg of N, 19 Kg of P, 360 Kg of K, and 180 Kg of calcium (Piemental and Krummel, 1987). Compared to the average annual fertilizer application per hectare of corn production in the United States (152 Kg of N, 75 Kg of P, 96 Kg of K, and 426 Kg of calcium) (Piemental and Krummel, 1987), the loss of nutrients due to soil erosion is very significant. If the organic content of the soil is allowed to decline, the ability of the soil to retain nitrogen and water is affected in a number of complex ways. This means that higher rates of irrigation and larger amounts of fertilizer will be applied which will accelerate leaching of nitrate to aquifers and watercourses (OECD, 1988).

Therefore, the potential for erosion control will be an important criterion in selecting a biomass species wherever erosion is a problem. Erosion tends to be significant during the year following planting. Thus, annual herbaceous crops like sorghum are no better in controlling erosion than annual agricultural row crops like corn, whereas perennial grass crops, for which planting is infrequent, can provide good erosion control (Turhollow, 1991). For example, with conventional techniques on Morley clay loam with a 4% slope, production of annual crops resulted in 40.9 Mg/ha/year erosion for soybean and 21.8 Mg/ha/year for corn (Piemental and Krummel, 1987; Johnson, 1994) whereas annual soil erosion rates for perennials such as alfalfa and switchgrass are reported to range between 0.2 to 3.0 Mg/ha/year (Peterson and Swan, 1979; Johnson, 1994). These soil erosion rates for perennials are even lower than the natural soil formation rate, 1 Mg/ha/year (D'Souza, Hoque, and Bohae, 1989).

The effectiveness of perennial grasses and trees in controlling erosion is indicated by recent experience with the Conservation Reserve Program of the United States Department of Agriculture. The erosion rate declined 92% on the 14 million hectares of highly erodible U.S. cropland taken out of annual production under this program and planted with perennial grasses and trees (Hall et al., 1993; Turhollow, 1991).

According to Colletti's survey of Iowa biomass resources (1994), an estimated 4.89 million acres of marginal land, which includes the marginal land currently cropped, and the marginal acres currently used as pastureland, could be devoted to dedicated herbaceous energy crops (HEC) (perennials) and short rotation woody crops (SRWC) for biomass energy production. Land availability for biomass energy crop production could increase by shifting some of the land currently enrolled in the Crop Reserve Program (CRP)/Wetland Reserve Program (WRP) program (most in the CRP), which is 2.225 million acres. The first 10 year contracts expire in 1996. Given the acreage of erodible soils in Iowa, an opportunity to increase the land devoted to the production of HEC and SRWC exists. This is considerably more than the acreage enrolled in the CRP/WRP program. By assuming 50% of land in CRP program is devoted to produce herbaceous energy crops (switchgrass), Colletti (1994) estimates that 5.46 million dry tons of feedstocks could be produced annually in Iowa. This is equivalent to 84.66 trillion BTUs of energy per year. The energy contention rate in herbaceous energy crops is 7,750 Btu per dry pounds.

Perennial species such as alfalfa, switchgrass, big bluestem, and reed canarygrass are established with typical farm practices and require intensive management for optimal biomass yield. Management practices include the use of herbicides, cultivation, and fertilizers. After initial establishment, perennials can be harvested one or more times each year for the standing life of perennials. Perennial grasses offer many potential environmental benefits associated with soil erosion and water quality and carbon sequestering (Colletti, 1994). Carbon sequestering could be a very important environmental benefit of growing perennial grasses because coal is responsible for 36% of primary energy consumption in Iowa, compared to 22% for the nation as a whole. Coal use to generate electricity is even larger, 86%, as opposed to 53% for the entire country (Brower et al., 1993). Of fossil fuels, coal is the largest contributor of carbon dioxide (CO_2) (WCED, 1987).

Potential annual energy crops include hybrid grain corn, sorghum, and specialty corn. The production practices for these potential energy crops are the same as typical corn and soybean crops in Iowa. Management practices include intensive inputs of fertilizers, pesticides, cultivation. The expected positive environmental effects from perennial grasses may not exist for these types of energy crops (Colletti, 1994).

Land value and rent will play an important role in biomass production as well as machinery costs and input costs. The average rental rate in Iowa is $82/acre for corn, $71/acre for oats, $55/acre for grass hay, $48/acre for tillable pasture, and $26/acre for permanent pasture (Edwards and Davis, 1994). Large acreage of low and medium quality agricultural land is concentrated in the southern portion of Iowa and their rental values are low (Colletti, 1994). Utilization of this land could lower biomass production costs significantly.

Summary

Concerns over energy resource depletion and environmental degradation related to current dependence on fossil fuels (oil, coal, and natural gas) have initiated research to develop sustainable and environmentally benign alternative energy sources. Of the many alternative energy sources, utilization of biomass energy sources, especially herbaceous energy crops, has been recognized as having great potential to meet future energy demands with a less negative impact on the environment.

Herbaceous energy crops, especially perennial grasses, are favored for dedicated energy crops, although their yields are lower than annual crops such as sorghum and corn, because they have excellent soil erosion control properties and can be grown productively on rolling lands and marginal lands that are generally unsuitable for tillage of row crops. They also protect the soil from wind and water erosion by leaving the herbage sod in the field after harvest. Furthermore, they are available in all parts of the nation and production technologies are known. Of the perennial grasses, switchgrass has been recognized as one of the most promising energy crops because of its high yields, persistency, good drought tolerance, and good erosion controllability.

Loss of soil nutrients due to soil erosion is believed to decrease crop yields and increase production costs by requiring more fertilizer use. Thus, production of herbaceous energy crops (perennials) not only helps meet future energy demands but also prevents soil erosion and water contamination. Furthermore, perennials may contribute to reducing carbon dioxide (CO_2). All of these properties of perennials are very important in Iowa. Iowa is a heavily agriculturally oriented state. In Iowa, coal is responsible for 36% of primary energy consumption, which is far higher than national average (22%) and 86% of electricity in Iowa is generated by using coal. The national average is 53%.

Iowa could devote more than about 5 million acres of marginal and highly erosive land to herbaceous energy production (perennials). Utilization of lower quality land in the herbaceous energy crop production could reduce production costs significantly.

CHAPTER 3

CONCEPTUAL MODEL AND ASSUMPTIONS USED FOR ESTIMATING PRODUCTION COSTS

Costs and returns estimates are developed and used for many purposes. In general, the objective is to accumulate or to develop information about costs and returns that can be used in making or analyzing decisions related to production of commodities. These estimates are especially important to producers faced with making a decision on whether to produce new product(s), such as biomass energy crops in these study.

There is a similarity between biomass energy crop production and traditional crop production. However, knowing specific cost structures involved in energy crop production will help potential producers significantly in making decisions. This chapter discusses the major conceptual issues that influence the components of costs and returns, methods of calculation, and types of data used to analyze them. Furthermore, this chapter also discusses the assumptions used in estimating costs and returns for the energy cropping systems considered.

Specific methods of calculation discussed in this chapter are the ones actually used in the estimation of energy crops costs discussed in the later chapters and are the ones used by the Mississippi State Budget Generator (MSBG), a computer program designed to aid in the calculation of costs and returns.

Enterprise Budgets

Costs and returns estimates for an agricultural product, referred to as an enterprise budget in this study, are commonly estimated by production enterprise. A production enterprise (or an enterprise) is defined in different ways depending on the products produced, the technology used, or restrictions on the use of various inputs. An enterprise is commonly distinguished by its end products (Hallam, 1995; Osburn and Scheeberger, 1983), e.g., alfalfa, switchgrass, sorghum, and so on. However, in this study, an enterprise is distinguished by the cropping system since the primary interest is to compare production costs of different energy crop production systems.

For given enterprise, there can be as many enterprise budgets as there are many different production practices (technologies) such as no-till versus conventional till or one harvest versus multiple harvests. Furthermore, for a given enterprise and a given set of production practices, there can also be as many budgets as there are many different combinations of input use. In this case, each enterprise budget would be analogous to a point on a given production function for a specific dry matter yield of alfalfa and the costs related directly to harvesting it. For example, switchgrass dry matter yield responds differently to four different levels of nitrogen (N) fertilizer use, 0 lb., 62.5 lb., 125 lb., and 250 lb. per acre, for a given technology while other production practices are the same. Each of these four points on the production function represents a different enterprise budget. Thus, the selection of a point on a given production technology is required to estimate an enterprise budget.

An enterprise budget generally consists of three parts: revenue, expenses (costs), and profit. Quantity, unit, and price are included to provide full information to the user. Revenue or income from the enterprise is typically shown first. The cost section comes next and is generally divided into two parts: variable and fixed costs. Variable costs, which arise from the actual operation of the enterprise, are also called operating costs or direct costs. These costs change with the level of outputs. Examples of costs normally included in variable costs are seed, fuel, lubrication, pesticide, operator labor, machinery repair and maintenance, harvesting, hauling costs, and interest on operating inputs (Kay and Edwards, 1994; Boehlje and Eidman, 1984).

Fixed costs, which may also be called ownership costs or indirect costs, for a crop enterprise budget include the fixed costs for the machinery used in the crop production and a charge for land used. Depreciation on buildings, taxes on the farm, property and liability insurance are also examples of economic fixed costs. These costs remain the same whether or not output is produced (Kay and Edwards, 1994; Boehlje and Eidman, 1984). Notice that these costs are fixed only in the short-run. In the long-run, they also become variable.

The estimated profit per unit is the final value reported in a crop enterprise budget and is obtained by subtracting total costs from total revenue. The estimated profit appearing in enterprise budgets are economic profit. That is, in addition to cash expenses and depreciation, opportunity costs are also included. Opportunity costs included in enterprise budgets are operator labor, interest on capital used to cover variables costs, and on capital invested in machinery and land (Kay and Edwards, 1994).

In this study, variable costs are called direct expenses, and fixed costs are called fixed expenses. In estimating fixed expenses, taxes on the farm and insurance are not included since data on these is not directly available. This is consistent with the Mississippi State Budget Generator (MSBG) program which is used for estimation.

Types of Production Cost and Return Estimates

There are many types of production cost and return (an enterprise budget) estimates. Which method is employed depends on the purpose of cost and return estimation, availability of the necessary information, the product(s) in question and their use. In general, there are two types of cost and return estimates: historical estimates and projected estimates (Hallam, 1995; Ahearn and Vasavada, 1992).

Historical estimates for production enterprises are a summary of enterprise costs and returns for a previous period. They are based on actual costs and returns that were incurred over a previous production period. Projected estimates for production enterprises are forecasts of enterprise costs and returns for some future periods based on information available at a certain point in time (Hallam, 1995).

Projected enterprise budget estimates are used by producers to determine financial requirements, plan for profit increasing production adjustments, make marketing decisions, and to resolve many other business management problems. They also can be used to evaluate alternative production practices and management systems or to provide a starting point for individual producers. They are often used in evaluating new technologies, the feasibility of new products, or the offsite (environmental) effects of alternative cropping systems (Hallam, 1995).

Using existing crops as biomass is new to most farmers, although some of the biomass crops in this study, such as alfalfa and switchgrass, have been produced for other purposes like animal feed. Thus, to participate in biomass energy crop production, the representative farmer needs projected enterprise budgets for different biomass energy crops. To estimate enterprise budgets, much information is needed, such as output levels, output prices, input prices, input levels, interest rates, hours of machine use, and so forth. In many instances, a projected enterprise budget can be estimated based on general information available from historical data, such as time series data on output (yield), output prices, input prices, and so forth (Hallam, 1995).

There are some difficulties involved with projecting enterprise budget(s) for new technologies, new products, and the offsite effects of alternative cropping systems of new products as for biomass energy crops. For such cases, experimental or engineering data and expert opinion are used, especially for yields and amount of input to be used, to construct a projected enterprise budget (Hallam, 1995). This is the method used in this study to evaluate biomass crop production along with available historical data, such as input prices and interest rates. Sources of historical data will be discussed in detail in a later section of this chapter.

Constructing a Enterprise Budget

Earlier in this chapter it was mentioned that an enterprise budget consisted with three parts: revenue, expenses, and profit. In this section, components of each of three parts and methods of estimation will be discussed in detail by applying economic principles. Specific assumptions presented in this section are the ones used by this analysis and the Mississippi State Budget Generator (MSBG) in estimating an enterprise budget for each biomass energy crop.

Revenue

The revenue section includes cash revenue from the crop sales. It is a function of yield and output price and is obtained by multiplying yield by the market price of the crop. Therefore, to estimate the projected revenue, data on crop yield and output price are essential.

The accuracy of the projected profit for the enterprise may depend more on the estimates made in this section than in any other (Kay and Edwards, 1994).

If there exists historical data for the crop(s) in study, then time series data can be used to forecast yield and price. For example, projected yield can be obtained by examining historical yield, yield trends, and the type and amount of inputs to be used. To project output price, a review of historical price levels, price trends, and outlook for the future should also be conducted before selecting a price (Kay and Edwards, 1994; Osburn and Schneeberger, 1983). However, for new commodities, it is difficult to estimate yield and price because the commodities in consideration have not been commercialized in the market, so that there is no historical data available.

To obtain projected yield, experimental or engineering data can be used for new crops as in this study. Projected yield of each biomass energy crop in this study is the average yield over the agronomic experimental period, 1988 through 1992 for all annual crops. This average yield is also used to estimated the projected revenue of corn and soybean involved in rotation systems. Revenue for each perennial grass during the establishment year was estimated by using establishment year dry matter yield only.

Obtaining price data for biomass energy crops is a problem since there is no market for such commodities. Competing commodity prices can be used as a proxy for the commodity in consideration. For example, in this study, hay price might be used as a price indicator for biomass energy crops.

Operating or Variable Costs

These section includes those costs that will be incurred only if the energy crop is produced. Factors of production included in these costs are raw materials, or produced factors that are completely consumed during a single production period. Examples of these factors are seed, fertilizer, herbicides, fuel, and lubrication. Labor, and machinery repair and maintenance are also included in these costs.

Seed, Fertilizer, and Chemicals. Costs for these items are relatively easy to determine once the quantity used in the current production period is determined. The amount used for each of these inputs is usually determined by agronomists after soil test. Cost of these inputs is obtained by multiplying the quantity used by the market determined purchase price. Prices can be found by contacting input suppliers.

The input use rates used in this study were determined by agronomists, experimental data, and extension specialists at Iowa State University. Prices quoted in this study for these items are listed in Table 3.2 and were obtained from an extension specialist of forage, Dr. Steven Barnhart of Iowa State University, Economics Department extension specialists at Iowa State University, and local COOP managers in Nevada, Iowa.

Fuel, Oil, and Lubrication. Cost of each of these inputs are obtained simply by multiplying the quantity used by the market price. A difficulty associated with cost estimation for these items is quantity determination. Quantity of fuel, oil, and lubrication used in production are related to the type and size of machinery used and to the number and type of machinery operations performed for an energy crop (Kay and Edwards, 1994). Assumptions for machinery used in estimation of an enterprise budget in this study are shown in Table 3.2.

There are different ways to obtain costs related to these items. A quick and simple way is to divide the total farm expenses for fuel, oil, and lubrication by the number of crop acres. A more accurate method is to determine fuel consumption per acre for each machine operation and simply sum the fuel usage for all the operations scheduled for a crop. The result can be multiplied by the price of fuel to find the per acre costs. Another method is to compute fuel consumption per hour of tractor use and then determine how many hours will be needed to perform the machine operations (Kay and Edwards, 1994). In this analysis, engineering estimates are used to predict fuel, oil, and lubrication costs based on equipment size and use. These equations are given in the next section of this chapter.

Machinery Repair and Maintenance. Estimating machinery repairs cost per acre also depends on some parameters related to the machinery used in production. A method must be devised that allocates repair expense relative to the type of machinery used and amount of use. Any of the methods discussed for estimating fuel expense can also be used to estimate machinery repair and maintenance expense (Kay and Edwards, 1994). Similar engineering equations were used for these expenses.

Labor. Total labor hours needed for crop production are heavily influenced by the size of the machinery used and the number of machine operations. In addition to the labor needed to operate machinery in the field, care must be taken to include time needed to get to and from fields, adjust and repair machinery, and perform any other tasks related directly to the crop being budgeted (Kay and Edwards, 1994, p. 144). The labor coefficients are determined by the following factors: performance rate of the implement, the number of times that a given field operation is implemented, the hours of tractor use in relation to the hours that the tractor is in use, and the hours of tractor use in relation to the hours that the implement is in use.

Interest. This interest is on capital tied up in operating expenses. Thus, this interest is an opportunity cost of the operating expenses. Since it is generally less than a year from the time of expenditure until harvest when income is or can be received, interest is charged for some time less than a year. Interest is charged on operating expenses without regard to how much is borrowed or even if any is borrowed. Even if no capital is borrowed, there is an opportunity cost on the farm operator's capital (Kay and Edwards, 1994, p 144). For example, if a farm operator deposited financial capital into bank instead of investing in crop production, he/she could have earned interest. There charges are computed from the time the expenses are incurred until the last harvest of the season which is point of evaluation of costs and returns.

Transportation Costs. These costs are related to the costs of transporting biomass feedstocks from field to the biofuel plant. In this study, these costs involve transporting the harvested energy crop dry matter to the nearest power plant or conversion plant. This cost depends on yield and distance to the plant, biofuel plant capacity, fuel type, cropland availability, farmer participation in biomass production, transportation input costs, and the shape of the harvested biomass, for example, large round bale or square bale (Bhat, English, and Ojo, 1992).

Fixed Expenses

The values discussed in this section relate to the costs associated with owning a fixed input. In general, capital inputs, such as tractors and implements, are categorized as fixed inputs in crop production. These inputs can be used for several production periods and provide a flow of capital services.

Fixed costs do not change as the level of production changes in the short run. These are the costs that are incurred even if the input is not used. In general, total fixed costs in crop production are composed of depreciation, insurance, repairs, taxes (property taxes, not income taxes), and interest (Kay and Edwards, 1994, p. 123). However, in this study, fixed costs include only machinery depreciation, interest on machinery, and a land charge.

Notice that the cost of these must be allocated over several production periods. The number of periods of which they are allocated will affect the annual fixed cost (Hallam, 1995).

Machinery Depreciation. The amount of machinery depreciation to charge to a crop in production will depend on many factors, such as the size and type of machinery used, the number and type of machine operations, and the useful life of machinery. The problem generally related to machinery depreciation is proper allocation of the total machinery depreciation to a specific enterprise (Kay and Edwards, 1994). This is done in this study based on hours of annual use and hours allocated to the crop in question.

Machinery Interest. Estimating interest on machinery is the same as estimating an opportunity cost of investment on the machine. Interest on machinery is based on the average investment in the machine over its life and is computed the same way regardless of how much, if any, money was borrowed to purchase it (Kay and Edwards, 1994).

Land Charge. There are several ways to calculate a land charge: first, what it would cost to cash rent similar land; second, the net cost of a share rent lease for a crop on similar land; and, third, for owned land, the opportunity cost of the capital invested, that is, the value of an acre multiplied by the opportunity cost of the owner's capital. The three methods can give widely different values (Kay and Edwards, 1994).

Most enterprise budget use one of the rental charges even if the land is owned. Assuming a short-run enterprise budget, the land owner/operator could not sell the acre and invest the resulting capital. As long as the land is owned, if it is not farmed by the owner, the alternative is to rent it to another farm operator. The rental amount then becomes the short-run opportunity cost for the land charge (Kay and Edwards, 1994).

In this study, the market rental price on land is used to generate the enterprise budgets for biomass energy crops. In case of double cropping systems, where two crops are grown on the same land in the same year, it is suggested to that the budgets for each crop with the annual ownership costs for land divide the costs equally between the two crops (Kay and Edwards, 1994). However, since the double crops are considered as a system in the analysis this is not necessary.

Establishment Costs

These are the costs related to perennial crops in the establishment year. Unlike annual crops, once established, the perennial crops can produce output continuously without planting, over the assumed life span of the crops without additional costs for planting and other tillage practices. This is assumed to be 4 years after the first for alfalfa, and 10 years for reed canarygrass, switchgrass, and big bluestem in this study. During the assumed life span, the only other production activities involved are maintenance and harvesting activities.

To develop annual budgets for perennial crops, the budgets for the establishment year must be estimated first, then, the establishment year net production costs are prorated over the life span of the perennial crops, and finally, the prorated establishment costs are added to the annual enterprise budgets for each perennial crop.

Profit or Return to Management

The estimated profit is found by subtracting total costs from the total revenue. If a charge for management is not included in the budget, this value should be considered as the return to management. Management is an economic cost and should be recognized in an economic budget as a specific expense or as part of the net return or loss (Kay and Edwards, 1994, p. 145).

Definitions of Parameters, Assumptions, and Input Prices Used to Estimate Enterprise Budgets

Cost and return estimation for biomass energy crop production is influenced by many factors of production, such as land, labor, machinery, fertilizer, chemicals, seed, fuel, lubrication, and so on. Production costs for each input are estimated in principle by multiplying the price of an input by the amount of input used in production. For some inputs, such as land, seed, fertilizer, and chemicals, price and quantity are generally assumed to be given, that is, they are treated as exogenous variables. However, price and quantity for some inputs like labor, fuel and lubrication, and machinery related inputs are not given. They are dependent on the type of machinery used, the amount of use, and other factors directly related with machinery. For example, the price of machine repair and maintenance is dependent on exogenously given parameters, such as the purchase price of the machine, repair and maintenance percent (percent of purchase price), the useful life of the machine, and annual use of the machine. Thus, it is important to know the parameters influencing these production costs and their values.

This section presents, as listed in Tables 3.1 and 3.2, assumed values of parameters used to estimate machine related costs and definitions of these parameters. Definitions of parameters are cited directly from the Mississippi State Budget Generator User's Guide by Spurlock and Laughlin (1992). Furthermore, this section also lists input prices used in estimating enterprise budgets.

Definitions of Variables

Variables defined Table 3.1 are the ones actually used by the budget generation process. The letters in parenthesis are the notation for that variable.

Parameter Values and Input Prices

Tables 3.2, 3.3, and 3.4 in this section list the parameter values used to estimate the production cost of biomass energy crops in this study. Table 3.2 lists values related to tractors, Tables 3.3 and 3.4 list values associated with implements. Notice that additional labor (AL) is assumed to be zero.

Annual use in Table 3.3 has two different values for each implement. One (A) is annual

Table 3.1 Definitions of variables

Variable name	Definition
Additional labors (AL)	the number of laborers required for an operation in addition to the tractor driver.
Annual use (U)	the estimated number of hours per year the machine is expected to be used.
Fuel multiplier (FM)	a number associated with an implement that is multiplied by the tractor's base fuel consumption to obtain the fuel consumed for a particular field operation.
Fuel consumption rate (FC)	fuel consumed by a tractor per hour.
Interest rate (IR)	the rate of interest charged to calculate interest on investment for durable inputs and for operating inputs.
Labor multiplier (LM)	a number associated with a powered machine that is multiplied by the machine's operating time to obtain the operator's labor time required for a particular field operation.
Performance rate (PR)	the estimated hours per acre that an implement requires to complete a field operation, including any normal downtime.
Purchase price (V)	the estimated price of a new piece of machinery.
Repair and maintenance rate (R)	the estimated cost of upkeep over the life of the machine expressed as a percentage of purchase price.
Salvage value (S)	the estimated vale of a piece of machinery at the end of its useful life, expressed as a percentage of purchase price.
Tractor multiplier (TM)	a number that is multiplied by the implement performance rate to obtain the time the tractor is being used.
Useful life (L)	the estimated number of years that a piece of machinery is expected to be used.
Times over (t)	the number of times a tractor is used for a specific field operation. Since a tractor is used once for a specific operation, its value equals 1.

Source: Spurlock, R. And Laughlin, D. H. 1992 Mississippi State Budget Generator User's Guide to MSBG.

hours of use of a typical Iowa farm. The other (B) is annual hours of use estimated by assuming that 160 acres of land is allocated to biomass energy crop production. The values in A are based on the assumption that a farmer who owns farm machinery uses the machinery to produce biomass energy crops in addition to crops already in production. Thus, the assumed

Table 3.2 Salvage value, useful life, and annual hours of use of tractors

Tractors	U (hours)	FC (gal/hr)	LM	R (%)	S (%)	L (years)	V ($)
75 HP tractor	400	3.30	1.15	91	10	20	30192.0
95 HP tractor	400	4.18	1.15	91	10	20	33441.0
105 HP tractor	400	4.62	1.15	91	10	20	40650.0
125 HP tractor	400	5.50	1.15	91	10	20	53057.0
130 HP combine	275	5.72	1.15	158	10	20	63784.0
145 HP tractor	400	6.38	1.15	91	10	20	58024.0
165 HP tractor	400	7.26	1.15	91	10	20	64281.0

Source: Dr. William Edwards, Economics Department at Iowa State University and MSBG.
Note: U = annual use; FC = fuel consumption rate; LM = labor multiplier; V = purchase price; R = repair and maintenance rate; S = salvage value as a percent of purchase price; L = useful life.

annual hours of use may be higher than that needed to produce the biomass crops unless the acreage produced is fairly large. The values in B are estimated based on the assumption that biomass energy crop production requires new implements and these implements will be used only on 160 acres of land allocated to biomass energy crop production. The annual hours of implement use are obtained by dividing 160 acres by the performance rate expressed in acres per hour. For example, if the performance rate is 8 acres per hour, then the annual use is $\frac{160 \text{ acres}}{8 \text{ acres / hour}} = 20 \text{ hours}$.

The purposes of using two different values for each implement is to compare production cost differences between using machinery already owned and fully utilized by a farmer and using new machinery to grow biomass energy crops on a limited basis. If a farmer finds that growing biomass energy crops does not require new machinery, he may be more willing to grow the energy crops. As an example, consider the implement depreciation cost (fixed cost) of a bulk fertilizer spreader using the following formula,

Depreciation cost = Price (P) x Quantity (Q) where $P = \frac{(V \times (1-(S \times 0.01))}{(L \times U)}$ and Q = t x PR. Here V = purchase price ($); S = salvage value percent (percent of purchase price); L = useful life (years); U = annual use (hours/year); t = times over; PR = performance rate (hours/acre) (Spurlock and Laughlin, 1992) (See Tables 3.3 and 3.4 for values of the variables appearing in the formula). With annual hours of use of a bulk fertilizer spreader similar to a typical Iowa operation, the cost per acre is

$$\frac{(\$1700 \times (1-(10 \times 0.01))}{(15\ years \times 30\ hours/year)}\ x\ (1\ x\ 0.10\ \frac{hours}{acre}) = \$0.34/acre$$

while by assuming 160 acres of land, the cost is

$$\frac{(\$1700 \times (1-(10 \times 0.01))}{(15\ years \times 16\ hours/year)}\ x\ (1\ x\ 0.10\ \frac{hours}{acre}) = \$0.64/acre,$$ which is almost twice as expensive. Notice that the annual hours of bulk fertilizer use with 160 acres of land is 16 hours/year, which is obtained by dividing the allocated land (160 acres) by the performance rate of a bulk fertilizer spreader (10.2 acres/hour). Thus, this information will help a farmer, who is interested in biomass energy crop production, make a decision whether to participate or not.

Table 3.5 shows the input prices used in estimating production costs of biomass energy crops. All prices in Table 3.5 are in nominal dollars for 1993. Price data were collected from many different sources. Price data for fertilizers, fungicides and herbicides were obtained from the local COOP in Nevada, Iowa. Corn and soybean seed prices are cited from the Iowa State University publication, "Estimated Costs of Crop Production in Iowa, 1993," (Duffy and Judd, 1993). Other seed prices were collected from a extension agronomist, Dr. S. K. Barnhart, who is an Extension Forage Specialist in the College of Agriculture at Iowa State University.

Transportation costs to a conversion plant are assumed to be $4.15 per ton of dry matter for all crops. This cost is estimated by using the biomass product transportation cost formula developed by Baht et al (1992). The assumed distance is a 30 mile round trip. A semi-truck hauling 15.42 tons of hay is assumed to be used.

Table 3.3 Performance rate and annual hours of use of implements

Description	Annual Use (A)	Annual Use (B)	Performance Rate
	(Hours)		(Acre/Hour)
FERTILIZATION			
Bulk fertilizer, 25 ft	30	16	10.2
NH_3 applicator, 15 ft	60	28	5.7
TILLAGE			
Chisel plow, 15 ft	80	22	7.4
Tandem disk, 17 ft	100	18	9.2
Disk with sprayer, 21 ft	100	21	7.8
Peg-tooth harrow, 7 section	40	9	18.0
Field cultivator, 18 ft	40	18	8.7
PLANTING			
Grain drill, 30 ft	40	13	12.7
Planter, 12 row NR	60	13	12.7
No-till planter, 8 row NR	60	18	8.7
Cultipacker, 15 ft	120	23	7.1
WEED CONTROL			
Sprayer, 40 ft	50	14	11.8
Cultivator, 12 row NR	80	13	12.4
HARVESTING			
Mower-conditioner, 12 ft	120	27	5.9
Flail chopper, 10 ft	80	24	6.7
Rake, 9 ft	100	34	4.7
Large round baler, 14 ft	120	29	5.6
Silage harvester, 3 row NR	200	80	2.0
Forage blower, 14 ft	50	27	6.0
Corn head, 8 row NR	170	34	4.7
Soybean platform, 24 ft	80	30	5.3
Haul hay, 15 ft trailer	80	40	4.0
Haul grain, 300 bu wagon	150	27	6.0
Haul silage, 14 ft	140	80	2.0
Haul stover, 14 ft	140	80	2.0

Note: Data on performance rate and annual hours of machine used in (A) are from Dr. William Edwards, Economics Department, Iowa State University. Annual hours of use in (B) are calculated by dividing the assumed allocated land to biomass energy crop production, 160 acres, by the performance rate in the last column.

Table 3.4 Other parameter values for implements

Implement	FM	V ($)	R (%)	S (%)	TM	L (years)
FERTILIZATION						
Bulk fertilizer, 25 ft	1.0	1700.0	88	10	1.0	15
NH_3 applicator, 15 ft	1.0	4114.0	88	10	1.0	15
TILLAGE						
Chisel plow, 15 ft	1.0	3825.0	52	10	1.0	15
Tandem disk, 17 ft	1.0	13515.0	88	10	1.0	15
Disk with sprayer, 21 ft	1.0	13557.5	88	10	1.0	15
Peg-tooth harrow, 7 section	1.0	3655.0	88	10	1.0	15
Field cultivator, 18 ft	1.0	4955.5	88	10	1.0	15
PLANTING						
Grain drill, 30 ft	1.0	17000.0	71	10	1.0	15
Planter, 12 row NR	1.0	21692.0	77	10	1.0	15
No-till planter, 8 row NR	1.0	23655.5	117	10	1.0	15
Cultipacker, 15 ft	1.0	5400.0	88	10	1.0	15
WEED CONTROL						
Sprayer, 40 ft	1.0	2125.0	110	10	1.0	15
Cultivator, 12 row NR	1.0	8882.5	88	10	1.0	15
HARVESTING						
Mower-conditioner, 12 ft	1.0	15300.0	198	10	1.0	15
Flail chopper, 10 ft	1.0	7947.5	32	10	1.0	15
Rake, 9 ft	1.0	3825.0	66	10	1.0	15
Large round baler, 14 ft	1.0	16575.0	94	10	1.0	15
Silage harvester, 3 row NR	1.0	29750.0	71	10	1.0	15
Forage blower, 14 ft	1.0	4207.5	26	10	1.0	15
Corn head, 8 row NR	1.0	25500.0	104	10	1.0	15
Soybean platform, 24 ft	1.0	12435.0	32	10	1.0	15
Haul hay, 15 ft trailer	1.0	654.5	32	10	1.0	15
Haul grain, 300 bu wagon	1.0	4930.0	80	10	1.0	15
Haul silage, 14 ft	1.0	7650.0	88	10	1.0	15
Haul stover, 14 ft	1.0	7650.0	88	10	1.0	15

Source: MSBG

Note: FM = fuel multiplier; V = purchase price; R = repair and maintenance rate; S = salvage value as percent of purchase price; TM = tractor multiplier; L = useful life.

Table 3.5 List of input prices

Item	Unit	Price ($)
FERTILIZERS		
Phosphorus	lb.	0.25
Potash	lb.	0.17
Nitrogen (bulk)	lb.	0.21
Anhydrous	lb.	0.12
Lime	ton	6.00
FUNGICIDES		
Eptom	pt	2.81
HERBICIDES		
Atrazine	pt	1.58
Bladex	pt	3.07
Dual	pt	7.88
Lasso	pt	3.28
Lorsban 4E	pt	1.81
Paraquat	pt	4.46
2,4D	pt	2.31
SEED		
Alfalfa	lb.	2.50
Reed canarygrass	lb.	4.50
Switchgrass	lb.	3.50
Big bluestem	lb.	9.00
Sweet sorghum	lb.	0.50
Sorghum x sudangrass hybrid	lb.	0.35
Rye	lb.	0.31
Corn	1000 kernels	0.90
Soybean	unit	14.00
TRANSPORTATION COST	ton	4.15
INTEREST	%	10.00
LABOR	hour	6.00
DIESEL FUEL	gal	0.83
LAND, Ames	acre	115.00
Chariton		80.00

Calculation Method

This section deals with the actual calculation method used for biomass production costs and returns estimation with an example. The example given is for the per acre bulk fertilizer field operation performed in estimating the annual cost of switchgrass in Ames with Iowa equipment use. For this field operation, a 105 hp tractor and a 25 ft bulk fertilizer implement is used. The values of parameters associated with these machines are as follows: t (times over) = 1, FM (fuel multiplier) = 1, TM (tractor multiplier) = 1, PR (performance rate) = 0.1 hours/acre, FC (fuel consumption rate) = 4.62 gallons/hour, V (purchase price) = $40649.55 for the tractor and $1700.0 for the implement, R (repair and maintenance rate) = 91% for tractor and 88% for the implement, L (useful life) = 20 years for the tractor and 15 years for the implement, U (annual use) = 400 hours/year for the tractor and 30 hours/year for the implement, LM (labor multiplier) = 1.15, AL (additional labor) = 0.0, and S (salvage value) = 10% for both tractor and implement. The real interest rate(r) is assumed to be 6.5% per year. The diesel price is $0.83/gallon, and wages are $6.0/hour.

All incomes and costs ($/acre), with the exception of allocated cost items - land and establishment cost - are calculated by multiplying a price ($/unit of measure) by a quantity (unit of measure/acre).

Direct Expenses of Tractors and Implements

Fuel, oil, and lubrication cost. In general, fuel cost can be obtained by using the following equation:

Fuel cost = Price (P) x Quantity (Q)

where P = price of fuel ($/gallon) and Q is amount of fuel, oil, and lubrication consumed by a tractor. Quantity of fuel, oil, and lubrication for a tractor is estimated as follows:

Quantity (Q) = t x PR x TM x FC x FM,

where t = times over ; PR = performance rate (hours/acre) of a implement ; TM = tractor multiplier; FC = fuel consumption rate (gallon/hour); FM = the fuel multiplier (Spurlock and Laughlin, 1992). For example, the fuel cost of bulk fertilization is estimated as follows:

Fuel cost = $0.83/gal x (1 x 0.10 hours/acre x 1 x 4.62gal/hours x 1) = $0.38/acre.

Repair and maintenance cost: This cost is estimated by using the following formula:

Repair and maintenance costs = Price (P) x Quantity (Q)

where $P = \frac{(V \times R \times 0.01)}{(L \times U)}$ for both tractors and implements and Q = t x PR x TM for tractors and Q = t x PR for implements where V = purchase price ($); R = repair and maintenance rate; L = useful life (years); U = annual use (hours/year); t = times over; PR = performance rate (hours/acre); TM = tractor multiplier (Spurlock and Laughlin, 1992). For example, by substituting values given above, we can obtain repair and maintenance costs of

$\frac{(\$40649.55 \times 91 \times 0.01)}{(20 \text{ years} \times 400 \text{ hours/year})} \text{ x } (1 \text{ x } 0.10 \frac{\text{hours}}{\text{acre}} \text{ x } 1) = \$0.46/\text{acre}$ for a tractor and

$\frac{(\$1700 \times 88 \times 0.01)}{(15 \text{ years} \times 30 \text{ hours/year})} \text{ x } (1 \text{ x } 0.10 \frac{\text{hours}}{\text{acre}}) = \$0.32/\text{acre}$ for an implement.

Labor cost: The labor costs are estimated as follows:

Labor cost = Wage (W) x Quantity (Q)

where Q = t x PR x TM x LM for tractors, and Q = t x PR x AL for implements, where LM = labor multiplier; PR = performance rate; TM = tractor multiplier; t = times over; and AL = additional laborers (Spurlock and Laughlin, 1992). For example, by substituting values given above, we can obtain labor cost of

$6.0/hour x (1 x 0.1 hours/acre x 1 x 1.15) = $0.69/acre for the tractor and

$6.0/hour x (1 x 0.1 hours/acre x 0.0) = 0 for the implement.

Fixed Expenses for Tractors and Implements

Machinery depreciation. In this study, depreciation is estimated in the following way.

Depreciation costs = Price (P) x Quantity (Q)

where $P = \frac{V \times (1-(S \times 0.01))}{(L \times U)}$ for both tractors and implements, Q = t x PR x TM for tractors, and Q = t x PR for implements, where V = purchase price ($), S = salvage value percent (percent of purchase price), L = useful life (years), U = annual use (hours/year), t = times over, PR = performance rate (hours/ acre), and TM = tractor multiplier (Spurlock and

Laughlin, 1992). For example, by substituting given values for each parameter, the following machinery depreciation is obtained:

$$\frac{\$40649.55\times(1-(10\times0.01))}{(20\text{ years}\times400\text{ hours/year})}\times(1\times0.10\frac{\text{hours}}{\text{acre}}\times1)=\$0.46/\text{acre}\text{ for a tractor and}$$

$$\frac{\$1700.0\times(1-(10\times0.01))}{(15\text{ years}\times30\text{ hours/year})}\times(1\times0.10\frac{\text{hours}}{\text{acre}})=\$0.34/\text{acre}\text{ for an implement.}$$

This is basically straightling depreciation over the life of the machine.

Interest on average investment. Interest on capital invested in machinery is estimated in the following way:

Interest = Price (P) x Quantity (Q),

where $P=\frac{0.5\times(V\times(1+(S\times0.01)))\times r\times0.01}{U}$ for both tractors and implements, Q = t x PR x TM for tractors, and Q = t x PR for implements, where r = real interest rate (Spurlock and Laughlin, 1992). For example, interest on the 105 hp tractor and bulk fertilizer implement is

$$\frac{0.5\times(\$40649.55\times(1+(10\times0.01)))\times6.5\times0.01}{400\text{ hours}}\times(1\times0.1\frac{\text{hours}}{\text{acre}}\times1)=\$0.36/\text{acre}\text{ for the}$$

tractor and

$$\text{P}=\frac{0.5\times(\$1700.0\times(1+(10\times0.01)))\times6.5\times0.01}{30\text{ hours}}\times(1\times0.1\frac{\text{hours}}{\text{acre}})=\$0.20/\text{acre}\text{ for the}$$

spreader.

Total fixed expense related to bulk fertilization is the sum of machinery depreciation and interest on average investment for both the tractor and the implement, which is $1.36/acre for this example.

Direct Expenses from Operating Inputs

Direct expenses include costs related to the nondurable inputs, such as seed, fertilizer, and herbicides. The cost of a nondurable input = Price (P) x Quantity (Q), where P is the market price of the input ($/unit of measure) and Q = t x Q, where t = times over and Q = quantity applied per one time over (unit of measure/acre). For example, switchgrass received 32 pounds of phosphorus per acre each standing year. The cost of phosphorus is obtained by simply multiplying this amount by the price of this input, \$0.25/pound, which is \$0.25/pound x 32 pounds/acre = \$8.0/acre.

Interest on Operating Capital

Each production activity in crop production is performed at a different time of the year, for example, planting in spring, herbiciding in summer, and harvesting in fall. Thus, it is important to define clearly the number of months that interest is charged. MSBG calculates the number of months for which interest is charged as follows:

first, if the month the operation (mo) occurred is less than the ending interest month (em), then

month = 1 + em - mo,

second, if the month the operation occurred is equal to the ending interest month, then

month =1, and

third, if month of operation occurred is greater than the ending interest month, then

month = 13 + em - mo.

The interest on operating capital is estimated as follows:

$$\text{interest} = \left(r \times 0.01 \times \frac{m}{12} \right) \times Q,$$

where r = real interest rate, m = months, and Q = direct expense of operation calculated by MSBG (Spurlock and Laughlin, 1992). For example, since the month of phosphorus application is October of the year previous to the ending interest month, which is September of the following year, interest charging month (m) is estimated as follows: m = 13 + 9 - 10 = 12. The quantity (Q) is estimated by the adding direct expenses of operation - fuel cost, repair and maintenance costs, and labor costs for both a tractor and an implement, which is \$2.26/acre for this example. By using these values and the given real interest rate, interest for this operation is estimated as follows:

$$\left(6.5\text{x}0.01\text{x}\frac{12}{12} \right) \times \left(\frac{\$0.38}{\text{acre}} + \frac{\$0.79}{\text{acre}} + \frac{\$0.69}{\text{acre}} \right) = \frac{\$0.12}{\text{acre}}.$$

Notice that the estimated interest on operating expenses in this study is an approximation. A more accurate method would use the following formula:

$$\text{interest} = q\left(1+(r \times 0.01)\right)^{\frac{m}{12}} - q,$$

where q is direct expenses of operation, r is a real interest rate, and m is the number of months between operating expenses occurreing and the ending period. By substituting the same values for q, r, and m, this formula estimates interest of bulk fertilization as $0.15/acre.

Interest on operating capital as estimated by the MSBG is slightly lower; however, it is a good approximation.

Transportation Costs

This is the cost related to transporting biomass feedstocks to a biofuel plant and is estimated by using the following equation:

Transportation cost = 34.8 + 0.62d,

where d is the mean round-trip distance between farm and processing plant (Bhat, English, and Ojo, 1992), which is assumed to be 30 miles (about 48.279 Km) in this study. Since this is a cost per truck load, which is 15.42 tons for herbaceous crops, this cost estimate is converted to average per ton cost by dividing the cost per truck load by 15.42 tons per truckload. For example,

Average cost/ton = [34.8 + (0.62 x 48.279)]/15.42 = 4.15/ton.

