An Assessment of the Impact of Landscape Soil, Government Programs and Crop Insurance on the Profitability of Perennial Grass Cropping Systems Grown for Bioenergy

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By

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The undersigned, appointed by the dean of the Graduate School,

have examined the Thesis entitled

AN ASSESSMENT OF THE IMPACT OF LANDSCAPE SOIL, GOVERNMENT PROGRAMS AND CROP INSURANCE ON THE PROFITABILITY OF PERENNIAL GRASS CROPPING SYSTEMS GROWN FOR BIOENERGY

Presented by Joseph P. Dolginow

A candidate for the degree of

Master of Science

And hereby certify that, in their opinion, it is worthy of acceptance.

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Dr. Raymond Massey, Agricultural Economics

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ABSTRACT

Cellulosic biomass is among the most promising alternatives to fossil fuels being considered in Missouri. In order to become a viable energy source, there needs to be a reliable supply of cellulosic material. Miscanthus, switchgrass, or a native prairie mix are posed to meet that supply. This study analyzes the profitability of those three cropping systems when grown for bioenergy relative to corn and soybeans. It uses a stochastic budgeting model with actual grain yields, FAPRI baseline prices, and ALMANAC modeled grass yields to demonstrate how landscape soils, government programs like Biomass Crop Assistance Program (BCAP), and crop insurance affect the decision to plant bioenergy crops. The analysis assumes that the producers are risk averse and seek to maximize utility. Results show that perennial grasses grown for bioenergy have a higher relative profitability on flooded Belknap soils and Armstrong and Armster eroded upland soils versus Putnam soil which is non-eroded and upland, that government support increases profitability of these bioenergy crops but not enough for utility maximizing producers to choose them, and crop insurance decreases the likelihood of planting them by mitigating the risks associated with corn and soybeans.

1 INTRODUCTION

The United States currently relies on fossil fuels to meet most of our energy needs; however, concerns about rising prices, greenhouse gas (GHG) emissions, political instability in exporting regions and increasingly scarce supplies has motivated research into viable substitutes. Bioenergy is among the most promising alternatives being considered; this energy source is renewable, domestically produced, can diversify rural economies, and potentially release less GHGs. Still, doubts exist about their sustainability and potential to help meet our future energy demands. Corn (*Zea mays*) has been considered a good feedstock for bioenergy purposes but now questions exist about its viability.

Now, Missouri, among other states, has an emerging cellulosic-based bioenergy industry using C4 warm-season perennial grasses including miscanthus (*Miscanthus × giganteus*), switchgrass (*Panicum virgatum*), and a polyculture of a native grasses and legumes such as Illinois bundleflower (*Desmanthus illinoensis*), partridge pea (*Chamaecrista fasciculate*) and tic tree foil (*Desmodium Canadense*). The United States Department of Agriculture (USDA) has incentivized the planting of these grasses through BCAP as a part of a greater effort to stimulate cellulosic bioenergy production and wean the country off of foreign and/or traditional fossil fuels energy sources. Producers across the state of Missouri have benefited from this assistance.

A dependable and consistent feedstock biomass supply is a necessary condition for the development of a cellulosic-based bioenergy market in Missouri. However, utility maximizing producers will not be willing to supply that feedstock if they cannot be assured of returns comparable to those of corn and soybeans *(Glycine max)*, the two most commonly grown crops in northeast Missouri. Understanding the factors affecting the relative profitability of each system can serve three purposes: help producers make a more informed decision about whether or not to plant these perennial grasses, help producers know what type of soil within their landscape these bioenergy crops perform best economically, and help the government design better assistance programs. Also, if the United States government is truly committed to establishing this industry and meeting bioenergy mandates set by the Renewable Fuel Standard (RFS), insights from this thesis can help overcome obstacles to achieving those goals.

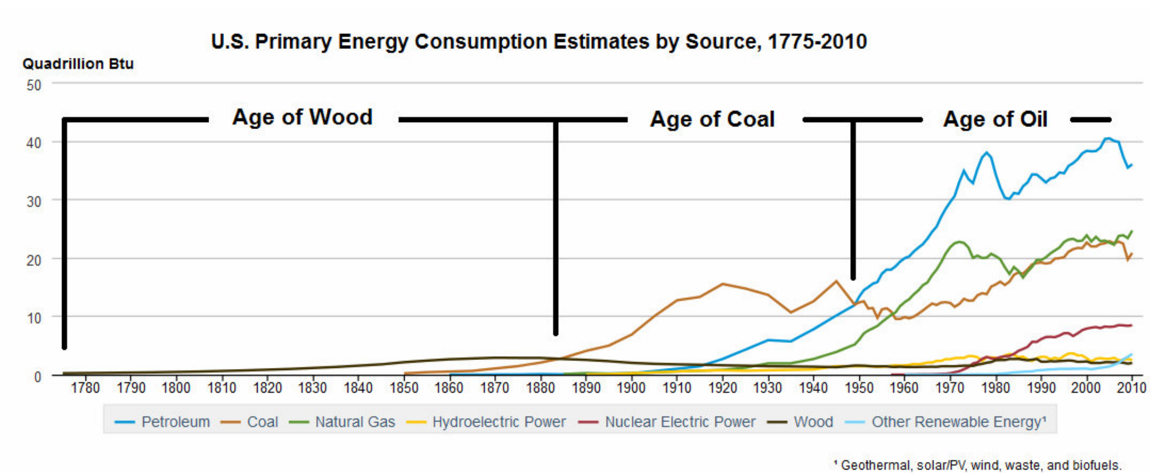
The primary objective of this thesis is to investigate the impact of landscape soils, government programs and crop insurance on the economic decision to grow dedicated bioenergy crops. It examines three bioenergy cropping systems, miscanthus as a monoculture, switchgrass as a monoculture, and native prairie compared to corn and soybeans. The conclusions are made based on a model which simulated 1000 different yields and prices and the resulting profits. Stochastic variables include corn and soybeans yields from different landscape soils, corn and soybean prices, and grass yields.