Establishment Cost

This is a cost related only to perennial species, such as alfalfa, reed canarygrass, switchgrass, and big bluestem, for their establishment year. Establishment costs are prorated using the formula for an annuity (Hallam, 1995),

$$a = \frac{\dfrac{\left(V_o - \dfrac{V_n}{(1+r)^n}\right)}{1 - \dfrac{1}{(1+r)^n}}}{r}.$$

where a is an annuity, V_o is the beginning value or the establishment cost, V_n is the ending value or value of the crop stand the end of the assumed life span of the perennial grass, r is a real interest rate, and n is the assumed life span of each perennial grass following the first. Notice that V_n is zero in this study because the crop is assumed to be unproductive and requiring reestablishment at the end of its productive life. For example, as shown in Table 5.4 in chapter 5, total expenses for switchgrass during the establishment year are $239.55/acre and dry matter yield is 3.62 ton/acre. By assuming that switchgrass dry matter would be sold as biomass at $55/ton, total revenue, $199.10/acre, is estimated. By subtracting total revenue from total establishment cost, a net cost of $40.45/acre is obtained. Since switchgrass lasts for approximately 10 years after the establishment, the net establishment cost is prorated over the remaining years at the given real interest rate. By substituting net establishment cost for V_O, the real interest rate (6.5%/year), and standing years (10 years) into the annuity formula, we estimate prorated the establishment costs of $5.63/year. The estimation procedure is as follows:

$$a = \frac{\dfrac{\left(\$40.45/\text{acre} - \dfrac{0}{(1+0.065)^{10}}\right)}{1 - \dfrac{1}{(1+0.065)^{10}}}}{0.065} = \$5.63/\text{acre}.$$

This cost is added to the annual production costs as an allocated cost.

Analyzing Enterprise Budgets

The enterprise budget discussed is an economic budget which means that opportunity costs on labor, capital, and land are included as expenses. The resulting profit (or loss) is the revenue remaining after covering all expenses including opportunity costs. This can be thought as an economic profit. In the case of zero profit, all labor, capital, and land are just earning their opportunity costs, that is, the earnings from next best alternatives other than the choice made. In this study, the choice made is to produce the biomass energy crop. A positive projected profit means that factors used in production earn more than their opportunity costs.

The data in an enterprise budget can be used to perform several types of analyses. These include calculating the cost of production and computing break-even prices and yields. These are especially important for biomass energy crop production primarily for two reasons: first, they can be used as benchmarks for what market price should be for energy crops since there is currently no commercial market for them; and second, they can be used to compare economic competitiveness of energy crops to fossil fuels.

Cost of production is a term used to describe the average total cost of producing one unit of the commodity. The cost of production equation for energy crops is

$$\text{Cost of production} = \frac{\text{total costs per acre}}{\text{yield per acre}}\ .$$

Units are dollars per acre for total costs and ton per acre for yield. Thus, the cost of production unit is $/ton. Notice that cost of production changes if either costs or yield change (Kay and Edwards, 1994).

A break-even analysis on prices and yields can be done with the data contained in a budget. The break-even yield per acre can be estimated for a given output price by using the following formula:

$$\text{Break - even yield} = \frac{\text{total costs per acre}}{\text{output price per ton}}\ .$$

Units are dollars per acre for total costs and dollars per ton for output price. Thus, the break-even yield unit is tons/acre. This is the yield necessary to cover all costs at a given output price. This analysis is used to compute the break-even yield for a range of possible prices. It can provide some useful information about the sensitivity of the break-even yield to changes in the output price (Kay and Edwards, 1994). Notice that break-even yield changes if either costs or output price change.

The break-even price is the output price needed to just cover all costs at a given output level and can be found from the following equation:

$$\text{Break - even price} = \frac{\text{total costs per acre}}{\text{yield per acre}}\ .$$

Units are dollars per acre for total costs and tons per acre for yield. Units for break-even price are $/ton. This can be used to compute the break-even price for different levels of yield (Kay and Edwards, 1994). Notice that break-even price changes if either costs or yield change.

As shown above, the break-even price per ton is the same as the cost of production per ton. They are just two different ways of looking at the same value. Thus, any time the product can be sold for more than the cost of production or break-even price, a economic profit is being made as long as opportunity costs are included in the costs. Break-even price can also be calculated from total variable cost rather than total costs. These results will help farm operators make the decisions about whether to produce a commodity. For example, if market price is lower than the break-even price calculated by just using total variable costs, then a manager will consider stopping production because continuing production results not only in losing on fixed costs but also losing on the variable costs.

In this study, break-even price analysis will be used to analyze the economic feasibility of biomass energy crops Break-even price analysis is used because market prices for energy crops are not available. Data on yields are available through agronomic experiments and estimation of production costs is possible because of the similarity of the biomass energy crop production technology to traditional crops.

Summary

Enterprise budgets (or costs and returns) in this study are estimated by using data from various sources: experimental data for yields and nondurable inputs, such as fertilizer, seed, and chemicals, extension data for machine related values, personal interviews for field operations, and so on.

Enterprise budgets in this study show projected income and expenses for a single enterprise. An enterprise is defined by a cropping systems, for example, monocrop, double crop, crop rotation, and intercrop systems, for one acre. Enterprise budgets in this study are economic budgets and include all operating expenses, all fixed expenses, as well as opportunity costs on factors like operator labor, operating inputs, capital investment on machinery, and land.

Income is influenced by yield and output price. Factors influencing costs are nondurable inputs - such as fertilizer, seed, and chemicals - and durable inputs, that is, machine related parameters. Costs related to machinery use are influenced by machinery types, annual use, useful life, performance rate, fuel consumption rate, and so on.

This projected enterprise budgets can be used to compare profitability of alternative enterprises, that is, cropping systems in this study, in different regions. This enterprise budget contains the data needed to compute production cost, the break-even price, and break-even yield.

CHAPTER 4

PHYSICAL ASPECTS OF BIOMASS PRODUCTION AND DESCRIPTION OF THE AGRONOMIC EXPERIMENTS

Introduction

Knowledge of the production technologies related to the production of biomass energy crops is important for number of reasons. First, it is the production technology that influences the production costs of biomass energy crops. For example, using no-till technology might reduce operating costs of machinery use compared to a conventional tillage system. Second, different production technologies might have different external costs, such as costs related to soil erosion. For example, an annual crop intercroped into a perennial species has less of a soil erosion problem and will result in reduced soil erosion costs. This will be discussed in more detail in the chapter on environmental impacts of dedicated biomass energy crops (chapter 9). Third, because of the uncertainty involved with new products, when a representative farmer faces a decision as to whether to produce biomass energy crops, he is more likely consider participation in production if the biomass energy crops can be produced using current technology. As shown in the following sections in this chapter, the production technologies of dedicated biomass energy crops are similar to traditional crop production technologies such as corn, soybean, and forages.

This chapter presents physical aspects of the production of dedicated biomass energy crops and a description of the agronomic experiments performed for this study. A number of factors influence the costs of producing biomass energy crops including: cropping systems, cultivation systems, species, treatments, regions, and site variability (Turhollow, 1994). These factors will be discussed in the following sections of this chapter.

This chapter also presents the costs of each machine used in biomass energy crop production. Two sets of machinery costs are presented. The first are machinery costs assuming average Iowa annual equipment use, the second are custom rates for the machinery considered in this study. The first set are estimated using a computer assisted budget generator, the Mississippi State Budget Generator (MSBG). The purpose of presenting the machinery costs is to give potential farmers information on production costs under different scenarios.

Discussion of Experimental Sites

The dedicated biomass energy crops were planted at two sites in Iowa, Ames and Chariton, from 1988 to 1992. Each location has a different Land Use Capability, soil type, and slightly different weather pattern. The purpose of growing energy crops at two different sites was to compare yield responses and production costs of energy crops under different soil and weather conditions.

The Ames site, located in the central Iowa, is a low erosive, highly productive soil having a Land Use Capability classification of I. The soil is a Harps (fine loamy mesic typic Calciaquoll) silty clay loam with a slope of less than 1% and no impervious layer present. Rooting depth can extend to 2 m. The soil is capable of storing 305 mm of available water in the rooting zone. The soil pH averages 8.0. Organic matter concentration was 7%, and available phosphorus (P) and potassium (K) was 6.5 and 123 kg/ha, respectively. The frost free growing season averages 160 days. Rainfall averages 813 mm per year (Anderson, Buxton, and Hallam, 1994).

The Chariton site, located in the southern Iowa, is a lower productive soil having a Land Use Capability classification of III. The soils are susceptible to drought. The soils are a mixture of Clarinda (fine silty montmorillonitic mesic typic Argiaquoll), Clearfield (fine silty mixed mesic typic Argiaquoll), and Grundy (fine montmorillonitic mesic aquic Argiaquoll) silty clay loams. The soils have slopes ranging from 2% to 7%. The soils have a high clay content layer in the B horizon which retards rooting at a depth of 45 cm. The soils have the capacity to store 250 mm of available water to a 2 m depth. The site was in conventionally managed red clover before initiation of the experiments. Soil samples taken before the initiation of the experiments revealed an average pH of 6.8. Available P and K was 28 kg/ha and 166 kg/ha, respectively, and soil organic matter content was 4%. The area has an average growing season of 165 frost free days and rainfall averages 854 mm per year (Anderson, Buxton, and Hallam, 1994).

Discussion of the Experimental Cropping Systems

A cropping system is an alternative way to produce biomass energy crops. The purpose of using different cropping systems is to compare total biomass production, soil loss potential, and economic feasibility of different species and systems. Table 4.1 shows the cropping systems used in the experiments, number of harvests per year for perennials, and the different levels of nitrogen applied in each system.

There are thirteen cropping systems and nine crop species (four perennial species and five annual crops) as shown in Table 4.1. As will be seen in the following chapters, sorghums have a higher yield than perennials. However, perennials have the following advantages: first, they have excellent soil erosion control properties and can be grown productively on both highly productive land and marginal land that is unsuitable for production of row crops. All of the harvestable material can be removed without creating soil erosion because the permanent root system remains in the field after harvest, thereby protecting the soil from wind and water erosion, and another advantage is that cutting and hauling of these forage crops need not conflict with crop harvests of corn and soybean (Sperling, 1990).

Of the thirteen cropping systems, the first six systems are pure monoculture systems. Of the first six monoculture systems, the first four systems involve the production of perennial grasses, a legume (alfalfa), a cool-season introduced grass (reed canarygrass), and two native warm-season grasses (switchgrass, and big bluestem), that have been grown mostly for the feeding of animals. The other two monoculture systems, systems 5 and 6, involve annual crops: sweet sorghum and sorghum x sudangrass hybrid.

Systems 7 and 8 are doublecrop systems of annual crops. Rye was doublecropped with sweet sorghum for system 7 and sorghum x sudangrass hybrid for system 8.

Systems 9 to 11 were grown as a three year fixed rotation. This can be treated as two different rotation systems since the crop in the third year varied. The first system is monocrop sweet sorghum in rotation, and second one is rye/sweet sorghum double crop in rotation. These rotation systems were managed in the following way: given initially allocated land, corn was produced first, then soybean, followed by either sweet sorghum or a sweet sorghum/rye double crop depending on the cropping system within the rotation.

Table 4.1 Cropping systems

Cropping Systems	Remark
1. Alfalfa (2-cut vs. 3-cut)	Monocrop
2. Reed canarygrass (2-cut) (N = 0,62.5, 125, 250 lbs/acre)	Monocrop
3. Switchgrass (one cut) (N = 0,62.5, 125, 250 lbs/acre)	Monocrop
4. Big bluestem (one cut) (N = 0,62.5, 125, 250 lbs/acre)	Monocrop
5. Sweet sorghum (N = 0,62.5, 125, 250 lbs/acre)	Monocrop
6. Sorghum x sudangrass hybrid (N = 0,62.5, 125, 250 lbs/acre)	Monocrop
7. Sweet sorghum/Rye (N = 0,62.5, 125, 250 lbs/acre)	Double crop
8. Sorghum x sudangrass hybrid/Rye (N = 0,62.5, 125, 250 lbs/acre)	Double crop
9a. Sweet sorghum (monocrop)	Monocrop in rotation[1]
9b. Sweet sorghum/Rye (double crop) (N = 0,62.5, 125, 250 lbs/acre)	Double crop in rotation[1]
10. Corn (N = 0,62.5, 125, 250 lbs/acre)	Rotation[1]
11. Soybean	Rotation[1]
12a. Sweet sorghum/Alfalfa (N = 62.5 and 125 lbs/acre)	Intercrop
12b. Sorghum x sudangrass hybrid/Alfalfa (N = 62.5 and 125 lbs/acre)	Intercrop
13a. Sweet sorghum/Reed canarygrass (N = 62.5 and 125 lbs/acre)	Intercrop
13b. Sorghum x sudangrass hybrid/Reed canarygrass (N = 62.5 and 125 lbs/acre)	Intercrop

[1] The rotation is a three year sequence of corn, soybean, and either sweet sorghum monocrop (9a) or rye/sweet sorghum double crop(9b) in the third year.

The final two systems, systems 12a and 12b and 13a and 13b, are intercropping systems. Systems 12a and 13a are sweet sorghum intercropped into alfalfa and reed canarygrass already established. Systems 12b and 13b are sorghum x sudangrass hybrid intercropped into alfalfa and reed canarygrass already established.

Characteristics and Assumed Production Practices for the Biomass Species

The herbaceous biomass species considered in this study are the four perennial grasses and five annual crops as shown in Table 4.2. In this section, the general characteristics of the herbaceous biomass species involved in the agronomic experiments and the production practices involved in production of each cropping system are discussed. Two things should be noticed here. First, the production practices assumed in this study are a combination of those from trial experiments and typical best management practices in Iowa. Second, perennials have two sets of production practices: one for the establishment year and other for the standing year. The standing year production practices associated with perennials are just maintenance and harvesting activities.

Notice that the nitrogen level (125 lbs/acre) appearing in the tables are the ones selected to estimate production costs presented in Chapters 5 through 7.

Table 4.2 Characteristics of selected energy crop species

Species	Growth Habit	Stand Life	Storage and Harvest Method
Alfalfa	Perennial	5 years	Hay
Reed canarygrass	Perennial	10 years	Hay
Switchgrass	Perennial	10 years	Hay
Big bluestem	Perennial	10 years	Hay
Sweet sorghum	Annual	1 year	Silage
Sorghum x sudangrass hybrid	Annual	1 year	Silage
Rye	Annual	1 year	Hay
Corn	Annual	1 year	Grain/Silage
Soybean	Annual	1 year	Grain

Note: Intercrop sorghums were harvested and stored as a hay rather than silage. Corn stover was stored as silage.

Characteristics of Alfalfa

Alfalfa is a herbaceous perennial legume, one of only a few crops that can be grown in every state in the USA Alfalfa is regularly produced in the North Central states. Alfalfa is a highly drought tolerant species. It becomes dormant for up to two years, if necessary, during periods of severe drought and resumes growth when moisture conditions become favorable (Barnes and Sheaffer, 1985).

Alfalfa has been produced primarily as a feedstuff for livestock because it possesses the highest feeding values among all commonly grown hay crops. It produces more protein per acre than grain or oil seed crops (Barnes and Sheaffer, 1985). Alfalfa can be harvested for fuel or chemicals, or used in a cropping rotation to provide nitrogen for other crops, thus reducing the need for expensive inputs of fossil fuel derived nitrogen (Barnes and Sheaffer, 1985; Bungay, 1980; Sperling, 1990).

Alfalfa has the potential to be a highly productive crop; however, the success of its production depends on the following factors: a fertile soil, adequate water, and good seedbed preparation at establishment (Barnes and Sheaffer, 1985; Undersander, et al., 1991). Proper fertility management is the key to optimum economic yields. Proper fertilization of alfalfa allows for good stand establishment and promotes early growth, increases both yield and quality, and also improves alfalfa's winter hardiness and stand persistence. Good fertility also improves the ability of alfalfa to compete with weeds and strengthens disease and insect resistance (Undersander et al., 1991). Alfalfa is sensitive to soil acidity. Thus, soil pH is a critical factor for establishment and maximum production of alfalfa. Soil pH influences symbiotic nitrogen (N) fixation and the availability of essential and toxic elements (Barnes and Sheaffer, 1985). Lime application before seeding is important to achieve and maintain proper soil pH level (6.8 or higher) for alfalfa. Benefits of liming alfalfa include "increased stand establishment and persistence, more active nitrogen-fixing of Rhizobium bacteria, added calcium and magnesium, improved soil structure and tilth, increased availability of phosphorus and molybdenum, and decreased manganese, iron and aluminum toxicity" (Undersander et al., 1991).

Other nutrients commonly recommended for alfalfa production include phosphorus and potassium, which are relatively immobile nutrients when added to soil. Research has shown that maintaining yields, reducing susceptibility to certain diseases, and increasing winter hardiness and stand survival are highly dependent on an adequate potassium supply. It has also been shown that adequate soil phosphorus levels increases seeding success at establishment by encouraging root development (Undersander et al., 1991; Barnes and Sheaffer, 1985).

Alfalfa typically obtains enough nitrogen for production from its symbiotic relationship with nitrogen fixing *Rhizobia* bacteria and from soil organic matter-released nitrogen. Thus, nitrogen application is not generally recommended for alfalfa, except when alfalfa is seeded on low-N soils or when alfalfa is seeded with a companion crop (Undersander et al., 1991; Barnes and Sheaffer, 1985).

Diseases and winter hardiness are the key factors for the persistence of an alfalfa stand. Lack of winter hardiness may result in winter injury or winterkill. Winter injury causes reduced plant density and a lower yield. Diseases may cause seedling death, reduced stand density, lower yield and shortened stand life (Undersander et al., 1991). Choosing disease resistant cultivars and utilizing proper fertilizer management practices are two widely suggested practices to overcome diseases and lack of winter hardiness (Undersander et al., 1991; Barnes and Sheaffer, 1985). The expected stand life of alfalfa can be up to 10 years (Barnes and Sheaffer, 1985) but the typical stand life of alfalfa in Iowa is three to four years. A four year stand life after establishment is assumed in this research.

Production Practices Used in Growing Alfalfa

The production practices assumed in this study are a combination of those from the trial experiments and typical best management practices in Iowa. A summary of these practices is presented in Table 4.3. Table 4.3 presents the production practices during the establishment year and the production practices during the standing year.

As shown in Table 4.3, the most commonly recommended fertilizers - lime, phosphorus, and potassium were applied in this research during the establishment year and are assumed to be used for cost estimation. Although some have recommended applying lime 12 months before seeding to get better results (Undersander et al., 1991), in the experiments, lime was applied in the fall of the year previous to establishment of alfalfa at Chariton. Lime was not applied at Ames because the soil had a pH above 7 (Anderson, Buxton, and Hallam, 1994). Application time for both phosphorus and potassium during establishment is not specified. In the experiments and in computing costs of production, both phosphorus and potassium were applied once in the fall of the year previous to the establishment of alfalfa. There is no annual fertilizer application beyond the establishment year since all fertilizer is applied during the establishment year.

Fertilizer application rates are usually determined by soil test. In this research, 160 lbs per acre of phosphorus and 625 lbs per acre of potassium were applied at both Ames and Chariton during the establishment year.

The time of alfalfa seeding is influenced by the following factors: precipitation patterns, temperature, and cropping patterns (Barnes & Sheaffer, 1985). Alfalfa seeding in the US generally occurs either in the early spring or in the late summer. Adequate moisture and cool temperatures at the time of seedling germination is crucial for successful establishment. Since alfalfa is extremely cold tolerant at emergence, spring seeding of alfalfa can begin as soon as the potential for damage from spring frosts has passed. This early seeding brings less weed competition and less moisture stress during germination because of cooler temperatures. For northern states, including Iowa, spring seeding is preferred because of a greater chance of successful stand establishment for the reasons explained above (Undersander et al., 1991). Recommended seeding dates in Iowa are April for North and Central Iowa and between the middle of March and April for Southern Iowa (Undersander et al., 1991). Alfalfa was seeded in the middle of April at both of the experimental sites, Ames and Chariton.

Optimum seeding depths of alfalfa vary with soil types. Shallower depths may be used when moisture is adequate while the deeper depths should be used for drier soil conditions. In general, alfalfa seed should be planted in a firm seedbed to a depth of 0.52 inches with a cultipacker seeder or with press wheels on a conventional drill in order to obtain good soil-seed contact (Barnes & Sheaffer, 1985; Undersander et al., 1991).

Optimal seeding rates are influenced by soil conditions, the method of seeding used, and weather conditions. Generally recommended seeding rates are between 12 and 15 pounds per acre (Undersander et al., 1991). In this research, a grain drill was used to seed alfalfa seed at the rate of 12 pounds per acre in Ames and 14 pounds per acre in Chariton, respectively. A cultipacker was used to firm the soil (see Table 4.3).

Field preparation is important for controlling weeds and smoothing the soil. Controlling the weeds prior to seeding helps ensure a long-lasting, productive stand. As suggested by Undersander et al. (1991), field preparation began in the fall before spring seeding. In this research, a chisel plow was used to loosen the soil and help control weeds. This was followed in the spring by disking for further weed control, land leveling, and breaking up large soil clods before seeding. Harrowing was practiced as the final tillage in the spring to smooth out soil. Eptam, a preplant incorporated herbicide for controlling annual grasses and broadleaf weeds (Undersander et al., 1991), was applied in this research at the rate of 3 pints per acre (2.8 lb a.i./acre). Field preparation activities during the establishment year are illustrated in detail in Table 4.3.

Harvest schedules are important to provide the highest yield of high quality forage. Optimum harvest schedules for biomass use of alfalfa are different than those used for producing forage for livestock. Research shows that there exists a correlation between yield, forage quality, and harvesting time. Biomass yields increase with longer intervals between cuttings, while forage quality for livestock rapidly declines. It also has been shown that, as the plant matures, the leaf portion, which is more nutritious than stems, decreases and the stem increases in lignin and other fibrous constituents (cellulose and hemicellulose) (Undersander et al., 1991). Thus, it has been recommended, for livestock, to take an early first cutting, usually early May in Iowa, with 28-33 day-intervals after the first cut (Undersander et al., 1991). However, in this research, since the goal is to maximize yield and fibrous constituents content, the first cut occurred in June with longer intervals for the second and third cuts than

Table 4.3 Description of establishment and standing year tillage systems for alfalfa

Field Operation	Rate per Acre Ames	 Chariton	Time of Year
	Establishment year		
Fertilizer Broadcast			October
Phosphorus (P), lbs	160	160	
Potassium (K), lbs	625	625	
Lime, ton	0	5	
Chisel Plow			October
Tandem Disk			April
Harrow			April
Herbicide			April
Eptom, pt (2.8 lb a.i./a[1])	3	3	
Grain Drill			April
Seed, lbs	12	14	
Cultipack			April
Harvest (2x[2])			June and September
Mow-conditioner			
Large round bale			
Haul			
	Standing year		
Herbicide			
Lorsban, 4E, pt	2	2	
Harvest			June, August, and October
Mower-conditioner			
Rake[3]			
Large round bale			
Haul			

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[1] active ingredient per acre.

[2] Implies that alfalfa is harvested twice in the establishment year. For the establishment year, both monocrop and intercrop alfalfa have the same tillage systems.

[3] Raking is practiced only for the first harvest in the three cut system. Raking is not practiced for the two cut system. For two cuts, hay was harvested in June and September.

the suggested harvest schedule for livestock. All the following practices were employed in harvesting: mowing, mechanical conditioning, raking, and large round baling. Raking is assumed to occur on a sporadic basis, as needed depending on rainfall. For the purpose of cost estimation, one raking per year is assumed for the three cut system, with no raking in the establishment year. If alfalfa is harvested only twice each year, no raking is assumed. Mechanical conditioning was practiced to increase the drying rate. Despite the transportation inefficiency of large round bales, they are assumed because of wide spread use in Iowa. Furthermore, they are easy to store and can be left near the field on a well-drained good site.

The standing year production practices involved with alfalfa production are primarily harvesting activities. For weed control, Lorsban, 4E was applied following the first harvest (Table 4.3).

Characteristics of Reed Canarygrass

Reed canarygrass is a grass found in temperate portions of all six continents. It is well adapted to the northern half of the 48 states in the US and southern Canada. Although its natural habitat is poorly drained and wet areas, it is also drought tolerant. It is very tolerant of flooding and can withstand standing water for up to 35 or more days at any stage of development with no damaging effects (Marten, 1985).

Reed canarygrass is a tall, coarse, cool-season, sod forming perennial that spreads underground by short, scaly rhizomes, which forms a heavy sod under well managed conditions but cannot tolerate continued close clipping. It is frequently used in soil conservation programs, such as gully control, the maintenance of grassed waterways, stream channel banks, and edges of farm ponds, because its vigorous, spreading growth prevents soil erosion. Reed canary is unsurpassed for land utilization of N and other nutrients that occur in municipal and industrial waste effluents because it has superior capacity to remove N from soil treated with large amounts of waste water effluent. Reed canarygrass also has a high yield capacity with good regrowth throughout the pasture season (Marten, 1985). It tends to be slow in establishment but once established it is very disease resistant and long lived (Carlson, et al., 1978). In this study, the stand life of reed canarygrass is assumed to be 10 years.

As with alfalfa, diseases and winter hardiness are important factors for the persistence of reed canarygrass. Reed canarygrass has long been identified as a good forage producing species because of its winter hardiness, adoption to a wide range of environmental conditions, good seasonal distribution of high yields, disease resistance, drought tolerance, and persistence under a wide range of management and fertilization systems (Barnhart, 1984; Carlson et al., 1978; Marten, 1985). For these reasons, it has been lately recognized as a good candidate for biomass production.

Production Practices for Reed Canarygrass

Reed canarygrass can be seeded either in spring or late summer if sufficient moisture is available (Marten, 1985). As with alfalfa, weed control is a key to establishment because weed competition can cause failure in establishment and at best slow establishment. If seed is planted in the late summer, success is often higher because weeds are less of a problem (Carson et al., 1978). However, spring seeding is the most common for reed canarygrass, and the experiments carried out spring planting (April) as well. The reason for spring seeding is that reed canarygrass seedlings are more susceptible to killing by cold temperatures than those of most other cool-season grasses (Marten, 1985); thus, plants must be well developed before the start of winter.

The seed can be sown with a grain drill, broadcast, or with a band seeder equipped with press wheels. The seedbed should be well prepared and firm. The seed should not be placed deeper than 1.5 cm and should be cultipacked or rolled (Barnhart, 1984). Reed canarygrass can be seeded with or without a companion crop. An oat companion crop can be used for spring seeding. In this study, reed canarygrass was seeded with a grain drill because it is a practice widely used in Iowa for forage production (See Table 4.4). Although reed canarygrass in Iowa is generally seeded with an oat companion crop, it was seeded without a companion crop in this study and the same assumption was made for cost estimation.

Seeding rates can be influenced by the soil conditions, seeding method, weather conditions, soil water available, and the use of a companion crop. The recommended seeding rate falls between 8 to 10 pounds per acre for direct seeded reed canarygrass and between 4 to 5 pounds per acre with a companion crop (Carlson et al., 1978). Reed canarygrass was seeded at a rate of 9 pounds per acre in Ames and 11 pounds in Chariton.

Management of perennial cool-season grasses for biomass production consists of maximizing economic yield, while fostering persistence of the stand (Cherney et al., 1986).

Proper fertility management is the key to optimum economic yield because proper fertilization of reed canarygrass allows for good stand establishment and promotes early growth, increases yield, and improves stand persistence. To maintain high productivity, fertilization with nitrogen, phosphorus, and potassium is recommended, especially nitrogen. Although reed canarygrass responds mainly to nitrogen, increased yield may occur with added potassium and phosphorus (Marten, 1985; Carlson et al., 1978). As mentioned for alfalfa, an adequate potassium supply is essential for maintaining yields, reducing susceptibility to diseases, and increasing winter hardiness and stand survival. To increase seeding success at establishment, adequate maintenance of phosphorus is important.

Recommended rates for nitrogen range from 80 to 240 pounds per acre, depending on soil conditions and the need for forage. Split application of nitrogen is recommended when nitrogen is applied at over 120 pounds per acre. Split application is also recommended during the growing season to assure more uniform production and to lengthen the productive period (Marten, 1985; Carlson et al., 1978). As recommended, nitrogen is assumed to be applied twice in this research, once in spring at 100 pounds per acre and again in the summer at 100 pounds per acre, over the stand life. However, it is applied only once in the late spring during the establishment year. Rates for phosphorus and potassium are usually based on soil test results (Carlson et al., 1978). Based on typical soil test results for Iowa, it is assumed that 32 pounds of phosphorus per acre and 94 pounds of potassium per acre are required, which is three-fourths of the potash applied for alfalfa on an annualized basis, (625/5)*0.75.

In this experiment, four levels of nitrogen were applied to the separate plots at the experimental farms. The levels of nitrogen used were 0, 62.5, 125, and 250 pounds per acre, while 125 lbs/acre was selected to estimate production costs. See Table 4.4 for phosphorous and potassium rates.

As with alfalfa, field preparation is important for controlling weeds and smoothing the soil. The success of reed canarygrass establishment depends on good field preparation. An adequate seedbed can insure good germination. In this research, field preparation began in the fall before spring seeding. Chisel plowing was practiced in the fall to loosen the soil and help control weeds. It was followed by disking in spring for further weed control, and breaking up of large soil clods. To smooth the soil, harrowing was practiced as the final tillage in the spring. See Table 4.4 for a description of tillage during the establishment year.

Infrequent harvests with high yields are desired. Reed canarygrass stands were unaffected and no great difference in yield was found between a two and four cut harvest system (Marten and Hovin, 1980). Thus, a two cut harvest was practiced in this research.

Harvest intervals to obtain high reed canarygrass biomass yields assumed in this study are longer than those recommended for livestock forage as explained previously for alfalfa. The first harvest occurred some time in June with a long interval for the second cut (some time in October) for the standing year. The practices employed in harvesting were mowing, mechanical conditioning, and large round baling. Mowing is assumed to be done early in the day to allow full day's drying. Mechanical conditioning was practiced to increase drying rate. Large round baling was practiced because of ease of storage and wide spread current use. Raking was not practiced because reed canary-grass was harvested only twice each year.

As shown in Table 4.4, during the standing year, only fertilization and harvesting activities are necessary for reed canarygrass. During the standing years, reed canarygrass is harvested twice per year.

Characteristics of Perennial Warm-season Grasses

Switchgrass and big bluestem are warm-season grasses, which are native to the much of the Central and Lake States of the US (Van Keuren and George, 1985). Switchgrass is a tall, sod forming perennial bunchgrass that grows 3 to 5 feet tall. Big bluestem is an erect, robust, perennial bunchgrass. It grows 3 to 6 feet tall. Big bluestem is a deep rooted grass well adapted to loamy soils and is able to withstand drought conditions (Barnhart and Hintz, 1989).

These warm-season perennial grasses start growing in late spring as air and soil temperatures increase. Maximum growth occurs from June through September. As temperatures cool in fall, growth slows and ceases with the first killing frost (Barnhart and Hintz, 1989).

Table 4.4 Description of establishment and standing year tillage systems for reed canarygrass

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
	Establishment year		
Fertilizers Broadcast			October
Phosphorus (P), lbs	32	32	
Potassium (K), lbs	94	94	
Chisel Plow			October
Tandom Disk			April
Harrow			April
Grain Drill			April
Seed, lbs	9	11	
Cultipack			April
Herbicide			June
2,4-D, pt (0.9 lb a.i./a)	2	2	
Harvest			October
Mow-conditioner			
Large round bale			
Haul			
	Standing year		
Fertilization			
Phosphorus, lb	32	32	October
Potash, lb	94	94	October
Nitrogen, lb	125	125	April
Harvesting (2x)			June and October
Mower-conditioner			
Large round bale			
Haul			

Note: For the establishment year, both monocrop and intercrop reed canarygrass have the same tillage systems.

Switchgrass and big bluestem are winterhardy and will grow in all areas of Iowa. Although they are most productive on fertile and well-drained soils with a good moisture supply where corn grows best, they also grow well on less fertile and droughty soils because they have a greater tolerance to low-available soil water than the cool-season grasses (Barnhart and Hintz, 1989; Jung et al., 1988); and they also use soil nutrients more efficiently and have lower macronutrient requirements than cool-season grasses (Jung et al., 1988). These warm season grasses also use nitrogen more efficiently than cool-season grasses (Buxton, 1994; Jung et al. 1988). These properties make them practical choices to grow as biomass crops and for soil conservation on infertile, acid, and droughty soils.

Switchgrass is more tolerant than big bluestem to variability of soil conditions. It persists better in moderately wet soil conditions and occasional flooding. Switchgrass may also be better suited to droughty soils (Barnhart and Hintz, 1989) than big bluestem.

Production Practices for Big bluestem and Switchgrass

As with the other perennial grasses, seedbed preparation and fertilization are important to have successful establishment. Research has shown that an adequate potassium supply is needed to maintain yields, reduce susceptibility to disease, and increase winter hardiness and stand survival. It also has been shown that keeping adequate phosphorus levels is important to increase seeding success at establishment by encouraging root development (Undersander et al., 1991; Barnes and Sheaffer, 1985).

Soil deficiencies in lime, phosphorus, and potassium should be corrected before or at seeding time. Application of lime and fertilizer should be based on soil tests. The pH levels should be at least 6.0 (Barnhart and Hintz, 1989). Soil tests at the both experimental farms indicated that lime application was not needed for these grasses because the soil pH was well above 6.0 at both locations (Anderson, Buxton, and Hallam, 1994). Phosphorus and potassium levels were low so that 32 pounds of phosphorus and 94 pounds of potassium per acre, respectively, were applied at both experimental sites, Ames and Chariton. Suggested phosphorus and potash application rates are at least 60 pounds of each per acre (Barnhart and Hintz, 1989). These fertilizers were assumed to be applied in the fall before the spring seeding.

Experience in Iowa suggests not applying nitrogen in the seeding year because even small amounts stimulate weeds and retard warm-season grass establishment. To stimulate more rapid switchgrass establishment, it has been suggested to apply 30 pounds of nitrogen per acre in midsummer if weed control has been good in the seeding year (Barnhart and Hintz, 1989). In this research, nitrogen was not applied during the establishment year; however, nitrogen was applied during production in later years. For cost estimation, 125 pounds per acre of nitrogen was assumed to be used during the standing years.

As suggested to create a quality seedbed, chisel plowing, tandem disking, and harrowing were practiced for field preparation. The first two of these activities are practiced to loosen soil, help weed control, and break up large soil clods in the spring before seeding. Harrowing was practiced in spring to smooth out the soil.

These grasses can be seeded alone or as a mixture; however, seeding a single grass species is recommended because mixed species are more difficult to manage (Barnhart and Hintz, 1989). Warm-season grasses can be seeded from late April to mid-June (Barnhart and Hintz, 1989), but better germination, establishment and seedling development often occurs during mid-to-late April or May when precipitation patterns are more favorable. Successful stand establishment is possible with later seeding dates if adequate precipitation occurs, but first year forage yield is reduced (Vassey et al, 1985). Early seeding provides more time for these grasses to become well established before winter (Barnhart and Hintz, 1989). To take advantage of this, both switchgrass and big bluestem are assumed to be seeded in early May in this study.

Switchgrass can be seeded with a grain drill or other standard forage seeding equipment. The use of a grain drill with packing over the row to get better results is recommended. If possible, grasses should be drilled into mulched seedbeds, which helps control erosion and conserve soil water (Barnhart and Hintz, 1989). Switchgrass was seeded with a grain drill at a rate of 7.2 pounds per acre at both Ames and Chariton.

Big bluestem is difficult to seed without a special grassland drill because big bluestem seeds are light weight and 'bearded'. Seed conditioning equipment has been developed to remove the 'beard' or the long hairy appendages from big bluestem making it free flowing and more easily seeded with standard forage seeders (Barnhart and Hintz, 1989). This seed is more expensive, however. A grain drill was used to seed big bluestem, and the seeding rate was 12 pounds per acre at both Ames and Chariton. To firm the soil, cultipacking was usually used immediately after seeding.

Switchgrass and big bluestem often establish slowly and compete poorly with weeds. When established under heavy weed infestation, plants grow slowly and may take 2 to 3 years for production of good yields (Barnhart and Hintz, 1989). Thus, effective weed control is a key to the success of warm-season grass establishment. There is no herbicide currently registered for use in establishing switchgrass or big bluestem. Old supplies of labeled "atrazine" were used in the field practice of the study and these were applied at about 2.5 pounds per acre before the germination of summer annual weeds. To control broadleaved weeds, if this is a serious problem, 2,4-D application at about 0.5 pound per acre is suggested. Mowing at a height of 3 to 4 inches in early spring during the seeding year can also reduce competition by weeds (Barnhart and Hintz, 1989).

Summer mowing should be restricted to 6 inches to avoid removing any of the desired grass. Clipping should be discontinued after August 1. 2,4-D can also be used to control broadleaf weeds, once the grasses have reached the 3 to 4 leaf stage (Barnhart and Hintz, 1989). Activities employed in harvesting were the same as for alfalfa and reed canarygrass.

For the standing year, switchgrass and big bluestem have the same production activities, fertilization and harvesting. The same amount of fertilizer is applied to both switchgrass and big bluestem (see Table 4.5).

Characteristics of Sorghum

Sorghums have been used primarily for forage or grain in the US; however, there has been increased interest in production of sorghum for biomass. Sorghum production ranges from Texas to Minnesota and North Dakota in the central grassland regions. In the East, they are grown from Florida to 42° N. Sorghum is a coarse, erect grass. Although sorghums grow better with more adequate moisture, sorghums are known to be more drought tolerant than corn and soybean. During a drought period, sorghum has the capability to become dormant, then resume growth when water becomes available. The drought-tolerance capability of sorghum and its versatility make sorghum a practical choice in conventional crop rotations and conservation-tillage programs (Duncan, 1985; Fribourg, 1985). This characteristic may be useful for production in southern Iowa during relatively dry summers.

Production Practices for Sorghum

Recommended seeding temperatures for sorghums are soil temperatures of 65 to 70 F because adequate germination of sorghum takes place at this level (Duncan, 1985; Fribourg,

Table 4.5 Description of establishment and standing year tillage systems for switchgrass

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
	Establishment year		
Fertilizers Broadcast			October
Phosphorus (P), lbs	32	32	
Potassium (K), lbs	94	94	
Chisel Plow			October
Tandem Disk			April
Harrow			April
Grain Drill			May
Seed, lbs	7.2	7.2	
Cultipack			May
Herbicide			June
Atrazine 4L, pt (1.1 lb a.i./a)	2.5	2.5	
Harvest			October
Mow-conditioner			
Large round bale			
Haul			
	Standing year[1]		
Fertilization			
Phosphorus, lb	32	32	October
Potash, lb	94	94	October
Nitrogen, lb	125	125	May
Harvesting			October
Mower-conditioner			
Large round bale			
Haul			

1 For the standing year switchgrass and big bluestem have the same tillage system

Table 4.6 Description of establishment year tillage systems for big bluestem

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Fertilizers Broadcast			October
Phosphorus (P), lbs	32	32	
Potassium (K), lbs	94	94	
Chisel Plow			October
Tandem Disk			April
Harrow			April
Grain Drill			May
Seed, lbs	12	12	
Cultipack			May
Herbicide			June
Atrazine 4L, pt (1.1 lb a.i./a)	2.5	2.5	
Harvest			October
Mow-conditioner			
Large round bale			
Haul			

1985). If sorghum must be planted before the soil temperature reaches 65 F, use of a starter fertilizer is recommended to provide critically needed N and P and to enhance early season growth (Duncan, 1985).

The planting depth of sorghum depends on the soil type. The planting depth is important because the sorghum seedling does not emerge from the soil as easily as a corn seedling. Planting depth in general should not exceed 1 to 2 inches. For good emergence, the recommended depth is 3/4 to 1 inch in clay soils and 1.5 to 2 inches in sandy soils. Although sorghum can be planted in a dry soil if rain is expected or if irrigation water can be applied within two weeks after planting, sorghum growth and seedling development are usually better when the seed is planted in a moist soil (Duncan, 1985).

Seeding rates of sorghum are extremely important for economical yields. If plant populations are too high, the plants tend to compete for nutrients and moisture with each other. In addition, high populations often result in slender and weak stalks (Duncan, 1985).

The recommended seeding rates for silage are 6 to 8 pounds per acre (Duncan, 1985). Seeding rates used in this research are 7 pounds per acre for all sorghum cropping systems.

Sorghums can be drilled, broadcast, or sown in rows (Fribourg, 1985). Narrow rows, 30 inches or less, are suggested because weed control and moisture conservation may be more difficult in wider rows. With wider row spacing, sorghum has difficulty producing a closed canopy that will control weeds and reduce water losses caused by evaporation (Duncan, 1985). As suggested by Duncan (1985), a narrow row planter was assumed to be used for this study.

Although sorghum will grow on low-fertility and/or moderately acid soils, good fertility management is necessary for optimum yields in sorghum. The fertility program should be based on soil test results. The recommended fertilization is as follows: 80 to 100 pounds of N per acre for dry land and 100 to 120 pounds of nitrogen per acre for irrigated land; 60, 40, 0 pounds of P per acre for low, medium, high levels of P containing soil, respectively and 80, 60, 0 pounds of K per acre for low, medium, high levels of K containing soil, respectively (Duncan, 1985).

Phosphorus should be applied preplant or at planting while potassium may be applied before or after planting. Nitrogen should generally be applied in split applications, with about a third of the requirement applied as a preplant or starter fertilizer. The remainder should be applied in one application approximately 20-25 days after emergence (about a month after planting) or at 10-inch plant height (Duncan, 1985).

Relative to other major row crops such as corn or soybean, chemical weed control choices for sorghum are somewhat limited. The herbicide most widely used for sorghum production in Iowa and elsewhere in the US is Dual. Dual is registered for application to sorghum either as a preplant soil incorporated treatment or a preemergence treatment. Dual is recommended for use on sorghum grown from "Concep" treated seed. Concep acts as a safer, herbicide antidote, which reduces the potential for Dual injury to the crop. Suggested application rates are 1.5 to 2 pt/acre (1.8 lb a.i/a). For the double crop sorghums, paraquat provides good to excellent control of both the annual grass in the doublecrop and broadleaf weeds. The recommended application rates depend on the height of the grass or broadleaf weeds. For control of grass and broadleaf weeds 2 inches in height or less, 1 pt per acre (0.9 lb a.i/a) is suggested. For control of grass and broadleaf weeds 2 to 3 inches in height, 2 pts per acre (1.8 lb a.i/a) are suggested (Duncan, 1985).