The thesis is divided into five parts. First, bioenergy is explained in the context of the United States. This first part includes an explanation of the policies supporting bioenergy, and the bioenergy cropping systems examined in this thesis. Second, the relevant literature, including that addressing the profitability of bioenergy crop and how crop insurance can affect decision-making, is reviewed. The next section is the theoretical framework of the model. The fourth part discusses the data and procedures in detail. Last, the results and conclusions are explained.

2 CONTEXT

2.1 Development of Bioenergy in the United States

Energy production in the United States has evolved over the past century and will continue to do so. Figure 2.1 adopted from EIA (2011) depicts the evolution of primary energy sources in the United States since 1775. Originally, wood met most of our energy needs. In the 1880s, coal was introduced and grew to provide most of the energy until oil surpassed it around 1950. In the 20th century, natural gas and hydroelectric also entered the picture. Later, nuclear and renewables including geothermal, solar, wind, and biofuels joined the portfolio of potential energy sources. In the 21st century, the United States continues to expand that portfolio in an effort to find a mix of sources that meets our growing demand at competitive prices without depleting resources, degrading our environment or exacerbating social problems.



2.1: Primary energy sources in the United States from 1780 until 2010

Growing cellulosic material or biomass could be an important contributor to energy production in the 21st century. Biomass can be pelletized and burned to produce electricity or converted into liquid fuels and used in transportation or transformed into syngas. Recently, bioenergy from cellulosic material has gained attention as it can substitute for two of the more controversial energy sources, coal and petroleum. In addition, cellulosic bioenergy relies on renewable resources, can be produced domestically, offers an opportunity to diversify rural economies, and can potentially decrease emissions of GHGs.

Converting crops into energy is not new. Figure 2.1 shows wood has been an important source of energy in the United States since its founding. Typically, wood has been burned as a source of heat. Commercial-scale bioenergy is not new either. Converting corn into ethanol dates back to the Model T (Solomon, Barnes, and Halvorsen 2007); however, leaded gasoline distilled from petroleum became the standard. By World War II, new sources of inexpensive petroleum deterred research into substitutes. Similarly, the abundance of coal within the United States and its relatively inexpensive price has made coal a choice energy source since its introduction.

Government policies began to revive the ethanol industry in the 1970s largely as a response to the Organization of the Petroleum Exporting Countries (OPEC) price controls, environmental concerns, and to stimulate a domestic industry (Solomon, Barnes, and Halvorsen 2007). Through the Energy Tax Act of 1978, ethanol which at the time was only made from corn, received exemption from the $0.40 per gallon gasoline tax. Similar exemptions, subsidies, and regulations kept ethanol processors afloat through the 1980s and 1990s despite low prices in petroleum and some weak corn harvests (Solomon, Barnes, and Halvorsen 2007). Production grew only slightly and in one year (1996) dropped.

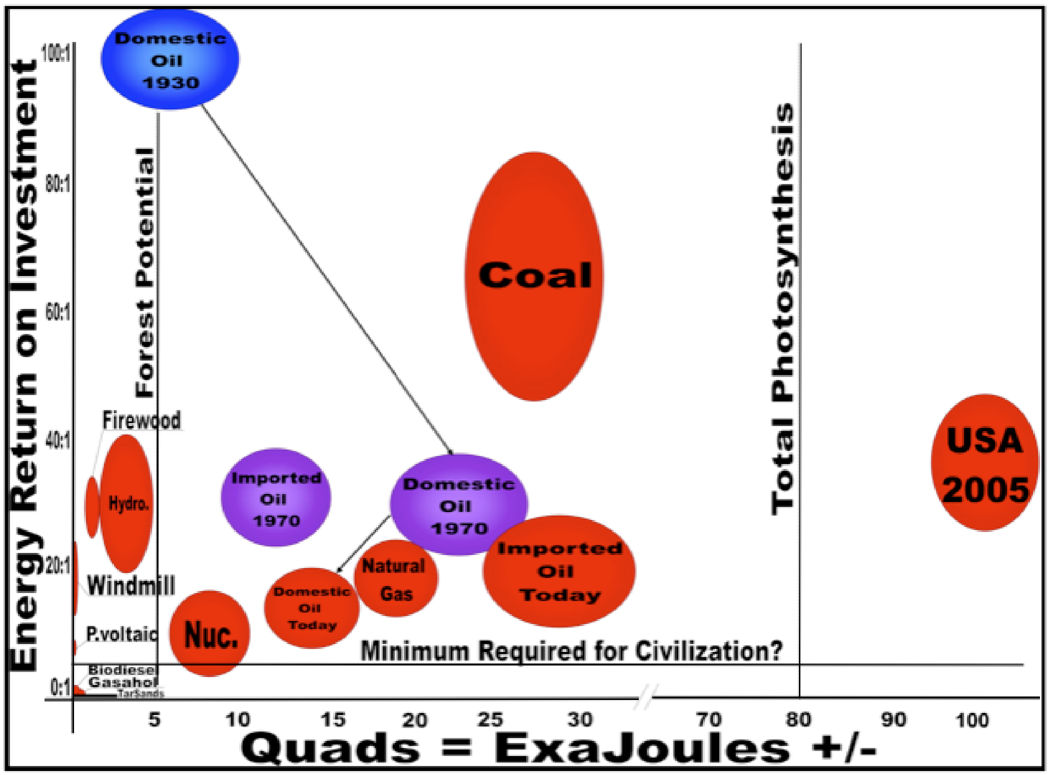
In the 2000s, corn ethanol greatly expanded. In 2011, the United States produced 13,900 million gallons of ethanol representing a significant increase from 2001 when 1,765 million gallons were produced (EIA 2011). Higher oil prices, restrictions on methyl tert-butyl ether (MTBE) in gasoline and the Volumetric Ethanol Tax Credit introduced in 2004 help stimulate the industry (Solomon, Barnes, and Halvorsen 2007).

With the expansion and market changes in the past ten years, corn ethanol faced criticism particularly from environmentalists on four fronts: low net energy yield, changes in land use, taking food to make fuels, and production issues. The first concern is that corn ethanol was found to yield very little or no energy output when considering the amount of input. The energy return on investment (EROI) reports the amount of energy output divided by the amount of nonrenewable energy input needed to produce that energy. A higher EROI is more desirable as it shows its relative efficiency in producing energy. Since EROI is a ratio, the measurement does not have units and can be compared across energy sources. A ratio of one means the energy output equals amount of nonrenewable energy used to produce the energy. The following equation sums up EROI (Hammerschlag 2006):

$$EROI = Eout \ / \ E \ in, nonrenewable$$

This index is calculated at a particular time and will undoubtedly change with resource depletion and technological improvements (Hall, Balogh, and Murphy 2009).

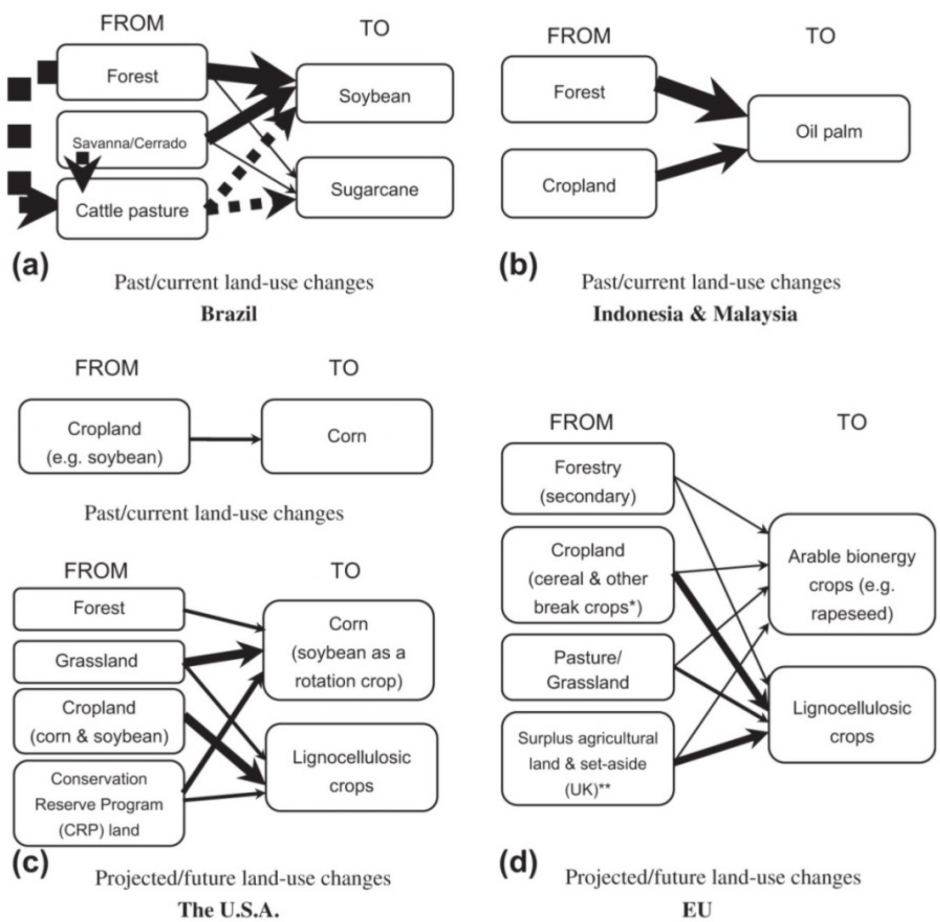
The EROI varies between 0.84 and 1.65 across six studies for corn ethanol (Hammerschlag 2006). Difference in these numbers is due to procedural, boundary, and quality adjustment differences among researchers (Hall, Dale, and Pimentel 2011).



2.2: EROI of different energy sources and amount of energy each source produces in the United States

Figure 2.2 adapted from Hall, Balogh, and Murphy (2009) provides some comparison of the EROI of energy sources. The ovals represent energy sources with the vertical axis the EROI and horizontal axis the amount of energy they supply to the United States. The size of the oval represents the relative uncertainty in each calculation for that energy source. Domestic oil in the 1930s, domestic oil in the 1970s, and imported oil in 1970s are exhausted; thus, those circles just give an idea of how EROI has changed. Domestic oil had a higher EROI in 1930 than it currently does, and the arrows show that evolution. The ratio calculated for domestic coal is 70 and provides the United States with 25 exajoules of energy. Domestic oil is between 11 and 18 depending on the extraction method (Hall, Balogh, and Murphy 2009) and provides less than 15 exajoules. Near the origin, in the lower left corner, are two bioenergy sources: biodiesel and gasohol, which is ethanol. Their ratio is significantly lower due to the amount of inputs such as herbicides, diesel, and fertilizer required to grow corn and the amount of energy needed to convert the grain into ethanol. Furthermore, they provide relatively little energy versus the other sources discussed. Relative to the energy in those inputs, corn ethanol yields little, if any, energy.