In this research, the dry matter yield of sorghum was investigated under different cropping systems. Two sorghum cultivars, sweet sorghum and a sorghum x sudangrass hybrid were planted. The cropping systems used for sorghums were as follows: monocrop, doublecrop with winter rye, rotation following corn and soybean, double cropping with winter rye following corn and soybean rotation, and intercrop with alfalfa or reed canarygrass.

Monocrop Sorghums. Monocrop sorghum systems were fertilized before planting in the middle of May. Both sites, Ames and Chariton, received 58 pounds of phosphorus, 47 pounds of potassium, and 125 pounds of nitrogen per acre.

Monocrop sorghum fields were disked followed by field cultivation and harrowing in the middle of the spring to control weeds, break up large soil clods, and smooth the soil. A narrow-row planter was used to plant sorghum seeds in the spring. Post-planting cultivation was practiced to control weeds in summer. For weed control, Dual was applied at the rate 2 pt per acre (1.8 lb a.i/ac) at the time of disking in spring. Monocrop sorghums were harvested with a silage harvester in the late fall. Table 4.7 describes the tillage systems for monocrop sorghums.

Double Crop Sorghums with Rye. Phosphorus and potassium were applied in the fall before planting winter rye. Both sites, Ames and Chariton, received 58 pounds per acre of phosphorus and 47 pounds per acre of potassium. A split application of nitrogen was used. About one-third of the nitrogen was applied in the late March for the double crop rye/sorghum systems. The remainder was applied at the time of sorghum planting, late May (Anderson, Buxton, and Hallam, 1994).

The double crop sorghum/winter rye systems were disked followed by harrowing in the fall before planting the winter rye. Rye was planted by grain drill in the Fall and the sorghum was planted no-till into the rye stubble immediately after the rye was harvested as

Table 4.7 Description of tillage systems for monocrop sweet sorghum and sorghum x sudangrass

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Field Cultivate			May
Harrow			May
Fertilizers Application			May
Phosphorus (P), lbs	58	58	
Potassium (K), lbs	47	47	
Nitrogen, lbs	125	125	
Tandem Disk and Herbicide			May
Dual, pt (1.8 lb a.i./a)	2	2	
Plant			May
Seed, lbs	7	7	
Cultivate			July
Harvest			October
Silage harvester			
Haul			
Forage blower			

Note: Sorghum was harvested as silage.

forage in May. Winter rye was seeded at 100 pounds per acre in Ames and 120 pounds per acre in Chariton, respectively. Sorghum was seeded at 7 pounds per acre in both sites.

Winter rye was harvested as hay in late May while sorghums were harvested as silage in the fall. See Table 4.8 for a description of the tillage systems for the double crop sorghum.

Sweet Sorghum and Sweet Sorghum/Rye in Rotation. These systems are very much like the other sorghum systems except for the use of nitrogen. For the sorghum/rye in rotation with corn and soybean, no nitrogen was applied in the early spring because soybean is a nitrogen fixer. Nitrogen was applied only once in late spring, at the time of sorghum planting.

Monocrop sweet sorghum in rotation with corn and soybean was fertilized in the spring. The amount of phosphorus and potassium applied for this system was the same as the amount used for the other systems involved with sorghum, except the intercrop sorghum systems. Smaller amounts of nitrogen can be applied for this system than the other systems involving sorghum because sweet sorghum in this system was planted after soybean, which is a nitrogen fixer. However, to be consistent with other cropping systems in the experiment, four different levels of nitrogen were applied to observe the yield response. Of the four, it is assumed that nitrogen was applied at 125 pounds per acre in spring before the sorghum planting. Tables 4.9 and 4.10 give the tillage systems practiced for the sorghums in rotation with corn-soybean.

Table 4.8 Description of tillage systems for doublecrop rye/sweet sorghum and sorghum x sudangrass hybrid

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Fertilizers Application			October
Phosphorus (P), lbs	58	58	
Potassium (K), lbs	47	47	
Tandem Disk			October
Harrow			October
Grain Drill			October
Rye seed, lbs	100	120	
Fertilizer Application			March
Nitrogen, lbs	62.5	62.5	
Harvest Rye			May
Mow-condition			
Large round bale			
Haul			
Plant			May
Sorghum seed, lbs	7	7	
Fertilizer Application			May
Nitrogen, lbs	62.5	62.5	
Herbicide			June
Paraquat, pt (0.6 lb a.i./a)	2	2	
Harvest			October
Silage harvester			
Haul			
Forage blower			

Note: Sorghum was harvested as silage.

Table 4.9 Description of tillage systems for sweet sorghum in rotation with corn-soybean

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Harrow			May
Fertilizers Application			May
Phosphorus (P), lbs	58	58	
Potassium (K), lbs	47	47	
Nitrogen, lbs	125	125	
Tandem Disk and Herbicide			May
Dual, pt (1.8 lb a.i./a)	2	2	
Plant			May
Seed, lbs	7	7	
Harvest			October
Silage harvester			
Haul			
Forage blower			

Note: Sorghum was harvested for silage.

Corn and Soybean Rotation. The primary purpose of producing corn and soybean in this research was to compare sorghum yields in a crop rotation system with the sorghum yields in the other systems. An additional purpose was to consider the effects of growing biomass on farms where corn and soybean are the major crops.

For corn production in Iowa, the conventional tillage systems typically include the following activities: chisel plow, tandem disk, N application, field cultivation, planting, cultivation, and spraying. Chisel plowing is usually omitted for the crop rotation systems such as corn following soybean (Duffy and Judd, 1992). As indicated by the short description of tillage systems above, fertilizers are applied before planting while herbicides are applied after sufficient growth of corn.

As shown in Table 4.11, the tillage systems practiced in this research are somewhat different than what has been conventionally practiced in Iowa for corn production. Chisel plowing and field cultivation activities were not practiced in this research because the soil was loose enough even without plowing, and preplant herbicides were applied instead of field cultivation. Thus, the field was tandem disked followed by harrowing.

To control weeds during field preparation, herbicides were applied before planting in the spring. By attaching the sprayer on the tandem disk, disking and herbicide application activities were practiced simultaneously. The post-planting weed problems were controlled entirely by the cultivation in the summer.

Fertilizers were applied in the spring before planting. Both sites, Ames and Chariton, received the same amount of P and K, 58 pounds of P per acre and 47 pounds of K per acre, respectively. Four levels of fertilizer nitrogen, 0, 62.5, 125, and 250 pounds per acre, were applied to subplots at both sites. However, in estimating net production costs, 125 pounds of

Table 4.10 Description of tillage systems for double crop sweet sorghum/rye in rotation with corn-soybean

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Fertilizers Application			October
Phosphorus (P), lbs	58	58	
Potassium (K), lbs	47	47	
Tandem Disk			October
Harrow			October
Grain Drill			October
Rye seed, lbs	100	100	
Harvest Rye			May
Mow-condition			
Large round bale			
Haul			
Plant			May
Sorghum seed, lbs	7	7	
Fertilizer Application			May
Nitrogen, lbs	125	125	
Harvest			October
Silage harvester			
Haul			
Forage blower			

Note: Sorghum was harvested for silage.

N per acre was chosen.

Corn was planted in early May. The seeding rate was 30,000 kennels per acre. This rate allows an approximate final population of 26,506 plants per acre (Anderson, Buxton, and Hallam, 1994).

Grain and stover were harvested separately. Grain was harvested first. A corn head was attached to the combine to harvest corn grain. Stover was harvested by a flail chopper. Then, raking, large round baling, and hauling activities were followed in order on the stover.

Field preparation activities for soybean in Iowa include chisel plow, tandem disk, and field cultivation. Field preparation is practiced in the spring before planting. Soybean planting is done in the spring at a rate of 60 pounds per acre. After sufficient growth of the soybean, cultivation and herbicide applications are used to control weeds. Harvesting was done by combining in the fall (Duffy and Judd, 1992).

Table 4.11 Description of tillage systems for corn

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Harrow			April
Fertilization			April
Phosphorus (P), lbs	58	58	
Potassium (K), lbs	47	47	
Nitrogen, lbs	125	125	
Tandem Disk & Herbicide			April
Bladex 4L, pt (2.2 lb a.i./a)	5	5	
Lasso, pt (2.4 lb a.i./a)	5	5	
Plant			May
Corn seed, 1000 k	30	30	
Cultivator			July
Harvest			October
Combine with corn head			
Flail chopper			
Rake			
Large round bale			
Haul stover			

Fertilizers were applied in the early spring. Phosphorus was applied at a rate of 40 pounds per acre, and potassium was applied at a rate of 75 pounds per acre in both sites. Nitrogen was not used because soybean is a nitrogen fixer. The field was harrowed and then tandem disked in the spring. By attaching a sprayer to the tandem disk, disking and herbicide application were done simultaneously. Lasso was applied at a rate of 6 pt per acre (2.8 lb a.i/ac) in both sites to control weeds.

Soybean was planted in the Spring at a rate of 60 pounds per acre (Anderson, Buxton, and Hallam, 1994). After sufficient growth of soybeans, cultivation was practiced to control weeds in the summer. Soybeans were harvested using a combine with a soybean platform in the fall (see Table 4.12).

Intercrop Sorghum/Alfalfa Systems. For the establishment year, the intercrop sweet sorghum/alfalfa and sorghum x sudangrass hybrid/alfalfa systems have the same tillage practices as for monocrop alfalfa. The difference in tillage practices appears only during the production years of alfalfa following the establishment year. During the standing years,

Table 4.12 Description of tillage systems for soybean

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Harrow			April
Fertilization			April
Phosphorus (P), lbs	58	58	
Potassium (K), lbs	47	47	
Tandem Disk & Herbicide			April
Lasso, pt (2.8 lb a.i./a)	5	5	
Plant			May
seed, 1000 k	30	30	
Cultivator			July
Harvest			October
Combine with corn head			
Flail chopper			
Rake			
Large round bale			
Haul stover			

sorghums are intercropped into the established alfalfa. Sorghums, both sweet sorghum and sorghum x sudangrass hybrid, are planted in the late spring right after the first harvest of alfalfa. A custom made "slot tiller" was used at the experimental farm to till the soil for the sorghum rows in the established alfalfa before planting the sorghum into alfalfa. However, in description of tillage systems and estimation of production costs, use of a no-till planter was assumed since a "slot tiller" is not commercialized. Costs will be similar. As with all other sorghum systems, sorghum seeding rates were 7 pounds per acre at both Ames and Chariton.

After planting the sorghum and before emergence, Paraquat was sprayed at a rate of 2 pt per acre around sorghum slots to suppress the foliage of established alfalfa to reduce competition for the emerging sorghum.

For the description of the tillage systems for intercrop sorghum, see Table 4.13. The same tillage system was used for both sweet sorghum/alfalfa and sorghum x sudangrass hybrid/alfalfa. All P and K was applied during the alfalfa establishment year. The alfalfa intercrop system received split applications of nitrogen in early April and again at the time of sorghum planting (Anderson, Buxton, and Hallam, 1994).

Intercrop Sorghum/Reed Canarygrass System. For the establishment year, this system has the same tillage practices as for the monocrop reed canarygrass. Both sweet sorghum and sorghum x sudangrass are interplanted into the established reed canarygrass.

In the fall of each year, maintenance rates of phosphorus and potassium were applied to the both of experimental sites at a rate of 32 pounds per acre and 94 pounds per acre, respectively. This intercrop system received half of the nitrogen in mid April with the remainder applied again at the time of sorghum planting (Anderson, Buxton, and Hallam, 1994).

As with the intercrop sorghum/alfalfa, sorghum was planted into established reed canarygrass with a no-till planter in early June after the first harvest of reed canarygrass. Seeding rates were the same as monocrop sorghum systems, 7 pounds per acre. Paraquat was applied at a rate of 2 pt per acre to the foliage of established reed canarygrass to reduce

Table 4.13 Description of tillage systems for intercrop crop alfalfa/sorghum

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Fertilization			May
Nitrogen, lb	62.5	62.5	
Harvest (Alfalfa)			May
Mow-conditioning			
Rake			
Round bale			
Haul			
No-till Plant			May
Sorghum seed, lbs	7	7	
Fertilization			May
Nitrogen, lb	62.5	62.5	
Herbicide			June
Paraquat, pt (0.6 lb a.i./a)	2	2	
Harvest (Sorghum/Alfalfa)			August
Mow-conditioning			
Large round bale			
Haul			
Harvest (Sorghum/Alfalfa)			October
Mow-conditioning			
Large round bale			
Haul			

competition for the emerging sorghum after planting and before emergence in the middle of June. Table 4.14 illustrates in detail the tillage schedule and the tillage practices for this system.

Comparison of Machinery Costs

This section presents costs of each machine used in production of biomass energy crops. There are three sets of machinery costs. One is the set of costs estimated using MSBG, one a set from ISU extension, and one a set using custom rates for Iowa in 1993.

Table 4.15 shows the machinery costs estimated using MSBG, ISU extension, and Iowa custom rates. The machinery costs estimated by the MSBG are estimated based on

Table 4.14 Description of tillage systems for intercrop crop sorghum/reed canarygrass

Field Operation	Rate per Acre		Time of Year
	Ames	Chariton	
Fertilization			
Phosphorus (P), lbs	32	32	October
Potassium (K), lbs	94	94	October
Nitrogen, lbs	62.5	62.5	April
Harvest (Reed canarygrass)			May
Mow-conditioning			
Rake			
Round bale			
Haul			
No-till Plant			May
Sorghum seed, lbs	7	7	
Fertilization			May
Nitrogen, lbs	62.5	62.5	
Herbicide			June
Paraquat, pt (0.6 lb a.i./a)	2	2	
Harvest (Sorghum/Reed canary)			August
Mow-conditioning			
Large round bale			
Haul			
Harvest (Sorghum/Reed canary)			October
Mow-conditioning			
Large round bale			
Haul			

average annual Iowa equipment use. As shown in Table 4.15, the MSBG estimated values are divided into direct costs (variable costs), labor cost, and fixed costs. Direct costs are the sum of repair and maintenance costs for both implements and tractors, and fuel costs. Labor costs are listed separately because variable costs estimated by ISU extension (Duffy and Judd, 1992) exclude labor cost. Fixed costs are the sum of depreciation costs for both implements and tractors. All costs are estimated for per acre bases.

Some of the important values assumed to estimate production costs with MSBG are 6% real rate of interest, 10% salvage value for both tractors and implements, 20 years useful life for tractors, and 15 years for implements (see section on "Parameter values and input prices"in Chapter 3).

ISU extension estimates do not include labor cost in estimating variable costs. The variable costs include only fuel, oil, and repair costs. Fixed costs include depreciation, interest, insurance, and housing. Thus, it should be expected that ISU extension estimates of fixed cost are higher than the MSBG estimates. All costs are estimated on a per acre base with a few exceptions. The following are not expressed on a per acre base: haul grain ($/bushel), haul silage ($/ton), round bale ($/bale), and haul hay ($/ton) (Duffy and Judd, 1992).

Values associated with Iowa custom rates in Table 4.15 reflect rates expected to be charged or paid, including fuel and labor (Judd and Edwards, 1993). Thus, Iowa custom rates for each field operation reflect the cost of completing a given field operation per acre. Iowa custom rates are based on a survey of Iowa farmers, custom operators, and farm managers (Judd and Edwards, 1993). They include the cost of the labor to perform the operation.

Notice that although the MSBG and ISU extension estimated machinery costs use the same annual hours of use for the same machinery, the estimated costs differ due to the different assumptions on other variables, such as salvage value, repair and maintenance rates, and methods of calculating depreciation. These estimated costs will change as machine related variables change for both the MSBG and ISU estimates. For example, repair and maintenance costs and fixed costs will be greater if annual machine use is lower, and vice versa. Furthermore, both the MSBG and ISU estimates on machinery include tractor costs as well.

As shown in Table 4.15, machinery costs associated with some of the field operations are different among the three estimates, the MSBG, ISU estimates, and Iowa custom rates. The differences can be attributed by many factors. Despite the differences in estimates, Table 4.15 can be a useful guidelines for potential farmers considering biomass energy crop production.

Table 4.15 Comparison of machinery costs

Implements	Annual Hours of Use	MSBG				ISU Extention Estimated Cost[1]			Iowa Custom Rate[2]	
		Variable Cost		Fixed Cost	Total Cost	Variable Cost	Fixed Cost	Total Cost	Average	Range
		R & M & Fuel	Labor							
	(hrs/yr)	($/acre)				($/acre)			($/acre)	
FERTILIZATION										
Bulk furtilizer	30	1.18	0.69	1.36	3.23	1.01	2.65	3.66	1.40	0.50-4.00
NH3 applicator	60	2.24	1.24	2.66	6.14	2.14	3.20	5.34	1.60	1.00-3.00
TILLAGE										
Chisel plow	80	2.72	0.97	3.04	6.73	1.81	2.54	4.35	9.50	7.50-12.00
Tandem disk	100	1.67	0.76	2.17	4.60	0.94	2.13	3.07	6.80	5.00-10.00
Disk with sprayer	100	2.41	0.90	2.99	6.30	1.62	3.51	5.13	na	na
Peg-tooth harrow	40	0.76	0.41	0.93	2.10	0.55	1.41	1.96	3.90	3.00-9.00
Field cultivator	40	1.60	0.76	2.05	4.41	1.01	3.18	4.19	6.40	4.50-10.50
PLANTING										
Grain drill	40	2.77	0.55	4.29	7.52	1.15	4.28	5.43	7.50	6.00-11.00
Planter	60	2.16	0.55	3.43	6.14	1.63	4.57	6.20	8.10	6.00-13.50
No-till planter	60	4.31	0.76	5.06	10.13	1.24	4.54	5.78	10.70	6.00-16.50
Cultipacker	40	1.59	1.10	1.77	4.46	na	na	na	na	na
WEED CONTROL										
Sprayer	50	0.93	0.55	0.98	2.46	0.75	1.54	2.29	3.90	2.75-6.50
Cultivator	80	1.37	0.55	1.65	3.57	0.84	1.55	2.39	5.40	4.00-8.50

Table 4.15 (Continued)

Implements	Annual Hours of Use	MSBG				ISU Extention Estimated Cost[1]			Iowa Custom Rate[2]	
		Variable Cost		Fixed Cost	Total Cost	Variable Cost	Fixed Cost	Total Cost	Average	Range
		R & M & Fuel	Labor							
	(hrs/yr)	($/acre)				($/acre)			($/acre)	
HARVESTING										
Mow-conditioing	120	4.30	1.17	3.47	8.94	2.47	4.43	6.90	8.00	5.00-13.00
Flail chopper	80	1.91	1.04	2.93	5.88	na	na	na	na	na
Rake	100	1.88	1.45	2.19	5.52	1.58	2.43	4.01	3.20	1.50-6.00
Large round bale[a]	120	3.09	1.24	3.86	8.28	2.07	3.14	5.21	6.30	4.00-9.00
Silage harvester	200	10.18	3.45	13.61	27.24	7.19	8.60	15.79	2.90	1.55-4.00
Forage blower	50	1.48	1.17	2.52	5.17	na	na	na	na	na
Corn head	170	6.69	1.45	8.50	16.64	9.42	16.39	25.81	22.80	18.00-27.00
Soybean platform	80	6.00	1.66	10.09	17.75	7.14	14.06	21.20	21.90	18.00-28.50
Haul hay[b]	80	1.58	1.73	1.72	5.03	0.60	0.47	1.07	na	na
Haul grain[c]	150	2.10	1.17	2.23	5.51	0.02	0.02	0.04	0.041	0.020-0.080
Haul silage[d]	140	5.83	3.45	6.72	16.00	0.34	0.40	0.74	na	na
Haul stover	140	5.83	3.45	6.72	16.00	na	na	na	na	na

Note: All costs are expressed in 1993 nominal dollars. [a] Unit is $/bale. [b] Unit is $/ton. [c] Unit is $/bu (on farm) for both ISU estimates and Iowa custom rate. [d] Unit is $/ton.

Sources: [1] Duffy, Mike and Judd, Dennis. 1992. Estimated Costs of Crop Production in Iowa, ISU University Extension, Ames, IA.

[2] Judd, Dennis and Edwards, William. 1993. 1993 Iowa Farm Custom Rate Survey, ISU University Extension; Ames, IA.

Summary

To investigate yield, economic feasibility, and environmental impacts (especially with regard to soil erosion) of different energy crop species in different cropping systems, four different perennial grasses (alfalfa, reed canarygrass, switchgrass, and big bluestem) and five annual crops (sweet sorghum, sorghum x sudangrass hybrid, winter rye, corn, and soybean) were planted in 13 different cropping systems in two different locations, Ames and Chariton, Iowa.

The two different locations were selected based on soil quality, soil erosion, and growing season factors to compare energy crops based on yield, production costs, and soil erosion. The Ames site is located in the central Iowa and Chariton site is located in the south-central Iowa. Thus, Chariton has a longer growing period. Land in Ames is categorized as more productive land than that in Chariton in corn production.

Perennial grasses are assumed to last 4 years beyond establishment for alfalfa, and 10 years for reed canarygrass, switchgrass, and big bluestem. This means that once established, only maintenance and harvesting activities are necessary for the perennials. Maintenance activities involved with perennials are fertilization and herbicide, if necessary. On the other hand, annual crops have to be planted annually.

The cropping systems are categorized into: six monocrop systems with four perennials and two annuals (sweet sorghum and sorghum x sudangrass), two double crop systems (rye/sweet sorghum and rye/sorghum x sudangrass hybrid), two three year rotation systems with corn and soybean (monocrop sweet sorghum in rotation and rye/sweet sorghum in rotation), and two intercrop systems (alfalfa with sorghums and reed canarygrass with sorghums).

To investigate the yield response to nitrogen use, four different levels of nitrogen (0, 62.5, 125, 250 lbs/acre) were applied to all systems except the rotation systems and intercrop systems, which received only two levels of nitrogen (62.5 and 125 lbs/acre). Of these different levels of nitrogen, 125 lbs/acre are selected to estimate the production costs of the cropping systems.

For the perennials, alfalfa was harvested either twice or three times a year for the life of the standing crop. Reed canarygrass was harvested twice a year. Both switchgrass and big bluestem were harvested only once a year. The amount of annual fertilizer and herbicide use were determined by the agronomists after the soil test.

Machinery costs estimates for each field operation between the MSBG generated ones, ISU extension estimates, and Iowa custom rates show some differences. However, this comparison of machinery costs gives some information to potential farmers on whether to invest in machinery or custom hire if they decide to produce biomass energy crops.

CHAPTER 5

COSTS OF PRODUCING PERENNIAL GRASSES AS BIOMASS FOR ENERGY USE

The objective of this chapter is to analyze production costs of the perennial grasses, alfalfa, reed canarygrass, switchgrass, and big bluestem. The first section deals with use of inputs and production activities in growing perennial grasses as a biomass energy crop. The actual quantities of machinery related inputs are not listed in this section because they are generated using the standard assumptions about equipment use and the field operations discussed in Chapter 4. The actual amounts used of these inputs are listed in the budgets in the Appendix. The second section presents yield data obtained from two agricultural experimental farms in Ames and Chariton, Iowa. Yield data are on a dry matter basis with 0% moisture. The third section discusses the production costs of perennial grasses, both establishment year costs and annual costs for the standing years. There are two sets of production cost estimates for each perennial grass. The first is estimated based on typical Iowa equipment use, and second one is estimated based on equipment use if only 160 acres of land is allocated to biomass production and this is the sole use of this equipment. Thus, the only difference between these two sets of cost estimates comes from the annual hours of use of the equipment, given the performance rate of each piece of machinery. The higher costs in the second are related to the lower annual use and less spreading of fixed costs. The last section discusses the impact of the changes in annual hours of implement use on the production costs.

Input Use and Production Activities

Tables 5.1 and 5.2 show the quantity of each input and the field operations necessary to produce each perennial grass for the establishment year, and each standing year, respectively. As shown in Table 5.1, no nitrogen was applied to the perennial grasses during the establishment year. However, as shown in Table 5.2, reed canarygrass, switchgrass, and big bluestem received nitrogen annually throughout the standing years. Alfalfa did not receive any nitrogen even during the standing years because it is "nitrogen fixer", that is, it produces nitrogen as it grows (Barnes and Sheaffer, 1985).

Four levels of nitrogen (0, 62.5, 125, 250 lbs per acre) were applied to reed canarygrass, switchgrass, and big bluestem to observe the yield response to nitrogen. Of the four levels of nitrogen, 125 pounds per acre is selected to estimate an annual enterprise budget for perennial grasses (see Table 5.2).

For reed canarygrass, switchgrass, and big bluestem, phosphorus (P) and potash (K) were applied each year throughout the life time of these grasses at 32 pound per acre for P

Table 5.1 Input use and field operations during establishment year

Operation/Operating input	Amount							
	Alfalfa		Reed canarygrass		Switchgrass		Big bluestem	
	A	C	A	C	A	C	A	C
Fertilizer								
Phosphorus, lbs	160	160	32	32	32	32	32	32
Potash, lbs	625	625	94	94	94	94	94	94
Lime, ton		5						
Chisel plow								
Tandem disk								
Peg-tooth harrow								
Sprayer								
Eptom, pt	3	3						
Lorsban 4E, pt	1	1.5						
2,4-D, pt			2	2			2.5	2.5
Atrazine 4L, pt					2.5	2.5		
Grain drill								
Seed, lbs	12	14	9	11	7.2	7.2	12	12
Cultipacker								
Mower-conditioner								
Baler (large round)								
Haul hay								

Note: A=Ames; C=Chariton. Alfalfa and reed canarygrass were harvested twice during the establishment year. Thus, harvest related field operations (mow, condition, bale, and haul) were performed twice.

and 94 pounds per acre for K at both Ames and Chariton. Alfalfa received phosphorus and potash only during the establishment year (see Tables 5.1 and 5.2).

Alfalfa is sensitive to soil acidity. Thus, soil pH is a critical factor for establishment and maximum production of alfalfa (Barnes and Sheaffer, 1985). Proper soil pH level for alfalfa is 6.8 or higher (Undersander, et al., 1991). The soil tests revealed an average pH of 8.0 at Ames and 6.8 at Chariton (Anderson, Buxton, and Hallam, 1995). Therefore, lime was applied only at Chariton to increase pH level.

Both locations, Ames and Chariton, received the same level of herbicide treatment, except Lorsban 4E on alfalfa (see Table 5.1). The seeding rates for alfalfa and reed canarygrass at Ames and Chariton were not the same while seeding rate for switchgrass and big bluestem were the same for both locations (Table 5.1).

Table 5.2 Input use and field operations during standing years

Operation/Operating input	Amount							
	Alfalfa		Reed canarygrass		Switchgrass		Big bluestem	
	A	C	A	C	A	C	A	C
Fertilizer								
Phosphorus, lbs			32	32	32	32	32	32
Potash, lbs			94	94	94	94	94	94
Nitrogen			125	125	125	125	125	125
Sprayer								
Lorsban 4E, pt	2	2						
Mower-conditioner								
Rake[1]								
Baler (large round)								
Haul hay								

Note: 1 This operation was performed only for alfalfa. A=Ames; C=Chariton. Alfalfa was harvested three times each standing year, and reed canarygrass was harvested twice during the standing year. Thus, harvest related field operations (mow-conditioner, bale, and haul) were performed three times for alfalfa and twice for reed canarygrass.

Discussion on Yield

Table 5.3 shows dry matter yield data for both the establishment year and the standing years. For the establishment year, only two-harvest yield data is available for alfalfa because alfalfa was harvested only twice during the establishment year. For other perennial grasses, yield data only on 0 pounds of nitrogen is available because no nitrogen was used during the establishment year. Standing year yield data is available for two-harvests and three-harvests for alfalfa and for all different levels of nitrogen use for reed canarygrass, switchgrass, and big bluestem at both locations, Ames and Chariton. Standing year yield data is the average dry matter yield over the standing years. Alfalfa, switchgrass, and big bluestem are averaged over a four year time period, from 1989 to 1992, for both Ames and Chariton. Reed canarygrass yield data at Ames is averaged over four years (1989-1992) while that of at Chariton is averaged over three years (1990-1992). Annual data for all grasses in all years are reported in an appendix.

For the establishment year, alfalfa at Chariton shows a higher yield than at Ames (Table 5.3). The reason for this is that alfalfa was not harvested at Chariton in the establishment year (1988) because of a weak stand. The stress from the 1988 drought caused a limited stand at Chariton so that alfalfa was frost seeded in March of 1989 to increase the stand and was not harvested till 1989 (Anderson, Buxton, and Hallam, 1994). Thus, dry matter yield from 1989 is used as if it were establishment year yield. This is an overestimate of what might occur in practice but seems the best alternative for this analysis.

Table 5.3 shows the same dry matter yield for reed canarygrass at both Ames and Chariton for the establishment year. This is so because the yield data at Ames is used in place of yield data for Chariton. There was no yield data available at Chariton for the establishment year because of establishment failure. Because of the establishment failure at Chariton in 1988, reed canarygrass was reseeded in April 1989. Establishment was successful but weak and reed canarygrass at Chariton was not harvested until 1990 with no cuttings in the establishment year (Anderson, Buxton, and Hallam, 1994). The establishment year yield data shown in Table 5.3 for both alfalfa and reed canarygrass at Chariton are thus rather ad hoc, but give some sense of establishment year yields. These data are used solely to estimate establishment year net production cost and have only a minor impact on total annual costs over the standing lifetime of the grasses.

During the establishment year, switchgrass produced about 40% more dry matter in Ames than in Chariton and big bluestem in Ames produced about 20% more dry matter than in Chariton. Of the perennial grasses produced in each location, switchgrass produced the highest dry matter. Switchgrass produced about 33%, 36%, and 19% more dry matter than alfalfa, reed canarygrass, and big bluestem, respectively, in Ames. Switchgrass produced about 88% more dry matter than big bluestem in Chariton (see Table 5.3).

Table 5.3 Average dry matter yields of perennial species and yield response to nitrogen

Species	Yield (ton/acre)							
	Establishment year				Standing year			
	A	B	A	B	A	B	A	B
	Ames		Chariton		Ames		Chariton	
Alfalfa								
2 cut	2.72		3.04		4.54		3.90	
3 cut					4.85	0.31	3.99	0.09
Reed canarygrass								
0 lbs N/acre	2.67		2.67		1.82		2.70	
62.5 lbs N/acre					2.71	0.89	3.94	1.24
125 lbs N/acre					3.67	0.96	4.34	0.40
250 lbs N/acre					5.06	1.39	4.72	0.38
Switchgrass								
0 lbs N/acre	3.62		2.59		2.71		3.25	
62.5 lbs N/acre					4.98	2.27	3.60	0.35
125 lbs N/acre					4.97	-0.01	4.61	1.01
250 lbs N/acre					5.22	0.25	4.64	0.03
Big bluestem								
0 lbs N/acre	3.04		1.38		3.64		2.77	
62.5 lbs N/acre					4.13	0.49	3.63	0.86
125 lbs N/acre					4.23	0.10	3.91	0.28
250 lbs N/acre					4.61	0.38	4.12	0.21

Note: Standing year data for all species are averaged over 1989-1992 in Ames and 1990-1992 in Chariton. A = yield; B = change in yield over change in nitrogen level.

For the standing years, it can be observed that overall yield increases as the amount of fertilizer nitrogen increases and that switchgrass produces more dry matter in both locations than any other perennial grasses at any level of nitrogen, except at the 62.5 pound nitrogen level at Chariton. At the levels selected for economic analysis, (three-cut harvest for alfalfa, and 125 pounds of nitrogen per acre for the other perennial grasses) switchgrass produced the most dry matter. It produced about 2%, 35%, and 17% more dry matter than alfalfa, reed canarygrass, and big bluestem in Ames . It also produced about 16%, 6%, and 18% more dry matter than alfalfa, reed canarygrass, and big bluestem in Chariton (see Table 5.3).

In short, switchgrass appears to be a good candidate for a biomass energy crop because it produces relatively higher dry matter yield even on the rather marginal land in Chariton.

Discussion on Production Costs

This section discusses production costs of perennial grasses for both the establishment year and the standing years. Table 5.4 show establishment year production costs in Ames and Table 5.5 show establishment year production costs in Chariton. Annual production costs for standing years are presented in Table 5.6 for Ames and Table 5.7 for Chariton. Each table shows both the production costs based on Iowa equipment use and the production cost based on equipment use if the biomass energy crop was produced utilizing equipment for only 160 acres of cropland. As a result, differences in production costs in the top and bottom portions are primarily based on machinery related costs, specifically implements.

Differences in the total production costs shown in Tables 5.4 through 5.7 are primarily caused by the following factors: land cost, machinery related costs, and transportation cost. Land costs are different between Ames and Chariton because of the quality difference of the land. Land in Ames is generally more productive than the land in Chariton (Anderson, Buxton, and Hallam, 1994). Because of the higher productivity, rental cost of farm land in Ames is higher than in Chariton: $115/acre in Ames and $80/acre in Chariton. This is primarily due to the higher corn yield potential of the land in Ames.

Table 5.4 Estimated establishment year cost for perennial grasses at Ames, Iowa assuming average Iowa equipment use and assuming 160 acres of biomass production (per acre).

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		(dollars) Iowa equipment use		
DIRECT EXPENSES				
Fertilizer				
Phosphorus	40.00	8.00	8.00	8.00
Potash	106.25	15.98	15.98	15.98
Herbicide	10.24	4.62	3.95	5.78
Seed	30.00	40.50	25.20	108.00
Operator labor	13.87	13.32	9.18	9.18
Fuel	7.83	7.52	5.49	5.49
Repair and maintenance				
Implements	13.21	12.96	8.50	8.50
Tractors	9.34	8.97	6.49	6.49
Interest[1]	11.87	4.02	3.15	5.42
Transportation	11.29	11.08	15.02	12.62
TOTAL DIRECT EXPENSES	253.90	126.97	100.96	185.46
FIXED EXPENSES				
Implements	17.03	16.71	12.05	12.05
Tractors	16.59	15.94	11.54	11.54
Land	115.00	115.00	115.00	115.00
TOTAL FIXED EXPENSES	148.62	147.65	138.59	138.59
TOTAL EXPENSES	402.52	274.62	239.55	324.05
TOTAL REVENUE	176.80	160.20	199.10	167.20
NET COST[2]	225.72	114.42	40.45	156.85
ESTABLISHMENT COST (prorated)	65.89	15.92	5.63	21.82

Table 5.4 (Continued)

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
	(dollars) 160 acres of biomass production			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	40.00	8.00	8.00	8.00
Potash	106.25	15.98	15.98	15.98
Herbicide	10.24	4.62	3.95	5.78
Seed	30.00	40.50	25.20	108.00
Operator labor	13.87	13.32	9.18	9.18
Fuel	7.83	7.52	5.49	5.49
Repair and maintenance				
Implements	34.96	34.96	34.96	34.96
Tractors	9.34	8.97	6.49	6.49
Interest[1]	12.38	4.53	3.60	5.87
Transportation	11.29	11.08	15.02	12.62
TOTAL DIRECT EXPENSES	276.16	149.48	127.87	212.37
FIXED EXPENSES				
Implements	47.69	47.69	47.69	47.69
Tractors	16.59	15.94	11.54	11.54
Land	115.00	115.00	115.00	115.00
TOTAL FIXED EXPENSES	179.28	178.63	174.23	174.23
TOTAL EXPENSES	455.44	328.11	302.10	386.60
TOTAL REVENUE	176.80	160.20	199.10	167.20
NET COST[2]	278.64	167.91	103.00	219.40
ESTABLISHMENT COST (prorated)	81.34	23.36	14.33	30.52

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses. Total revenue is estimated assuming $65.00 per ton for alfalfa, $60.00 per ton for reed canarygrass, and $55.00 per ton for switchgrass and big bluestem. The net establishment cost for each perennial grass is prorated over the standing life by using an annuity equation. Each perennial grass is prorated over the following years: 4 years for alfalfa and 10 years for other perennial grasses.

Table 5.5 Estimated establishment year cost for perennial grasses at Chariton, Iowa assuming average Iowa equipment use and assuming 160 acres of biomass production (per acre).

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		(dollars) Iowa equipment use		
DIRECT EXPENSES				
Fertilizer				
Phosphorus	40.00	8.00	8.00	8.00
Potash	106.25	15.98	15.98	15.98
Lime	30.00			
Herbicide	11.15	4.62	3.95	5.78
Seed	35.00	49.50	25.20	108.00
Operator labor	14.56	13.32	9.18	9.18
Fuel	8.21	7.52	5.49	5.49
Repair and maintenance				
Implements	13.55	12.96	8.50	8.50
Tractors	9.80	8.97	6.49	6.49
Interest[1]	14.13	4.31	3.13	5.38
Transportation	12.62	11.08	10.75	5.73
TOTAL DIRECT EXPENSES	295.27	136.26	96.67	178.53
FIXED EXPENSES				
Implements	17.57	16.71	12.05	12.05
Tractors	17.41	15.94	11.54	11.54
Land	80.00	80.00	80.00	80.00
TOTAL FIXED EXPENSES	114.98	112.65	103.59	103.59
TOTAL EXPENSES	410.25	248.91	200.26	282.12
TOTAL REVENUE	197.60	160.20	142.45	75.90
NET COST[2]	212.65	88.71	57.81	206.22
ESTABLISHMENT COST (prorated)	62.07	12.34	8.04	28.69

Table 5.5 (Continued)

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		(dollars) 160 acres of bomass production		
DIRECT EXPENSES				
Fertilizer				
Phosphorus	40.00	8.00	8.00	8.00
Potash	106.25	15.98	15.98	15.98
Lime	30.00			
Herbicide	11.15	4.62	3.95	5.78
Seed	35.00	49.50	25.20	108.00
Operator labor	14.56	13.32	9.18	9.18
Fuel	8.21	7.52	5.49	5.49
Repair and maintenance				
Implements	34.96	34.96	34.96	34.96
Tractors	9.80	8.97	6.49	6.49
Interest[1]	14.63	4.83	3.59	5.87
Transportation	12.62	11.08	10.75	5.73
TOTAL DIRECT EXPENSES	317.18	158.78	123.59	205.48
FIXED EXPENSES				
Implements	47.69	47.69	47.69	47.69
Tractors	17.41	15.94	11.54	11.54
Land	80.00	80.00	80.00	80.00
TOTAL FIXED EXPENSES	145.10	143.63	139.23	139.23
TOTAL EXPENSES	462.28	302.41	262.82	344.71
TOTAL REVENUE	197.60	160.20	142.45	75.90
NET COST[2]	264.68	142.21	120.37	268.81
ESTABLISHMENT COST (prorated)	77.26	19.78	16.74	37.39

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses. Total revenue is estimated assuming $65.00 per ton for alfalfa, $60.00 per ton for reed canarygrass, and $55.00 per ton for switchgrass and big bluestem. The net establishment cost for each perennial grass is prorated over the standing life by using an annuity equation. Each perennial grass is prorated over the following years: 4 years for alfalfa and 10 years for other perennial grasses.

Table 5.6 Estimated annual production cost of perennial grasses at Ames, Iowa assuming average Iowa equipment use and assuming 160 acres of biomass production (per acre).

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		(dollars) Iowa equipment use		
DIRECT EXPENSES				
Fertilizer				
Phosphorus		8.00	8.00	8.00
Potash		15.98	15.98	15.98
Nitrogen		15.00	15.00	15.00
Herbicide	3.62			
Operator labor	14.97	11.45	6.07	6.07
Fuel	7.42	5.82	3.10	3.10
Repair and maintenance				
Implements	14.24	10.71	5.52	5.52
Tractors	8.97	7.08	3.77	3.77
Interest[1]	1.14	2.58	2.36	2.35
Transportation	20.13	15.23	20.63	17.55
TOTAL DIRECT EXPENSES	70.50	91.85	80.43	77.34
FIXED EXPENSES				
Implements	15.38	12.21	6.38	6.38
Tractors	15.92	12.57	6.69	6.69
Land	115.00	115.00	115.00	115.00
TOTAL FIXED EXPENSES	146.30	139.78	128.07	128.07
ESTABLISHMENT COST (prorated)	65.89	15.92	5.63	21.82
TOTAL EXPENSES	282.69	247.55	214.13	227.23
BREAK-EVEN PRICE ($/ton)	58.29	67.45	43.08	53.72

Table 5.6 (Continued)

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
	(dollars) 160 acres of biomass production			
DIRECT EXPENSES				
Fertilizer				
Phosphorus		8.00	8.00	8.00
Potash		15.98	15.98	15.98
Nitrogen		15.00	15.00	15.00
Herbicide	3.62			
Operator labor	14.97	11.45	6.07	6.07
Fuel	7.42	5.82	3.10	3.10
Repair and maintenance				
Implements	21.25	21.40	21.43	21.43
Tractors	8.97	7.08	3.77	3.77
Interest[1]	1.28	2.71	2.49	2.47
Transportation	20.13	15.23	20.63	17.55
TOTAL DIRECT EXPENSES	77.64	102.68	96.46	93.37
FIXED EXPENSES				
Implements	22.98	22.97	23.02	23.02
Tractors	15.92	12.57	6.69	6.69
Land	115.00	115.00	115.00	115.00
TOTAL FIXED EXPENSES	153.90	150.54	144.71	144.71
ESTABLISHMENT COST (prorated)	81.34	23.36	14.33	30.52
TOTAL EXPENSES	312.88	276.58	255.50	305.23
BREAK-EVEN PRICE ($/ton)	64.51	75.36	51.41	72.16

Note: Dry matter yield used to estimate the break-even prices are 4.85 tons/acre for alfalfa, 3.67 tons/acre for reed canarygrass, 4.97 tons/acre for switchgrass, and 4.23 tons/acre for big bluestem.

[1] Interest on operating costs.

Table 5.7 Estimated annual production cost of perennial grasses at Chariton, Iowa assuming average Iowa equipment use and assuming 160 acres of biomass production (per acre).

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		(dollars) Iowa equipment use		
DIRECT EXPENSES				
FERTILIZER				
Phosphorus		8.00	8.00	8.00
Potash		15.98	15.98	15.98
Nitrogen		15.00	15.00	15.00
Herbicide	3.62			
Operator labor	14.97	11.45	6.07	6.07
Fuel	7.42	5.82	3.10	3.10
Repair and maintenance				
Implements	14.24	10.71	5.52	5.52
Tractors	8.97	7.08	3.77	3.77
Interest[1]	1.10	2.60	2.36	2.34
Transportation	16.56	18.01	19.13	16.23
TOTAL DIRECT EXPENSES	66.89	94.65	78.93	76.01
FIXED EXPENSES				
Implements	15.38	12.21	6.38	6.38
Tractors	15.92	12.57	6.69	6.69
Land	80.00	80.00	80.00	80.00
TOTAL FIXED EXPENSES	111.30	104.78	93.07	93.07
ESTABLISHMENT COST (prorated)	62.07	12.34	8.04	28.69
TOTAL EXPENSES	240.26	211.77	180.04	199.77
BREAK-EVEN PRICE ($/ton)	60.22	48.79	39.05	50.58

Table 5.7 (Continued)

Item	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		(dollars) 160 acres of biomass production		
DIRECT EXPENSES				
FERTILIZER				
Phosphorus		8.00	8.00	8.00
Potash		15.98	15.98	15.98
Nitrogen		15.00	15.00	15.00
Herbicide	3.62			
Operator labor	14.97	11.45	6.07	6.07
Fuel	7.42	5.82	3.10	3.10
Repair and maintenance				
Implements	21.25	21.40	21.43	21.43
Tractors	8.97	7.08	3.77	3.77
Interest[1]	1.24	2.73	2.48	2.46
Transportation	16.56	18.01	19.13	16.23
TOTAL DIRECT EXPENSES	74.03	105.47	94.96	92.04
FIXED EXPENSES				
Implements	22.98	22.97	23.02	23.02
Tractors	15.92	12.57	6.69	6.69
Land	80.00	80.00	80.00	80.00
TOTAL FIXED EXPENSES	118.90	115.54	109.71	109.71
ESTABLISHMENT COST (prorated)	77.26	19.78	16.74	37.39
TOTAL EXPENSES	270.19	240.79	221.41	239.14
BREAK-EVEN PRICE ($/ton)	67.71	55.48	48.03	61.16

Note: Dry matter yield used to estimate the break-even prices are 3.99 tons/acre for alfalfa, 4.34 tons/acre for reed canarygrass, 4.61 tons/acre for switchgrass, and 3.91 tons/acre for big bluestem.

[1] Interest on operating costs.

Differences in the machinery related costs - repair and maintenance costs and fixed costs of implements are caused solely by the differences in the annual hours of use of implements, other things being equal (see Calculation Method sections in Chapter 3 and Chapter 5). In each table, the production costs listed under "160 acres of biomass production" have higher machinery related costs than the ones under "Iowa equipment use" because of the lower annual hours of use of implements with 160 acres of production. For example, as shown in Table 3.2, the annual hours of use of a grain drill used to estimate production costs under "160 acres of biomass production" is 13 hours while annual hours of use of grain drill used to estimate production costs under "Iowa equipment use" is 40 hours. Comparing repair and maintenance in the direct expenses section and implement costs in the fixed expenses section under "Iowa equipment use" and "160 acres of biomass production", it is evident that the higher the annual hours of use of machinery, the lower the allocated costs.

Since annual hours of use of implements is determined by land allocation, given performance rate, it can be said that there exist economies of scale in biomass energy crop production. This means that production costs can be reduced as production increases by allocating more land. More allocation of land decreases annual allocated costs for repair and maintenance and fixed costs by increasing the annual hours of use of implements.

Notice also that, as repair and maintenance costs change, interest on operating input changes as well although the change is very small. This is evident if we compare interest in the Tables under "Iowa equipment use" and "160 acres of biomass production." Transportation costs are different due to the differences in yield per ton.

Other factors causing significant differences in total production costs among perennial grasses are differences in field operations, specifically number of harvests, amount of input use, and input price. For example, alfalfa was harvested twice during the establishment year and three times during the standing years, and reed canarygrass was harvested twice for both the establishment year and standing years, while switchgrass and big bluestem were harvested only once during the establishment and standing years (see Tables 5.1 and 5.2). For the establishment year, although alfalfa and reed canarygrass have the same field operations

(Table 5.1), total variable costs are different primarily due to the differences in amount of fertilizer used (phosphorous and potash). For switchgrass and big bluestem, despite the same field operations, total variable costs of big bluestem are about 85% higher during the establishment year than switchgrass. This is primarily caused by the higher big bluestem seed price, \$3.50/lbs for switchgrass and \$9.00/lbs for big bluestem.

To estimate annual production costs of perennial grasses, it is important first to know the establishment year production costs and second to amortize the net establishment costs and then include these amortized net establishment costs in the annual production cost of each perennial grass. Amortization is necessary because, once established, perennial grasses can produce biomass dry matter for many years without planting. We assume 4 years for alfalfa and 10 years for the other perennial grasses.

Net rather than gross establishment costs are amortized because it is assumed that the establishment year yield is sold at a market price. Thus, net establishment cost (total establishment cost less total revenue) is the producer's investment in biomass production. As pointed out in Chapter 3, there is currently no active biomass market. Therefore, to estimate total revenue for the establishment year, the following prices are assumed for perennial grasses: \$65.0/ton for alfalfa, \$60.0/ton for reed canarygrass, and \$55.0/ton for both switchgrass and big bluestem. Selling prices are assumed as if each perennial grasses was hay for animal feed. In 1993, the average auction price of alfalfa hay at Rock Valley, Iowa, ranged from \$104.6/ton for premium quality to \$63.7/large round stack (USDA, 1993: Annual Hay Report).

Establishment Costs

As shown in Tables 5.4 through 5.5, alfalfa has the highest establishment year production costs at both locations, Ames and Chariton. It is primarily due to higher fertilizer costs, which account for 36.3% of costs at Ames and 43.0% of costs at Chariton while fertilizer costs account for 8.7% and 9.6% for reed canarygrass, 10% and 12% for switchgrass, and 7.4% and 8.5% for big bluestem at Ames and Chariton, respectively.

Big bluestem has the second highest production cost at both Ames and Chariton. It is primarily due to the higher seed price. As shown in Table 3.4 in Chapter 3, big bluestem seed price is $9.00/lb while other perennial's seed prices are $2.50/lb for alfalfa, $4.50/lb for reed canarygrass, and $3.50/lb for switchgrass. For big bluestem, seed cost accounts for about 33.3% (38.3%) of the total costs while it accounts for 7.5% (8.6%) for alfalfa, 14.7% (19.9%) for reed canarygrass, and 10.5% (12.6%) for switchgrass at Ames (Chariton).

Of the variable inputs, fertilizer, seed, and machinery related inputs including operator labor, fuel, repair and maintenance, and part of the interest on operating inputs account for most of the total costs. Of all inputs, land cost is the highest, except for alfalfa.

Alfalfa has the highest amortized establishment cost ($65.89/acre at Ames and $61.78/acre at Chariton) and switchgrass has the lowest ($5.63/acre at Ames and $8.04/ acre at Chariton) (see Tables 5.4 and 5.5 under "Iowa equipment use"). Alfalfa has the highest amortized establishment cost primarily due to high establishment year cost (see Tables 5.4 and 5.5) and shorter standing life (4 years for alfalfa and 10 years for the other perennial grasses).

By comparing the costs under "Iowa equipment use" and "160 acres of biomass production" in each table, it can be observed that production costs increase significantly as annual hours of use of equipment decreases, given the performance rate and useful life of the implements. For example, the total production cost of alfalfa is increased by 13.1% at Ames and 12.7% at Chariton with lower annual hours of use of implements (Tables 5.4 and 5.5). Amortized establishment costs with lower equipment use (production costs under "160 acres of biomass production") are higher by 23.4% for alfalfa, 46.7% for reed canarygrass, 154.5% for switchgrass, and 39.9% for big bluestem, compared to amortized establishment costs with typical Iowa equipment use in Ames (Table 5.4). Thus, decreasing production costs are observed as annual hours of use of implements increases.

Annual Production Costs

As shown in Tables 5.6 and 5.7, alfalfa has the highest annual production costs at both Ames and Chariton. The high annual production cost of alfalfa is primarily caused by the high establishment cost. However, the break-even price of alfalfa is lower than that of reed canarygrass at Ames (Tables 5.6). Thus, higher production costs do not necessarily mean a higher break-even price (or cost per ton) because break-even price is affected by yield.

The break-even price ranges from $43.08/ton for switchgrass to $67.45/ton for reed canarygrass at Ames and from $39.05/ton for switchgrass to $60.22/ton for alfalfa at Chariton (Tables 5.6 and 5.7). Although dry matter yield at Ames is higher than that at Chariton for all the perennial grasses, except reed canarygrass (see Table 5.3), the break-even price is lower at Chariton for all perennial grass, except alfalfa, due to the lower land cost at Chariton (Tables 5.6 and 5.7). Land cost at Chariton is lower than that of at Ames because of lower productivity in corn production due to a shallow soil (Buxton, 1996).

Switchgrass has both the lowest annual production cost and break-even price at both Ames and Chariton, $43.08/ton at Ames and $39.05/ton at Chariton (Tables 5.6 and 5.7 under "Iowa equipment use"). This is primarily due to a lower establishment cost and higher yield compared to other perennial grasses.

As annual hours of use of implements decrease given performance rate and useful life, production costs and break-even prices increase. With lower use of implements implied by only 160 acres of production, break-even prices are increased by 10.7% for alfalfa, 11.7% for reed canarygrass, 19.3% for switchgrass, and 34.3% for big bluestem at Ames (Table 5.6). The same increase is observed at Chariton with different rates (Table 5.7). Thus, decreasing costs are observed as annual hours of use of equipment increase.

Discussion of the Impact of Annual Use of Equipment on Costs

This section discusses the impact of the annual hours of implement use on the production costs of perennial grasses. The discussion is primarily focused on the costs related to implement use; repair and maintenance costs of implements (variable costs) and depreciation costs of implements (fixed costs). Although interest on operating inputs also changes due to the changes in annual use of implements, it is not discussed in this section because its impact on production costs are insignificant. For example, as annual hours of implement use decrease, interest on operating inputs increase during the establishment year for reed canarygrass (from $4.02/acre to $4.53/acre). However, interest on operating inputs accounts only about 1.4% of the total production costs and its change accounts even less than 1% of the total change in production costs caused by the decrease in implement use (the total change in reed canarygrass establishment costs is $53.49/acre and the change in interest expenses are $0.51/acre) (see Table 5.4). Notice that impact of the annual use of implements on production costs is discussed based on the Ames production costs. This is because field operations are the same for both locations, Ames and Chariton.

Decreases in annual hours of implement use increase production costs significantly by increasing variable and fixed costs associated with implement use. This is so because of the inverse relationship between machinery costs and annual hours of implement use. Let's first examine the impact of the changes in implement use on the establishment year production costs and amortized establishment costs by considering production cost estimates for Ames. Table 5.4 shows the following. Repair and maintenance costs of implements for each monocrop perennial grass are increased, as annual hours of implement use decreases, by about 165% for alfalfa (from $13.21 to $34.96 per acre), 170% for reed canarygrass (from $12.96 to $34.96 per acre), and 311% for both switchgrass and big bluestem (from $8.50 to $34.96 per acre). Its impact on the fixed costs are similar. This change increases fixed costs related to implements by about 180% for alfalfa (from $17.03 to $47.69 per acre), 185% for reed canarygrass (from $16.71 to $47.69 per acre), and 296% for both switchgrass and big bluestem (from $12.05 to $47.69 per acre).

Total production costs are increased by about 13% for alfalfa (from $402.52 to $455.44 per acre), 19% for reed canarygrass (from $274.62 to $328.11 per acre), 26% for switchgrass (from $239.55 to $302.10 per acre), and 19% for big bluestem (from $324.05 to $386.60 per acre). Amortized establishment costs are increased by about 23% for alfalfa (from $65.89 to $81.34 per ton), 47% for reed canarygrass (from $15.92 to $23.36 per ton), 154% for switchgrass (from $5.63 to $14.33 per ton), and 40% for big bluestem (from $21.82 to $30.52 per ton) (Table 5.4).

During the establishment year, a decrease in implement use increases machinery related costs for all perennial grasses. The increase in the machinery related costs for switchgrass and big bluestem is especially large because of the differences in the number of harvest times. Switchgrass and big bluestem are assumed to be harvested once while alfalfa and reed canarygrass are assumed to be harvested twice during the establishment year. Fewer harvest times means lower annual use of harvest machinery given allocated land.

The impact of the changes in annual use of implements on annual production costs are not as high as establishment year production costs because of the lower number of field operations involved with annual production of perennial grasses. However, its impact is still significant. For example, as annual hours of implement use decrease, repair and maintenance costs of implements are increased by about 49% for alfalfa, 100% for reed canarygrass, 288% for both switchgrass and big bluestem (increased from $14.24/acre to $21.25/acre for alfalfa, from $10.71/acre to $21.40/acre for reed canarygrass, and from $5.52/acre to $21.43/acre for both switchgrass and big bluestem). Fixed costs on implements are increased by about 49% for alfalfa, 88% for reed canarygrass, and 261% for both switchgrass and big bluestem (increased from $15.38/acre to $22.98/acre for alfalfa, from $12.21/acre to $22.97/acre for reed canarygrass, and from $6.38/acre to $32.02/acre for both switchgrass and big bluestem) (Table 5.6).

Production costs are increased by about 11% for alfalfa (from $282.69 to $312.88 per acre), 12% for reed canarygrass (from $247.55 to $276.58 per acre), 19% for switchgrass ($214.13 to $255.50 per acre), and 34% for big bluestem (from $227.23 to $305.23 per acre). Break-even prices are increased by about 11% for alfalfa (from $58.29 to $64.51 per ton), 12% for reed canarygrass (from $67.45 to $75.36 per ton), 19% for switchgrass (from $43.08 to $51.41 per ton), and 34% for big bluestem (from $53.72 to $72.16 per ton) (Table 5.6).

The impact of the decrease in implement use on annual production costs of perennial grasses is very large, especially on repair and maintenance costs and fixed costs of implements. Increase in the machinery related costs for switchgrass and big bluestem are especially large because of the differences in the number of harvest times compared to the other grasses. Switchgrass and big bluestem are assumed to be harvested once while alfalfa is harvested three times and reed canarygrass is harvested twice every year.

Summary

Field operations involved in growing perennial grasses for both the establishment year and remaining years are the same for all perennial grasses, except the number of harvest times. Types of fertilizer inputs applied to the perennial grasses are also the same. In other words, the production technology for biomass energy crop production is the same for all perennial grasses. Therefore, the significant differences in the production costs of perennial grasses are caused by the number of harvest times, the amount of fertilizer applied, and input prices, especially seed price, for the establishment year, while the differences in the annual production costs are caused by the number of harvest times, the amount of fertilizer applied, and prorated net establishment costs.

For the establishment year, no nitrogen was applied to all monocrop perennial grass systems. The switchgrass monocrop system at Ames produced the highest dry matter yield (3.62 tons/acre) of all monocrop perennial systems at both Ames and Chariton. The big bluestem monocrop system at Chariton produced the least dry matter yield (1.38 tons/acre).

For the standing year, at the selected nitrogen level (125 lbs/acre), switchgrass produced more dry matter than any other perennial grass systems at both Ames and Chariton and switchgrass at Ames produced higher dry matter yield (4.97 tons/acre) than that at Chariton (4.61 tons/acre).

Alfalfa has the highest establishment costs and amortized establishment costs at both Ames and Chariton due primarily to the high fertilizer input costs for the establishment year and shorter life-span, four years for alfalfa and ten years for the other perennial grasses.

Although switchgrass and big bluestem have the same production technology, that is, the same field operations, for both the establishment year and standing year, big bluestem has a higher amortized establishment cost because of higher seed price and lower dry matter yield than switchgrass.

Switchgrass produced the highest dry matter and has the lowest break-even price among perennial grasses at both Ames and Chariton. Lower break-even prices are due to combination of lower production costs and higher dry matter yield. Break-even prices for switchgrass are $43.08/ton at Ames and $39.05/ton at Chariton. Having higher productivity with lower production cost even on the marginal land (Chariton) makes switchgrass a good candidate for a biomass energy crop.

Machinery required to perform field operations involved in production of perennial grasses are the same as the ones used for hay production. This means that a farmer who is interested in growing perennial grasses as energy crops can produce them without significant additional investment in capital and enjoy decreasing costs as the annual hours of implement use increases. Annual production costs can be reduced significantly by taking advantage of economies of scale involved with machinery use since maintenance and harvesting activities are the only field operations necessary once perennial grasses are established.

Presence of the economies of scale related with machinery use suggest that more allocation of land to biomass energy crop production is a way to reduce the production cost of biomass energy crops.

CHAPTER 6

COST OF PRODUCING ANNUAL CROPS FOR BIOMASS ENERGY USE

The objective of this chapter is to analyze the production costs of the annual energy crops; sweet sorghum, sorghum x sudangrass hybrid, and rye, in different cropping systems. The cropping systems discussed in this chapter are as follows: monocrop sweet sorghum and sorghum x sudangrass hybrid; doublecrop rye/sweet sorghum and rye/sorghum x sudangrass; and monocrop sweet sorghum and doublecrop rye/sweet sorghum in rotation with soybean and corn.

The first section presents inputs used and production activities involved with different cropping systems. The input levels presented in this section are for disposable inputs, such as fertilizer, herbicide, and seed. Their amounts, except nitrogen fertilizer, were determined after soil test by agronomists, Dr. I. C. Anderson and Dr. D. Buxton at Iowa State University and are appropriate for the different soils. As mentioned in the previous chapter, four different levels of nitrogen were applied to four different experimental plots, for most of cropping systems except monocrop sweet sorghum in rotation and rye/sweet sorghum in rotation system, to test yield response to nitrogen fertilizer. For rotation systems, only two levels of nitrogen treatment, 62.5 lbs and 125 lbs/acre, were applied. The 125 lbs/acre nitrogen level is presented in Tables 6.1 and 6.2 for primarily two reasons: first, marginal yield response to the changes in nitrogen level increase significantly up to this level of nitrogen and second, the production costs are estimated for this level for nitrogen. The second section discusses dry matter yield from the different cropping systems. The data presented in this section are the experimental data collected from the two agricultural experimental farms located at Ames and Chariton. Dry matter yields are with 0% moisture for sorghum and corn stover. Corn grain yield has 15% moisture. The third section discusses the production costs of the biomass annual crops from different cropping systems. There are two sets of production cost estimates for each cropping systems. The first set is estimated based on typical Iowa equipment use, and the second set is estimated based on equipment use if only 160 acres of land is allocated to biomass energy crop production. The only difference between the two sets of cost estimates comes from annual hours of use for equipment given the performance rate of each piece of equipment. The last section discusses how these changes in annual hours of implement use affect production costs.

Input Use and Production Activities

Tables 6.1 and 6.2 show the quantity of each disposable input and field operations necessary to grow the annual energy crops. Table 6.1 shows input use and field operations involved in the monocrop systems including monocrop sweet sorghum in rotation. Table 6.2 shows input use and field operations for the doublecrop systems including the doublecrop in rotation system.

Table 6.1 Input use and field operations of monocrop sorghums

Operation/Operating input	Amount					
	SS		SSH		SS in Rotation	
	A	C	A	C	A	C
Field cultivator					n	n
Peg-tooth harrow						
Fertilizer						
Phosphorus, lbs	58	58	58	58	58	58
Potash, lbs	47	47	47	47	47	47
Nitrogen, lbs	125	125	125	125	125	125
Disk sprayer						
Dual, pt	2	2	2	2	2	2
Planter						
Sweet sorghum, lbs	7	7			7	7
Sorghum x sudangrass, lbs			7	7		
Cultivator					n	n
Silage harvester						
Haul silage						
Forage blower						

Note: SS = sweet sorghum; SSH = sorghum x sudangrass hybrid; A = Ames; C = Chariton.
"n" means that this operation is not necessary for this system.

Table 6.2 Input use and field operations for double crop sorghum systems

Operation/Operating input	Amount					
	Rye/SS		Rye/SSH		Rye/SS in Rotation	
	A	C	A	C	A	C
Fertilizer						
Phosphorus, lbs	58	58	58	58	58	58
Potash, lbs	47	47	47	47	47	47
Tandem disk						
Peg-tooth harrow						
Grain drill						
Rye, lbs	100	120	100	120	100	120
Fertilizer						
Nitrogen, lbs	62.5	62.5	62.5	62.5	n	n
Mower-conditioner						
Baler						
Haul hay						
Planter						
Sweet sorghum, lbs	7.0	7.0			7.0	7.0
Sorghum x sudangrass, lbs			7.0	7.0		
Fertilizer						
Nitrogen, lbs	62.5	62.5	62.5	62.5	125	125
Silage harvester						
Haul silage						
Forage blower						

Note: SS = sweet sorghum; SSH = sorghum x sudangrass; A = Ames; C = Chariton.
"n" means that this operation is not necessary for this system.

As shown in Tables 6.1 and 6.2, the monocrop and doublecrop systems received the same amount of phosphorus (P) and potash (K), 58 lbs/acre of P and 47 lbs/acre of K, at both Ames and Chariton. The doublecrop in rotation system received nitrogen fertilizer once in the spring while the doublecrop systems received a split nitrogen treatment; once in the fall with the second in the spring (Table 6.2). Herbicide was applied to the monocrop systems, 2 pint of Dual per acre at both Ames and Chariton (Table 6.1).

Seeding rates were the same for both sweet sorghum and sorghum x sudangrass in monocrop and doublecrop systems, 7 pounds per acre, at both Ames and Chariton. The seeding rates for rye in doublecrop were different at Ames and Chariton: 100 pounds per acre at Ames and 120 pounds per acre at Chariton (Table 6.2).

Notice that field cultivation and cultivation for weeds were not performed for the monocrop sweet sorghum in rotation systems because of minimal crop residues on soil with these systems. The rye seeding rates were different between Ames and Chariton without specific reason. Thus, the same seeding rate could be applied to both sites (Buxton, 1996).

Discussion on Yield

Tables 6.4 through 6.6 show dry matter yield data and yield response to different levels of nitrogen treatment for the annual crops in different cropping systems. The yield data shown are the average yield over the experimental period. Yield data are averaged over the following years: 1988-1992 for the monocrop systems (Table 6.3); 1988-1991 in Ames and 1988-1992 in Chariton for the doublecrop systems (Table 6.4); 1989-1991 for sweet sorghum (mono and doublecrop) in rotation (Table 6.5), and 1988-1992 for the corn and soybean in rotation system (Table 6.6).

Table 6.3 Average dry matter yield of monocrop sorghum systems and yield response to nitrogen

Species	Yield (ton/acre)			
	Yield	Change in Yield	Yield	Change in Yield
	Ames		Chariton	
Sweet sorghum				
0 lbs N/acre	5.79		6.47	
62.5 lbs N/acre	7.24	1.45	7.78	1.31
125 lbs N/acre	7.80	0.56	8.03	0.25
250 lbs N/acre	7.50	-0.30	7.90	-0.13
Sorghum x sudangrass				
0 lbs N/acre	5.72		6.16	
62.5 lbs N/acre	6.35	0.63	7.40	1.24
125 lbs N/acre	7.01	0.66	7.41	0.01
250 lbs N/acre	7.04	0.03	7.71	0.30

Note: Data are averaged over 1988-1992.

Table 6.4 Average dry matter yield of double crop sorghum/rye and yield response to nitrogen

Species	Yield (ton/acre)			
	Yield	Change in Yield	Yield	Change in Yield
	Ames		Chariton	
Sweet sorghum				
0 lbs N/acre	3.24		3.27	
62.5 lbs N/acre	4.42	1.18	4.11	0.84
125 lbs N/acre	5.57	1.15	4.94	0.83
250 lbs N/acre	5.79	0.02	6.04	1.10
Rye				
0 lbs N/acre	1.31		1.65	
62.5 lbs N/acre	1.99	0.68	1.89	0.24
125 lbs N/acre	2.37	0.38	2.04	0.15
250 lbs N/acre	2.62	0.25	2.11	0.07
Total				
0 lbs N/acre	4.54		4.92	
62.5 lbs N/acre	6.41	1.87	6.00	1.08
125 lbs N/acre	7.94	1.53	6.97	0.97
250 lbs N/acre	8.42	0.48	8.15	1.18
Sorghum x sudangrass				
0 lbs N/acre	2.95		3.23	
62.5 lbs N/acre	4.19	1.24	4.04	0.81
125 lbs N/acre	5.00	0.81	4.90	0.86
250 lbs N/acre	6.46	1.46	5.72	0.82
Rye				
0 lbs N/acre	1.17		1.38	
62.5 lbs N/acre	1.73	0.56	1.86	0.48
125 lbs N/acre	2.10	0.37	2.00	0.14
250 lbs N/acre	2.47	0.37	2.15	0.15
Total				
0 lbs N/acre	4.12		4.61	
62.5 lbs N/acre	5.92	1.65	5.89	1.28
125 lbs N/acre	7.10	1.19	6.90	1.01
250 lbs N/acre	8.93	1.97	7.88	0.98

Note: Data are averaged over 1988-1991 in Ames and 1988-1992 in Chariton.

Table 6.5 Average dry matter yields of sweet sorghum and sweet sorghum/rye in rotation and yield response to nitrogen

Species	Yield (tons/acre)			
	Yield	Change in Yield	Yield	Change in Yield
	Ames		Chariton	
Sweet sorghum				
62.5 lbs N/acre	7.37		7.82	
125 lbs N/acre	7.93	0.56	8.24	0.42
Sweet sorghum/Rye				
Sweet sorghum				
62.5 lbs N/acre	6.46		6.44	
125 lbs N/acre	6.85	0.39	7.90	1.46
Rye				
62.5 lbs N/acre	2.40		1.93	
125 lbs N/acre	2.45	0.05	1.98	0.05
Total				
62.5 lbs N/acre	8.86		8.37	
125 lbs N/acre	9.30	0.44	9.88	1.51

Note: Data are averaged over 1989-1991.

Table 6.6 Average yields for corn and soybean in rotation and yield response to nitrogen

Species	Yield	Change in yield	Yield	Change in yield
	Ames		Chariton	
CORN				
Grain (bushels/acre)				
0 lbs N/acre	43.46		48.49	
62.5 lbs N/acre	68.96	25.50	45.98	-2.51
125 lbs N/acre	85.34	16.38	54.79	8.81
250 lbs N/acre	91.64	6.30	52.27	-2.52
Stover (ton/acre)				
0 lbs N/acre	2.48		2.48	
62.5 lbs N/acre	2.72	0.24	2.33	-0.15
125 lbs N/acre	3.28	0.56	2.83	0.50
250 lbsN/acre	3.38	0.10	3.03	0.20
SOYBEAN				
Grain (bushels/acre)	27.92		40.41	

Note: Data are averaged over 1988-1992.

For all the cropping systems associated with annual crops, yield increases as the amount of nitrogen applied increases with a few exception (Tables 6.3 through 6.6). For example, the monocrop sweet sorghum systems at both Ames and Chariton show a decrease in yield as amount of nitrogen increases from 125 pounds per acre to 250 pounds per acre while it shows positive relationship between yield response and nitrogen treatment level at lower nitrogen levels (Table 6.3). Corn yields at Chariton also show a decrease in yield from 0 to 62.5 and 125 to 250 pounds of nitrogen per acre (Table 6.6). Monocrop sorghum x sudangrass hybrid yield at Chariton had almost no response when nitrogen level increased from 62.5 lbs to 125 lbs/acre (only 0.01 ton/acre increase). There is no reasonable explanation for this, except that it might have been caused by experimental design failure (Buxton, 1996).

The yield data on monocrop sorghum systems shows that dry matter yield at Chariton was higher than at Ames at all levels of nitrogen treatment. For example, at the selected level of nitrogen, 125 lbs/acre, used to estimated production costs, it produced about 2.9% more sweet sorghum dry matter and about 5.7% more sorghum x sudangrass dry matter at Chariton than at Ames. This is consistent with a longer growing period at the southern Iowa location at Chariton (Anderson, Buxton, and Hallam, 1994).

Of the doublecrop systems, the rye/sorghum x sudangrass system at Ames produced more dry matter yield, 8.93 tons/acre, than any other rye/sorghum double crop system at the two locations. This is about 6.1% higher than rye/sweet sorghum at Ames, 9.6% higher than rye/sweet sorghum at Chariton, and 13.3% higher than rye/sorghum x sudangrass at Chariton (Table 6.4).

Of the two systems in rotation (monocrop sweet sorghum and rye/sweet sorghum doublecrop), doublecrop sweet sorghum/rye in rotation at Chariton produced more dry matter, 9.88 tons/acre (Table 6.5), at the selected nitrogen level. It produced about 24.6% and 20.0% more dry matter than monocrop sweet sorghum in rotation at Ames and Chariton, respectively, and about 6.2% more dry matter than rye/sweet sorghum double crop at Ames

(Table 6.5). The higher dry matter yield at Chariton is probably caused by climate effects and the longer growing period (Anderson, Buxton, and Hallam, 1994).

The corn in rotation system shows higher yield at Ames, except at no nitrogen level. At the selected nitrogen level (125 pounds per acre), corn grain and stover yield at Ames were about 55.8% and 15.9% higher, respectively, than at Chariton. Soybean in rotation shows about 44.7% higher yield at Chariton than at Ames. Notice that the lower soybean yield at Ames was caused by iron deficiency at the chosen experimental site at Ames and is not representative of yields on better quality soils (Buxton and Hallam, 1996).

At the selected nitrogen level in this study, 125 pounds per acre, sole sweet sorghum and doublecrop sweet sorghum/rye in rotation produced more dry matter than any other systems. Sweet sorghum, both mono and doublecrop, in rotation at Chariton produced more dry matter than the same system at Ames. Within the rotation system, rye/sweet sorghum at Chariton produced more dry matter (Table 6.7).

In short, if we are only concerned about dry matter yield, then the doublecrop sweet sorghum/rye in rotation system could be a good system to grow biomass energy crops among the cropping systems with annual crops.

Table 6.7 Summary of average dry matter yield of annual crops in different cropping systems at 125 lbs/acre nitrogen

System	Yield (tons/acre)	
	Ames	Chariton
Sweet sorghum	7.80	8.03*
Sorghum x sudangrass	7.01	7.41
Rye/sweet sorghum	7.94*	6.97
Rye/sorghum x sudangrass	7.10	6.90
Sweet sorghum in rotation	7.93	8.24
Rye/sweet sorghum in rotation	9.30**	9.88**

Note: * = the highest yield at location (non rotation); ** = the highest at location (rotation).

Discussion on Production Costs

This section discusses the production costs of annual crops in the different cropping systems. Of the four different levels of nitrogen fertilizer application, production costs are estimated with 125 pound per acre of nitrogen and corresponding yield at that level is used to calculate a break-even price. For the sorghum systems, differences in production costs are caused by the following factors: seed price, interest on operating inputs, transportation cost, and land cost, since field operations, fertilizer use, herbicide use, and seeding rate are the same within the two cropping systems at both sites (see Tables 6.1 and 6.2).

This section has two subsections. One subsection discusses the production costs of each system. The other subsection discusses the sweet sorghum and rye/sweet sorghum in rotation system as a whole. The difference between the two sections is that the later section uses the separately estimated production costs of the crops in each rotation system to estimate the production costs of the rotation system as a whole. These production costs are shown in Table 6.13.

Notice that corn and soybean net production costs shown in Tables 6.11 and 6.12 are used to estimate rotation system costs because it is assumed that corn and soybean are sold as animal feed grain, not as biomass energy feedstock. Break-even prices are estimated by dividing total production costs of the system by dry matter yield, which is the sum of corn stover and either sweet sorghum or rye/sweet sorghum. Corn stover is assumed to be sold as a biomass energy feedstock.

Production Costs of Each System

Of the monocrop sorghum systems, production costs of both sweet sorghum and sorghum x sudangrass at Ames are higher than at Chariton. This is primarily due to a higher land cost at Ames. Land cost at Ames is $35.00/acre higher than at Chariton. Monocrop sweet sorghum at Chariton has the lowest break-even price, $31.53 per ton (Table 6.8 under "Iowa equipment use"). As annual hours of use of implements decreases, production costs increase. For example, both total production costs and break-even price are increased by 24.4% for the monocrop sweet sorghum at Chariton (Table 6.8).

Of the doublecrop rye/sorghum systems, total production costs at Chariton are lower than at Ames for both the rye/sweet sorghum and rye/sorghum x sudangrass systems. The rye/sweet sorghum at Ames has the highest production costs of the doublecrop systems, $331.75/acre at Ames and $299.62/acre at Chariton with Iowa equipment use (Table 6.9 under "Iowa equipment use").

Table 6.8 Estimated annual production cost of monocrop sorghum systems assuming both Iowa equipment use and 160 acres of biomass production (per acre)

Item	SS	SSH	SS	SSH
	(dollars)			
	Ames		Chariton	
	Iowa equipment use			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	15.76	15.76	15.76	15.76
Seed	3.50	2.45	3.50	2.45
Operator Labor	13.18	13.18	13.18	13.18
Fuel	8.45	8.45	8.45	8.45
Repair and Maintenance				
Implements	10.59	10.59	10.59	10.59
Tractors	10.19	10.19	10.19	10.19
Interest[1]	2.65	2.60	2.66	2.61
Transportation	32.37	29.09	33.32	30.75
TOTAL DIRECT EXPENSES	134.18	129.81	135.14	131.47
FIXED EXPENSES				
Implements	19.97	19.97	19.97	19.97
Tractors	18.09	18.09	18.09	18.09
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	153.06	153.06	118.06	118.06
TOTAL EXPENSES	287.24	282.87	253.20	249.53
BREAK-EVEN PRICE ($/ton)	36.83	40.35	31.53	33.67

Table 6.8 (Continued)

Item	SS	SSH	SS	SSH
	(dollars)			
	Ames		Chariton	
	160 acres of biomass production			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	15.76	15.76	15.76	15.76
Seed	3.50	2.45	3.50	2.45
Operator labor	13.18	13.18	13.18	13.18
Fuel	8.45	8.45	8.45	8.45
Repair & maintenance				
Implements	32.29	32.29	32.29	32.29
Tractors	10.19	10.19	10.19	10.19
Interest[1]	3.12	3.08	3.12	3.08
Transportation	32.37	29.09	33.32	30.75
TOTAL DIRECT EXPENSES	156.34	151.98	157.30	153.64
FIXED EXPENSES				
Implements	59.52	59.52	59.52	59.52
Tractors	18.09	18.09	18.09	18.09
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	192.61	192.61	157.61	157.61
TOTAL EXPENSES	348.95	344.59	314.91	311.25
BREAK-EVEN PRICE ($/ton)	44.74	49.16	39.22	42.00

Note: SS = Sweet sorghum; SSH = Sorghum x sudangrass hybrid. Yield data used to estimate the break-even prices are 7.80 tons/acre for sweet sorghum, 7.01 tons/acre for sorghum x sudangrass at Ames and 8.03 tons/acre for sweet sorghum and 7.41 tons/acre for sorghum x sudangrass at Chariton.

[1] Interest on operating costs.

Despite the higher production costs, the rye/sweet sorghum doublecrop system at Ames has lower break-even prices, $41.78/ton and $53.19/ton (Table 6.9), because of the higher yield (see Table 6.4). The double crop systems have higher break-even prices than the monocrop systems because the yields are only marginally higher and the costs are about 15-20% higher.

Table 6.9 Estimated annual production cost of sorghum/rye double crop systems assuming both Iowa equipment use and 160 acres of biomass production (per acre)

Item	SS/Rye	SSH/Rye	SS/Rye	SSH/Rye
	(dollars)			
	Ames		Chariton	
	Iowa equipment use			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Seed				
Rye	31.00	31.00	37.20	37.20
Sweet sorghum	3.50	2.45	3.50	2.45
Operator labor	17.66	17.66	17.66	17.66
Fuel	10.69	10.69	10.69	10.69
Repair & maintenance				
Implements	15.90	15.90	15.90	15.90
Tractors	12.82	12.82	12.82	12.82
Interest[1]	5.35	5.29	6.00	5.65
Transportation	32.95	29.47	28.97	28.64
TOTAL DIRECT EXPENSES	167.36	162.77	170.23	168.50
FIXED EXPENSES				
Implements	26.64	26.64	26.64	26.64
Tractors	22.75	22.75	22.75	22.75
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	164.39	164.39	129.39	129.39
TOTAL EXPENSES	331.75	327.16	299.62	297.89
BREAK-EVEN PRICE ($/ton)	41.78	46.08	42.93	43.17

Table 6.9 (Continued)

Item	SS/Rye	SSH/Rye	SS/Rye	SSH/Rye
	(dollars)			
	Ames		Chariton	
	Iowa equipment use			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Seed				
Rye	31.00	31.00	37.20	37.20
Sweet sorghum	3.50	2.45	3.50	2.45
Operator labor	17.66	17.66	17.66	17.66
Tractors				
Fuel	10.69	10.69	10.69	10.69
Repair and maintenance				
Implements	51.40	51.40	51.40	51.40
Tractors	12.82	12.82	12.82	12.82
Interest[1]	6.36	6.30	6.36	6.30
Transportation	32.95	29.47	28.97	28.64
TOTAL DIRECT EXPENSES	203.88	199.28	206.42	205.01
FIXED EXPENSES				
Implements	80.70	80.70	80.70	80.70
Tractors	22.75	22.75	22.75	22.75
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	218.45	218.45	183.45	183.45
TOTAL EXPENSES	422.33	417.73	389.87	388.46
BREAK-EVEN PRICE	53.19	58.84	55.86	56.30

Note: SS = Sweet sorghum; SSH = Sorghum x sudangrass hybrid. Yield data used to estimate the break-even prices are 7.94 tons/acre for sweet sorghum/rye, 7.10 tons/acre for sorghum x sudangrass/rye at Ames and 6.97 tons/acre for sweet sorghum/rye and 6.90 tons/acre for sorghum x sudangrass/rye at Chariton.

[1] Interest on operating costs.

Of the sweet sorghum in the rotation systems, monocrop sweet sorghum and doublecrop rye/sweet sorghum in rotation at Chariton have lower production costs and break-even prices. Monocrop sweet sorghum in rotation at Chariton has the lowest production costs and break-even price, $246.05/acre ($298.04/acre) and $29.86/ton ($36.17/acre) (Table 6.10).

Table 6.10 Estimated annual production cost of sole sweet sorghum in rotation and sweet sorghum/rye in rotation assuming both Iowa equipment use and 160 acres of biomass production (per acre)

Item	SS	SS/Rye	SS	SS/Rye
	(dollars)			
	Ames		Chariton	
	Iowa equipment use			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	15.76		15.76	
Seed				
Rye		31.00		37.20
Sweet sorghum	3.50	3.50	3.50	3.50
Operator labor	11.87	16.42	11.87	16.42
Fuel	7.70	10.00	7.70	10.00
Repair and maintenance				
Implements	9.27	15.18	9.27	15.18
Tractors	9.29	11.99	9.29	11.99
Interest[1]	2.67	5.37	2.67	5.76
Transportation	32.91	38.60	34.20	41.00
TOTAL DIRECT EXPENSES	130.46	169.55	131.75	178.54
FIXED EXPENSES				
Implements	17.81	25.46	17.81	25.46
Tractors	16.49	21.27	16.49	21.27
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	149.30	161.73	114.30	126.73
TOTAL EXPENSES	279.76	331.28	246.05	305.27
BREAK-EVEN PRICE	35.28	35.62	29.86	30.90

Table 6.10 (Continued)

Item	SS	SS/Rye	SS	SS/Rye
		(dollars)		(dollars)
	Ames		Chariton	
	160 acres of biomass production			
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	15.76		15.76	
Seed				
Rye		31.00		37.20
Sweet sorghum	3.50	3.50	3.50	3.50
Operator labor	11.87	16.42	11.87	16.42
Fuel	7.70	10.00	7.70	10.00
Repair and maintenance				
Implements	27.30	51.43	27.30	51.43
Tractors	9.29	11.99	9.29	11.99
Interest[1]	3.04	6.42	3.05	6.81
Transportation	32.91	38.60	34.20	41.00
TOTAL DIRECT EXPENSES	148.87	206.84	150.16	215.83
FIXED EXPENSES				
Implements	51.39	80.74	51.39	80.74
Tractors	16.49	21.27	16.49	21.27
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	182.88	217.01	147.88	182.01
TOTAL EXPENSES	331.75	423.85	298.04	397.84
BREAK-EVEN PRICE	41.83	45.58	36.17	40.27

Note: SS = sweet sorghum. Yield data used to estimate the break-even prices are 7.93 tons/acre for sweet sorghum, 9.30 tons/acre for sweet sorghum/rye at Ames and 8.24 tons/acre for sweet sorghum and 9.88 tons/acre for sweet sorghum/rye at Chariton.

[1] Interest on operating costs.

Production costs for corn at Ames are higher than that at Chariton primarily due to the higher land cost. Despite this higher production cost, net production costs and break-even prices are lower at Ames because of higher yield. There is a significant difference in net production costs between the two sites (about 30.6% higher with Iowa equipment use and 18.7% higher with 160 acres equipment); differences in break-even prices are much greater (about 51.3% higher with Iowa equipment use and 37.6% higher with 160 acres equipment use) due to lower stover yield at Chariton. Notice that without stover corn is produced at loss using 1993 prices. Thus, utilizing corn stover, a by-product of corn grain production, can help to reduce losses or to break-even in corn production.

For soybean in rotation, production costs and net production costs at Ames are higher than at Chariton. Production costs are higher at Ames because of higher land cost, and net costs are higher at Ames because of lower yield. At Chariton, soybean even shows economic profit, $39.11/acre, with Iowa equipment use. Over the experimental period (1982-1992), average soybean yields were 27.92 bushels/acre at Ames and 40.41 bushels/acre at Chariton. The lower yield at Ames was caused by iron deficiency at the chosen experimental site at Ames and is probably not representative of yields on the quality soils (Buxton and Hallam, 1996).

If we compare net costs at both sites with lower equipment usage, the difference is large. Net production cost at Ames is about 16 times higher than that at Chariton with lower equipment use (see columns with B inTable 6.12). This big difference in net costs is caused solely by the differences in yield.

Sweet Sorghum and Rye/Sweet sorghum in Rotation System as a Whole

Table 6.13 shows production costs and break-even prices of monocrop sweet sorghum and doublecrop rye/sweet sorghum in the rotation system as a whole. Production costs of the rotation system are estimated by adding net production costs of corn and soybean (Tables 6.11 and 6.12) and total production costs of either sweet sorghum (sole) or rye/sweet sorghum (Table 6.10) together.