In addition to the energy balance questions, criticisms about GHG emissions exist. Central to determining whether bioenergy results in more or less GHG emissions is indirect land use changes (iLUC). In 2008, Searchinger et al. (2008) wrote a widely cited article which included GHG emissions associated with changes in land use in developing countries. Subsequent studies (Di Lucia, Ahlgren, and Ericsson 2012; Plevin et al. 2010; Melillo et al. 2009) back his findings even though criticism and evidence to the contrary exists (Mathews and Tan 2009). Searchinger et al. (2008) finds that bioenergy increases GHG emissions by 100 percent for corn ethanol and 50 percent for cellulosic ethanol. The theory behind iLUC is that bioenergy drives up the price of corn. As corn prices increase because of higher demand, farmers plant more corn driving down the production of wheat and soybeans. With less wheat and soybeans production, prices go up, and exports from the United States decrease. Farmers elsewhere who have the ability to grow these crops react by planting more land with these crops. Those farmers tend to be in countries like Brazil, Indonesia, and Malaysia where there is available but undeveloped arable land and the necessary resources to grow commodity row crops or oil crops competitively. The GHGs are emitted when forested or savannah lands are cleared and tilled into cropland. For example, the once forested region of Mato Grosso in Brazil has proven to be productive cropland for growing soybeans (Elizabeth et al. 2010).



2.3: The countries or regions where land use change would occur, the type of land that would be converted, and the magnitude reflected in the size of the arrows

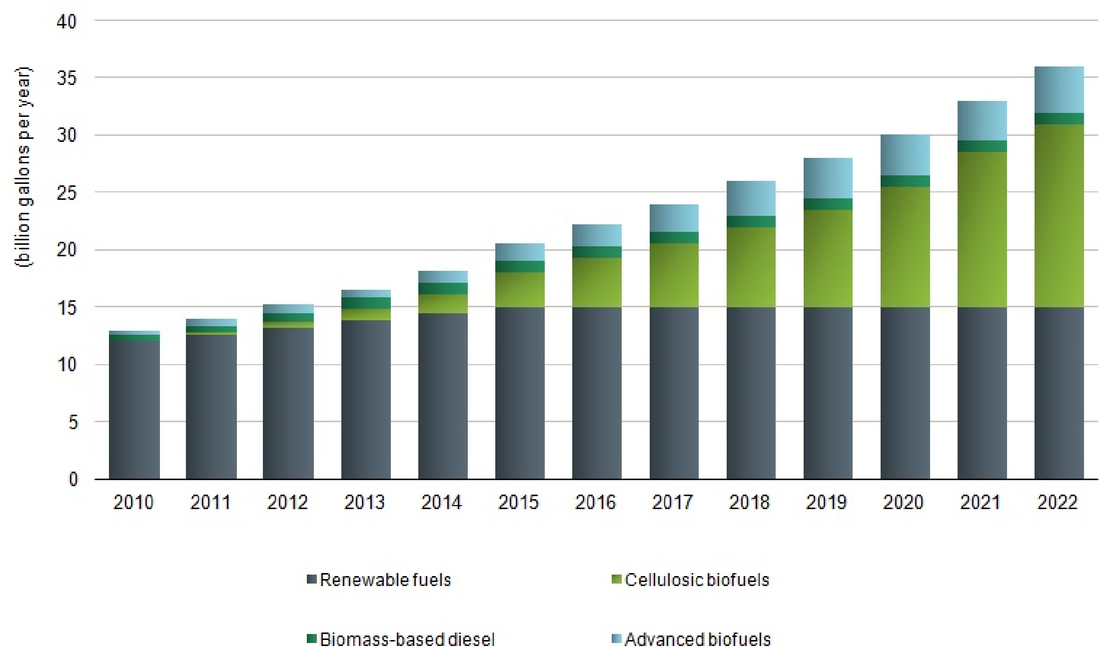
Figure 2.3 adapted from Miyake et al. (2012) deconstructs iLUC resulting from bioenergy production in the United States and Europe. Although the figure includes details beyond the scope of this paper, it highlights the major changes expected to occur: forest and savannah in Brazil converted to produce soybeans and more land in the United States producing corn.

Beyond iLUC, criticisms exist about diverting land out of food production. With a growing global population and only a limited amount of arable land, meeting the food demand will become increasingly difficult. Diverting land to produce energy could exacerbate those difficulties. A World Bank study details them as faced by impoverished countries as a result of increasing food prices and links those higher prices to production of bioenergy crops (Mitchel 2008).

Growing corn or soybeans in a monoculture can have detrimental effects on the local ecosystem reducing biodiversity for both vegetation and wildlife (McLaughlin and Walsh 1998). Growing annual row crops can also have detrimental hydraulic effects on soil quality (Jiang et al. 2007). In addition, farmers will use a mix of fertilizers, herbicides, and pesticides to grow corn. These chemicals can be harmful to local water sources if runoff occurs and often result in more GHG emissions as these inputs are energy intensive and derived from fossil fuels (Jiang et al. 2007).

The 2006 State of the Union speech, given by President George Bush, and resulted in policies that gave impetus to bioenergy from feedstock other than grains or oilseeds. Research existed prior to that speech; however, beginning with that State of the Union, the government devoted more resources to cellulosic bioenergy. The president said, “we'll also fund additional research in cutting-edge methods of producing ethanol, not just from corn but from wood chips and stalks or switchgrass. Our goal is to make this new kind of ethanol practical and competitive” (Bush 2006).

In 2006 and 2007, government policies began incorporating what President Bush said in his speech. The Advanced Energy Initiative (AEI) allotted funds towards research of clean transportation and stationary power energy. Research into cellulosic materials that could be converted into ethanol received special attention (Milliken et al. 2007). More importantly, Congress passed the Energy Independence and Security Act (EISA) in 2007 establishing production mandates for transportation fuels from bio-materials (Scarlat and Dallemand 2011). This standard, which is administered by the Environmental Protection Agency (EPA), is known as the Renewable Fuel Standard 2 (RFS2).