Table 6.11 Estimated production cost of corn (per acre)

Item	A	B	A	B
	Ames		Chariton	
		(dollars)		
DIRECT EXPENSES				
Fertilizer				
Phosphorus	14.50	14.50	14.50	14.50
Potash	7.99	7.99	7.99	7.99
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	31.75	31.75	31.75	31.75
Seed	27.00	27.00	27.00	27.00
Operator labor	14.15	14.15	14.15	14.15
Fuel	8.80	8.80	8.80	8.80
Repair and maintenance				
Implements	10.73	42.37	10.73	42.37
Tractors	12.09	12.09	12.09	12.09
Interest[1]	4.24	4.80	4.23	4.79
Transportation	13.61	13.61	11.74	11.74
TOTAL DIRECT EXPENSES	159.86	192.06	157.98	190.18
FIXED EXPENSES				
Implements	18.30	71.20	18.30	71.20
Tractors	21.52	21.52	21.52	21.52
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	154.82	207.72	119.82	172.72
TOTAL EXPENSES	314.68	399.78	277.80	362.90
TOTAL REVENUE	200.55	200.55	128.76	128.76
NET COST($/acre)	114.13	199.23	149.03	234.14
BREAK-EVEN PRICE ($/ton)	34.80	60.13	52.66	82.73

Note: [1] Interest on operating costs. A = Iowa equipment use; B = 160 acres equipment use. The average yield of corn was 85.34 bushel/acre at Ames and 54.79 bushel/acre at Chariton, and average yield of corn stover was 3.28 ton/acre at Ames and 2.83 ton/acre at Chariton over the experimental period, 1988-1992. The price of corn was $2.35/bu in 1993 (USDA, 1993). Revenue is calculated by multiplying corn yield by corn price. The break-even price is calculated by dividing net cost by the corn stover yield.

Table 6.12 Estimated production cost of soybean (per acre)

Item	A	B	A	B
	Ames		Chariton	
		(dollars)		
DIRECT EXPENSES				
Fertilizer				
Phosphorus	10.00	10.00	10.00	10.00
Potash	12.75	12.75	12.75	12.75
Herbicide	19.68	19.68	19.68	19.68
Seed	14.00	14.00	14.00	14.00
Operator labor	5.59	5.59	5.59	5.59
Fuel	4.30	4.30	4.30	4.30
Repair and maintenance				
Implements	4.62	20.23	4.62	20.23
Tractors	6.44	6.44	6.44	6.44
Interest[1]	2.49	2.79	2.49	2.79
TOTAL DIRECT EXPENSES	79.87	95.78	79.88	95.78
FIXED EXPENSES				
Implements	9.74	39.68	9.74	39.68
Tractors	11.50	11.50	11.50	11.50
Land	115.00	115.00	80.00	80.00
TOTAL FIXED EXPENSES	136.24	166.18	101.24	131.18
TOTAL EXPENSES	216.11	261.96	181.12	226.96
TOTAL REVENUE	152.16	152.16	220.23	220.23
NET COST ($/acre)	63.95	109.80	-39.11	6.73

Note: A = Iowa equipment use; B = 160 acres of biomass production. Average soybean yield was 27.92 bushel/acre at Ames and 40.41 bushel /acre at Chariton over the experimental period, 1988-1992. Soybean price was $5.45/bu in 1993 (USDA, 1993). Revenue is calculated by multiplying soybean yield by soybean price.

[1] Interest on operating costs.

For the monocrop sweet sorghum and rye/sweet sorghum in rotation systems as a whole, production costs and break-even prices of the system at Chariton are lower than those at Ames. They are lower at Chariton because of the high land cost at Ames and lower net production costs of soybean at Chariton, although there is not much difference in dry matter yield. Production costs are about 22% lower for sweet sorghum and about 18% lower for rye/sweet sorghum in the rotation system with Iowa equipment use. Break-even prices are about 21% lower for sweet sorghum and about 19% lower for rye/sweet sorghum in the rotation system with Iowa equipment use (Table 6.13).

Notice that the production costs of rotation system are affected by the net production costs of corn and soybean since it is assumed that corn and soybean grains are sold as feed grain at market price. In other words, the production costs of the rotation system as a whole are influenced either by price of corn and soybean given yields or by yields of corn and soybean given market prices.

Table 6.13 Production costs and break-even prices of sole sweet sorghum and rye/sweet sorghum in rotation system as a whole.

Item	SS	SS	Rye/SS	Rye/SS
	A	B	A	B
		Ames		
TOTAL EXPENSES ($/system)	457.84	640.78	509.36	732.88
Expenses for sorghum ($/acre)	279.76	331.75	331.28	423.85
Net expenses of corn ($/acre)	114.13	199.23	114.13	199.23
Net expenses of soybean ($/acre)	63.95	109.80	63.95	109.80
TOTAL EXPENSES ($/acre)	152.61	213.59	169.79	244.29
TOTAL YIELD (ton/acre)	11.21	11.21	12.58	12.58
BREAK-EVEN PRICE ($/ton)	40.84	57.16	40.49	58.26
		Chariton		
TOTAL EXPENSES ($/system)	355.97	538.91	415.19	638.71
Expenses for sorghum ($/acre)	246.05	298.04	305.27	397.84
Net expenses of corn ($/acre)	149.03	234.14	149.03	234.14
Net expenses of soybean ($/acre)	-39.11	6.73	-39.11	6.73
TOTAL EXPENSES ($/acre)	118.66	179.64	138.40	212.90
TOTAL YIELD (ton/acre)	11.07	11.07	12.71	12.71
BREAK-EVEN PRICE ($/ton)	32.16	48.68	32.67	50.25

Note: Per acre total expenses are estimated by dividing total expenses of the system by three. Total yield is a sum of corn stover and sweet sorghum yield for monocrop and rye/sweet sorghum yield for doublecrop in rotation (125 lbs/acre of nitrogen). The yields are as follows: corn stover, 3.28 ton/acre at Ames and 2.83 ton/acre at Chariton; sweet sorghum, 7.93 ton/acre at Ames and 8.24 ton/acre at Chariton; and rye/sweet sorghum, 9.30 ton/acre at Ames and 9.88 ton/acre at Chariton. A = Iowa equipment use; B = 160 acres of biomass production.

Of all the cropping systems with annual crops (Iowa equipment use), the monocrop sweet sorghum has the least break-even price at both Ames and Chariton ($36.83/acre and $31.53/acre, respectively). Comparing all cropping systems at two locations, monocrop sweet sorghum at Chariton has the least break-even price of all systems. Notice that, from Table 6.14, it appears to be that the monocrop sweet sorghum in rotation has the least break-even price at both locations. However, this cannot represents the true break-even price for the rotation system because it does not count corn and soybean production costs or revenues. When the production costs of corn and soybean are added to the monocrop sweet sorghum

Table 6.14 Break-even prices of the cropping systems

System	Yield	Total cost	Average cost	Total cost	Average cost
	(ton/acre)	($/acre)	($/ton)	($/acre)	($/ton)
		A		B	
			Ames		
Sweet sorghum	7.80	287.24	36.83*	348.95	44.74
Sorghum x sudangrass	7.01	282.87	40.35	344.59	49.16
Sweet sorghum/rye	7.94	331.75	41.78	422.33	53.19
Sorghum x sudangrass/rye	7.10	327.16	46.08	417.73	58.84
Sweet sorghum (R)	7.93	279.76	35.28	331.75	41.83
Sweet sorghum/rye (R)	9.30	331.28	35.62	423.85	45.58
Sweet sorghum (whole)	11.21	457.84	40.84	640.78	57.16
Sweet sorghum/rye (whole)	12.58	509.36	40.49	732.88	58.26
			Chariton		
Sweet sorghum	8.03	253.20	31.53*	314.91	39.22
Sorghum x sudangrass	7.41	249.53	33.67	311.25	42.00
Sweet sorghum/rye	6.97	299.62	42.93	389.87	55.94
Sorghum x sudangrass/rye	6.90	297.89	43.17	388.46	56.30
Sweet sorghum (R)	8.24	246.05	29.86	298.04	36.17
Sweet sorghum/rye (R)	9.88	305.27	30.90	397.84	40.27
Sweet sorghum (whole)	11.07	355.97	32.16	538.91	48.68
Sweet sorghum/rye (whole)	12.71	415.19	32.67	638.71	50.25

Note: A = Iowa equipment use; B = 160 acres equipment use. R means the system in rotation. The unit for sweet sorghum (whole) and rye/sweet sorghum (whole) is $/system.
* = lowest break-even price at location.

and sweet sorghum/rye double crop in the rotation systems, the break-even prices increase to \$40.84/acre for monocrop sweet sorghum and \$40.49/acre for sweet sorghum/rye double crop at Ames, and to \$32.16/acre and \$32.67/acre, at Chariton (compare the break-even prices of sweet sorghum (R) and sweet sorghum/rye (R) to sweet sorghum (whole) and sweet sorghum/rye (whole) in Table 6.14).

By comparing break-even prices of each cropping system, it can be said that the sweet sorghum systems at Chariton are the cropping systems to choose to grow biomass energy crops among the cropping systems with annual crops because of their low break-even prices.

Discussion of Machinery Costs

Up to this point, the production costs and break-even prices of each cropping system were discussed by using the enterprise budgets estimated with Iowa equipment use. This section briefly discusses how annual hours of implement use affect production costs and break-even prices. The discussion is primarily focused on the costs associated with implements since changes in the annual hours of implement use affect only the costs related to implements. Notice that although the changes in annual hours of implement use affect direct expense on interest for operating inputs, this is not discussed here because the impact on total production cost is very minimal. For example, annual interest expense increases by about 18% as annual hours of implement use decreases from Iowa equipment use to 160 acres of use for monocrop sweet sorghum at Ames. However, interest accounts only for about 2% of the variable costs and about 0.9% of the total costs (Table 6.8).

The increase in repair and maintenance costs of implements from changes in the annual hours of implement use for each cropping system are as follows: about 205% higher for monocrop sorghum systems, about 223% higher for rye/sweet sorghum and rye/sorghum x sudangrass double crop systems, about 194% higher for monocrop sweet sorghum in rotation, and about 239% higher for double crop sweet sorghum/rye in rotation system at both Ames and Chariton, when the annual hours of implement use changes from Iowa equipment use (production costs under "Iowa equipment use") to lower equipment use (production costs under "160 acres of biomass production") (see Tables 6.8 through 6.12).

Fixed costs related to the implements are about 200% higher for all cropping systems associated with sorghums when annual hours of implement use change from Iowa equipment use to lower equipment use (see Tables 6.8 through 6.12).

Total production costs and break-even prices increase, as annual hours of implement use decrease, by about 21.5% for monocrop sweet sorghum at Ames (the lowest increase) to about 65.9% for sweet sorghum in the rotation system as a whole at Chariton (the highest increase) (see Tables 6.8 through 6.12). At both locations, the sweet sorghum and rye/sweet sorghum in rotation systems as a whole show the most increase in production costs and break-even prices because more field operations are involved with these systems.

In short, by increasing annual hours of implement use by allocating more land to energy crop production, production costs and break-even prices can be reduced by 22% to 66% depending on the cropping system chosen. This is an important factor in reducing production costs when we notice that for the non-machinery related inputs used in energy crop production such as fertilizers and seed, there is no possibility to reduce associated costs, at least in the short-run because their amount and use are more or less independent of the land allocation. The only other alternative is to increase yield per acre through improved varieties or more efficient practice.

Summary

The monocrop sorghum systems at Chariton have higher dry matter yield than those at Ames at all levels of nitrogen use (Table 6.3). The monocrop sweet sorghum in rotation system also shows higher yields at Chariton at all levels of nitrogen treatment (Table 6.5). This is suspected to be caused by the longer growing period in the southern Iowa (Anderson, Buxton, and Hallam, 1994).

As a system, the rye/sweet sorghum doublecrop in rotation system has higher yield than any other sorghum system at both Ames and Chariton. Within the systems, the system at

Chariton has a higher yield than at Ames at the selected nitrogen level (125 lbs/acre) (Table 6.7).

The monocrop sweet sorghum system at Chariton has the lowest break-even price, $31.53/ton, of all the cropping systems involved with sweet sorghum and sorghum x sudangrass (Table 6.14). This system also produces relatively high dry matter yield, 8.03 tons/acre. Thus, lower break-even price and higher yield even on marginal land (Chariton) make this system a good candidate for biomass energy production among the cropping systems with annual crops.

By comparing costs and break-even prices between Iowa equipment use and 160 acres of equipment use, economies of scale are observed given yield per acre. Based on our cost estimation, production costs and break-even prices can be reduced by about 22% to 66% depending on the cropping system selected. This is an encouraging fact for the potential biomass energy crop producing farmer since field operations needed in biomass production can be done with implements that may be already owned and used in other crop production.

CHAPTER 7

COST OF PRODUCTION FOR THE INTERCROP SYSTEMS FOR BIOMASS ENERGY USE

The objective of this chapter is to analyze the production costs of the intercrop systems. Species in this systems are sweet sorghum, sorghum x sudangrass hybrid, alfalfa, and reed canarygrass. The cropping systems discussed in this chapter are as follows: alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass hybrid, and reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass hybrid. Notice that only alfalfa/sweet sorghum and alfalfa/ sorghum x sudangrass are analyzed using Chariton data since the reed canarygrass intercrop was not established there.

The first section presents the inputs used and production activities involved with the intercrop systems. The input levels presented in this section are for disposable inputs, such as fertilizer, herbicide, and seed. These values, except nitrogen fertilizer, were determined after soil test by agronomists, Dr. I. C. Anderson and Dr. D. Buxton at Iowa State University and are appropriate for the different soils. Two different levels of nitrogen treatment, 62.5 lbs/acre and 125 lbs/acre, were applied to two different experimental plots to test yield response to nitrogen fertilizer. Of the two levels of nitrogen treatment, 125 lbs/acre is shown in Table 7.1 because this level is selected to estimate production costs of the intercrop systems. The second section discusses dry matter yield (0% moisture) from the different intercrop systems. The data presented in this section are the experimental data collected from the two agricultural experimental farms located at Ames and Chariton. The third section discusses the production costs of the different intercrop biomass systems. There are two sets of production cost estimates for each cropping systems. The first set is estimated based on typical Iowa equipment use, and the second set is estimated based on equipment use if only 160 acres of land is allocated to biomass energy crop production. The first set is shown under "Iowa equipment use" and the second is under "160 acres of biomass production" in each table. The only difference between the two sets of cost estimates comes from annual hours of implement use given the performance rate of each piece of equipment. Annual hours of implement use for biomass energy production on 160 acres of land is calculated by dividing 160 acres of land by the acres per hour performance rate. The last section discusses the impact of the changes in annual hours of implement use on the production costs.

Notice that the field operations performed in establishing the perennials in the alfalfa and reed canarygrass systems are not listed in this chapter because they are the same as the ones performed in the monocrop alfalfa and reed canarygrass systems (see Chapter 5).

Input Use and Production Activities

Table 7.1 shows the quantity of each disposable input and field operations necessary for the intercrop energy cropping systems.

As shown in Table 7.1, the intercrop systems with alfalfa did not receive any phosphorus (P) and potash (K) because this system received P and K necessary for alfalfa standing years during the establishment year (Anderson, Buxton, and Hallam, 1994) while the intercrop systems with reed canarygrass received 32 pounds of P and 94 pounds of K per acre annually.

The intercrop systems with alfalfa received a nitrogen treatment (125 lbs/acre) once in the late spring after sorghum was planted. On the other hand, the intercrop system with reed canarygrass received a split nitrogen treatment; once before the first harvest of reed canarygrass and a second treatment after sorghum was planted (Anderson, Buxton, and Hallam, 1994).

All intercrop systems received the same amount of seed and herbicide treatment at both locations, Ames and Chariton. Seeding rates were 7 pounds per acre for both sweet sorghum and sorghum x sudangrass. Herbicide treatments were 2 pints per acre (Table 7.1). The intercrop systems were harvested three times every year; once with the grass only and twice with the combined crops.

Table 7.1 Input use and field operations for intercrop systems

Operation/Operating input	Amount					
	Al/SS		AL/SSH		RD/SS	RD/SSH
	A	C	A	C	A	A
Fertilizer						
Phosphorus, lbs					32	32
Potash, lbs					94	94
Nitrogen					62.5	62.5
Mower-conditioner						
Rake						
Baler						
Haul hay						
No-till planter						
Sweet sorghum, lbs	7	7			7	
Sorghum x sudangrass, lbs			7	7		7
Sprayer						
Parquet, pt						
Fertilizer						
Nitrogen	125	125	125	125	62.5	62.5
Mower-conditioner						
Baler						
Haul hay						
Mower-conditioner						
Baler						
Haul hay						

Note: SS = sweet sorghum; SSH = sorghum x sudangrass hybrid; AL = alfalfa; RD = reed canarygrass; A = Ames; C = Chariton.

Discussion on Yield

Table 7.2 shows dry matter yield data and yield response to different levels of nitrogen treatment for the intercrop systems. These systems have only two levels of nitrogen treatment, 62.5 lbs/acre and 125 lbs/acre. Yield data shown are the average yield over the experimental period. Yield data are averaged over the following years: 1989-1992 in Ames and 1989-1990 in Chariton. As mentioned at beginning of this chapter, the reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass systems were not initiated at Chariton because of the establishment failure of reed canarygrass at Chariton in 1988 (Anderson, Buxton, and Hallam, 1994).

At all levels of nitrogen treatment, the alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass intercrop systems at Ames produced a higher dry matter yield than at Chariton. At the selected nitrogen level (125 lbs/acre), the alfalfa/sweet sorghum system and alfalfa/sorghum x sudangrass system at Ames produced about 30% and 18% more dry matter, respectively, than the same system at Chariton. Between the two systems at Ames, alfalfa/sweet sorghum produced slightly higher dry matter than alfalfa/sorghum x sudangrass (Table 7.2).

Reed canarygrass/sorghum x sudangrass produced more dry matter than reed canarygrass/sweet sorghum. It produced about 1.7% more dry matter.

Of the intercrop systems, alfalfa/sweet sorghum produced higher dry matter than any other intercrop system. Compared to the reed canarygrass/sorghum x sudangrass at Ames, it produced about 40% more dry matter.

Table 7.2 Average dry matter yields of intercrop systems and yield response to nitrogen

Species	Yield (ton/acre)			
	Yield	Change in Yield	Yield	Change in Yield
	Ames		Chariton	
Alfalfa/Sweet sorghum				
62.5 lbs N/acre	6.73		4.73	
125 lbs N/acre	6.84	0.11	5.27	0.54
Alfalfa/Sorghum x sudangrass				
62.5 lbs N/acre	6.60		5.40	
125 lbs N/acre	6.66	0.06	5.65	0.25
Reed canarygrass/Sweet sorghum				
62.5 lbs N/acre	3.78			
125 lbs N/acre	4.79	1.01		
Reed canarygrass/Sorghum x sudangrass				
62.5 lbs N/acre	3.88			
125 lbs N/acre	4.87	0.99		

Note: Data are averaged over 1989-1992 in Ames and 1989-1990 in Chariton.

Discussion on Production Costs

This section discusses production costs for the intercrop systems. Of the two different levels of nitrogen treatment, production costs are estimated with 125 pound per acre of nitrogen and corresponding yield at that level is used to calculate a break-even price. For each intercrop system, differences in production costs are caused by the following factors: seed price, interest on operating inputs, transportation cost, and land cost since field operations, fertilizer use, herbicide use, and seeding rate are the same within the same cropping systems (see Table 7.1).

Tables 7.3 and 7.4 show production costs and break-even prices of the intercrop systems at Ames and Chariton, respectively. At Ames, the reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass hybrid intercrop systems have lower production costs than alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass despite higher variable and fixed costs (other than establishment costs) of the intercrop sorghum systems with reed canarygrass. This is due to the very high establishment cost of alfalfa. The amortized establishment cost of alfalfa is about four times higher than that of reed canarygrass with Iowa equipment use: $65.89/acre for alfalfa and $15.92/acre for reed canarygrass (Table 7.3 under "Iowa equipment use"). The results are similar with lower equipment use (Table 7.3 under "160 acres of biomass production").

Although sorghums intercropped with alfalfa have higher production costs than sorghums intercropped with reed canarygrass, the break-even prices of sorghums intercropped with alfalfa are significantly lower than those with reed canarygrass, about 24.6% lower for alfalfa/sweet sorghum system and 21.5% lower for alfalfa/sorghum x sudangrass system at Ames (Table 7.3 under "Iowa equipment use") due to high yields.

At Chariton, there is almost no difference in production costs between the alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass systems. However, there is a slight difference in break-even prices between the two systems due to the dry matter yield differences. The break-even price of alfalfa/sorghum x sudangrass system is about 7% lower than that of the alfalfa/sweet sorghum system (Table 7.4 under "160 acres of biomass production").

Of all the intercrop systems, the alfalfa/sweet sorghum system at Ames has the lowest break-even price, $48.14/ton with Iowa equipment use, which is about 2% lower than alfalfa/sorghum x sudangrass at Ames, 25% lower than reed canarygrass/sweet sorghum system at Ames, 23% lower than reed canarygrass/sorghum x sudangrass at Ames, 10% lower than alfalfa/sweet sorghum at Chariton, and 4% lower than alfalfa/sorghum x sudangrass at Chariton (see Tables 7.3 and 7.4 under "Iowa equipment use"). As mentioned, the higher dry matter yield of alfalfa/sweet sorghum system is the primary reason for the lower break-even price despite its higher production costs caused by the higher amortized establishment cost.

In short, the alfalfa/sweet sorghum system is a good choice for a biomass energy cropping system among the intercrop systems.

Discussion on the Impact of Annual Use of Equipments on Costs

This section discusses the impact of the annual hours of implement use on the production costs of the intercrop systems. The focus of the discussion is on the impacts of annual use of implements on the cost related to implements, repair and maintenance costs (variable costs) and depreciation costs (fixed costs) since the changes in annual use of implements affect primarily repair and maintenance costs and depreciation costs of implements. Interest expenses on operating inputs are also influenced by the changes in implement use, but this impact on the production costs is insignificant. Notice that, as shown in Chapter 3, annual hours of implement use with Iowa equipment use are higher than those with 160 acres of biomass production.

By comparing Table 7.3 under "Iowa equipment use" with Table 7.3 under "160 acres of biomass production" with Table 7.4, we can observe that the decrease in annual hours of implement use increases both repair and maintenance costs and fixed costs. As annual hours of implement use changes from higher annual use (Iowa equipment use) to lower annual use (160 acres of biomass production), repair and maintenance expenses of the implements increase by about 73% (from $18.10/acre to $31.28/acre) for both alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass and by about 66% (from $19.15/acre to 31.88) for both reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass at both Ames and Chariton.

Table 7.3 Estimated production cost of intercrop systems at Ames, Iowa assuming both Iowa equipment use and 160 acres of biomass production (per acre)

Item	Alfalfa/SS	Alfalfa/SSH	RC/SS	RC/SSH
		(dollars) Iowa equipment use		
DIRECT EXPENSES				
Fertilizer				
Phosphorus			8.00	8.00
Potash			15.98	15.98
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	8.92	8.92	8.92	8.92
Seed	3.50	2.45	3.50	2.45
Operator labor	16.42	16.42	18.35	18.35
Fuel	8.23	8.23	9.30	9.30
Repair and maintenance				
Implements	18.10	18.10	19.15	19.15
Tractors	9.94	9.94	11.24	11.24
Interest[1]	1.88	1.87	3.66	3.64
Transportation	28.39	27.64	19.88	20.21
TOTAL DIRECT EXPENSES	110.38	108.56	132.99	132.24
FIXED EXPENSES				
Implements	20.38	20.38	22.11	22.11
Tractors	17.64	17.64	19.94	19.94
Land	115.00	115.00	115.00	115.00
TOTAL FIXED EXPENSES	153.02	153.02	157.05	157.05
ESTABLISHMENT COST (prorated)	65.89	65.89	15.92	15.92
TOTAL EXPENSES	329.29	327.47	305.96	305.21
BREAK-EVEN PRICE ($/ton)	48.14	49.17	63.87	62.67

Table 7.3 (Continued)

Item	Alfalfa/SS	Alfalfa/SSH	RC/SS	RC/SSH
	(dollars) 160 acres of biomass production			
DIRECT EXPENSES				
Fertilizer				
Phosphorus			8.00	8.00
Potash			15.98	15.98
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	8.92	8.92	8.92	8.92
Seed	3.50	2.45	3.50	2.45
Operator labor	16.42	16.42	18.35	18.30
Fuel	8.23	8.23	9.30	9.30
Repair and maintenance				
Implements	31.28	31.28	31.88	31.88
Tractors	9.94	9.94	11.24	11.24
Interest[1]	2.18	2.14	3.95	3.92
Transportation	28.39	27.64	19.88	20.21
TOTAL DIRECT EXPENSES	123.86	122.02	146.00	145.25
FIXED EXPENSES				
Implements	39.35	39.35	40.33	40.33
Tractors	17.64	17.64	19.94	19.94
Land	115.00	115.00	115.00	115.00
TOTAL FIXED EXPENSES	171.99	171.99	175.27	175.27
ESTABLISHMENT COST (prorated)	81.34	81.34	23.36	23.36
TOTAL EXPENSES	377.19	375.35	344.63	343.88
BREAK-EVEN PRICE ($/ton)	55.14	56.86	71.95	70.61

Note: SS = Sweet sorghum; SSH = Sorghum x sudangrass hybrid; RC = Reed canarygrass.

[1] Interest on operating costs.

Table 7.4 Estimated per acre production cost of intercrop systems at Chariton, Iowa

Item	Alfalfa/SS		Alfalfa/SSH	
	A	B	A	B
	(dollars)			
DIRECT EXPENSES				
Fertilizer				
Nitrogen	15.00	15.00	15.00	15.00
Herbicide	8.92	8.92	8.92	8.92
Seed	3.50	3.50	2.45	2.45
Operator labor	16.42	16.42	16.42	16.42
Fuel	8.23	8.23	8.23	8.23
Repair and maintenance				
Implements	18.10	31.28	18.10	31.28
Tractors	9.94	9.94	9.94	9.94
Interest[1]	1.84	2.14	1.83	2.12
Transportation	21.87	21.87	23.45	23.45
TOTAL DIRECT EXPENSES	103.82	117.30	104.34	117.81
FIXED EXPENSES				
Implements	20.38	39.35	20.38	39.35
Tractors	17.64	17.64	17.64	17.64
Land	80.00	80.00	80.00	80.00
TOTAL FIXED EXPENSES	118.02	136.99	118.02	136.99
ESTABLISHMENT COST (prorated)	62.07	77.26	62.07	77.26
TOTAL EXPENSES	283.91	331.55	284.43	332.06
BREAK-EVEN PRICE ($/ton)	53.87	62.91	50.34	58.77

Note: [1] Interest on operating costs. A = Iowa equipment use: B = 160 acres. SS = Sweet sorghum; SSH = Sorghum x sudangrass hybrid.

Fixed expenses increase by about 93% (from $20.38/acre to $39.35/acre) for both alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass at both Ames and Chariton and by about 80% (from $22.11/acre to $40.33/acre) for both reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass at Ames as the annual use of implements decreases.

A decrease in the annual use of implements increases production costs by about 14.5% for alfalfa/sweet sorghum system at Ames, by about 14.6% for alfalfa/sorghum x sudangrass system at Ames, by about 12.6% for both reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass at Ames, and by about 16.8% for both alfalfa/sweet sorghum and alfalfa/sorghum x sudangrass at Chariton. Thus, effective utilization of equipment is important in reducing biomass production costs. An alternative to using equipment for the smaller acreages is to custom hire the necessary operations.

Summary

The intercrop systems with alfalfa do not receive a phosphorus (P) and potash (K) treatment annually while the intercrop systems with reed canarygrass received the same amount of P and K, at both Ames and Chariton, annually. This is because the intercrop systems with alfalfa receive P and K during the establishment year.

Seeding rates for sweet sorghum and sorghum x sudangrass and herbiciding rates are the same for all intercrop systems at both Ames and Chariton. Nitrogen was applied only once right after the annual crop planting for the systems with alfalfa while the intercrop systems with reed canarygrass received a split nitrogen treatment, once before the first harvest and a second time after the sorghum planting.

Of all intercrop systems, alfalfa/sweet sorghum at Ames had the highest dry matter yield (6.84 tons/acre) while reed canarygrass/sweet sorghum at Ames had the lowest dry matter yield (4.79 tons/acre).

Intercrop systems with alfalfa have higher production costs because of the higher amortized establishment costs, which is caused by the shorter standing life (half of reed canarygrass) and higher establishment year costs (see Chapter 5). Despite the higher production costs for the alfalfa/sweet sorghum intercrop system as compared to reed canarygrass, the alfalfa/sweet sorghum system has a lower break-even price ($48.14/ton) due to the higher dry matter yield.

The changes in annual use of implements has a negative relationship with production costs, that is, the lower the annual use, the higher the production costs. Therefore, if production of intercropped biomass energy crops can be done with the equipment normally used by Iowa farmers, some economies of scale are possible. An alternative is the use of custom operators for harvesting.

CHAPTER 8

COMPARISON OF ALTERNATIVE BIOMASS SYSTEMS WITH EACH OTHER, OTHER CROPS, AND WITH OTHER ENERGY RESOURCES

In the previous three chapters, the production costs of growing biomass energy crops were discussed. In Chapter 5, the production costs of monocrop perennial grasses were discussed. In Chapter 6, the production costs of growing annual energy crops in different cropping systems were discussed, and in Chapter 7, the production costs of growing intercrop biomass crop systems were discussed.

In this chapter, the production costs and break-even prices of alternative biomass energy crop systems discussed in the pervious chapters will be compared with each other and with other studies. The chapter will also discuss how changes in yield affect the production costs. Furthermore, the production costs of biomass energy crops in this study will be compared with the production costs of woody crops in Iowa. Production costs of woody crops in Iowa are obtained from "Short-Rotation Woody Crops" by Joe Colletti (1994) and other sources.

The Department of Energy (DOE) has established a target range of biomass production costs between $2.35 and $2.50 per million (MM) BTUs (Turnbull, 1993). For herbaceous energy crops, this is equivalent to about $36.43/ton to $38.75/ton for switchgrass in Iowa if we use either our yields or production costs as given. The conversion factor is 15.5 MM BTUs per dry matter. Biomass produced (harvested and transported) within this range is expected to be competitive with certain fossil fuels and supply feedstocks for the next generation of biomass conversion technologies (Colletti, 1994). Thus, the chapter examines whether the production costs of biomass energy crops in this study are within a DOE target range to test the competitiveness of biomass energy crops with fossil fuels.

Comparison of Break-even Prices of Herbaceous Biomass Energy Crops

This section discusses the break-even prices of herbaceous biomass energy crops. Break-even prices of perennial grasses are compared first. Then, the break-even prices of annual crops in the different cropping systems are compared. Thirdly, break-even prices of the intercrop systems are compared. And lastly, the break-even prices of all cropping systems in the study are compared. The break-even prices in parentheses are the ones estimated assuming only 160 acres of land per production unit.

Break-Even Prices of Perennial Grasses

The break-even prices of perennial grasses at Ames ranged from $43.08/ton ($51.41/ton) for swichgrass to $67.45/ton ($75.36/ton) for reed canarygrass. At Chariton, they ranged from $39.05/ton ($48.03/ton) for switchgrass to $60.22/ton ($67.71/ton) for alfalfa. Thus, switchgrass has the least break-even price at both Ames and Chariton. The break-even prices at Chariton are all lower than those at Ames.

Break-Even Prices of Annual Crops

Annual crops in this study are sweet sorghum, sorghum x sudangrass hybrid, winter rye, corn, and soybean. The cropping systems considered are monocrop sweet sorghum and sorghum x sudangrass, rye/sweet sorghum and rye/sorghum x sudangrass double crop, and sole sweet sorghum and rye/sweet sorghum double crop in a rotation. For monocrop sweet sorghum and rye/sweet sorghum double crop in the rotation system with corn and soybean, the break-even prices of the whole system are compared to the other systems with annual crops.

The break-even prices of annual crops in the different cropping systems ranged from $36.83/ton ($44.74/ton) for the monocrop sweet sorghum to $46.08/ton ($58.84/ton) for the rye/sorghum x sudangrass double crop system at Ames. At Chariton, they ranged from $31.53/ton ($39.22/ton) for the monocrop sweet sorghum system to $43.17/ton ($56.30/ton) for rye/sorghum x sudangrass. Thus, monocrop sweet sorghum at Chariton has the lowest break-even price.

Break-Even Prices of Intercrop Systems

For the intercrop systems, the break-even prices ranged from $48.14/ton ($55.14/ton) for alfalfa/sweet sorghum to $63.87/ton ($71.95/ton) for reed canarygrass/sweet sorghum at Ames and ranged from $50.34/ton ($58.77/ton) for alfalfa/sorghum x sudangrass to

$53.87/ton ($62.91/ton) for alfalfa/sweet sorghum at Chariton. Thus, of the all intercrop systems at both Ames and Chariton, the alfalfa/sweet sorghum system has the lowest break-even price.

In short, as shown in Table 8.1, the break-even prices of the different cropping systems for herbaceous energy crops range from $31.53/ton ($39.22/ton) for monocrop sweet sorghum at Chariton to $67.45/ton ($76.50/ton) for reed canary grass at Ames. Therefore, of all cropping systems employed in this study, monocrop sweet sorghum at Chariton has the lowest break-even price

Discussion on Cost Sensitivity to Changes in Yield

This section discusses how production costs and break-even prices are affected by changes in dry matter yield. It is important to examine this because crop yields are influenced by many factors, such as proper fertilization, weed control, harvest and storage technologies, genetic improvements, and weather. These factors can increase or decrease crop yields at any given time.

Changes in production costs and break-even prices as yield changes as presented in Tables 8.2 through 8.4 are examined based on Iowa equipment use. Yield (B) in the tables is a base yield which is the actual yield obtained from the experiments and used in the other chapters. Yield (D) is 15% less than the base yield and Yield (U) is 15% more than the base yield. A 15% fluctuation in yield is chosen because, given the preharvest technology, harvest and storage technology alone could increase or decrease crop yields by 15-20% (Buxton and Anderson, 1996). This is also consistent with the variation in yields across the experiments.

Table 8.2 shows cost changes for the perennial grass systems, Table 8.3 shows cost changes for annual crops in different cropping systems, and Table 8.4 shows cost changes for the intercrop systems. Notice that, for a given production technology, changes in yield only affect transportation cost since this is the only cost directly influenced by yield. As a result, the changes in production costs shown in tables are estimated as follows:

$$\Delta TC = a \times \Delta Y$$

where ΔTC = the change in total costs, a = transportation cost per ton which is $4.15/ton

Table 8.1 Break-even prices of the cropping systems assuming both Iowa equipment use and 160 acres of biomass production.

System	Yield (ton/acre)	Total cost ($/acre)	Average cost ($/ton)
		Iowa equipment use	
		Ames	
Alfalfa	4.85	282.69	58.29
Reed canarygrass	3.67	247.55	67.45
Switchgrass	4.97	214.13	43.08
Big bluestem	4.23	227.23	53.72
Sweet sorghum	7.80	287.24	36.83
Sorghum x sudangrass	7.01	282.87	40.35
Sweet sorghum/rye	7.94	331.75	41.78
Sorghum x sudangrass/rye	7.10	327.16	46.08
Sweet sorghum (R)	7.93	279.76	35.28
Sweet sorghum/rye (R)	9.30	331.28	35.62
Sweet sorghum (whole)	11.21	457.84	40.84
Sweet sorghum/rye (whole)	12.58	509.36	40.49
Alfalfa/sweet sorghum	6.84	329.29	48.14
Alfalfa/sorghum x sudangrass	6.66	327.47	49.17
Reed canarygrass/sweet sorghum	4.79	305.96	63.87
Reed canarygrass/sorghum x sudangrass	4.87	305.21	62.67
		Chariton	
Alfalfa	3.99	240.26	60.22
Reed canarygrass	4.34	211.77	48.79
Switchgrass	4.61	180.04	39.05
Big bluestem	3.91	199.77	51.09
Sweet sorghum	8.03	253.20	31.53
Sorghum x sudangrass	7.41	249.53	33.67
Sweet sorghum/rye	6.97	299.62	42.93
Sorghum x sudangrass/rye	6.90	297.89	43.17
Sweet sorghum (R)	8.24	246.05	29.86
Sweet sorghum/rye (R)	9.88	305.27	30.90
Sweet sorghum (whole)	11.07	355.97	32.16
Sweet sorghum/rye (whole)	12.71	415.19	32.67
Alfalfa/sweet sorghum	5.27	283.91	53.87
Alfalfa/sorghum x sudangrass	5.65	284.43	50.34

Table 8.1 (Continued)

System	Yield (ton/acre)	Total cost ($/acre)	Average cost ($/ton)
	160 acres of biomass production		
		Ames	
Alfalfa	4.85	312.88	64.51
Reed canarygrass	3.67	276.58	75.36
Switchgrass	4.97	255.50	51.41
Big bluestem	4.23	305.23	72.16
Sweet sorghum	7.80	348.95	44.74
Sorghum x sudangrass	7.01	344.59	49.16
Sweet sorghum/rye	7.94	422.33	53.19
Sorghum x sudangrass/rye	7.10	417.73	58.84
Sweet sorghum (R)	7.93	331.75	41.83
Sweet sorghum/rye (R)	9.30	423.85	45.58
Sweet sorghum (whole)	11.21	640.78	57.16
Sweet sorghum/rye (whole)	12.58	732.88	58.26
Alfalfa/sweet sorghum	6.84	377.19	55.14
Alfalfa/sorghum x sudangrass	6.66	375.35	56.36
Reed canarygrass/sweet sorghum	4.79	344.63	71.95
Reed canarygrass/sorghum x sudangrass	4.87	343.88	70.61
		Chariton	
Alfalfa	3.99	270.19	67.71
Reed canarygrass	4.34	240.79	55.48
Switchgrass	4.61	221.41	48.03
Big bluestem	3.91	239.14	61.16
Sweet sorghum	8.03	314.91	39.22
Sorghum x sudangrass	7.41	311.25	42.00
Sweet sorghum/rye	6.97	389.87	55.94
Sorghum x sudangrass/rye	6.90	388.46	56.30
Sweet sorghum (R)	8.24	298.04	36.17
Sweet sorghum/rye (R)	9.88	397.84	40.27
Sweet sorghum (whole)	11.07	538.91	48.68
Sweet sorghum/rye (whole)	12.71	638.71	50.25
Alfalfa/sweet sorghum	5.27	331.55	62.91
Alfalfa/sorghum x sudangrass	5.65	332.06	58.77

Note: Sweet sorghums with (whole) are rotation systems including net production costs from corn and soybean. Sweet sorghums with (R) are in the same rotation system without net production costs from corn and soybean.

in this study, and ΔY = the change in yield. This change in total costs is either added to or subtracted from the base total costs (Total cost (B) in Tables 8.2 through 8.4) to obtain total costs with higher or lower yields.

Tables 8.2 through 8.4 also show the sensitivity of break-even prices to changes in yield. Sensitivity1 corresponds to the sensitivity of the break-even prices when yields decrease by 15 percent and sensitivity3 corresponds to the sensitivity of the break-even prices when yields increase by 15 percent. They are the percentage change in break-even prices over the percentage change in yields.

Notice that the 15 percent change in yield assumed for sensitivity test is chosen based on the harvest and storage loss rates. However, there is another way to look at yield fluctuation, that is, using the standard deviation of yield over the years. This information is provided in Appendix C.

Cost Changes for Perennial Grasses

As shown in Table 8.2, changes in yield by 15% have a very small impact on the production costs for all perennial grasses. It changes total production costs of perennial grasses by less than 2%. For example, it changes total production costs only by about 1.1% for alfalfa at both Ames and Chariton and about 1.5% at Ames and 1.6% at Chariton for switchgrass. This is because the changes in yield affect only transportation costs given the production technology. However, the impacts of the yield change on break-even prices are significant. The average cost per ton is the same as the break-even price. With 15% less yield, break-even prices increase about 16.5% for alfalfa and 16.6% for reed canarygrass (from $58.29/ton to $67.84/ton for alfalfa and from $67.45/ton to $78.62/ton for reed canarygrass) and 16.0% for switchgrass and 16.3% for big bluestem (from $43.08/ton to $49.96/ton and from $53.72/ton to $62.47/ton, respectively) at Ames; and about 16.4% for alfalfa (from $60.22/ton to $70.11/ton), 16.2% for reed canarygrass (from $48.79/ton to $56.67/ton), 15.8% for switchgrass (from $39.05/ton to $45.21/ton), and 16.2% for big bluestem (from $51.09/ton to $59.38/ton) at Chariton. In short, the break-even prices increase around 16% at both sites (depending on the species) with 15% lower yield.

With 15% higher yield, the break-even prices decrease around 11% to 12% depending on the location and species. For example, break-even prices for alfalfa decrease by 12.1% (from $58.29/ton to $51.23/ton) at Ames and 12.2% (from $60.22/ton to $52.90/ton) at Chariton. The break-even price for reed canarygrass decreases by 12.2% (from $67.45/ton to

Table 8.2 Sensitivity of costs to changes in yield (based on Iowa equipment use)

	Alfalfa	Reed canarygrass	Switchgrass	Big bluestem
		Ames		
Yield(D) (ton/acre)	4.12	3.12	4.22	3.60
Yield(B) (ton/acre)	*4.85*	*3.67*	*4.97*	*4.23*
Yield (U) (ton/acre)	5.58	4.22	5.72	4.86
Total cost (D) ($/acre)	279.67	245.27	211.04	224.60
Total cost (B) ($/acre)	*282.69*	*247.55*	*214.13*	*227.23*
Total cost (U) ($/acre)	285.72	249.83	217.22	229.86
Average cost (D) ($/ton)	67.84	78.62	49.96	62.47
Average cost (B) ($/ton)	*58.29*	*67.45*	*43.08*	*53.72*
Average cost (U) ($/ton)	51.23	59.20	38.01	47.25
Sensitivity (D)	1.09	1.10	1.06	1.09
Sensitivity (U)	0.81	0.82	0.79	0.80
		Chariton		
Yield(D) (ton/acre)	3.39	3.69	3.92	3.32
Yield(B) (ton/acre)	*3.99*	*4.34*	*4.61*	*3.91*
Yield (U) (ton/acre)	4.59	4.99	5.30	4.50
Total cost (D) ($/acre)	237.78	209.07	177.17	197.34
Total cost (B) ($/acre)	*240.26*	*211.77*	*180.04*	*199.77*
Total cost (U) ($/acre)	242.74	214.47	182.91	202.20
Average cost (D) ($/ton)	70.11	56.67	45.21	59.38
Average cost (B) ($/ton)	*60.22*	*48.79*	*39.05*	*51.09*
Average cost (U) ($/ton)	52.90	42.97	34.50	44.97
Sensitivity (D)	1.10	1.08	1.05	1.08
Sensitivity (U)	0.81	0.80	0.78	0.80

Note: Yield (D) is 15% less then the yield from the experiments (Yield (B)). Yield (B) is the yield data from the experiments. Yield (U) is 15% more then the yield2. Total cost (D), (B), (U) and average cost (D), (B), and (U) are the costs corresponding to the Yield (D), (B), and (U), respectively. Sensitivity (D) is the percentage change in the break-even price over the percentage change in yield when yield is decreased by 15%. Sensitivity (U) is the percentage change in the break-even price over the percentage change in yield when yield is increased by 15%.