2.4: RFS mandates for each type of transportation fuel

Figure 2.4 depicts the amount of renewable transportation fuels RFS2 mandates. Actual bioenergy production has been mostly in the form of corn ethanol. It shows the mandate for bioenergy production at 36 billion gallons by 2022. RFS2 has corn ethanol quantity leveling off at 15.0 billion gallons in 2015, only slightly more than the 13.2 billion gallons produced in 2012. Figure 2.4 also shows how production of non-corn starch bioenergy will increase to 21.0 billion gallons in 2022 with 16.0 billion gallons coming from cellulosic ethanol and 4.0 billion gallons coming from other sources (Schnepf 2011). These sources must be derived from feedstock and processes with lower GHG emissions, according a lifecycle analysis, than corn ethanol (Scarlat and Dallemand 2011).

Evidence strongly suggests that energy derived from perennial grasses produces less GHGs than energy derived from corn starch. Two notable emission sources of corn ethanol are iLUC and inputs derived from fossil fuels. Fargione et al. (2008) evaluates iLUC for different bioenergy situations finding that ethanol derived from perennial grasses grown on degraded soils “could spare the destruction of native ecosystems and reduce GHG emissions”.

Beyond reducing estimated iLUC effects, perennial grass cropping systems being researched require fewer inputs leading to additional reductions in GHG emissions. Planting, spraying, harvesting, and transporting corn requires diesel fuel. Perennials grown for bioenergy purposes are not planted annually. Also, they do not require spraying after establishment. Corn requires more nitrogen fertilizer, which is a product of a fossil fuels. If the plant or soil does not absorb that nitrogen, it can be released into the atmosphere emitting GHGs. With perennials, that likelihood is reduced because there are fewer inputs (Heaton, Dohleman, and Long 2008).

Additionally, perennial grasses sequester carbon in their root system decreasing atmospheric carbon dioxide, which is a GHG. Sequestering carbon into soils is one way in which agricultural lands can reduce the amount of GHGs (McCarl and Schneider 2000). Perennial grasses establish a deep root system comprised largely of carbon elements. Lal (2004) discusses the possibilities of carbon sequestration in degraded soils arguing that there is great potential for mitigating increasing levels of atmospheric carbon dioxide while rejuvenating those soils. That study calculates that carbon sequestration removes 0.4 to 1.2 gigatons of carbon from the atmosphere per year, which would offset 5 to 15 percent of global emissions from fossil fuels.

2.2 Cropland in Northeast Missouri

Northeast Missouri has suitable cropland for the production of perennial grasses. The central claypan region, or Major Land Resource Area (MLRA) 113, comprises more than 8 million acres of “marginally productive, highly erodible land” of which roughly one-third is in Missouri with the rest in southern Illinois (Landers et al. 2012). Similarities in the soil profile define this cropland and, depending on the particular soil, its agricultural productivity. The soil has a well-defined argillic horizon or claypan usually underneath a layer of more productive topsoil. The amount of top soil often depends on slope of the landscape and its history of grain cropping (Landers et al. 2012); however, the top soil and claypan below it affect productivity of corn and soybeans by limiting water inflitration and plant available nutrients (Landers et al. 2012). Currently, claypan soil fields are cropped in corn, soybeans, and other annual grain crops despite those limiting factors. Perennial grasses with their stronger root structure largely overcome problems associated with the claypan and could potentially grow well there (Jiang et al. 2007).

Similarly, cropland located in floodplains also offers potential to grow perennial grasses. As the name suggests, this cropland tend to flood frequently reducing the potential to grow corn and soybeans. Yet, perennial grasses with their deep root structure are more tolerant of flooding (Mann et al. 2012).

2.3 BCAP

BCAP incentivizes farmers to plant perennial grass cropping systems for bioenergy purposes and reduces risks associated with planting them. The program was created in the 2008 Farm Bill to:

> *address a classic chicken-or-egg challenge around the startup of commercial scale bioenergy activities. If commercial-scale bioenergy facilities are to have sufficient feedstocks, then a large-scale energy crop must exist. Conversely, if profitable crop production is to occur, then viable consumers must exist to purchase the crop. (Anonymous 2011a)*

BCAP incentives are in three forms. First, the program pays for 75 percent of establishment costs up to a predetermined maximum for planting a biomass feedstock. These establishment costs can be in the first or second years of production. The second is an annual payment for five years based on the Conservation Reserve Program (CRP) rates (Anonymous 2012a). The third incentive is matching payments for delivery of biomass to an aggregator making cellulosic ethanol or another advanced biofuel. This matching payment is up to $45 per delivered ton to a qualified bioenergy processor. Those payments meant incentivize the production of ethanol, which will receive the highest matching payments. They are also uncertain because they are subject to availability of funds (Anonymous 2012a). Lastly, there is a chance that BCAP does not get fully funded from Congress in future years in which case these payments would disappear altogether.

As of June 2012, Congress has funded 11 BCAPs including three in Missouri. The first project funded was a cooperative based in the western Missouri and aimed at planting 50,000 acres of three different mixes of native grasses. The second two BCAPs were organized through a processor in central Missouri. Those BCAPs focused in southwest Missouri and central Missouri aimed at planting 7,250 acres of miscanthus.

2.4 Explanation of Bioenergy Cropping Systems

This thesis evaluates three different perennial grass cropping systems: miscanthus, switchgrass and native prairie. All of these croppings systems are C4 perennial grasses. Blanco-Canqui (2010) discusses the potential soil benefits of these grasses versus annual row crops including reduced runoff, less sediment loss, increased levels of soil organic carbon, and improved soil structure. These benefits factor into the decision what which crops to grow for bioenergy.

2.4.1 Miscanthus

Miscanthus planted as a monoculture is the first cropping system being considered. The grass originated in Asia. A natural sterile hybrid variety has been grown in Europe as a bioenergy crop since 1983 (Anderson et al. 2011) and is now being planted in Missouri under BCAP. Miscanthus has the highest biomass yields of cropping system considered with average of 10 tons per acre (James, Swinton, and Thelen 2010). Researchers believe miscanthus will be able to yield at least that amount in the Midwestern United States despite not having extensive field studies to prove it. Miscanthus grows from rhizomes which are planted in the spring and do not reach a full potential yield until its third year. Researchers say miscanthus does not have any value as a forage crop (Heaton, Dohleman, and Long 2008) and its effect on wildlife is unknown. Unlike switchgrass, miscanthus is not native to North American, which causes questions about its invasiveness (Anderson et al. 2011). Miscanthus is a relatively new crop in the United States and conclusive research has not been published on either of those issues, or almost as important on how to best grow it.

2.4.2 Switchgrass

Switchgrass has been extensively studied as a bioenergy crop in the United States. Like miscanthus, it is a C4 perennial grass; however, it is native to North America and was found extensively throughout Missouri at one time. Alamo and Kanlow are the most commonly researched lowland varieties. Cave-in-rock is a widely researched upland variety. McLaughlin and Adams Kszos (2005) show how Kanlow lowland variety is the most suitable for Missouri based on its higher yield potential. For this thesis, when switchgrass is mentioned, it refers to the Kanlow lowland variety. Switchgrass is propagated through seeds making it much easier to plant than miscanthus; however, like miscanthus, a stand of switchgrass does not mature until after its second year. Its yields are almost half of miscanthus averaging 4 tons per acre in one study (James, Swinton, and Thelen 2010). Switchgrass does have forage value although it is not the best quality (Heaton, Dohleman, and Long 2008).

2.4.3 Native Prairie

The third cropping system is a polyculture of switchgrass and native legumes referred to as native prairie. There are many mixes of grasses and legumes which could be evaluated. The BCAP in Missouri lists four alternatives which include grasses like big bluestem (*Andropogon gerardii*) and indiangrass (*Sorghastrum nutans*). Because of ongoing agronomic research, the native prairie cropping system considered in this thesis is switchgrass planted alongside three native legumes: Illinois bundleflower, partridge pea, and tic tree foil. This polyculture is representative of prairies in Missouri with a dominant long stem grass and a mix of native legumes. The legumes were selected on the basis of not only their ability to fix nutrients but also because they are believed to be resilient enough to grow multiple years in a stand of switchgrass. The forage value of a native prairie is similar to that of switchgrass or grasses grown as a part of the Conversation Reserve Program (CRP). Similarly, it takes two years for a stand to mature and yields approximately 2 tons per acre according to that study which said that switchgrass yielded 4 tons per acre (James, Swinton, and Thelen 2010). For the purpose of this thesis, this cropping system does not get any chemical inputs. The native legumes are intended to provide fertility.

2.5 Crop Insurance

A producer has options about how to insure crops in the United States. The Risk Management Agency (RMA), a branch of USDA, administers many aspects of the programs including establishing premium rates, issuing subsides, and reinsuring private companies that sell the actual insurance policy to producers (Milhollin and Massey 2012). There are six general plans available: yield protection, revenue protection, revenue protection with harvest price exclusion, group risk plan, group risk income protection, and group risk income protection with harvest revenue option.

2.1: Six different insurance plans for corn and soybeans and some characteristics of each

Characteristic	Yield protection	Revenue protection	Revenue protection with harvest price exclusion	Group risk plan	Group risk income protection	Group risk income protection with harvest revenue option
Insures against	Individual production risk	Individual revenue risk	Individual revenue risk	County level production risk	County level revenue risk	County level revenue risk
Yield coverage	50% to 85% of actual production history yield	50% to 85% of actual production history yield	50% to 85% of actual production history yield	70% to 90% of county yield	70% to 90% of county yield	70% to 90% of county yield
Price coverage	55% to 100% of Feb. new crop futures contract price (base price)	Higher of new crop futures contract price in Feb. (base price) or Oct. (harvest price)	New crop futures contract price in Feb. (base price)	60% to 100% of the maximum coverage level	60% to 100% of the maximum coverage level	60% to 100% of the maximum coverage level (using higher of Feb or Oct futures price)
Results on which indemnity is based	Actual yield	Actual yield and futures prices in Oct.	Actual yield and futures prices in Oct.	County yield	County yield and futures price in Oct.	County yield and futures price in Oct.
Insurable units	Basic, optional and enterprise units	Basic, optional, enterprise and whole farm units	Basic, optional, enterprise and whole farm units	Enterprise units	Enterprise units	Enterprise units

Table 2.1 adopted from Milhollin and Massey (2012) elaborates on specifics of each plan. There are two important details. First, actual production history (APH) is an average yield from the last four to 10 years of continuous production on a particular field as proven by sale receipts, farm or commercial storage records, or feed consumption records. RMA establishes detailed guidelines for APH including information on new producers and transition years. Second, insurable units allow for flexibility in insurance policies of a particular field or enterprise. Table 2.2 adopted from Milhollin and Massey (2012) describes each unit in detail.