$59.20/ton) at Ames and 11.9% (from $48.79/ton to $42.97/ton) at Chariton. The break-even price for switchgrass decreases 11.8% (from $43.08/ton to $38.01/ton) at Ames and 11.6% (from $39.05/ton to $34.50/ton) at Chariton. The break- even price decreases 12.0% for big bluestem (from $53.72% to $47.25) at Ames and 12.0% (from $51.09/ton to $44.97/ton) at Chariton.

Cost Changes for Annual Crops

As shown in Table 8.3, the changes in production costs are insignificant. This is because, as explained before, a change in yield has an impact only on transportation costs given the production technology. With changes in yield of 15%, production costs change only around 1.5% at Ames and around 0.4% at Chariton for all cropping systems with annual energy crops. However, changes in yield by 15% have a significant effect on break-even prices. These changes increase break-even prices by about 16% at Ames for all cropping systems with annual crops when yield decreases by 15%. At Chariton, these change increase break-even prices by about 17% for all cropping systems except sole sweet sorghum and rye/sweet sorghum double crop in the rotation systems. Break-even prices of the rotation systems increase by about 15% at Chariton with a 15% decrease in yield. For example, break-even prices increase about 15.4% (from $36.83/ton to $42.59/ton) for monocrop sweet sorghum system and about 15.9% (from $40.84/ton to $47.32/ton) for sole sweet sorghum in the rotation system as a whole with a 15% decrease in yield at Ames. For the same percentage decrease, break-even prices increase about 17% (from $31.53/ton to $36.90/ton) for the monocrop sweet sorghum system and about 15.4% (from $32.16/ton to $37.10/ton) for sole sweet sorghum in the rotation system as a whole at Chariton.

With a 15% increase in yield, break-even prices decrease about 12% for all cropping systems at Ames and about 13% for all cropping systems except sole sweet sorghum and the rye/sweet sorghum double crop in the rotation system as a whole at Chariton. For example, break-even prices decrease about 11.6% (from $36.83/ton to $32.56/ton) for the monocrop sweet sorghum system and about 11.7% (from $40.84/ton to $36.06/ton) for the sole sweet sorghum system at Ames. At Chariton, break-even prices decrease about 12.6% (from

Table 8.3 Sensitivity of costs to changes in yield

	SS	SSH	SS/R	SSH/R	SS[1]	SS/R[1]
Ames						
Yield(D) (ton/acre)	6.63	5.96	6.75	6.04	9.53	10.69
Yield(B) (ton/acre)	*7.80*	*7.01*	*7.94*	*7.10*	*11.21*	*12.58*
Yield (U) (ton/acre)	8.97	8.06	9.13	8.17	12.89	14.47
Total cost (D) ($/acre)	282.38	278.51	326.81	322.76	450.86	501.53
Total cost (B) ($/acre)	*287.24*	*282.87*	*331.75*	*327.16*	*457.84*	*509.36*
Total cost (U) ($/acre)	292.10	287.23	336.69	331.56	464.82	517.19
Average cost (D) ($/ton)	42.59	46.73	48.42	53.44	47.32	46.90
Average cost (B) ($/ton)	*36.83*	*40.35*	*41.78*	*46.08*	*40.84*	*40.49*
Average cost (U) ($/ton)	32.56	35.64	36.88	40.58	36.06	35.75
Sensitivity (D)	1.09	1.06	1.06	1.07	1.06	1.06
Sensitivity (U)	0.77	0.78	0.78	0.79	0.78	0.78
Chariton						
Yield(D) (ton/acre)	6.83	6.30	5.92	5.87	9.41	10.80
Yield(B) (ton/acre)	*8.03*	*7.41*	*6.97*	*6.90*	*11.07*	*12.71*
Yield (U) (ton/acre)	9.23	8.52	8.02	7.94	12.73	14.62
Total cost (D) ($/acre)	252.00	248.42	298.57	296.86	349.08	407.28
Total cost (B) ($/acre)	*253.20*	*249.53*	*299.62*	*297.89*	*355.97*	*415.19*
Total cost (U) ($/acre)	254.40	250.64	300.67	298.92	362.86	423.10
Average cost (D) ($/ton)	36.90	39.43	50.43	50.57	37.10	37.70
Average cost (B) ($/ton)	*31.53*	*33.67*	*42.93*	*43.17*	*32.16*	*32.67*
Average cost (U) ($/ton)	27.56	29.42	37.49	37.65	28.50	28.95
Sensitivity (D)	1.02	1.03	1.06	1.06	1.02	1.03
Sensitivity (U)	0.76	0.76	0.79	0.79	0.76	0.76

Note: [1] Rotation system as a whole. Yield (D) is 15% less then the yield from the experiments (Yield (B)). Yield (B) is the yield data from the experiments. Yield (U) is 15% more then the yield2. Total cost (D), (B), (U) and average cost (D), (B), and (U) are the costs corresponding to the Yield (D), (B), and (U), respectively. Sensitivity (D) is the percentage change in the break-even price over the percentage change in yield when yield is decreased by 15%. Sensitivity (U) is the percentage change in the break-even price over the percentage change in yield when yield is increased by 15%. SS = sweet sorghum, SSH = sorghum x sudangrass, R = rye.

$31.53/ton to $27.56/ton) for the monocrop sweet sorghum system and about 11.4% (from $32.16/ton to $28.50/ton) for the sole sweet sorghum system.

Cost Changes for Intercrop Systems

Table 8.4 shows changes in production costs and break-even prices as yield increases or decreases for the intercrop systems. As before, changes in yield do not have a significant impact on production costs. Changes in yield of 15% change production costs by only about 1% at both Ames and Chariton for all intercrop systems. However, break-even prices change significantly with a 15% change in yield. With a 15% decrease in yield, break-even prices increase by about 16% at both Ames and Chariton for all intercrop systems. For example, break-even prices increase by about 16.2% for both the alfalfa/sweet sorghum system and the alfalfa/sorghum x sudangrass intercrop system (from $48.14/ton to $55.94/ton and from $49.17/ton to $57.12/ton, respectively) at Ames, and 16.3% (from $53.87/ton to $62.64/ton) for the alfalfa/sweet sorghum system and 16.2%

Table 8.4 Sensitivity of costs to yield change

	AL/SS	AL/SSH	RC/SS	RC/SSH	AL/SS	AL/SSH
	Ames				Chariton	
Yield(D) (ton/acre)	5.81	5.66	4.07	4.14	4.48	4.80
Yield(B) (ton/acre)	*6.84*	*6.66*	*4.79*	*4.87*	*5.27*	*5.65*
Yield (U) (ton/acre)	7.87	7.66	5.51	5.60	6.06	6.50
Total cost (D) ($/acre)	325.02	323.32	302.97	302.18	280.63	280.90
Total cost (B) ($/acre)	*329.29*	*327.47*	*305.96*	*305.21*	*283.91*	*284.43*
Total cost (U) ($/acre)	333.56	331.62	308.95	308.24	287.19	287.96
Average cost (D) ($/ton)	55.94	57.12	74.44	72.99	62.64	58.52
Average cost (B) ($/ton)	*48.14*	*49.17*	*63.87*	*62.67*	*53.87*	*50.34*
Average cost (U) ($/ton)	42.38	43.29	56.07	55.04	47.39	44.30
Sensitivity (D)	1.08	1.08	1.10	1.10	1.09	1.08
Sensitivity (U)	0.79	0.80	0.81	0.81	0.80	0.80

Note: Yield (D) is 15% less then the yield from the experiments (Yield (B)). Yield (B) is the yield data from the experiments. Yield (U) is 15% more then the yield2. Total cost (D), (B), (U) and average cost (D), (B), and (U) are the costs corresponding to the Yield (D), (B), and (U), respectively. Sensitivity (D) is the percentage change in the break-even price over the percentage change in yield when yield is decreased by 15%. Sensitivity (U) is the percentage change in the break-even price over the percentage change in yield when yield is increased by 15%. SS = sweet sorghum; SSH = sorghum x sudangrass; AL = alfalfa; RC = reed canarygrass.

(from $50.34/ton to $58.52/ton) for the alfalfa/sorghum x sudangrass intercrop system at Chariton. For both the reed canarygrass/sweet sorghum and reed canarygrass/sorghum x sudangrass intercrop systems at Ames, break-even prices increase by about 16.5% (from $63.87/ton to $74.44/ton and from $62.67/ton to $72.99/ton, respectively).

With a 15% increase in yield, break-even prices for all intercrop systems with alfalfa decrease by about 12% at both Ames and Chariton and break-even prices for all intercrop systems with reed canarygrass decrease by about 12.2% at Ames. For example, the break-even price of the alfalfa/sweet sorghum intercrop system at Ames decreases by about 12% (from $48.14/ton to $42.38/ton) while that at Chariton decreases also by about the same percentage (from $53.87/ton to $47.39). The break-even price of reed canarygrass/sweet sorghum at Ames decreases by 12.2% (from $63.87/ton to $56.07).

In short, changes in yield do not have a significant impact on production costs, but have a significant impact on break-even prices. The percentage changes in break-even prices are slightly different among the different cropping systems involved in this study. Percentage changes in break-even prices range from 15% to 17% when yields are decreased by 15% and from 11% to 13% when yields are increased by 15%. As indicated by sensitivity (D) and sensitivity (U), the break-even prices respond more sensitively when yields decrease (sensitivity (D) > 1 for all cropping systems) than when yields increase (sensitivity (U) < 1 for all cropping systems). This result is important because break-even prices are the ones that we are interested in when we examine the economic feasibility of biomass energy crops versus the competing energy sources. Efficient production management could increase yield and lower break-even prices and make biomass energy crops competitive to commercial energy sources, such as oil, coal, and natural gas.

The sensitivity tests presented here are based on production costs estimated at given input usage (especially nitrogen fertilizer, the selected nitrogen level used to estimate cost is 125 lbs/acre), given annual hours of machinery use and machine related parameters such as salvage value, purchase price, and so on, and land allocation. Therefore, if any one or combination of these variables change, we might have different cost estimates. Changes in costs have a direct impact on the break-even prices since

$$\%\Delta\, BP = \frac{\%\Delta\, Cost}{\%\Delta\, Yield},$$

where BP = break-even price. Therefore, if $\%\Delta\, Cost \geq \%\Delta\, Yield$, then $\%\Delta\, BP \geq 1$, and if $\%\Delta\, Cost \leq \%\Delta\, Yield$, then $\%\Delta\, BP \leq 1$. For example, if the production costs of the alfalfa/sweet sorghum system at Ames increased by 5% (from \$329.29/acre to \$345.75/acre) and yield increased by 5% (from 6.84 tons/acre to 7.18 tons/acre), then there would be no change in the break-even price. If the costs decrease or increase with no change in yield, then the percentage change in the break-even price is equal to the percentage change in cost.

Break-even Prices Comparison Between Herbaceous Energy Crops in This Study, in Other Studies and Woody Crops

Various studies have estimated the production costs of biomass energy crops (Bradsby, Sladden, and Kee, 1990; Colletti, 1994; Brower et al., 1993; Turhollow, 1991). This section compares estimated production costs of these studies to our estimates.

Tables 8.5 through 8.9 present production costs (\$/MM BTUs) of biomass energy crop production from various studies. The costs are compared in dollars per million BTUs (\$/MM BTUs). To compare costs in \$/MM BTUs, some of the data has to be converted. For example, for Table 8.5, gigajoules is converted to million Btu since the costs are expressed in gigajoules. The conversion factor is 1 gigajoule equal to 0.95 MM BTUs (1 gigajoule = 9.478 x 10^5 BTUs) (WRI, 1994). The analysis assumes 17 million BTUs per dry ton of energy in woody crops and 15.5 million BTUs per dry ton for herbaceous energy crops (Colletti, 1994). To convert Mg to tons, a conversion factor, 1 Mg = 1.102 tons, is used (Brown, 1996). Production costs are (\$/MM BTUs) obtained as follows:

$$Production\ costs\ (\$/MM\, Btus) = \frac{Production\ costs\ (\$/ha)}{Yield\ (ton/ha) \times E},$$

where E = 17 million BTUs for woody crops and 15.5 million BTUs for herbaceous crops.

As shown in the tables, the production costs ($/MM BTUs) vary among the studies. The differences in the production costs may be attributed to many factors, such as differences in land costs, differences in machine related assumptions, differences in input prices, differences in input use, or differences in yields in different regions, which is evident from the data. Among herbaceous energy crops, including both annual and perennials, the production costs of sorghum are in general lower within each study. Sorghum exhibits high yields in all regions. Sorghum yields can be as high as 18.3 dry tons/ha in the Midwest (Table 8.5). Energy from sorghum can be produced currently for as low as $1.70/MM BTUs at Chariton, Iowa (Table 8.9).

Switchgrass also shows high yield in all regions, around 9 dry tons per acre. Production costs of switchgrass vary widely by region. The estimated production costs are $4.06/MM BTUs in the Midwest (Table 8.5) and $2.23/MM BTUs at Chariton, Iowa (Table 8.9).

Our study shows that, with yield improvement (15% increase for our case) given the production technology, all species and cropping systems can produce energy crops within the DOE's target cost range (see Table 8.9).

Summary

Of all systems studied at both Ames and Chariton, monocrop sweet sorghum and the sweet sorghum/rye double crop in rotation system as a whole at Chariton have the lowest break-even prices. However, whether this rotation system can continuously produce at low costs crucially depends on both corn and soybean grain yields and the market prices of these crops because production costs of the rotation systems include net production costs of both corn and soybean.

Of the perennial grasses, switchgrass shows the highest yield and lowest production and break-even prices at both Ames and Chariton.

The break-even prices are very sensitive to the changes in yield given production technology. This is because, given production technology, yield changes only transportation

Table 8.5 Estimated current and projected productivity and production costs for biomass grown on dedicated plantations in the United States

	Annual yields dry tons per hectare per year				Production costs \$/gigajoule of net biomass[1]	
	1990		2010		1990	2010
	Gross[2]	Net[3]	Gross[2]	Net[3]		
Midwest						
Hybrid poplar	13.5	10.5	20.0	16.5	3.48 (3.66)	2.50 (2.63)
Switchgrass	13.0	9.0	20.0	14.4	3.86 (4.06)	2.73 (2.87)
Sorghum	22.4	18.3	35.0	29.3	2.73 (2.87)	1.87 (1.97)
Southeast						
Energy cane	22.6	18.5	35.0	29.3	2.97 (3.13)	1.86 (1.96)
Switchgrass	13.0	9.0	22.0	15.9	3.52 (3.74)	2.19 (2.31)

Source: Turhollow, 1991. Economics of dedicated energy crop production, ORNL

[1] Assumed heating values are 19.8 gigajoules/dry ton for hybrid poplar and 17.5 gigajoules/dry ton for the other herbaceous crops.

[2] This is the standing yield at the time of harvest.

[3] This is the yield net of the losses in harvesting and storage.

The unit for the numbers in parenthesis are in \$/MM BTUs. The conversion factor is 1 gigajoule = 0.95 MM BTUs.

Table 8.6 Comparison of cost per million BTUs for hybrid poplar and switchgrass given various production costs.

Production Cost (\$/dry ton)	Hybrid Poplar[1] (\$/MM BTUs)	Switchgrass[2] (\$/MM BTUs)
\$35	\$2.06	\$2.26
\$40	\$2.35	\$2.58
\$45	\$2.65	\$2.90
\$50	\$2.94	\$3.23
\$55	\$3.24	\$3.55

Source: Colletti, Joe, 1994. "Short-Rotation Woody Crops" In The Potential for Biomass Production and Conversion in Iowa. College of Engineering, ISU.

[1] Assumes 17 million BTUs per dry ton.

[2] Assumes 15.5 million BTUs per dry ton.

Table 8.7 Production costs of energy crops (for typical sites in the Midwest)

Cost component	Hybrid poplar Minnesota	Switchgrass Nebraska
Establishment ($/acre)		
Herbicides	6.91	0.26
Fertilizer/Liming	3.31	2.36
Machinery	2.64	1.27
Planting	5.01	4.65
Maintenance ($/acre)		
Pesticides	11.84	0.00
Fertilizer	5.52	39.90
Land rent and taxes	75.48	57.50
Managerial	16.57	16.57
Harvesting ($/acre)	128.63	45.98
Total ($/acre)	**255.92**	**168.48**
Gross yield (tons/acre)	7.00	5.00
Net yield (tons/acre)	5.95	4.25
Total production and Harvesting cost ($/ton)	**43.01**	**39.64**
Transportation and Baling ($/ton)	7.97	9.69
Total ($/ton)	**50.98**	**49.33**
Total ($/MM BTUs)[1]	**3.00**	**3.18**

Source: Brower, et al. 1993. Powering the Midwest: Renewable Electricity for the Economy and the Environment.

[1] Estimated by dividing total($/ton) cost by 17 MM BTUs for hybrid poplar and 15.5 MM BTUs for switchgrass.

Table 8.8 Production cost per hectare and per Mg for biomass species based on average yields obtained in 1988 and 1989

Species	Mean yield (Mg/ha)	Mean yield (ton/ha)	Production cost ($/ha)	Production cost ($/Mg)	Production cost ($/MM BTUs)
Sweet sorghum	11.03	(12.16)	458	41.5	(2.43)
Corn	8.49	(9.36)	419	49.4	(2.89)
Johnsongrass	5.92	(6.52)	323	54.6	(3.20)
Switchgrass	8.16	(8.99)	344	42.2	(2.47)
Bermudagrass	6.60	(7.27)	334	50.6	(2.96)
Sericea lespedeza	7.08	(7.80)	262	37.0	(2.17)
Rye	3.64	(4.01)	331	90.9	(5.33)
Tall fescue	7.23	(7.97)	322	44.5	(2.61)

Source: Brabsby, D. I., Sladden, S. E., Kee, D. D., 1990. Selection and Improvement Of Herbaceous Energy Crops for the Southeastern USA, ORNL.

Table 8.9 Production costs of the selected biomass energy production systems in Iowa

System	Yield	Total Cost	Production Cost	Yield	Total Cost	Production Cost
	ton/a	$/a	$/MM BTUs	ton/a	$/a	$/MM BTUs
			Ames			
Switchgrass	4.97	214.13	2.78	5.72	217.24	2.45
Sweet sorghum	7.80	287.24	2.38	8.97	292.10	2.10
Sweet sorghum[1]	11.21	457.84	2.64	12.89	464.81	2.33
Sweet sorghum/rye[1]	12.58	509.36	2.61	14.47	517.20	2.31
			Chariton			
Switchgrass	4.61	180.04	2.52	5.30	182.90	2.23
Sweet sorghum	8.03	253.20	2.03	9.23	254.40	1.78
Sweet sorghum[1]	11.07	355.97	2.07	12.73	335.50	1.84
Sweet sorghum/rye[1]	12.71	415.19	2.11	14.62	395.76	1.87

Note: This table is made by using data in this study. The conversion factor used is 15.5 MM BTUs per ton of dry matter.

cost, which is a very small portion of production costs. The break-even prices are more sensitive to a decrease in yield than to an increase in yield.

Switchgrass and sweet sorghum appear to be attractive as biomass energy crops because they can be grown in many regions in the United States with high yields and can be produced within the DOE's target price range even with current technology.

CHAPTER 9

THE ENVIRONMENTAL IMPACTS OF BIOMASS PRODUCTION

The major environmental issues associated with biomass production and utilization are soil erosion, nutrient depletion, and water quality degradation during crop production; and air pollution, water pollution, and health effects during conversion (Holdren, Morris, and Mintzer, 1980; Malanson, 1994; Johnson, 1994). Of these environmental issues, this chapter presents only the issues related to biomass energy feedstock production, focusing especially on the effects of herbaceous biomass energy production systems on soil erosion.

This chapter is divided into two parts: first, the effects on soil erosion of biomass production in general, and second, the effects of various biomass herbaceous energy crop production systems on soil erosion. The first part is a general overview of the effects of biomass production on soil erosion and a literature review on erosion costs while the second part deals specifically with empirical findings of soil erosion related to the species and cropping systems employed in the experiments used in this study.

Overview of Soil Erosion in Annual and Perennial crops

The environmental impacts of herbaceous energy crop production are similar to those for food and fiber production. The most severe impacts are to water quality and land degradation from soil erosion (Van Hook et al., 1982; Pimentel et al., 1984). However, it is believed that biomass feedstock production is less environmentally detrimental than production of more traditional agricultural row crops such as corn or soybean because of the more sustainable nature of biomass feedstocks (Malanson, 1994) and good vegetative cover of biomass feedstocks, especially perennials (Pimentel and Krummel, 1987).

Water Quality Issue Related to Disposable Input Use

With regard to water quality, growing annual crops such as corn and sorghum as biomass feedstocks has more severe effects on water quality than switchgrass because annual crops require more inputs of fertilizers, herbicides, and pesticides. For example, in 1993, an average of 621 kg/ha of nitrogen input was applied to corn in Iowa (Malanson, 1994) while, as shown in Table 9.1, an average 441 kg/ha of nitrogen input may expected to be applied to switchgrass for uplands and 218 kg/ha for wetlands. This is about a 29% reduction in nitrogen-fertilizer use for upland sites and about a 65% reduction for wetlands. Thus, with careful selection of biomass crop species, such as switchgrass, low inputs of fertilizers, herbicides, and pesticides, improvement of water quality can be achieved.

Table 9.1 Anticipated annualized fertilization rates for energy crops on upland and former wetland sites.

Crop type	Uplands			Former Wetlands		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Switchgrass	441	327	327	218	218	218
Reed canarygrass	686	327	490	545	272	436
Energy cane	762	272	436	653	272	436
Sorghum	707	381	490	545	327	436

Source: Ranney, J. W., J. T. Martin, M. A. Doan, and C. A. Thomas. 1994. Energy Crops: An opportunity for restoring wetland functions. Oak Ridge National Labs.
Note: Inputs averaged over life of the crop. Fertilizer rates for former wetlands are based on the very limited data. N = nitrogen; P_2O_5 = phosphorus; K_2O = Potassium.

Soil Erosion

Soil erosion continues to be a serious problem in the United States. A recent study shows that the annual average rate of soil erosion in the United States is about 18.1 Mg/ha/year for crop land (Lee, 1984) while natural soil formation rate is about 1 Mg/ha/year under normal conditions(Johnson, 1994). This erosion rate is far above the maximum sustainable soil erosion rate, 11 Mg/ha/year (D'Souza, Hoque, and Bohae, 1989). The estimated maximum sustainable soil erosion rate accepted in the United States is believed to be much high and should probably be reduced (Pimemtel et al., 1993).

Traditional row crops, such as corn and soybean, have more erosion problems than biomass energy feedstocks, especially perennials, because they provide a minimal amount of vegetative cover for soil protection, even during the growing season (Pimentel and Krummel, 1987; Malanson, 1994). With a conventional production technology, soybean produce less vegetative cover than corn during the growing season. Thus, erosion rates on soybean land are greater when compared to corn production. For example, with conventional techniques on Morley clay loam with a 4% slope, soybean production resulted in 40.9 Mg/ha/year of erosion, versus 21.8 Mg/ha/year for corn (Pimentel and Krummel, 1987; Johnson, 1994). Compared to traditional row crops, perennials and hay crops, once the stand is established, provide nearly complete cover throughout the standing years (for about 5 to 15 years depending on species). Annual soil erosion rates for perennials such as alfalfa and switchgrass, for example, are reported to range between 0.2 to 3.0 Mg/ha (Peterson and Swan, 1979; Johnson, 1994). A study by Hall et al. (1993) shows that a 92% reduction in soil erosion was observed on the 14 million hectares of highly erodable land taken out of annual production under the Conservation Reserve Program (CRP) and planted with perennial grasses and trees. However, this result should be carefully reviewed since these crops were not regularly harvested from the CRP land as a corn crop or biomass energy crop would be (Hall et al., 1993).

Soil erosion has adverse impacts both on and off farms. Loss of productivity due to the loss of fertile, nutrient-rich top soil, which eventually may lead to increased production costs while productivity falls, is the direct on farm impact of soil erosion. Productivity is reduced by the following outcomes of soil erosion: reduced rooting depth as the soil thins, decreased water-holding capacity, changed soil texture, reduced organic matter content, and accelerated further run-off (Pimentel and Krummel, 1987; D'Souza, Hoque, and Bohae, 1989). For example, some studies have demonstrated that corn crop yields increase from 130 to 326 kg/ha, wheat yields increase from 63 to 134 kg/ha, and sorghum yields increase from 167 to 177 kg/ha when a centimeter of water per hectare is added in crop production (Langdale et al., 1979; Follett et al., 1978; Piementel and Krummel, 1987).

Besides water, soil nutrients and organic matter are the most important factors affecting crop production. Significant amounts of nutrients are being lost each year because of soil erosion on agricultural lands. One megagram of agricultural soil may contain about 4 kg of nitrogen, 1 kg of phosphorus, 20 kg of potassium, and 10 kg of calcium. At an average annual erosion rate of 18 Mg/ha, the average loss of nutrients per hectare of cropland would be a total of 72 kg of nitrogen, 19 kg of phosphorus, 360 kg of potassium, and 180 kg of calcium. In the United States, average annual fertilizer applications per hectare of corn production are 152 kg of nitrogen, 75 kg of phosphorus, 96 kg of potassium, and 426 kg of calcium (Piementel and Krummel, 1987).

Organic matter is the primary resource of some nutrients in soil. 95% of the nitrogen in surface soil and 15-80% of the phosphorus is in the soil organic matter (Piementel and Krummel, 1987). A reduction of the organic matter content in soil from 1.8% to 3.8% can reduce corn yields at about 25%. Thus, without a constant replenishment of organic matter, soil can become depleted and barren. Switching row cropland to perennial energy crops annually adds 2.4 Mg of organic matter per hectare. This improves the structure, nutrient status, water holding capacity, and density of the soil. Compared to conventional row crops, biomass crops can increase soil organic matter, and this can lead to an increase in productivity and soil quality (Johnson, 1994).

Soil erosion has off-farm impacts. The off-farm impacts of soil erosion are divided in two: in-stream damages and off-stream damages. In-stream damages caused by sediment include losses of aquatic organisms, decreased utility derived from water-based recreation, damage to water storage and treatment facilities, premature obsolescence of dams and channels, and disrupted navigation. Off-stream damage from soil erosion is experienced during floods, with an increase in frequency and depth of flooding, an increase in the volume of the water-soil moisture in flood flows, and direct flood damage from sediment displacement (Clark, 1985; Johnson, 1994).

Environmental Costs of Soil Erosion

As discussed, soil erosion creates numerous environmental problems. Since the environmental problems caused by soil erosion are not typically reflected in the price of agricultural products and switching row-croplands to perennial crops can significantly reduce the environmental damage caused by erosion, information about the environmental costs caused by soil erosion is important in discussing the economic feasibility of biomass herbaceous energy crops.

It has been estimated that productivity losses and increased fertilizer costs caused by erosion in the United States cost farmers about $500 million to 1 billion per year. It is also estimated that erosion costs, including 1.2 billion erosion control costs, about $1.7 to $1.8 billion. Thus, for the year 1983, assessed on-farm damages range from $525 to $588 million (Colacicco et al., 1989). Another study estimates that farmers suffer $625 million annually in costs due to reduced yields, extra fertilizer, and soil conservation measures caused by erosion (McCullough et al., 1985). Piementel et al. (1993) estimate that the losses are much higher. With a minimum of 10% reduced annual crop yield and fertilizer loss of $5 billion, on-farm damages caused by soil erosion cost in total about $18 billion every year in the United States. In addition, over the next 100 years, it is predicted that corn yields will decline an average about 4.6% in the United States and 4.2% in the Corn Belt if erosion continues at the 1982 erosion rate (Colacicco et al., 1989).

According to a study done by agricultural economists and soil scientists published in *Successful Farming* 89 (1991), the economic costs of top soil loss are estimated to be between $5 to $40/ton. Colacicco et al. (1989) estimated the present value of the profit loss (per ton of soil erosion) by using the Erosion Productivity Impact Calculator (EPIC). Their estimate shows that the present value of the profit loss averaged over United States cropland to be $0.49 per ton of soil erosion.

Off-stream damages are those caused by floods and those that occur before sediment gets into a waterway or after sediment-laden water is taken from waterway for irrigation or other uses (Clark, 1985). Some studies (Clark, 1985; Pimentel et al. 1993) have tried to estimate off-farm damages of soil erosion. In 1980, the estimated off-stream damage costs in the United States were between $1.1 and $3.1 billion (Clack, 1985). In the United States, over 3 billion tons of sediments settle in the waterway every year (Piementel et al. 1993). The damages directly attributable to cropland were estimated at $660 million (Clark, 1985).

In-stream damages caused by sediment, nutrients and other erosion related contaminants in streams and lakes include losses of aquatic organisms, decreased utility derived from water-based recreation, damage to water storage and treatment facility, premature obsolescence of dams and channels, and disrupted navigation (Clack, 1985). In 1980, the total estimated in-stream damages were between $2.1 and $10 billion, and the estimated damages directly attributable to cropland were about 1.5 billion (Clark, 1985). Recreational impacts were the largest category of in-stream damages ($0.83 billion).

According to Clark's estimate, the total off-farm damage costs due to soil erosion and sedimentation in 1980, both in- and off-stream, was from $3.2 to $13 billion, or a single point estimate of $6 billion. Of this, $2.2 billion was directly attributable to crop land. Another study by Pimentel et al. (1993) estimated off-farm damages from soil erosion and its estimates were $2 to $6 billion per year in water quality, recreation, industry, and navigation losses.

Discussion on Soil Erosion by Species and Cropping Systems

In the previous section, studies on environmental issues related to soil erosion and economic cost estimation were reviewed. This section discusses the estimated soil loss per year of the species and cropping systems used in the agronomic experiments. Table 9.2 presents the estimated soil loss per year for the 13 cropping systems.

During the establishment year (1988), perennials had much higher soil loss than the standing year and their erosion rates were similar to row crops. This result is not surprising. The study shows that erosion rates for perennials may be similar to row crops during the establishment year if conservation measures are not practiced (Johnson, 1994). As many previous studies have mentioned, perennials had a much lower erosion rate than annuals once they were established. As expected, erosion rates at Chariton were much higher than Ames, except during the establishment year for perennials. The lower erosion for perennials at Chariton during the establishment year was due to a previous red clover sod in 1987, which was chemically killed in the spring of 1988, at Chariton (Anderson, Buxton, and Hallam, 1994).

At Ames, with essentially zero slope, soil losses for the standing years (1989-92) were under 0.25 Mg/ha per year for perennials (alfalfa, reed canarygrass, switchgrass, and big bluestem). This was also true for the two intercrop systems because of total year ground cover. For the row crop systems at Ames, the losses were under 5 Mg/ha per year. Of all systems at Ames, soil erosion rates of reed canarygrass, switchgrass, and big bluestem were the lowest, 0.04 Mg/ha, and monocrop sorghums were the largest, 4.89 Mg/ha.

At Chariton, from 1989 to 1992 soil losses in reed canarygrass, switchgrass, big bluestem were under 0.4 Mg/ha. For sole alfalfa and alfalfa intercrop with sorghum the losses were under 2 Mg/ha. The largest soil losses were observed with row crops (corn, soybean, and continuous sorghum). Losses were approximately 40 Mg/ha. Fall planting of rye after sorghum reduced the losses to under 25 Mg/ha.

Table 9.2 Estimated soil loss (Mg/ha) for 13 cropping systems at two locations for five years using the Universal Soil Loss Equation (USLE)

Cropping System	Year				
	1988	1989	1990	1991	1992
			Ames		
Monocrop					
ALF	3.79	0.25	0.25	0.25	0.25
RCG	3.79	0.04	0.04	0.04	0.04
SWG	3.92	0.04	0.04	0.04	0.04
BBS	3.92	0.04	0.04	0.04	0.04
SWS	4.89	4.89	4.89	4.89	4.89
SSH	4.89	4.89	4.89	4.89	4.89
Double crop					
SWS/R	3.06	3.06	3.06	3.06	3.06
SSH/R	3.06	3.06	3.06	3.06	3.06
Rotation					
CORN	4.41	4.41	4.41	4.41	4.41
SB	3.92	4.88	4.88	4.88	4.88
SWS/R	3.06	3.06	3.06	3.06	3.06
SWS	4.89	4.89	4.89	4.89	4.89
Intercrop					
ALF	3.79	0.25	0.25	0.25	0.25
RCG	3.79	0.04	0.04	0.04	0.04

Table 9.2 (Continued)

Cropping System	Year				
	1988	1989	1990	1991	1992
			Chariton		
Monocrop					
ALF	1.90	1.58	1.58	1.58	1.58
RCG	1.94	0.39	0.31	0.31	0.31
SWG	1.85	0.40	0.33	0.33	0.33
BBS	1.99	0.47	0.36	0.36	0.36
SWS	13.89	25.65	35.62	35.62	35.62
SSH	13.13	24.21	33.62	33.62	33.62
Double crop					
SWS/R	22.27	22.27	22.27	22.27	22.27
SSH/R	22.27	22.27	22.27	22.27	22.27
Rotation					
CORN	13.89	25.38	33.52	32.05	31.73
SB	14.53	26.71	35.26	37.25	35.62
SWS/R	22.02	23.27	22.27	22.04	23.27
SWS	11.46	37.25	35.62	35.26	37.25
Intercrop					
ALF	2.02	1.68	1.68	1.68	1.68
RCG	1.96	0.41	0.41	0.41	0.41

Note: ALF = alfalfa, RCG = reed canarygrass, SWG = switchgrass, BBS = big bluestem, SWS = sweet sorghum, SSH = sorghum x sudangrass, R = winter rye, CORN = corn in a corn-soybean-sorghum three year rotation, SB = soybean.

In summary, the sloping soils at Chariton had large soil losses associated with continuous row cropping systems, that were reduced some by double cropping with fall seeded rye. For the other systems, including intercropping of sorghum in alfalfa or reed canarygrass, the losses were low and acceptable for sustainable agriculture (Anderson, Buxton, and Hallam, 1994). The maximum sustainable soil erosion rate estimated by the Soil Conservation Service and the USDA is 11 metric tons per hectare per year (D'Souza, Hoque, and Bohae, 1989).

Impact of Soil Loss on Production Cost

In the previous section, economic costs of soil loss ($5 < soil loss costs < $40 per tone) published in *Successful Farming 89*, were cited. Estimated soil loss for the cropping systems used in this study were also presented in the previous section.

By this information, this section tries to approximate the production costs of the selected cropping systems including the economic costs of soil loss. In a sense, this is a rough estimation of the true production costs of each cropping system. The purpose is to embody environmental costs into conventional production cost estimation and to compare the environmental impact, in this case soil erosion, of the different cropping systems.

The selected cropping systems are as follows: monocrop switchgrass, monocrop sweet sorghum, sweet sorghum/rye double crop, monocrop sweet sorghum in rotation, and intercrop alfalfa/sorghum x sudangrass at Chariton. These crops are chosen because they have the lowest break-even prices within the same system. Chariton is considered because many studies on production of herbaceous energy crops have considered the utilization marginal land to grow energy crops. The soil erosion rates for the selected systems are 0.14 ton/acre for swichgrass, 10.55 ton/acre for monocrop sweet sorghum, 9.16 ton/acre for sweet sorghum/rye double crop, 12.25 ton/acre for monocrop sweet sorghum in rotation (note: this was estimated by adding the soil loss on corn, soybean, and sweet sorghum and then dividing it by three), and 0.69 ton/acre for intercrop alfalfa/sweet sorghum (see Table 9.2). Conversion factors used to convert *hectare* to *acre* and *Mg* to *ton* are 1 ha = 2.47 acre and 1 Mg = 1.016 ton. The lowest soil erosion rates from Table 9.2 are selected for each selected systems. Two soil loss costs are selected, $5/ton of soil and $10/ton of soil. These two soil loss costs are selected just to compare the break-even prices of different cropping systems when soil erosion costs are included in the production costs.

The estimated soil erosion costs for each selected system are added to the production costs for that system from Table 8.1.

As shown in Table 9.3, when soil loss cost is $5/ton, the production costs of each selected cropping increase by 0.4% for switchgrass, 20.8% for monocrop sweet sorghum, 15.4% for sweet sorghum/rye double crop, 17.2% for monocrop sweet sorghum in rotation, and 1.2% for alfalfa/sorghum x sudangrass.

Table 9.3 Production costs of the selected cropping systems at Chariton with soil erosion costs.

System	Yield	Total cost	Average cost[1]	Average cost[2]
	ton/acre	$/acre	$/ton	$/ton
		erosion cost = $5/ton of soil		
Switchgrass	4.61	180.74	39.05	39.20
Sweet sorghum	8.03	305.95	31.53	38.10
Sweet sorghum/rye	6.97	345.42	42.93	49.56
Sweet sorghum[3]	11.07	417.22	32.16	37.69
Alfalfa/sorghum x sudangrass	5.65	287.88	50.34	50.95
		erosion cost = $10/ton of soil		
Switchgrass	4.61	181.44	39.05	39.36
Sweet sorghum	8.03	358.70	31.53	44.67
Sweet sorghum/rye	6.97	391.22	42.93	56.13
Sweet sorghum[3]	11.07	478.47	32.16	43.22
Alfalfa/sorghum x sudangrass	5.65	291.33	50.34	63.20

[1] Average cost (or break-even price) without soil loss cost (see Table 8.1).

[2] Average cost with soil loss included.

[3] Monocrop sweet sorghum in rotation.

Total cost is a sum of production costs and soil erosion costs.

The impact of soil erosion on break-even price is significant for annual crops. The inclusion of soil erosion cost has almost no impact on switchgrass. As soil erosion costs increase, the ranking of break-even prices change. Without inclusion of soil erosion costs, monocrop sweet sorghum has the lowest break-even prices ($31.53/ton), followed by monocrop sweet sorghum in rotation system as a whole ($32.16/ton), monocrop switchgrass ($39.05/ton), sweet sorghum/rye double crop ($42.93), and alfalfa/sorghum x sudangrass intercrop system ($50.34/ton). At $5/ton soil erosion costs, the ranking does not change. It stays the same as without inclusion of soil erosion costs. However, at $10/ton soil erosion costs, the ranking changes. Switchgrass has the lowest break-even price ($39.36/ton) followed by monocrop sweet sorghum in rotation system as a whole ($43.22/ton), monocrop sweet sorghum ($44.67/ton), sweet sorghum/rye double crop ($56.13/ton), and alfalfa/sorghum x sudangrass intercrop system ($63.20/ton).

Summary

In this chapter, the environmental impacts of herbaceous biomass energy crop production are discussed, focusing specifically on water quality and land degradation from soil erosion.

With regard to water quality, studies indicate that biomass energy crops such as switchgrass can improve water quality because they requires lower inputs of fertilizers, herbicides, and pesticides than traditional row crops, such as corn.

Soil erosion in the United States is believed to be a serious problem. The annual average rate of soil erosion in the United States is about 18.1 Mg/ha/year while the estimated maximum sustainable erosion rate is 11 metric tons per hectare per year. Production of biomass energy crops, especially perennials, can reduce soil erosion rates even below the maximum sustainable erosion rate. The soil erosion rates associated with perennials are between 0.2 and 3.0 Mg/ha/year while that of soybean is about 40.9 Mg/ha/year and corn is about 21.8 Mg/ha/year. Our experimental data on soil erosion coincide with other studies. With perennials, estimates from the experiments show that soil erosion rates are not only well below the maximum sustainable erosion rate, but also below the natural soil formation rate (1 Mg/ha/year) as well, even on the marginal land (Chariton). The soil erosion rates estimated at the experimental farms were below 0.5 Mg/ha/year for all perennials.

Various studies have the estimated economic costs of soil erosion. Although it is difficult to estimate precise dollar damages from a specific amount of erosion, these studies indirectly indicate the possible economic benefits from growing biomass energy crops, especially perennial grasses. Inclusion of soil erosion cost has almost no impact on the break-even price of switchgrass. This is due to the low soil loss associated with swichgrass. However, inclusion of soil erosion costs significantly affects the cost of sorghum production.

CHAPTER 10

GENERAL CONCLUSION

Fossil fuels (oil, coal, and natural gas), the primary energy resources of today, are exhaustible resources and are responsible for some of the serious environmental problems of today, such as global warming and air pollution. Because of the exhaustibility and environmental degradation associated with fossil fuel use, there has been intensive research to develop alternative energy sources that are environmentally benign and renewable.

In addition, growing world population, especially in the current developing countries, and economic growth in those countries, which will eventually increase energy demand in the future, has intensified the need to develop energy sources that are available for an indefinite period of time.

Among the alternative energy sources, biomass (plant materials), especially herbaceous energy crops, has been considered as one of the most interesting energy sources because it is in principle renewable and its production and conversion technologies are known. Herbaceous energy crops, which include both annual and perennial grasses, can also be grown in most parts of the country.

In addition to its potential to meet future energy demand, if herbaceous energy crops are grown sustainably, there production could contribute to no net increase of carbon dioxide (CO_2) in the atmosphere because the CO_2 released during combustion is offset by the CO_2 extracted form the atmosphere during photosynthesis. It has been found that, for every 1 Mg of carbon produced by woody biomass, an estimated 3 Mg of carbon dioxide is sequestered.

However, growing herbaceous energy crops, especially annual crops such as sorghum and corn, for energy could have serious environmental problems such as soil erosion and water contamination. In the United States, annual average soil erosion is estimated to be 18.1 Mg/ha, which is almost twice the estimated maximum sustainable soil erosion rate (11 Mg/ha/year). Soil erosion will decrease crop yields due to the loss of nutrient-rich top soil and organic matter from soil. Some empirical studies have demonstrated that corn yields are reduced by 3-6 bushels per acre with a loss of 1 inch of topsoil and a reduction of the organic matter content in soil from 1.8% to 3.8% can reduce corn yields by about 25%. The loss of nutrient-rich top soil and organic matter leads to higher production costs because more fertilizers are required for production. It is predicted that corn yields will decline an average about 4.6% in the United States and 4.2% in the Corn Belt over the next 100 years if erosion continues at the 1982 erosion rate. Many studies have attempted to value the environmental costs resulted form soil erosion.