2.2: Elaboration of different insurable units

Units	Description
Basic Units	Basic units are used to organize by county all land that is owned or cash rented into one insurable unit for each crop. A crop that is shared among different landlords, tenants or sharecroppers would result in separate basic units for each arrangement. Basic units can be used in YP, RP and RP-HPE crop insurance policies.
Optional Units	Optional units present a way to further divide a farming operation into more units than the basic unit classification. Farms can be organized as separate insurable units based on different sections, section equivalents or USDA Farm Service Agency (FSA) farm numbers (in the absence of sections or section equivalents). Additionally, if certain farming practices such as irrigation or organic production are used, then separate units can be established for each parcel of land. Optional units can be used in YP, RP and RP-HPE crop insurance policies.
Enterprise Units	Enterprise units combine all acreage of a certain crop by county into one insurable unit. For example, corn and soybean acres in one county would result in two separate enterprise units. Enterprise units can be used in YP, RP, RP-HPE, GRP, GRIP and GRIP-HRO crop insurance policies.
Whole-Farm Units	Whole farm units combine all acreage into one insurable unit by county whether or not multiple crops are planted. Only revenue protection plans (RP or RP-HPE) can use this unit classification.

Crop insurance is among the most significant federal subsidies available for commodity farmers (Goodwin and Smith 2013). The United States began crop insurance programs in the 1930s but has increased the size of the program continually since the passing of the Federal Crop Insurance Improvement Act of 1980. That bill and subsequent ones expanded coverage and offers premium support in an attempt to boost participation rate. The premium supports continued to grow during the 1990s as natural disasters ruined crops. By 2011, crop insurance enrolled 265 million acres and federal subsidies cost taxpayers over $11 billion (Glauber 2013).

Producers enroll in crop insurance to transfer both production and price risk. In a competitive market, an insurance company would have premiums approximately equal to indemnity payouts and operating costs and contingency funds. In that market, producers pay to transfer that risk and expect negative returns from insurance. The crop insurance market, however, is not competitive, and producers received $1.90 in indemnity for every $1.00 in premiums paid over the period 1990 to 2011 for all crops eligible for insurance (Glauber 2013).

3 LITERATURE REVIEW

3.1 Profitability of Bioenergy Crops

The decision to plant of any bioenergy cropping system depends heavily on its profitability. Farmers who provide the feedstock each year need to be assured of returns on their investment. Thus, agricultural economists and extension specialists have conducted profitability studies to give farmers a better idea of the costs associated with growing a particular cropping system.

Profitability studies have been conducted on a plethora of bioenergy cropping systems including the three considered in this thesis, short rotation woody crops like hybrid poplars and willows, and corn stover. Switchgrass has been studied the most extensively out of the systems being considered. More recently, researchers began adding miscanthus to those switchgrass studies. Native prairie has been included as researchers investigate pro-conservation and less-input intensive approaches.

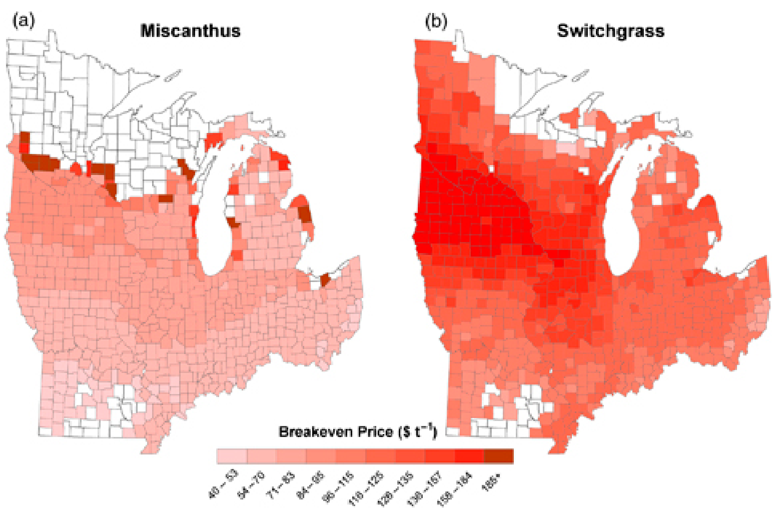
Studies of bioenergy profitability for the producer mainly focused in the Midwest. An extensive study reported actual yields and costs of growing switchgrass on fields in North Dakota, South Dakota, and Nebraska (Perrin et al. 2008). Studies in Missouri (Landers et al. 2012), Tennessee (Mooney et al. 2009), Indiana (Brechbill, Tyner, and Klein 2011), Michigan (James, Swinton, and Thelen 2010), and Iowa (Duffy 2007) have also been completed . Cost studies of miscanthus and native polyculture grasses are more limited to states in the Midwest like Illinois and Michigan; however, Jain et al. (2010) conducted profitability of bioenergy crops across the entire Corn Belt.

Normally, breakeven costs are reported in dollars per ton meaning a higher yield will decrease the breakeven cost all else being equal. The studies took the total production costs divided by yield to obtain a cost in dollars per ton. Two switchgrass studies (Perrin et al. 2008; Duffy 2007) reported both breakeven costs in dollars per acre of $132 and $328 as well as in dollars per ton, which were $53 per ton and $82 per ton respectively. Looking at breakeven costs in dollars per acre allowed for easier comparison to different cropping systems.

Three recent studies have further developed breakeven costs by making them into a comparative analysis in order to assess the potential of each cropping system. These studies provided a better decision-making tool for producers interested in planting bioenergy crops. James, Swinton, and Thelen (2010) developed the following equation to compare profitability of bioenergy cropping systems:

$$P_{BE} = \frac{VC_N + OC_{CS}}{Y_N - Y_{CS}}$$

P_{BE} is the breakeven price for bioenergy crop, and VC_N is the variable costs of the bioenergy crop, OC_{CS} is opportunity cost of lost net revenue by not planting corn and soybeans. Those costs were divided by an average yield for the bioenergy crop (Y_N) minus stover yield from corn and soybeans (Y_{CS}). Including the opportunity cost of corn and soybean rotation allowed for comparison across cropping systems and a more accurate breakeven decision-making tool as producers make planting decisions based on relative profitability of many options. Landers et al. (2012) also applied that equation to do a comparative analysis between switchgrass and corn-soybeans rotation to determine not only breakeven costs but also breakeven yields. That data was displayed graphically in nomograms. Jain et al. (2010) developed a biophysical model of eight states in the Corn Belt to determine locations where the breakeven costs would be the least. Figure 3.1 shows their results indicating that the southern corn belt including Missouri have the lowest breakeven costs for many of miscanthus because low opportunity costs.