For the environmental problems associated with growing annual crops, perennial grasses are considered excellent choices to grow for energy. Annual soil erosion rates for perennials such as alfalfa and switchgrass are reported to be range between 0.2 to 3.0 Mg/ha. This is low compared to the soil loss from corn production (21.8 Mg/ha/year). It is even lower than the natural soil formation rate. Indeed, the soil erosion rate declined 92% on the 14 million hectares of highly erodible cropland planted with perennial grasses and trees.

Our estimates on soil loss show that, of the different cropping systems with annual and perennial species, monocrop systems with perennial grasses have much less soil loss than systems with annual crops (sorghum, corn, and soybean). Estimated soil loss with monocrop perennials are 0.25 Mg/ha for alfalfa, and 0.04 Mg/ha for reed canarygrass, switchgrass, and big bluestem at Ames; and 1.58 Mg/ha for alfalfa, and around 0.40 Mg/ha for reed canarygrass, switchgrass, and big bluestem at Chariton for the standing year. These soil loss rates are even far less than the natural soil formation rate (1 Mg/ha/year). The soil erosion rate during the establishment year is larger, but this is expected.

Although soil losses with the perennials at Chariton are larger than at Ames, their loss is still far less than the soil loss with annual crops at Ames, which ranges from 3.06 Mg/ha for the sorghum double crop system (both pure and rotation) to 4.89 Mg/ha for the monocrop sorghum system (both pure and rotation). The soil erosion rate with annuals at Chariton is well above 20 Mg/ha for all systems, except the intercrop systems.

Therefore, a low erosion rate, even on the marginal lands, indirectly indicates the possible economic benefit from growing perennials for energy although it is difficult to estimate the precise dollar damage of soil erosion.

Of the cropping systems, the sweet sorghum/rye double crop system in rotation has the highest yields at both Ames and Chariton, 9.30 dry tons/acre and 9.88 dry tons/acre, respectively. Among the perennial grasses, switchgrass produces high yields at both Ames and Chariton, 4.97 dry tons/acre and 4.61 dry tons /acre, respectively.

The monocrop sweet sorghum in rotation system as a whole has the lowest break-even price (or average cost), $29.68/ton, at Chariton. However, using this to compare production cost with other systems creates some problem because the production costs and break-even prices of this system depends on the market price of corn and soybean grains.

Of the monocrop perennials, switchgrass has the lowest break-even price at both Ames and Chariton, $43.08/ton and $39.05/ton, respectively. Despite lower yields at Chariton, the break-even price is lower at Chariton because of lower land cost.

With current production technology, biomass energy can be produced at $2.23/MM BTUs with switchgrass on marginal land (Chariton) or $1.78/MM BTUs with sweet sorghum on marginal land. The target range of biomass production costs established by the DOE is between $2.35/MM BTUs and $2.50/MM BTUs.

Land cost is a important factor in production cost estimation. Land cost accounts more than 30% for all production costs of the different cropping systems. Land costs assumed in this study are $115/acre at Ames and $80/acre at Chariton. The average rental rate in Iowa ranges from $82/acre for corn cropland to $26/acre for permanent pasture land. Thus production costs can be lowered by utilizing marginal land or any land unsuitable for cropping.

The existence of economies of scale is observed. Production costs increase very significantly, through the increase in machinery costs, as less land is allocated to herbaceous energy crop production because, given machinery performance rates, less land allocation means less utilization of machinery. This increases machinery costs, such as repair and maintenance, and depreciation. Therefore, production costs can be reduced by devoting more land to dedicated herbaceous energy crops because more land available for energy crop production means more annual use of machinery, given the performance rate, which in turn reduces the machinery costs.

The herbaceous energy crops considered in this study can be produced without making significant capital investment in machinery since the production practices involved are the same as producing row crops or hay. This could be an incentive for potential energy crop growers.

In short, since the soil erosion associated with annual crop production creates serious environmental problems and sustainability of soil, switchgrass is a good choice as an energy crop. It prevents soil erosion and produces high dry matter even on the marginal land (Chariton).

The production costs of herbaceous energy crops, especially switchgrass, in Iowa can be reduced significantly by utilizing marginal land and erosive land to grow biomass energy crops and by allocating more land to energy crop production to take advantage of economies of scale.

Although the energy produced from herbaceous energy crops is not competitive with fossil fuels if we just compare the production costs, it can be competitive if we consider the social costs of environmental damage caused by the fossil fuel use. Furthermore, it can be competitive if we count environmental benefits from growing switchgrass, such as prevention of soil erosion.

APPENDIX A

PRODUCTION COSTS OF EACH SYSTEM WITH AVERAGE IOWA ANNUAL HOURS OF MACHINE USE

Table A.1 Estimated establishment year budget for alfalfa at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Alfalfa	ton	65.00	2.72	176.80
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	160.00	40.00
Potash	lbs	0.17	625.00	106.25
HERBICIDE				
Eptom	pt	2.81	3.00	8.43
Lorsban 4E	pt	1.81	1.00	1.81
SEED				
Alfalfa	lbs	2.50	12.00	30.00
OPERATOR LABOR				
Tractors	hour	6.00	2.31	13.87
FUEL				
Tractors	gal	0.83	9.43	7.83
REPAIR & MAINTENANCE				
Implements	acre	13.21	1.00	13.21
Tractors	acre	9.34	1.00	9.34
INTEREST[1]	acre	11.87	1.00	11.87
TRANSPORTATION				
Haul to plant	ton	4.15	2.72	11.29
TOTAL DIRECT EXPENSES				253.90
FIXED EXPENSES				
Implements	acre	17.03	1.00	17.03
Tractors	acre	16.59	1.00	16.59
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				148.62
TOTAL EXPENSES				402.52
NET COST[2]				225.72
ESTABLISHMENT COST (prorated)				65.89

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.2 Estimated establishment year budget for reed canarygrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Reed canarygrass	ton	60.00	2.67	160.20
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.00	4.62
SEED				
Reed canarygrass	lbs	4.50	9.00	40.50
OPERATOR LABOR				
Tractors	hour	6.00	2.22	13.32
FUEL				
Tractors	gal	0.83	9.06	7.52
REPAIR & MAINTENANCE				
Implements	acre	12.96	1.00	12.96
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	4.02	1.00	4.02
TRANSPORTATION				
Haul to plant	ton	4.15	2.67	11.08
TOTAL DIRECT EXPENSES				126.97
FIXED EXPENSES				
Implements	acre	16.71	1.00	16.71
Tractors	acre	15.94	1.00	15.94
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				147.65
TOTAL EXPENSES				274.62
NET COST[2]				114.42
ESTABLISHMENT COST (prorated)				15.92

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.3 Estimated establishment year budget for switchgrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Switchgrass	ton	55.00	3.62	199.10
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
Atrazine 4L	pt	1.58	2.50	3.95
SEED				
Switchgrass	lbs	3.50	7.20	25.20
OPERATOR LABOR				
Tractors	hour	6.00	1.53	9.18
FUEL				
Tractors	gal	0.83	6.62	5.49
REPAIR & MAINTENANCE				
Implements	acre	8.50	1.00	8.50
Tractors	acre	6.49	1.00	6.49
INTEREST[1] (6.5%)	acre	3.15	1.00	3.15
TRANSPORTATION				
Haul to plant	ton	4.15	3.62	15.02
TOTAL DIRECT EXPENSES				100.96
FIXED EXPENSES				
Implements	acre	12.05	1.00	12.05
Tractors	acre	11.54	1.00	11.54
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				138.59
TOTAL EXPENSES				239.55
NET COST[2]				40.45
ESTABLISHMENT COST (prorated)				5.63

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.4 Estimated establishment year budget for big bluestem at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Big bluestem	ton	55.00	3.04	167.20
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.50	5.78
SEED				
Big bluestem	lbs	9.00	12.00	108.00
OPERATOR LABOR				
Tractors	hour	6.00	1.53	9.18
FUEL				
Tractors	gal	0.83	6.62	5.49
REPAIR & MAINTENANCE				
Implements	acre	8.50	1.00	8.50
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	5.42	1.00	5.42
TRANSPORTATION				
Haul to plant	ton	4.15	3.04	12.62
TOTAL DIRECT EXPENSES				185.45
FIXED EXPENSES				
Implements	acre	12.05	1.00	12.05
Tractors	acre	11.54	1.00	11.54
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				138.59
TOTAL EXPENSES				324.04
NET COST[2]				156.84
ESTABLISHMENT COST (prorated)				21.82

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.5 Estimated establishment year budget for alfalfa at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Alfalfa	ton	65.00	3.04	197.60
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	160.00	40.00
Potash	lbs	0.17	625.00	106.25
Lime	ton	6.00	5.00	30.00
HERBICIDE				
Eptom	pt	2.81	3.00	8.43
Lorsban 4E	pt	1.81	1.50	2.72
SEED				
Alfalfa	lbs	2.50	14.00	35.00
OPERATOR LABOR				
Tractors	hour	6.00	2.54	14.56
FUEL				
Tractors	gal	0.83	13.21	8.21
REPAIR & MAINTENANCE				
Implements	acre	13.55	1.00	13.55
Tractors	acre	9.80	1.00	9.80
INTEREST[1]	acre	14.13	1.00	14.13
TRANSPORTATION				
Haul to plant	ton	4.15	3.04	12.62
TOTAL DIRECT EXPENSES				295.27
FIXED EXPENSES				
Implements	acre	17.57	1.00	17.57
Tractors	acre	17.41	1.00	17.41
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				114.98
TOTAL EXPENSES				410.25
NET COST[2]				212.65
ESTABLISHMENT COST (prorated)				62.07

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.6 Estimated establishment year budget for reed canarygrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Reed canarygrass	ton	60.00	2.67	160.20
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.00	4.62
SEED				
Reed canarygrass	lbs	4.50	11.00	49.50
OPERATOR LABOR				
Tractors	hour	6.00	2.33	13.32
FUEL				
Tractors	gal	0.83	12.07	7.52
REPAIR & MAINTENANCE				
Implements	acre	12.96	1.00	12.96
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	4.31	1.00	4.31
TRANSPORTATION				
Haul to plant	ton	4.15	2.67	11.08
TOTAL DIRECT EXPENSES				136.26
FIXED EXPENSES				
Implements	acre	16.71	1.00	16.71
Tractors	acre	15.94	1.00	15.94
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				112.65
TOTAL EXPENSES				248.91
NET COST[2]				88.71
ESTABLISHMENT COST (prorated)				12.34

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.7 Estimated establishment year budget for switchgrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Switchgrass	ton	55.00	2.59	142.45
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
Atrazine 4L	pt	1.58	2.50	3.95
SEED				
Switchgrass	lbs	3.50	7.20	25.20
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.18
FUEL				
Tractors	gal	0.83	8.82	5.49
REPAIR & MAINTENANCE				
Implements	acre	8.50	1.00	8.50
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	3.13	1.00	3.13
TRANSPORTATION				
Haul to plant	ton	4.15	2.59	10.75
TOTAL DIRECT EXPENSES				96.67
FIXED EXPENSES				
Implements	acre	12.05	1.00	12.05
Tractors	acre	11.54	1.00	11.54
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				103.59
TOTAL EXPENSES				200.26
NET COST[2]				57.81
ESTABLISHMENT COST (prorated)				8.04

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.8 Estimated establishment year budget for big bluestem at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Big bluestem	ton	55.00	1.38	75.90
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.50	5.78
SEED				
Big bluestem	lbs	9.00	12.00	108.00
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.18
FUEL				
Tractors	gal	0.83	8.82	5.49
REPAIR & MAINTENANCE				
Implements	acre	8.50	1.00	8.50
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	5.38	1.00	5.38
TRANSPORTATION				
Haul to plant	ton	4.15	1.38	5.73
TOTAL DIRECT EXPENSES				178.53
FIXED EXPENSES				
Implements	acre	12.05	1.00	12.05
Tractors	acre	11.54	1.00	11.54
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				103.59
TOTAL EXPENSES				282.12
NET COST[2]				206.22
ESTABLISHMENT COST (prorated)				28.69

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table A.9 Estimated annual production cost of alfalfa at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
HERBICIDE				
Lorsban 4E	pt	1.81	2.00	3.62
OPERATOR LABOR				
Tractors	hour	6.00	2.50	14.97
FUEL				
Tractors	gal	0.83	8.94	7.42
REPAIR & MAINTENANCE				
Implements	acre	14.24	1.00	14.24
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	1.14	1.00	1.14
TRANSPORTATION				
Haul to plant	ton	4.15	4.85	20.13
TOTAL DIRECT EXPENSES				70.50
FIXED EXPENSES				
Implements	acre	15.35	1.00	15.35
Tractors	acre	15.92	1.00	15.92
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				146.30
ESTABLISHMENT COST (prorated)				65.89
TOTAL EXPENSES				282.69
BREAK-EVEN PRICE				58.29

[1] Interest on operating costs.

4.85 tons/acre of dry matter yield is used to estimate the break-evenprice.

Table A.10 Estimated annual production cost of reed canarygrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.91	11.45
FUEL				
Tractors	gal	0.83	7.01	5.82
REPAIR & MAINTENANCE				
Implements	acre	10.71	1.00	10.71
Tractors	acre	7.08	1.00	7.08
INTEREST[1]	acre	2.58	1.00	2.58
TRANSPORTATION				
Haul to plant	ton	4.15	3.67	15.23
TOTAL DIRECT EXPENSES				91.85
FIXED EXPENSES				
Implements	acre	12.21	1.00	12.21
Tractors	acre	12.57	1.00	12.57
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				139.78
ESTABLISHMENT COST (prorated)				15.92
TOTAL EXPENSES				247.55
BREAK-EVEN PRICE				67.45

[1] Interest on operating costs.

$3.67 tons/acre dry matter yield is used to estimate the break-even price.

Table A.11 Estimated annual production cost of switchgrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	5.52	1.00	5.52
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.36	1.00	2.36
TRANSPORTATION				
Haul to plant	ton	4.15	4.97	20.63
TOTAL DIRECT EXPENSES				80.43
FIXED EXPENSES				
Implements	acre	6.38	1.00	6.38
Tractors	acre	6.69	1.00	6.69
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				128.07
ESTABLISHMENT COST (prorated)				5.63
TOTAL EXPENSES				214.13
BREAK-EVEN PRICE				43.08

[1] Interest on operating costs.

4.97 tons/acre dry matter yield is used to estimate the break-even price.

Table A.12 Estimated annual production cost of big bluestem at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	5.52	1.00	5.52
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.35	1.00	2.35
TRANSPORTATION				
Haul to plant	ton	4.15	4.23	17.55
TOTAL DIRECT EXPENSES				77.34
FIXED EXPENSES				
Implements	acre	6.38	1.00	6.38
Tractors	acre	6.69	1.00	6.69
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				128.07
ESTABLISHMENT COST (prorated)				21.82
TOTAL EXPENSES				227.23
BREAK-EVEN PRICE				53.72

[1] Interest on operating costs.

4.23 tons/acre dry matter yield is used to estimate the break-even price.

Table A.13 Estimated annual production cost of alfalfa at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
HERBICIDE				
Lorsban 4E	pt	1.81	2.00	3.62
OPERATOR LABOR				
Tractors	hour	6.00	2.50	14.97
FUEL				
Tractors	gal	0.83	8.94	7.42
REPAIR & MAINTENANCE				
Implements	acre	14.24	1.00	14.24
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	1.10	1.00	1.10
TRANSPORTATION				
Haul to plant	ton	4.15	3.99	16.56
TOTAL DIRECT EXPENSES				66.89
FIXED EXPENSES				
Implements	acre	15.38	1.00	15.38
Tractors	acre	15.92	1.00	15.92
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				111.30
ESTABLISHMENT COST (prorated)				62.07
TOTAL EXPENSES				240.26
BREAK-EVEN PRICE				60.22

[1] Interest on operating costs.

3.99 tons/acre dry matter yield is used to estimate the break-even price.

Table A.14 Estimated annual production cost of reed canarygrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.91	11.45
FUEL				
Tractors	gal	0.83	7.01	5.82
REPAIR & MAINTENANCE				
Implements	acre	10.71	1.00	10.71
Tractors	acre	7.08	1.00	7.08
INTEREST[1]	acre	2.60	1.00	2.60
TRANSPORTATION				
Haul to plant	ton	4.15	4.34	18.01
TOTAL DIRECT EXPENSES				94.65
FIXED EXPENSES				
Implements	acre	12.21	1.00	12.21
Tractors	acre	12.57	1.00	12.57
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				104.78
ESTABLISHMENT COST (prorated)				12.34
TOTAL EXPENSES				211.77
BREAK-EVEN PRICE				48.79

[1] Interest on operating costs.

4.34 tons/acre dry matter yield is used to estimate the break-even price.

Table A.15 Estimated annual production cost of switchgrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	5.52	1.00	5.52
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.36	1.00	2.36
TRANSPORTATION				
Haul to plant	ton	4.15	4.61	19.13
TOTAL DIRECT EXPENSES				78.93
FIXED EXPENSES				
Implements	acre	6.38	1.00	6.38
Tractors	acre	6.69	1.00	6.69
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				93.07
ESTABLISHMENT COST (prorated)				8.04
TOTAL EXPENSES				180.04
BREAK-EVEN PRICE				39.05

[1] Interest on operating costs.

4.61 tons/acre dry matter yield is used to estimate the break-even price.

Table A.16 Estimated annual production cost of big bluestem at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	5.52	1.00	5.52
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.34	1.00	2.34
TRANSPORTATION				
Haul to plant	ton	4.15	3.91	16.23
TOTAL DIRECT EXPENSES				76.01
FIXED EXPENSES				
Implements	acre	6.38	1.00	6.38
Tractors	acre	6.69	1.00	6.69
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				93.07
ESTABLISHMENT COST (prorated)				28.69
TOTAL EXPENSES				199.77
BREAK-EVEN PRICE				50.58

[1] Interest on operating costs.

3.91 tons/acre dry matter yield is used to estimate the break-even price.

Table A.17 Estimated annual production cost of sweet sorghum at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	10.59	1.00	10.59
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	2.65	1.00	2.65
TRANSPORTATION				
Haul to plant	ton	4.15	7.80	32.37
TOTAL DIRECT EXPENSES				134.18
FIXED EXPENSES				
Implements	acre	19.97	1.00	19.97
Tractors	acre	18.09	1.00	18.09
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				153.06
TOTAL EXPENSES				287.24
BREAK-EVEN PRICE				36.83

[1] Interest on operating costs.

7.80 tons/acre dry matter yield is used to estimate the break-even price.

Table A.18 Estimated annual production cost of sweet sorghum at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	10.59	1.00	10.59
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	2.66	1.00	2.66
TRANSPORTATION				
Haul to plant	ton	4.15	8.03	33.32
TOTAL DIRECT EXPENSES				135.14
FIXED EXPENSES				
Implements	acre	19.97	1.00	19.97
Tractors	acre	18.09	1.00	18.09
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				118.06
TOTAL EXPENSES				253.20
BREAK-EVEN PRICE				31.53

[1] Interest on operating costs.

8.03 tons/acre dry matter yield is used to estimate the break-even price.

Table A.19 Estimated annual production cost of sorghum x sudangrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	10.59	1.00	10.59
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	2.60	1.00	2.60
TRANSPORTATION				
Haul to plant	ton	4.15	7.01	29.09
TOTAL DIRECT EXPENSES				129.81
FIXED EXPENSES				
Implements	acre	19.97	1.00	19.97
Tractors	acre	18.09	1.00	18.09
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				153.06
TOTAL EXPENSES				282.87
BREAK-EVEN PRICE				40.35

[1] Interest on operating costs.

To estimate the break-even price, 7.01 tons/acre dry matter yield is used.

Table A.20 Estimated annual production cost of sorghum x sudangrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	10.59	1.00	10.59
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	2.61	1.00	2.61
TRANSPORTATION				
Haul to plant	ton	4.15	7.41	30.75
TOTAL DIRECT EXPENSES				131.47
FIXED EXPENSES				
Implements	acre	19.97	1.00	19.97
Tractors	acre	18.09	1.00	18.09
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				118.06
TOTAL EXPENSES				249.53
BREAK-EVEN PRICE				33.67

[1] Interest on operating costs.

7.41 tons/acre is used to estimate the break-even price.

Table A.21 Estimated annual production cost of sweet sorghum/rye double crop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	100.00	31.00
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	15.90	1.00	15.90
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	5.35	1.00	5.35
TRANSPORTATION				
Haul to plant	ton	4.15	7.94	32.95
TOTAL DIRECT EXPENSES				167.36
FIXED EXPENSES				
Implements	acre	26.64	1.00	26.64
Tractors	acre	22.75	1.00	22.75
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				164.39
TOTAL EXPENSES				331.75
BREAK-EVEN PRICE				41.78

[1] Interest on operating costs.

7.94 tons/acre dry matter yield is used to estimate the break-even price.

Table A.22 Estimated annual production cost of sweet sorghum/rye double crop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	37.20
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	15.90	1.00	15.90
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	6.00	1.00	6.00
TRANSPORTATION				
Haul to plant	ton	4.15	6.98	28.97
TOTAL DIRECT EXPENSES				170.23
FIXED EXPENSES				
Implements	acre	26.14	1.00	26.14
Tractors	acre	22.75	1.00	22.75
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				129.39
TOTAL EXPENSES				299.62
BREAK-EVEN PRICE				42.93

[1] Interest on operating costs.

6.98 tons/acre dry matter yield is used to estimate the break-even price.

Table A.23 Estimated annual production cost of sorghum x sudangrass/rye double crop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	100.00	31.00
Sweet sorghum	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	15.90	1.00	15.90
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	5.29	1.00	5.29
TRANSPORTATION				
Haul to plant	ton	4.15	7.10	29.47
TOTAL DIRECT EXPENSES				162.77
FIXED EXPENSES				
Implements	acre	26.64	1.00	26.64
Tractors	acre	22.75	1.00	22.75
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				164.39
TOTAL EXPENSES				327.16
BREAK-EVEN PRICE				46.08

[1] Interest on operating costs.

7.10 tons/acre dry matter yield is used to estimate the break-even price.

Table A.24 Estimated annual production cost of sorghum x sudangrass/rye double crop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	37.20
Sweet sorghum	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	15.90	1.00	15.90
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	5.65	1.00	5.65
TRANSPORTATION				
Haul to plant	ton	4.15	6.90	28.64
TOTAL DIRECT EXPENSES				168.50
FIXED EXPENSES				
Implements	acre	26.64	1.00	26.64
Tractors	acre	22.75	1.00	22.75
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				129.39
TOTAL EXPENSES				297.89
BREAK-EVEN PRICE				43.17

[1] Interest on operating costs.

6.90 tons/acre dry matter yield is used to estimate the break-even price.

Table A.25 Estimated annual production cost of sweet sorghum monocrop in rotation at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	1.98	11.87
FUEL				
Tractors	gal	0.83	9.28	7.70
REPAIR & MAINTENANCE				
Implements	acre	9.27	1.00	9.27
Tractors	acre	9.29	1.00	9.29
INTEREST[1]	acre	2.67	1.00	2.67
TRANSPORTATION				
Haul to plant	ton	4.15	7.93	32.91
TOTAL DIRECT EXPENSES				130.46
FIXED EXPENSES				
Implements	acre	17.81	1.00	17.81
Tractors	acre	16.49	1.00	16.49
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				149.30
TOTAL EXPENSES				279.76
BREAK-EVEN PRICE				35.28

[1] Interest on operating costs.

7.93 tons/acre dry matter yield is used to estimate the break-even price.

Table A.26 Estimated annual production cost of sweet sorghum monocrop in rotation at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	1.98	11.87
FUEL				
Tractors	gal	0.83	9.28	7.70
REPAIR & MAINTENANCE				
Implements	acre	9.27	1.00	9.27
Tractors	acre	9.29	1.00	9.29
INTEREST[1]	acre	2.67	1.00	2.67
TRANSPORTATION				
Haul to plant	ton	4.15	8.24	34.20
TOTAL DIRECT EXPENSES				131.75
FIXED EXPENSES				
Implements	acre	17.81	1.00	17.81
Tractors	acre	16.49	1.00	16.49
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				114.30
TOTAL EXPENSES				246.05
BREAK-EVEN PRICE				29.86

[1] Interest on operating costs.

8.24 tons/acre dry matter yield is used to estimate the break-even price.

Table A.27 Estimated annual production cost of sweet sorghum/rye double crop in rotation at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	100.00	31.00
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	12.05	10.00
REPAIR & MAINTENANCE				
Implements	acre	15.18	1.00	15.18
Tractors	acre	11.99	1.00	11.99
INTEREST[1]	acre	5.37	1.00	5.37
TRANSPORTATION				
Haul to plant	ton	4.15	9.30	38.60
TOTAL DIRECT EXPENSES				169.55
FIXED EXPENSES				
Implements	acre	25.46	1.00	25.46
Tractors	acre	21.27	1.00	21.27
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				161.73
TOTAL EXPENSES				331.28
BREAK-EVEN PRICE				35.62

[1] Interest on operating costs.

9.30 tons/acre dry matter yield is used to estimate the break-even price.

Table A.28 Estimated annual production cost of sweet sorghum/rye double crop in rotation at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	37.20
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	12.05	10.00
REPAIR & MAINTENANCE				
Implements	acre	15.18	1.00	15.18
Tractors	acre	11.99	1.00	11.99
INTEREST[1]	acre	5.76	1.00	5.76
TRANSPORTATION				
Haul to plant	ton	4.15	9.88	41.00
TOTAL DIRECT EXPENSES				178.54
FIXED EXPENSES				
Implements	acre	25.46	1.00	25.46
Tractors	acre	21.27	1.00	21.27
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				126.73
TOTAL EXPENSES				305.27
BREAK-EVEN PRICE				30.90

[1] Interest on operating costs.

9.88 tons/acre dry matter yield is used to estimate the break-even price.

Table A.29 Estimated production cost of corn at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Bladex 4L	pt	3.07	5.00	15.35
Lasso	pt	3.28	5.00	16.40
SEED				
Corn	1000 k	0.90	30.00	27.00
OPERATOR LABOR				
Tractors	hour	6.00	2.36	14.15
FUEL				
Tractors	gal	0.83	10.60	8.80
REPAIR & MAINTENANCE				
Implements	acre	10.73	1.00	10.73
Tractors	acre	12.09	1.00	12.09
INTEREST[1]	acre	4.24	1.00	4.24
TRANSPORTATION				
Haul to plant	ton	4.15	3.28	13.61
TOTAL DIRECT EXPENSES				159.86
FIXED EXPENSES				
Implements	acre	18.30	1.00	18.30
Tractors	acre	21.52	1.00	21.52
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				154.82
TOTAL EXPENSES				314.68
TOTAL REVENUE	bushel	2.35	85.34	200.55
NET COST ($/acre)				114.13
BREAK-EVEN PRICE				34.80

[1] Interest on operating costs.

3.28 tons/acre of dry corn stover is used to estimate the break-even price.

Table A.30 Estimated production cost of corn at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Bladex 4L	pt	3.07	5.00	15.35
Lasso	pt	3.28	5.00	16.40
SEED				
Corn	1000 k	0.90	30.00	27.00
OPERATOR LABOR				
Tractors	hour	6.00	2.36	14.15
FUEL				
Tractors	gal	0.83	10.60	8.80
REPAIR & MAINTENANCE				
Implements	acre	10.73	1.00	10.73
Tractors	acre	12.09	1.00	12.09
INTEREST[1]	acre	4.23	1.00	4.23
TRANSPORTATION				
Haul to plant	ton	4.15	2.83	11.74
TOTAL DIRECT EXPENSES				157.98
FIXED EXPENSES				
Implements	acre	18.30	1.00	18.30
Tractors	acre	21.52	1.00	21.52
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				119.82
TOTAL EXPENSES				277.80
TOTAL REVENUE	bushel	2.35	54.79	128.76
NET COST ($/acre)				149.03
BREAK-EVEN PRICE				52.66

[1] Interest on operating costs.

2.83 tons/acre dry corn stover is used to estimate the break-even price.

Table A.31 Estimated production cost of soybean at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	40.00	10.00
Potash	lbs	0.17	75.00	12.75
HERBICIDE				
Lasso	pt	3.28	6.00	19.68
SEED				
Soybean	unit	14.00	1.00	14.00
OPERATOR LABOR				
Tractors	hour	6.00	0.93	5.59
FUEL				
Tractors	gal	0.83	5.18	4.30
REPAIR & MAINTENANCE				
Implements	acre	4.62	1.00	4.62
Tractors	acre	6.44	1.00	6.44
INTEREST[1]	acre	2.49	1.00	2.49
TOTAL DIRECT EXPENSES				79.87
FIXED EXPENSES				
Implements	acre	9.74	1.00	9.74
Tractors	acre	11.50	1.00	11.50
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				136.24
TOTAL EXPENSES				216.11
TOTAL REVENUE	bushel	5.45	27.92	152.16
NET COST ($/acre)				63.95

[1] Interest on operating costs.

Table A.32 Estimated production cost of soybean at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	40.00	10.00
Potash	lbs	0.17	75.00	12.75
HERBICIDE				
Lasso	pt	3.28	6.00	19.68
SEED				
Soybean	unit	14.00	1.00	14.00
OPERATOR LABOR				
Tractors	hour	6.00	0.93	5.59
FUEL				
Tractors	gal	0.83	5.18	4.30
REPAIR & MAINTENANCE				
Implements	acre	4.62	1.00	4.62
Tractors	acre	6.44	1.00	6.44
INTEREST[1]	acre	2.49	1.00	2.49
TOTAL DIRECT EXPENSES				79.88
FIXED EXPENSES				
Implements	acre	9.74	1.00	9.74
Tractors	acre	11.50	1.00	11.50
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				101.24
TOTAL EXPENSES				181.12
TOTAL REVENUE	bushel	5.45	40.41	220.23
NET COST ($/acre)				-39.11

[1] Interest on operating costs.

Negative sign on net cost implies a profit.

Table A.33 Estimated production cost of alfalfa/sweet sorghum intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR[1]				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	18.10	1.00	18.10
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	1.88	1.00	1.88
TRANSPORTATION				
Haul to plant	ton	4.15	6.84	28.39
TOTAL DIRECT EXPENSES				110.38
FIXED EXPENSES				
Implements	acre	20.38	1.00	20.38
Tractors	acre	17.64	1.00	17.64
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				153.02
ESTABLISHMENT COST (prorated)				65.89
TOTAL EXPENSES				329.29
BREAK-EVEN PRICE				48.14

[1] Interest on operating costs.

6.84 tons/acre dry matter yield is used to estimate the break-even price.

Table A.34 Estimated production cost of alfalfa/sweet sorghum intercrop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	18.10	1.00	18.10
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	1.84	1.00	1.84
TRANSPORTATION				
Haul to plant	ton	4.15	5.27	21.87
TOTAL DIRECT EXPENSES				103.82
FIXED EXPENSES				
Implements	acre	20.38	1.00	20.38
Tractors	acre	17.64	1.00	17.64
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				118.02
ESTABLISHMENT COST (prorated)				62.07
TOTAL EXPENSES				283.91
BREAK-EVEN PRICE				53.87

[1] Interest on operating costs.

5.27 tons/acre dry matter is used to estimate the break-even price.

Table A.35 Estimated production cost of alfalfa/sorghum x sudangrass intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	18.10	1.00	18.10
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	1.87	1.00	1.87
TRANSPORTATION				
Haul to plant	ton	4.15	6.66	27.64
TOTAL DIRECT EXPENSES				108.56
FIXED EXPENSES				
Implements	acre	20.38	1.00	20.38
Tractors	acre	17.64	1.00	17.64
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				153.02
ESTABLISHMENT COST (prorated)				65.89
TOTAL EXPENSES				327.47
BREAK-EVEN PRICE ($/ton)				49.17

[1] Interest on operating costs.

6.66 tons/acre dry matter yield is used to estimate the break-even price.

Table A.36 Estimated production cost of alfalfa/sorghum x sudangrass intercrop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	18.10	1.00	18.10
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	1.83	1.00	1.83
TRANSPORTATION				
Haul to plant	ton	4.15	5.65	23.45
TOTAL DIRECT EXPENSES				104.34
FIXED EXPENSES				
Implements	acre	20.38	1.00	20.38
Tractors	acre	17.64	1.00	17.64
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				118.02
ESTABLISHMENT COST (prorated)				62.07
TOTAL EXPENSES				284.43
BREAK-EVEN PRICE				50.34

[1] Interest on operating costs.

5.65 tons/acre dry matter yield is used to estimate the break-even price.

Table A.37 Estimated production cost of reed canarygrass/sweet sorghum intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	3.06	18.35
FUEL				
Tractors	gal	0.83	11.21	9.30
REPAIR & MAINTENANCE				
Implements	acre	19.15	1.00	19.15
Tractors	acre	11.24	1.00	11.24
INTEREST[1]	acre	3.66	1.00	3.66
TRANSPORTATION				
Haul to plant	ton	4.15	4.79	19.88
TOTAL DIRECT EXPENSES				132.99
FIXED EXPENSES				
Implements	acre	22.11	1.00	22.11
Tractors	acre	19.94	1.00	19.94
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				157.05
ESTABLISHMENT COST (prorated)				15.92
TOTAL EXPENSES				305.96
BREAK-EVEN PRICE				63.87

[1] Interest on operating costs.

4.79 tons/acre dry matter yield is used to estimate the break-even price.

Table A.38 Estimated production cost of reed canarygrass/sorghum x sudangrass intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	3.06	18.35
FUEL				
Tractors	gal	0.83	11.21	9.30
REPAIR & MAINTENANCE				
Implements	acre	19.15	1.00	19.15
Tractors	acre	11.24	1.00	11.24
INTEREST[1]	acre	3.64	1.00	3.64
TRANSPORTATION				
Haul to plant	ton	4.15	4.87	20.21
TOTAL DIRECT EXPENSES				132.24
FIXED EXPENSES				
Implements	acre	22.11	1.00	22.11
Tractors	acre	19.94	1.00	19.94
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				157.05
ESTABLISHMENT COST (prorated)				15.92
TOTAL EXPENSES				305.21
BREAK-EVEN PRICE				62.67

[1] Interest on operating costs.

4.87 tons/acre dry matter yield is used to estimate the break-even price.

APPENDIX B

PRODUCTION COSTS OF EACH SYSTEM WITH ANNUAL HOURS OF MACHINE USE BASED ON 160 ACRES OF BIOMASS PRODUCTION

Table B.1 Estimated establishment year budget for alfalfa at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Alfalfa	ton	65.00	2.72	176.80
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	160.00	40.00
Potash	lbs	0.17	625.00	106.25
HERBICIDE				
Eptom	pt	2.81	3.00	8.43
Lorsban 4E	pt	1.81	1.00	1.81
SEED				
Alfalfa	lbs	2.50	12.00	30.00
OPERATOR LABOR				
Tractors	hour	6.00	2.43	13.87
FUEL				
Tractors	gal	0.83	12.58	7.83
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	9.34	1.00	9.34
INTEREST[1]	acre	12.38	1.00	12.38
TRANSPORTATION				
Haul to plant	ton	4.15	2.72	11.29
TOTAL DIRECT EXPENSES				276.16
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	16.59	1.00	16.59
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				179.28
TOTAL EXPENSES				455.44
NET COST[2]				278.64
ESTABLISHMENT COST (prorated)				81.34

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.2 Estimated establishment year budget for reed canarygrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Reed canarygrass	ton	60.00	2.67	160.20
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.00	4.62
SEED				
Reed canarygrass	lbs	4.50	9.00	40.50
OPERATOR LABOR				
Tractors	hour	6.00	2.33	13.32
FUEL				
Tractors	gal	0.83	12.07	7.52
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	4.53	1.00	4.53
TRANSPORTATION				
Haul to plant	ton	4.15	2.67	11.08
TOTAL DIRECT EXPENSES				149.48
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	15.94	1.00	15.94
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				178.63
TOTAL EXPENSES				328.11
NET COST[2]				167.91
ESTABLISHMENT COST (prorated)				23.36

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.3 Estimated establishment year budget for switchgrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Switchgrass	ton	55.00	3.62	199.10
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
Atrazine 4L	pt	1.58	2.50	3.95
SEED				
Switchgrass	lbs	3.50	7.20	25.20
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.18
FUEL				
Tractors	gal	0.83	8.82	5.49
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	3.60	1.00	3.60
TRANSPORTATION				
Haul to plant	ton	4.15	3.62	15.02
TOTAL DIRECT EXPENSES				127.87
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	11.54	1.00	11.54
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				174.23
TOTAL EXPENSES				302.11
NET COST[2]				103.00
ESTABLISHMENT COST (prorated)				14.33

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.4 Estimated establishment year budget for big bluestem at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Big bluestem	ton	55.00	3.04	167.20
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.50	5.78
SEED				
Big bluestem	lbs	9.00	12.00	108.00
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.18
FUEL				
Tractors	gal	0.83	8.82	5.49
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	5.87	1.00	5.87
TRANSPORTATION				
Haul to plant	ton	4.15	3.04	12.62
TOTAL DIRECT EXPENSES				212.37
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	11.54	1.00	11.54
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				174.23
TOTAL EXPENSES				386.60
NET COST[2]				219.40
ESTABLISHMENT COST (prorated)				30.52

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.5 Estimated establishment year budget for alfalfa at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Alfalfa	ton	65.00	3.04	197.60
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	160.00	40.00
Potash	lbs	0.17	625.00	106.25
Lime	ton	6.00	5.00	30.00
HERBICIDE				
Eptom	pt	2.81	3.00	8.43
Lorsban 4E	pt	1.81	1.50	2.72
SEED				
Alfalfa	lbs	2.50	14.00	35.00
OPERATOR LABOR				
Tractors	hour	6.00	2.54	14.56
FUEL				
Tractors	gal	0.83	13.21	8.21
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	9.80	1.00	9.80
INTEREST[1]	acre	14.63	1.00	14.63
TRANSPORTATION				
Haul to plant	ton	4.15	3.04	12.62
TOTAL DIRECT EXPENSES				317.18
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	17.41	1.00	17.41
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				145.10
TOTAL EXPENSES				462.28
NET COST[2]				264.68
ESTABLISHMENT COST (prorated)				77.26

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.6 Estimated establishment year budget for reed canarygrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Reed canarygrass	ton	60.00	2.67	160.20
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.00	4.62
SEED				
Reed canarygrass	lbs	4.50	11.00	49.50
OPERATOR LABOR				
Tractors	hour	6.00	2.33	13.32
FUEL				
Tractors	gal	0.83	12.07	7.52
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	4.83	1.00	4.83
TRANSPORTATION				
Haul to plant	ton	4.15	2.67	11.08
TOTAL DIRECT EXPENSES				158.78
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	15.94	1.00	15.94
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				143.63
TOTAL EXPENSES				302.41
NET COST[2]				142.21
ESTABLISHMENT COST (prorated)				19.78

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.7 Estimated establishment year budget for switchgrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Switchgrass	ton	55.00	2.59	142.45
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
Atrazine 4L	pt	1.58	2.50	3.95
SEED				
Switchgrass	lbs	3.50	7.20	25.20
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.18
FUEL				
Tractors	gal	0.83	8.82	5.49
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	3.59	1.00	3.59
TRANSPORTATION				
Haul to plant	ton	4.15	2.59	10.75
TOTAL DIRECT EXPENSES				123.59
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	11.54	1.00	11.54
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				139.23
TOTAL EXPENSES				262.82
NET COST[2]				120.37
ESTABLISHMENT COST (prorated)				16.74

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.8 Estimated establishment year budget for big bluestem at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
REVENUE				
Big bluestem	ton	55.00	1.38	75.90
TOTAL REVENUE				
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
HERBICIDE				
2,4-D	pt	2.31	2.50	5.78
SEED				
Big bluestem	lbs	9.00	12.00	108.00
OPERATOR LABOR				
Tractors	hour	6.00	1.64	9.18
FUEL				
Tractors	gal	0.83	8.82	5.49
REPAIR & MAINTENANCE				
Implements	acre	34.96	1.00	34.96
Tractors	acre	6.49	1.00	6.49
INTEREST[1]	acre	5.87	1.00	5.87
TRANSPORTATION				
Haul to plant	ton	4.15	1.38	5.73
TOTAL DIRECT EXPENSES				205.48
FIXED EXPENSES				
Implements	acre	47.69	1.00	47.69
Tractors	acre	11.54	1.00	11.54
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				139.23
TOTAL EXPENSES				344.71
NET COST[2]				268.81
ESTABLISHMENT COST (prorated)				37.39

[1] Interest on operating costs.

[2] Total revenue is subtracted from total expenses.

Table B.9 Estimated annual production cost of alfalfa at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
HERBICIDE				
Lorsban 4E	pt	1.81	2.00	3.62
OPERATOR LABOR				
Tractors	hour	6.00	2.50	14.97
FUEL				
Tractors	gal	0.83	8.94	7.42
REPAIR & MAINTENANCE				
Implements	acre	21.25	1.00	21.25
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	1.28	1.00	1.28
TRANSPORTATION				
Haul to plant	ton	4.15	4.85	20.13
TOTAL DIRECT EXPENSES				77.64
FIXED EXPENSES				
Implements	acre	22.98	1.00	22.98
Tractors	acre	15.92	1.00	15.92
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				153.90
ESTABLISHMENT COST (prorated)				81.34
TOTAL EXPENSES				312.88
BREAK-EVEN PRICE				64.51

[1] Interest on operating costs.

4.85 tons/acre of dry matter yield is used to estimate the break-evenprice.

Table B.10 Estimated annual production cost of reed canarygrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.91	11.45
FUEL				
Tractors	gal	0.83	7.01	5.82
REPAIR & MAINTENANCE				
Implements	acre	21.40	1.00	21.40
Tractors	acre	7.08	1.00	7.08
INTEREST[1]	acre	2.71	1.00	2.71
TRANSPORTATION				
Haul to plant	ton	4.15	3.67	15.23
TOTAL DIRECT EXPENSES				102.68
FIXED EXPENSES				
Implements	acre	22.97	1.00	22.97
Tractors	acre	12.57	1.00	12.57
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				150.54
ESTABLISHMENT COST (prorated)				27.53
TOTAL EXPENSES				280.75
BREAK-EVEN PRICE				76.50

[1] Interest on operating costs.

3.67 tons/acre dry matter yield is used to estimate the break-even price.

Table B.11 Estimated annual production cost of switchgrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	21.43	1.00	21.43
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.49	1.00	2.49
TRANSPORTATION				
Haul to plant	ton	4.15	4.97	20.63
TOTAL DIRECT EXPENSES				96.46
FIXED EXPENSES				
Implements	acre	23.02	1.00	23.02
Tractors	acre	6.69	1.00	6.69
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				144.71
ESTABLISHMENT COST (prorated)				14.33
TOTAL EXPENSES				255.50
BREAK-EVEN PRICE				51.41

[1] Interest on operating costs.

4.97 tons/acre dry matter yield is used to estimate the break-even price.

Table B.12 Estimated annual production cost of big bluestem at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	21.43	1.00	21.43
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.47	1.00	2.47
TRANSPORTATION				
Haul to plant	ton	4.15	4.23	17.55
TOTAL DIRECT EXPENSES				93.37
FIXED EXPENSES				
Implements	acre	23.02	1.00	23.02
Tractors	acre	6.69	1.00	6.69
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				144.71
ESTABLISHMENT COST (prorated)				30.52
TOTAL EXPENSES				305.23
BREAK-EVEN PRICE				72.16

[1] Interest on operating costs.

4.23 tons/acre dry matter yield is used to estimate the break-even price.

Table B.13 Estimated annual production cost of alfalfa at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
HERBICIDE				
Lorsban 4E	pt	1.81	2.00	3.62
OPERATOR LABOR				
Tractors	hour	6.00	2.50	14.97
FUEL				
Tractors	gal	0.83	8.94	7.42
REPAIR & MAINTENANCE				
Implements	acre	21.25	1.00	21.25
Tractors	acre	8.97	1.00	8.97
INTEREST[1]	acre	1.24	1.00	1.24
TRANSPORTATION				
Haul to plant	ton	4.15	3.99	16.56
TOTAL DIRECT EXPENSES				74.03
FIXED EXPENSES				
Implements	acre	22.98	1.00	22.98
Tractors	acre	15.92	1.00	15.92
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				118.90
ESTABLISHMENT COST (prorated)				77.26
TOTAL EXPENSES				270.19
BREAK-EVEN PRICE				67.71

[1] Interest on operating costs.

3.99 tons/acre dry matter yield is used to estimate the break-even price.

Table B.14 Estimated annual production cost of reed canarygrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.91	11.45
FUEL				
Tractors	gal	0.83	7.01	5.82
REPAIR & MAINTENANCE				
Implements	acre	21.40	1.00	21.40
Tractors	acre	7.08	1.00	7.08
INTEREST[1]	acre	2.73	1.00	2.73
TRANSPORTATION				
Haul to plant	ton	4.15	4.34	18.01
TOTAL DIRECT EXPENSES				105.47
FIXED EXPENSES				
Implements	acre	22.97	1.00	22.97
Tractors	acre	12.57	1.00	12.57
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				115.54
ESTABLISHMENT COST (prorated)				18.74
TOTAL EXPENSES				239.75
BREAK-EVEN PRICE				55.24

[1] Interest on operating costs.

4.34 tons/acre dry matter yield is used to estimate the break-even price.

Table B.15 Estimated annual production cost of switchgrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	21.43	1.00	21.43
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.48	1.00	2.48
TRANSPORTATION				
Haul to plant	ton	4.15	4.61	19.13
TOTAL DIRECT EXPENSES				94.96
FIXED EXPENSES				
Implements	acre	23.02	1.00	23.02
Tractors	acre	6.69	1.00	6.69
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				109.71
ESTABLISHMENT COST (prorated)				16.74
TOTAL EXPENSES				221.41
BREAK-EVEN PRICE				48.03

[1] Interest on operating costs.

4.61 tons/acre dry matter yield is used to estimate the break-even price.

Table B.16 Estimated annual production cost of big bluestem at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
OPERATOR LABOR				
Tractors	hour	6.00	1.01	6.07
FUEL				
Tractors	gal	0.83	3.74	3.10
REPAIR & MAINTENANCE				
Implements	acre	21.43	1.00	21.43
Tractors	acre	3.77	1.00	3.77
INTEREST[1]	acre	2.46	1.00	2.46
TRANSPORTATION				
Haul to plant	ton	4.15	3.91	16.23
TOTAL DIRECT EXPENSES				92.04
FIXED EXPENSES				
Implements	acre	23.02	1.00	23.02
Tractors	acre	6.69	1.00	6.69
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				109.71
ESTABLISHMENT COST (prorated)				37.39
TOTAL EXPENSES				239.14
BREAK-EVEN PRICE				61.16

[1] Interest on operating costs.

3.91 tons/acre dry matter yield is used to estimate the break-even price.

Table B.17 Estimated annual production cost of sweet sorghum at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	32.29	1.00	32.29
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	3.12	1.00	3.12
TRANSPORTATION				
Haul to plant	ton	4.15	7.80	32.37
TOTAL DIRECT EXPENSES				156.34
FIXED EXPENSES				
Implements	acre	59.52	1.00	59.52
Tractors	acre	18.09	1.00	18.09
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				192.61
TOTAL EXPENSES				348.95
BREAK-EVEN PRICE				44.74

[1] Interest on operating costs.

7.80 tons/acre dry matter yield is used to estimate the break-even price.

Table B.18 Estimated annual production cost of sweet sorghum at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	32.29	1.00	32.29
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	3.12	1.00	3.12
TRANSPORTATION				
Haul to plant	ton	4.15	8.03	33.32
TOTAL DIRECT EXPENSES				157.30
FIXED EXPENSES				
Implements	acre	59.52	1.00	59.52
Tractors	acre	18.09	1.00	18.09
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				157.61
TOTAL EXPENSES				314.91
BREAK-EVEN PRICE				39.22

[1] Interest on operating costs.

8.03 tons/acre dry matter yield is used to estimate the break-even price.

Table B.19 Estimated annual production cost of sorghum x sudangrass at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	32.29	1.00	32.29
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	3.07	1.00	3.07
TRANSPORTATION				
Haul to plant	ton	4.15	7.01	29.09
TOTAL DIRECT EXPENSES				151.97
FIXED EXPENSES				
Implements	acre	59.52	1.00	59.52
Tractors	acre	18.09	1.00	18.09
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				192.61
TOTAL EXPENSES				344.58
BREAK-EVEN PRICE				49.16

[1] Interest on operating costs.

To estimate the break-even price, 7.01 tons/acre is used.

Table B.20 Estimated annual production cost of sorghum x sudangrass at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Duel	pt	7.88	2.00	15.76
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.20	13.18
FUEL				
Tractors	gal	0.83	10.18	8.45
REPAIR & MAINTENANCE				
Implements	acre	32.29	1.00	32.29
Tractors	acre	10.19	1.00	10.19
INTEREST[1]	acre	3.08	1.00	3.08
TRANSPORTATION				
Haul to plant	ton	4.15	7.41	30.75
TOTAL DIRECT EXPENSES				153.64
FIXED EXPENSES				
Implements	acre	59.52	1.00	59.52
Tractors	acre	18.09	1.00	18.09
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				157.61
TOTAL EXPENSES				311.25
BREAK-EVEN PRICE				42.00

[1] Interest on operating costs.

7.41 tons/acre dry matter is used to estimate the break-even price.

Table B.21 Estimated annual production cost of sweet sorghum/rye double crop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	100.00	31.00
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	51.40	1.00	51.40
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	6.36	1.00	6.36
TRANSPORTATION				
Haul to plant	ton	4.15	7.94	32.95
TOTAL DIRECT EXPENSES				203.88
FIXED EXPENSES				
Implements	acre	80.70	1.00	80.70
Tractors	acre	22.75	1.00	22.75
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				218.45
TOTAL EXPENSES				422.33
BREAK-EVEN PRICE				53.19

[1] Interest on operating costs.

7.94 tons/acre dry matter yield is used to estimate the break-even price.

Table B.22 Estimated annual production cost of sweet sorghum/rye double crop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	37.20
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	51.40	1.00	51.40
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	6.69	1.00	6.69
TRANSPORTATION				
Haul to plant	ton	4.15	6.98	28.97
TOTAL DIRECT EXPENSES				206.42
FIXED EXPENSES				
Implements	acre	80.70	1.00	80.70
Tractors	acre	22.75	1.00	22.75
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				183.45
TOTAL EXPENSES				389.87
BREAK-EVEN PRICE				55.86

[1] Interest on operating costs.

6.98 tons/acre dry matter yield is used to estimate the break-even price.

Table B.23 Estimated annual production cost of sorghum x sudangrass/rye double crop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	31.00
Sweet sorghum	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	51.40	1.00	51.40
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	6.30	1.00	6.30
TRANSPORTATION				
Haul to plant	ton	4.15	7.10	29.47
TOTAL DIRECT EXPENSES				199.28
FIXED EXPENSES				
Implements	acre	80.70	1.00	80.70
Tractors	acre	22.75	1.00	22.75
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				218.45
TOTAL EXPENSES				417.73
BREAK-EVEN PRICE				58.84

[1] Interest on operating costs.

7.10 dry matter yield is used to estimate the break-even price.

Table B.24 Estimated annual production cost of sorghum x sudangrass/rye double crop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	37.20
Sweet sorghum	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.94	17.66
FUEL				
Tractors	gal	0.83	12.88	10.69
REPAIR & MAINTENANCE				
Implements	acre	51.40	1.00	51.40
Tractors	acre	12.82	1.00	12.82
INTEREST[1]	acre	6.66	1.00	6.66
TRANSPORTATION				
Haul to plant	ton	4.15	6.90	28.64
TOTAL DIRECT EXPENSES				205.01
FIXED EXPENSES				
Implements	acre	80.70	1.00	80.70
Tractors	acre	22.75	1.00	22.75
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				183.45
TOTAL EXPENSES				388.46
BREAK-EVEN PRICE				56.30

[1] Interest on operating costs.

6.90 tons/acre dry matter yield is used to estimate the break-even price.

Table B.25 Estimated annual production cost of sweet sorghum monocrop in rotation at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	1.98	11.87
FUEL				
Tractors	gal	0.83	9.28	7.70
REPAIR & MAINTENANCE				
Implements	acre	27.30	1.00	27.30
Tractors	acre	9.29	1.00	9.29
INTEREST[1]	acre	3.04	1.00	3.04
TRANSPORTATION				
Haul to plant	ton	4.15	7.93	32.91
TOTAL DIRECT EXPENSES				148.87
FIXED EXPENSES				
Implements	acre	51.39	1.00	51.39
Tractors	acre	16.49	1.00	16.49
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				182.88
TOTAL EXPENSES				331.75
BREAK-EVEN PRICE				41.83

[1] Interest on operating costs.

7.93 tons/acre dry matter yield is used to estimate the break-even price.

Table B.26 Estimated annual production cost of sweet sorghum monocrop in rotation at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Dual	pt	7.88	2.00	15.76
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	1.98	11.87
FUEL				
Tractors	gal	0.83	9.28	7.70
REPAIR & MAINTENANCE				
Implements	acre	27.30	1.00	27.30
Tractors	acre	9.29	1.00	9.29
INTEREST[1]	acre	3.05	1.00	3.05
TRANSPORTATION				
Haul to plant	ton	4.15	8.24	34.20
TOTAL DIRECT EXPENSES				150.16
FIXED EXPENSES				
Implements	acre	51.39	1.00	51.39
Tractors	acre	16.49	1.00	16.49
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				147.88
TOTAL EXPENSES				298.04
BREAK-EVEN PRICE				36.17

[1] Interest on operating costs.

8.24 tons/acre dry matter is used to estimate the break-even price.

Table B.27 Estimated annual production cost of sweet sorghum/rye double crop in rotation at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	100.00	31.00
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	12.05	10.00
REPAIR & MAINTENANCE				
Implements	acre	51.43	1.00	51.43
Tractors	acre	11.99	1.00	11.99
INTEREST[1]	acre	6.42	1.00	6.42
TRANSPORTATION				
Haul to plant	ton	4.15	9.30	38.60
TOTAL DIRECT EXPENSES				206.84
FIXED EXPENSES				
Implements	acre	80.74	1.00	80.74
Tractors	acre	21.27	1.00	21.27
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				217.01
TOTAL EXPENSES				423.85
BREAK-EVEN PRICE				45.58

[1] Interest on operating costs.

9.30 tons/acre dry matter yield is used to estimate the break-even price.

Table B.28 Estimated annual production cost of sweet sorghum/rye double crop in rotation at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
SEED				
Rye	lbs	0.31	120.00	37.20
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	12.05	10.00
REPAIR & MAINTENANCE				
Implements	acre	51.43	1.00	51.43
Tractors	acre	11.99	1.00	11.99
INTEREST[1]	acre	6.81	1.00	6.81
TRANSPORTATION				
Haul to plant	ton	4.15	9.88	41.00
TOTAL DIRECT EXPENSES				215.83
FIXED EXPENSES				
Implements	acre	80.74	1.00	80.74
Tractors	acre	21.27	1.00	21.27
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				182.01
TOTAL EXPENSES				397.84
BREAK-EVEN PRICE				40.27

[1] Interest on operating costs.

9.88 tons/acre dry matter yield is used to estimate the break-even price.

Table B.29 Estimated production cost of corn at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Bladex 4L	pt	3.07	5.00	15.35
Lasso	pt	3.28	5.00	16.40
SEED				
Corn	1000 k	0.90	30.00	27.00
OPERATOR LABOR				
Tractors	hour	6.00	2.36	14.15
FUEL				
Tractors	gal	0.83	10.60	8.80
REPAIR & MAINTENANCE				
Implements	acre	42.37	1.00	42.37
Tractors	acre	12.09	1.00	12.09
INTEREST[1]	acre	4.80	1.00	4.80
TRANSPORTATION				
Haul to plant	ton	4.15	3.28	13.61
TOTAL DIRECT EXPENSES				192.06
FIXED EXPENSES				
Implements	acre	71.20	1.00	71.20
Tractors	acre	21.52	1.00	21.52
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				207.72
TOTAL EXPENSES				399.70
TOTAL REVENUE	bushel	2.35	85.34	200.55
NET COST ($/acre)				199.23
BREAK-EVEN PRICE				60.74

[1] Interest on operating costs.

3.28 tons/acre dry corn stover is used to estimate the break-even price.

Table B.30 Estimated production cost of corn at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	58.00	14.50
Potash	lbs	0.17	47.00	7.99
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Bladex 4L	pt	3.07	5.00	15.35
Lasso	pt	3.28	5.00	16.40
SEED				
Corn	1000 k	0.90	30.00	27.00
OPERATOR LABOR				
Tractors	hour	6.00	2.36	14.15
FUEL				
Tractors	gal	0.83	10.60	8.80
REPAIR & MAINTENANCE				
Implements	acre	42.37	1.00	42.37
Tractors	acre	12.09	1.00	12.09
INTEREST[1]	acre	4.79	1.00	4.79
TRANSPORTATION				
Haul to plant	ton	4.15	2.83	11.74
TOTAL DIRECT EXPENSES				190.18
FIXED EXPENSES				
Implements	acre	71.20	1.00	71.20
Tractors	acre	21.52	1.00	21.52
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				172.72
TOTAL EXPENSES				362.90
TOTAL REVENUE	bushel	2.35	54.79	128.76
NET COST ($/acre)				234.14
BREAK-EVEN PRICE				82.73

[1] Interest on operating costs.

2.83 tons/acre dry corn stover is used to estimate the break-even price.

Table B.31 Estimated production cost of soybean at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	40.00	10.00
Potash	lbs	0.17	75.00	12.75
HERBICIDE				
Lasso	pt	3.28	6.00	19.68
SEED				
Soybean	unit	14.00	1.00	14.00
OPERATOR LABOR				
Tractors	hour	6.00	0.93	5.59
FUEL				
Tractors	gal	0.83	5.18	4.30
REPAIR & MAINTENANCE				
Implements	acre	20.23	1.00	20.23
Tractors	acre	6.44	1.00	6.44
INTEREST[1]	acre	2.79	1.00	2.79
TOTAL DIRECT EXPENSES				95.78
FIXED EXPENSES				
Implements	acre	39.68	1.00	39.68
Tractors	acre	11.50	1.00	11.50
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				166.18
TOTAL EXPENSES				261.96
TOTAL REVENUE	bushel	5.45	27.92	152.16
NET COST ($/acre)				109.80

[1] Interest on operating costs.

Table B.32 Estimated production cost of soybean at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phophorus	lbs	0.25	40.00	10.00
Potash	lbs	0.17	75.00	12.75
HERBICIDE				
Lasso	pt	3.28	6.00	19.68
SEED				
Soybean	unit	14.00	1.00	14.00
OPERATOR LABOR				
Tractors	hour	6.00	0.93	5.59
FUEL				
Tractors	gal	0.83	5.18	4.30
REPAIR & MAINTENANCE				
Implements	acre	20.23	1.00	20.23
Tractors	acre	6.44	1.00	6.44
INTEREST[1]	acre	2.79	1.00	2.79
TOTAL DIRECT EXPENSES				95.78
FIXED EXPENSES				
Implements	acre	39.68	1.00	39.68
Tractors	acre	11.50	1.00	11.50
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				131.18
TOTAL EXPENSES				226.96
TOTAL REVENUE	bushel	5.45	40.41	220.23
NET COST ($/acre)				6.73

[1] Interest on operating costs.

Table B.33 Estimated production cost of alfalfa/sweet sorghum intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	31.28	1.00	31.28
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	2.18	1.00	2.18
TRANSPORTATION				
Haul to plant	ton	4.15	6.84	28.39
TOTAL DIRECT EXPENSES				123.86
FIXED EXPENSES				
Implements	acre	39.35	1.00	39.35
Tractors	acre	17.64	1.00	17.64
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				171.99
ESTABLISHMENT COST (prorated)				81.743
TOTAL EXPENSES				377.19
BREAK-EVEN PRICE				55.14

[1] Interest on operating costs.

6.84 tons/acre dry matter yield is used to estimate the break-even price.

Table B.34 Estimated production cost of alfalfa/sweet sorghum intercrop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	31.28	1.00	31.28
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	2.14	1.00	2.14
TRANSPORTATION				
Haul to plant	ton	4.15	5.27	21.87
TOTAL DIRECT EXPENSES				117.30
FIXED EXPENSES				
Implements	acre	39.35	1.00	39.35
Tractors	acre	17.64	1.00	17.64
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				136.99
ESTABLISHMENT COST (prorated)				77.26
TOTAL EXPENSES				331.55
BREAK-EVEN PRICE				62.91

[1] Interest on operating costs.

5.27 tons/acre dry matter yield is used to estimate the break-even price.

Table B.35 Estimated production cost of alfalfa/sorghum x sudangrass intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	31.28	1.00	31.28
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	2.14	1.00	2.14
TRANSPORTATION				
Haul to plant	ton	4.15	6.66	27.64
TOTAL DIRECT EXPENSES				122.02
FIXED EXPENSES				
Implements	acre	39.35	1.00	39.35
Tractors	acre	17.64	1.00	17.64
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				171.99
ESTABLISHMENT COST (prorated)				81.34
TOTAL EXPENSES				375.35
BREAK-EVEN PRICE				56.86

[1] Interest on operating costs.

6.66 tons/acre dry matter yield is used to estimate the break-even price.

Table B.36 Estimated production cost of alfalfa/sorghum x sudangrass intercrop at Chariton, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	2.74	16.42
FUEL				
Tractors	gal	0.83	9.91	8.23
REPAIR & MAINTENANCE				
Implements	acre	31.28	1.00	31.28
Tractors	acre	9.94	1.00	9.94
INTEREST[1]	acre	2.12	1.00	2.12
TRANSPORTATION				
Haul to plant	ton	4.15	5.65	23.45
TOTAL DIRECT EXPENSES				117.81
FIXED EXPENSES				
Implements	acre	39.35	1.00	39.35
Tractors	acre	17.64	1.00	17.64
Land	acre	80.00	1.00	80.00
TOTAL FIXED EXPENSES				136.99
ESTABLISHMENT COST (prorated)				77.26
TOTAL EXPENSES				332.06
BREAK-EVEN PRICE				58.77

[1] Interest on operating costs.

5.65 tons/acre dry matter yield is used to estimate the break-even price.

Table B.37 Estimated production cost of reed canarygrass/sweet sorghum intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sweet sorghum	lbs	0.50	7.00	3.50
OPERATOR LABOR				
Tractors	hour	6.00	3.06	18.35
FUEL				
Tractors	gal	0.83	11.21	9.30
REPAIR & MAINTENANCE				
Implements	acre	31.88	1.00	31.88
Tractors	acre	11.24	1.00	11.24
INTEREST[1]	acre	3.95	1.00	3.95
TRANSPORTATION				
Haul to plant	ton	4.15	4.79	19.88
TOTAL DIRECT EXPENSES				146.00
FIXED EXPENSES				
Implements	acre	40.33	1.00	40.33
Tractors	acre	19.94	1.00	19.94
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				175.27
ESTABLISHMENT COST (prorated)				23.36
TOTAL EXPENSES				344.63
BREAK-EVEN PRICE				71.95

[1] Interest on operating costs.

4.79 tons/acre dry matter yield is used to estimate the break-even price.

Table B.38 Estimated production cost of reed canarygrass/sorghum x sudangrass intercrop at Ames, Iowa

Item	Unit	Price	Quantity	Amount
		(dollars)		(dollars)
DIRECT EXPENSES				
FERTILIZER				
Phosphorus	lbs	0.25	32.00	8.00
Potash	lbs	0.17	94.00	15.98
Nitrogen	lbs	0.12	125.00	15.00
HERBICIDE				
Paraquat	pt	4.46	2.00	8.92
SEED				
Sorghum x sudangrass	lbs	0.35	7.00	2.45
OPERATOR LABOR				
Tractors	hour	6.00	3.06	18.30
FUEL				
Tractors	gal	0.83	11.21	9.30
REPAIR & MAINTENANCE				
Implements	acre	31.88	1.00	31.88
Tractors	acre	11.24	1.00	11.24
INTEREST[1]	acre	3.92	1.00	3.92
TRANSPORTATION				
Haul to plant	ton	4.15	4.87	20.21
TOTAL DIRECT EXPENSES				145.25
FIXED EXPENSES				
Implements	acre	40.33	1.00	40.33
Tractors	acre	19.94	1.00	19.94
Land	acre	115.00	1.00	115.00
TOTAL FIXED EXPENSES				175.27
ESTABLISHMENT COST (prorated)				23.36
TOTAL EXPENSES				343.88
BREAK-EVEN PRICE				70.61

[1] Interest on operating costs.

4.87 tons/acre dry matter yield is used to estimate the break-even price.

APPENDIX C

ANNUAL YIELD DATA AND STATISTICS FOR EACH CROPPING SYSTEMS

Table C1 Annual dry matter yields of perennial grasses

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Average
Ames						
Alfalfa						
2-cut	2.72	4.96	4.55	4.51	4.15	4.54
3-cut	2.77	5.76	5.40	4.60	3.66	4.85
Reed canarygrass						
0.0 lbs N/acre	2.67	1.34	2.59	2.05	1.29	1.82
62.5 lbs N/acre		2.59	3.21	3.04	2.01	2.71
125.0 lbs N/acre		3.53	4.60	3.53	3.04	3.67
250.0 lbs N/acre		4.46	5.18	5.09	5.49	5.06
Switchgrass						
0.0 lbs N/acre	3.62	2.23	3.21	2.19	3.21	2.71
62.5 lbs N/acre		3.57	5.18	5.00	6.16	4.98
125.0 lbs N/acre		3.71	4.73	4.60	6.83	4.97
250.0 lbs N/acre		3.62	5.94	4.24	7.10	5.22
Big bluestem						
0.0 lbs N/acre	3.04	2.77	4.78	3.26	3.75	3.64
62.5 lbs N/acre		3.08	4.78	3.71	4.96	4.13
125.0 lbs N/acre		2.86	5.09	3.44	5.54	4.23
250.0 lbs N/acre		3.66	5.31	3.08	6.38	4.61
Chariton						
Alfalfa						
2-cut		3.04	4.42	3.30	3.97	3.90
3-cut		3.39	4.91	4.06	2.99	3.99
Reed canarygrass						
0.0 lbs N/acre			3.17	2.14	2.81	2.71
62.5 lbs N/acre			5.04	3.53	3.53	4.03
125.0 lbs N/acre			5.27	4.42	4.87	4.85
250.0 lbs N/acre			5.85	4.69	5.71	5.42
Switchgrass						
0.0 lbs N/acre	2.59		2.59	3.48	4.33	3.47
62.5 lbs N/acre			2.95	3.97	5.54	4.15
125.0 lbs N/acre			3.71	4.78	7.05	5.18
250.0 lbs N/acre			3.71	4.87	7.77	5.45
Big bluestem						
0.0 lbs N/acre		1.38	3.26	2.46	2.59	2.77
62.5 lbs N/acre		1.38	4.33	2.46	4.11	3.63
125.0 lbs N/acre		1.29	4.20	2.86	4.69	3.91
250.0 lbs N/acre		1.34	4.20	2.46	5.71	4.12

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C2 Annual dry matter yield of monocrop sorghum.

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Average
			Ames			
Sweet sorghum						
0.0 lbs N/acre	6.74	7.28	5.09	6.03	3.84	5.79
62.5 lbs N/acre	6.83	7.19	6.83	7.46	7.90	7.24
125.0 lbs N/acre	7.81	6.83	9.24	7.37	7.77	7.80
250.0 lbs N/acre	7.46	6.70	8.75	7.28	7.32	7.50
Sorghum x sudangrass						
0.0 lbs N/acre	6.43	5.85	4.82	6.38	5.13	5.72
62.5 lbs N/acre	6.07	6.56	5.09	7.28	6.74	6.35
125.0 lbs N/acre	6.52	7.28	6.83	7.46	6.96	7.01
250.0 lbs N/acre	6.56	7.32	7.54	6.29	7.46	7.04
			Chariton			
Sweet sorghum						
0.0 lbs N/acre	7.95	7.19	7.32	6.03	3.88	6.47
62.5 lbs N/acre	7.50	7.05	9.24	7.90	7.19	7.78
125.0 lbs N/acre	7.99	6.96	10.22	7.50	7.46	8.03
250.0 lbs N/acre	8.62	7.32	8.53	7.68	7.37	7.90
Sorghum x sudangrass						
0.0 lbs N/acre	5.71	6.74	8.17	6.29	3.88	6.16
62.5 lbs N/acre	6.29	6.34	9.11	7.37	7.90	7.40
125.0 lbs N/acre	6.21	6.03	9.73	7.32	7.77	7.41
250.0 lbs N/acre	7.01	6.29	10.13	7.54	7.59	7.71

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C3 Annual dry matter yield of sweet sorghum/rye double crop.

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Average
			Ames			
Sweet sorghum						
0.0 lbs N/acre	2.14	3.48	4.38	2.95	4.46	3.48
62.5 lbs N/acre	2.99	5.27	5.22	4.20	5.67	4.67
125.0 lbs N/acre	3.04	6.07	6.25	6.92	6.38	5.73
250.0 lbs N/acre	2.99	6.61	6.83	6.74	7.28	6.09
Rye						
0.0 lbs N/acre	1.92	1.03	0.80	1.47		1.31
62.5 lbs N/acre	2.23	1.79	1.79	2.14		1.99
125.0 lbs N/acre	2.32	2.41	2.50	2.23		2.37
250.0 lbs N/acre	2.50	3.08	2.41	2.50		2.62
Total						
0.0 lbs N/acre	4.06	4.51	5.18	4.42		4.54
62.5 lbs N/acre	5.22	7.05	7.01	6.34		6.41
125.0 lbs N/acre	5.36	8.48	8.75	9.15		7.94
250.0 lbs N/acre	5.49	9.69	9.24	9.24		8.42
			Chariton			
Sweet sorghum						
0.0 lbs N/acre	2.59	4.20	3.75	3.08	2.72	3.27
62.5 lbs N/acre	2.28	4.15	3.75	5.98	4.38	4.11
125.0 lbs N/acre	2.19	4.15	6.29	6.74	5.31	4.94
250.0 lbs N/acre	2.63	4.64	8.66	7.68	6.61	6.04
Rye						
0.0 lbs N/acre	2.01	1.07	1.79	2.14	1.25	1.65
62.5 lbs N/acre	2.14	1.12	2.90	2.41	0.89	1.89
125.0 lbs N/acre	2.10	1.16	3.13	2.77	1.03	2.04
250.0 lbs N/acre	2.46	1.07	3.21	2.86	0.94	2.11
Total						
0.0 lbs N/acre	4.60	5.27	5.54	5.22	3.97	4.92
62.5 lbs N/acre	4.42	5.27	6.65	8.39	5.27	6.00
125.0 lbs N/acre	4.29	5.31	9.42	9.51	6.34	6.97
250.0 lbs N/acre	5.09	5.71	11.88	10.54	7.54	8.15

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C4 Annual dry matter yield of sorghum x sudangrass/rye double crop.

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Average
			Ames			
Sorghum x sudangrass						
0.0 lbs N/acre	2.14	3.35	3.35	2.95	3.48	2.95
62.5 lbs N/acre	3.04	5.31	4.60	3.79	6.07	4.19
125.0 lbs N/acre	3.88	6.52	5.27	4.33	6.92	5.00
250.0 lbs N/acre	4.73	8.04	7.05	6.03	7.54	6.46
Rye						
0.0 lbs N/acre	2.14	0.80	0.71	1.03		1.17
62.5 lbs N/acre	2.28	1.38	1.70	1.56		1.73
125.0 lbs N/acre	2.37	2.01	2.01	2.01		2.10
250.0 lbs N/acre	2.59	1.92	2.72	2.63		2.47
Total						
0.0 lbs N/acre	4.29	4.15	4.06	3.97		4.12
62.5 lbs N/acre	5.31	6.70	6.29	5.36		5.92
125.0 lbs N/acre	6.25	8.53	7.28	6.34		7.10
250.0 lbs N/acre	7.32	9.96	9.78	8.66		8.93
			Chariton			
Sorghum x sudangrass						
0.0 lbs N/acre	2.99	4.06	2.90	2.81	3.39	3.23
62.5 lbs N/acre	2.95	5.09	3.75	4.64	3.75	4.04
125.0 lbs N/acre	2.86	5.27	5.76	5.67	4.96	4.90
250.0 lbs N/acre	3.08	5.13	7.59	6.65	6.16	5.72
Rye						
0.0 lbs N/acre	1.56	0.80	1.34	1.92	1.25	1.38
62.5 lbs N/acre	2.01	1.03	2.95	2.41	0.89	1.86
125.0 lbs N/acre	2.23	0.98	3.04	2.72	1.03	2.00
250.0 lbs N/acre	2.50	1.21	3.17	2.95	0.94	2.15
Total						
0.0 lbs N/acre	4.55	4.87	4.24	4.73	4.64	4.61
62.5 lbs N/acre	4.96	6.12	6.70	7.05	4.64	5.89
125.0 lbs N/acre	5.09	6.25	8.79	8.39	5.98	6.90
250.0 lbs N/acre	5.58	6.34	10.76	9.60	7.10	7.88

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C5 Annual dry matter yield of monocrop sweet sorghum and sweet sorghum/rye double crop in rotation.

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Average
			Ames			
Sweet sorghum						
62.5 lbs N/acre		6.56	8.79	5.94	8.17	7.37
125.0 lbs N/acre		8.44	8.08	6.29	8.89	7.93
Sweet sorghum/rye						
Sweet sorghum						
62.5 lbs N/acre		6.83	6.96	5.58	7.59	6.74
125.0 lbs N/acre		7.10	7.50	5.94	8.21	7.19
Rye						
62.5 lbs N/acre		2.55	2.15	2.51		2.40
125.0 lbs N/acre		2.55	2.32	2.48		2.45
Total						
62.5 lbs N/acre		9.38	9.11	8.09		8.86
125.0 lbs N/acre		9.65	9.82	8.42		9.30
			Chariton			
Sweet sorghum						
62.5 lbs N/acre		6.56	9.64	6.74	8.35	7.82
125.0 lbs N/acre		6.38	10.27	8.48	7.81	8.24
Sweet sorghum/rye						
Sweet sorghum						
62.5 lbs N/acre		4.64	6.16	7.68	7.28	6.44
125.0 lbs N/acre		5.40	8.71	9.02	8.48	7.90
Rye						
62.5 lbs N/acre		1.38	2.94	2.43	0.97	1.93
125.0 lbs N/acre		1.39	2.92	2.47	1.13	1.98
Total						
62.5 lbs N/acre		6.02	9.10	10.11	8.25	8.37
125.0 lbs N/acre		6.79	11.63	11.49	9.61	9.88

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C6 Annual grain and dry matter (stover) yield of corn.

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Average
			Ames			
Grain						
0.0 lbs N/acre	1.50	2.19	1.21	0.97	1.09	1.39
62.5 lbs N/acre	1.94	3.20	2.59	1.58	1.54	2.17
125.0 lbs N/acre	2.71	3.77	3.20	1.90	1.90	2.70
250.0 lbs N/acre	2.79	4.25	3.44	1.90	2.19	2.91
Stover						
0.0 lbs N/acre	1.79	2.28	3.62	2.14	2.59	2.48
62.5 lbs N/acre	1.70	3.21	3.88	2.81	2.01	2.72
125.0 lbs N/acre	2.50	3.84	3.88	3.04	3.13	3.28
250.0 lbs N/acre	2.23	3.75	4.55	3.26	3.08	3.38
			Chariton			
Grain						
0.0 lbs N/acre	1.17	0.89	1.94	1.58	1.66	1.45
62.5 lbs N/acre	1.26	1.05	1.46	1.50	2.11	1.48
125.0 lbs N/acre	1.17	1.05	2.35	1.86	2.19	1.72
250.0 lbs N/acre	1.17	0.89	1.86	2.19	2.11	1.64
Stover						
0.0 lbs N/acre	2.05	1.88	2.99	2.63	2.86	2.48
62.5 lbs N/acre	1.88	1.79	2.41	2.68	2.90	2.33
125.0 lbs N/acre	1.96	2.01	3.71	3.39	3.08	2.83
250.0 lbs N/acre	2.19	1.88	4.38	3.75	2.95	3.03

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C7 Annual dry matter yield of intercrop systems.

Species	Yield (tons/acre)					
	1988	1989	1990	1991	1992	Mean
			Ames			
Alfalfa/sweet sorghum						
62.5 lbs N/acre		7.54	6.65	7.77	4.96	6.73
125.0 lbs N/acre		7.10	6.92	8.04	5.31	6.84
Alfalfa/sorghum x sudangrass						
62.5 lbs N/acre		8.08	6.07	7.63	4.60	6.60
125.0 lbs N/acre		7.28	6.88	7.63	4.87	6.66
Reed canarygrass/sweet sorghum						
62.5 lbs N/acre		3.35	3.66	4.87	3.26	3.78
125.0 lbs N/acre		4.24	4.64	6.03	4.24	4.79
Reed canarygrass/sorghum x sudangrass						
62.5 lbs N/acre		3.84	3.75	4.78	3.17	3.88
125.0 lbs N/acre		4.51	4.51	6.03	4.42	4.87
			Chariton			
Alfalfa/sweet sorghum						
62.5 lbs N/acre		4.24	5.22			4.73
125.0 lbs N/acre		4.55	5.98			5.27
Alfalfa/sorghum x sudangrass						
62.5 lbs N/acre		4.51	6.29			5.40
125.0 lbs N/acre		4.42	6.88			5.65

Source: Anderson, I. C., Buxton, D. R., and Hallam, J. A., 1994. Selection of Herbaceous Energy Crops for the Western Corn Belt, Oak Ridge, TN: ORNL.

Table C8 Average statistics for perennial grasses over years of experiments

	Average	Standard Deviaton	Coefficient of variation	Average	Standard Deviaton	Coefficient of variation
		Ames			Chariton	
Alfalfa						
2-cut	4.54	0.33	0.07	3.90	0.56	0.14
3-cut	4.85	0.93	0.19	3.99	0.96	0.24
Reed canarygrass						
0 lbs N/acre	1.82	0.62	0.34	2.71	0.52	0.19
62.5 lbs N/acre	2.71	0.54	0.20	4.03	0.88	0.22
125 lbs N/acre	3.67	0.66	0.18	4.85	0.42	0.09
250 lbs N acre	5.06	0.43	0.09	5.42	0.64	0.12
Switchgrass						
0 lbs N/acre	2.71	0.58	0.21	3.47	0.87	0.25
62.5 lbs N/acre	4.98	1.07	0.21	4.15	1.30	0.31
125 lbs N/acre	4.97	1.32	0.27	5.18	1.71	0.33
250 lbs N acre	5.22	1.59	0.30	5.45	2.09	0.38
Big bluestem						
0 lbs N/acre	3.64	0.86	0.24	2.77	0.43	0.16
62.5 lbs N/acre	4.13	0.89	0.22	3.63	1.02	0.28
125 lbs N/acre	4.23	1.29	0.30	3.91	0.95	0.24
250 lbs N acre	4.61	1.51	0.33	4.12	1.63	0.40

Table C9 Average statistics for monocrop sorghum systems over years of experiments

	Average	Standard Deviaton	Coefficient of variation	Average	Standard Deviaton	Coefficient of variation
		Ames			Chariton	
Sweet sorghum						
0 lbs N/acre	5.79	1.37	0.24	6.47	1.60	0.25
62.5 lbs N/acre	7.24	0.40	0.06	7.78	0.88	0.11
125 lbs N/acre	7.80	0.90	0.11	8.03	1.28	0.16
250 lbs N acre	7.50	0.76	0.10	7.90	0.63	0.08
Sorghum x sudangrass						
0 lbs N/acre	5.72	0.73	0.13	6.16	1.56	0.25
62.5 lbs N/acre	6.35	0.83	0.13	7.40	1.17	0.16
125 lbs N/acre	7.01	0.37	0.05	7.41	1.49	0.20
250 lbs N acre	7.04	0.57	0.08	7.71	1.45	0.19

Table C10 Average statistics of doublecrop systems over years of experiments

	Average	Standard Deviaton	Coefficient of variation	Average	Standard Deviaton	Coefficient of variation
		Ames			Chariton	
Sweet sorghum						
0 lbs N/acre	3.48	0.98	0.28	3.27	0.69	0.21
62.5 lbs N/acre	4.67	1.08	0.23	4.11	1.33	0.32
125 lbs N/acre	5.73	1.54	0.27	4.94	1.83	0.37
250 lbs N acre	6.09	1.75	0.29	6.04	2.42	0.40
Rye						
0 lbs N/acre	1.31	0.49	0.38	1.65	0.47	0.28
62.5 lbs N/acre	1.99	0.23	0.12	1.89	0.86	0.45
125 lbs N/acre	2.37	0.12	0.05	2.04	0.94	0.46
250 lbs N acre	2.62	0.31	0.12	2.11	1.04	0.49
Total						
0 lbs N/acre	4.54	0.47	0.10	4.92	0.63	0.13
62.5 lbs N/acre	6.41	0.85	0.13	6.00	1.56	0.26
125 lbs N/acre	7.94	1.74	0.29	6.97	2.39	0.34
250 lbs N acre	8.42	1.96	0.23	8.15	2.97	0.36
Sorghum x sudangrass						
0 lbs N/acre	2.95	0.55	0.19	3.23	0.51	0.16
62.5 lbs N/acre	4.19	1.20	0.29	4.04	0.84	0.21
125 lbs N/acre	5.00	1.32	0.26	4.90	1.19	0.24
250 lbs N acre	6.46	1.32	0.20	5.72	1.72	0.30
Rye						
0 lbs N/acre	1.17	0.66	0.56	1.38	0.41	0.30
62.5 lbs N/acre	1.73	0.39	0.22	1.86	0.89	0.48
125 lbs N/acre	2.10	0.18	0.09	2.00	0.95	0.48
250 lbs N acre	2.47	0.37	0.15	2.15	1.02	0.47
Total						
0 lbs N/acre	4.12	0.13	0.03	4.61	0.23	0.05
62.5 lbs N/acre	5.92	0.69	0.12	5.89	1.06	0.18
125 lbs N/acre	7.10	1.06	0.15	6.90	1.61	0.23
250 lbs N acre	8.93	1.21	0.14	7.88	2.21	0.28

Table C11 Average statistics for the rotation systems over years of experiments

	Average	Standard Deviaton	Coefficient of variation	Average	Standard Deviaton	Coefficient of variation
		Ames			Chariton	
Sweet sorghum						
62.5 lbs N/acre	7.37	1.34	0.18	7.82	1.45	0.19
125 lbs N/acre	7.93	1.14	0.14	8.24	1.61	0.20
Sweet sorghum						
62.5 lbs N/acre	6.74	0.84	0.12	6.44	1.36	0.21
125 lbs N/acre	7.19	0.95	0.13	7.90	1.68	0.21
Rye						
62.5 lbs N/acre	2.40	0.22	0.09	1.93	0.91	0.47
125 lbs N/acre	2.45	0.12	0.05	1.98	1.86	0.43
Total						
62.5 lbs N/acre	8.86	0.68	0.08	8.37	1.74	1.01
125 lbs N/acre	9.30	0.76	0.82	9.88	2.26	1.03

Table C12 Average statistics for corn over years of experiments

	Average ton/acre	Standard Deviaton	Coefficient of variation	Average	Standard Deviaton	Coefficient of variation
		Ames			Chariton	
Corn (grain)						
0 lbs N/acre	1.40	0.49	0.35	1.45	0.42	0.29
62.5 lbs N/acre	2.17	0.71	0.33	1.49	0.40	0.27
125 lbs N/acre	2.70	0.82	0.30	1.72	0.59	0.34
250 lbs N acre	2.9	0.95	0.33	1.64	0.58	035
Corn (stover)						
0 lbs N/acre	2.48	0.70	0.28	2.48	0.49	0.20
62.5 lbs N/acre	2.72	0.89	0.33	2.33	0.49	0.21
125 lbs N/acre	3.28	0.59	0.18	2.83	0.80	0.28
250 lbs N acre	3.38	0.86	0.25	3.03	1.05	0.35

Table C13 Average statistics for intercrop systems over years of experiments

	Average ton/acre	Standard Deviaton	Coefficient of variation	Average	Standard Deviaton	Coefficient of variation
		Ames			Chariton	
AL/SS						
62.5 lbs N/acre	6.73	1.16	0.17	4.73	0.69	0.15
125 lbs N/acre	6.84	1.12	0.16	5.27	1.01	0.19
AL/SSH						
62.5 lbs N/acre	6.60	1.26	0.19	5.40	1.26	0.23
125 lbs N/acre	6.66	1.17	0.18	5.65	1.17	0.31
RC/SS						
62.5 lbs N/acre	3.78	0.74	0.20			
125 lbs N/acre	4.79	0.85	0.18			
RC/SSH						
62.5 lbs N/acre	3.88	0.67	0.17			
125 lbs N/acre	4.87	0.77	0.16			

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Now it is time to move on and do good for myself and for others. It is time to follow the examples set by many people helped me. It is the time to "pass it on."

I would like to dedicate this dissertation to my daughter, *Ji-Ah*.