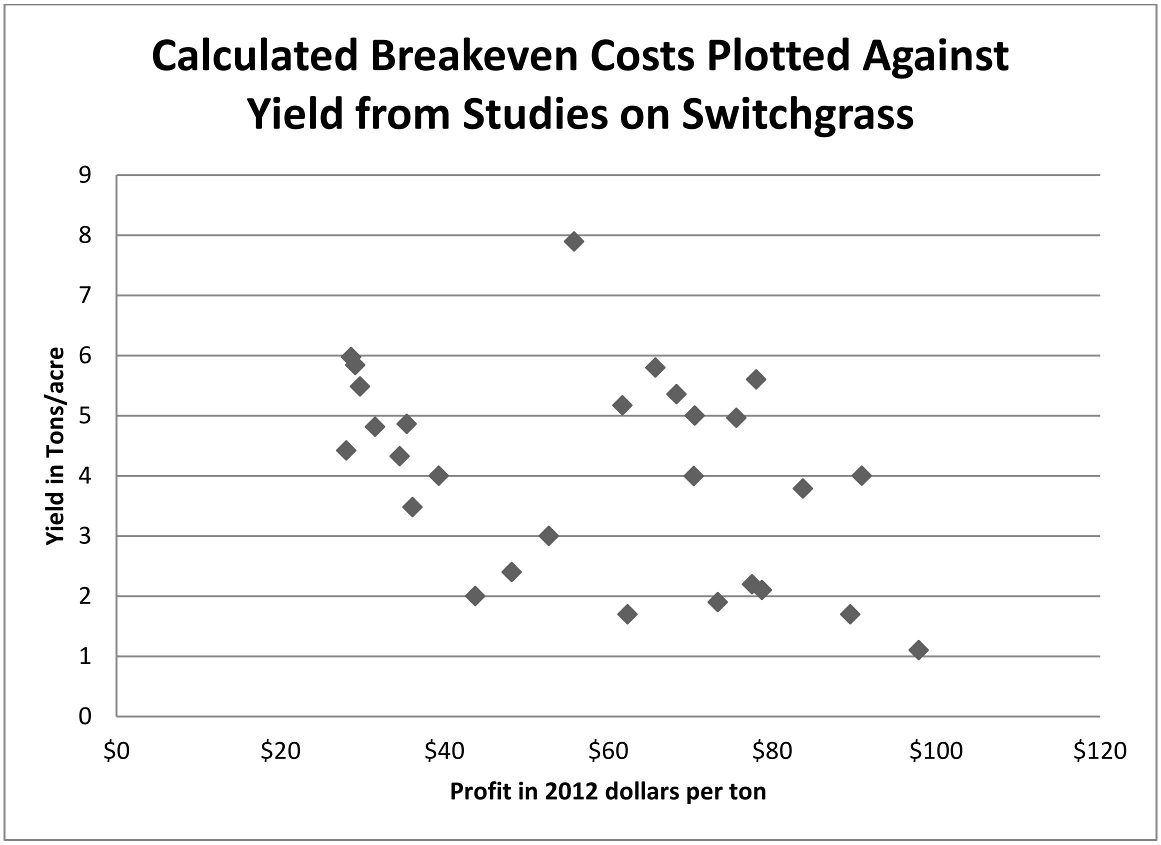


3.1: Findings of breakeven price for switchgrass and miscanthus across the Corn Belt

Only two of all the studies discussed accounted for revenue. Markets for cellulosic bioenergy crops were not and still are not fully developed leading to difficulty in determining the exact price or price range. Landers et al. (2012) acknowledged that uncertainty in creating nomograms which allowed for "numerous price and yield scenarios to be considered for grain and switchgrass systems for determining the breakeven price and yield". Those nonograms include scenarios for the price of biomass ranging from $40 per ton to $120 per ton. James, Swinton, and Thelen (2010) discussed price of biomass more thoroughly. That study accounted for the prices of hay and an estimate of the maximum price a bio-refinery could pay. They settled on three prices for the biomass, $30, $60, and $90 per megagram. These prices were $27, $54, and $81 per ton.

These comparative breakeven analyses require a cropping system to which biomass can be compared. James, Swinton, and Thelen (2010) found that miscanthus competes best with corn and soybeans but still has a breakeven price higher than corn and soybeans. Landers et al. (2012) used a rotation of corn and soybeans as their baseline and producers figures to determine various breakeven yields and prices based on assumptions about corn and soybean revenues. Researchers of the University of Tennessee have considered the difference between bioenergy production and pastureland and found switchgrass to be more profitable than a pastureland there (Watts 2012).

Any study of costs and breakeven points will differ largely depending on the dry mass yield achievement. A 20 percent change in yield can change the breakeven cost by as much as 10 percent (Brechbill, Tyner, and Klein 2011). Figure 3.2 is a graph of the results of 10 switchgrass studies (Duffy 2007; Popp 2007; Brechbill, Tyner, and Klein 2011; Perrin et al. 2008; Haque et al. 2008; Vadas, Barnett, and Undersander 2008; Mooney et al. 2009; Landers et al. 2012; Hallam, Anderson, and Buxton 2001; Walsh 1998). It shows their calculated breakeven costs in dollars per dry ton versus yield in tons per acre. The yield ranges from 7.9 tons per acre in Tennessee (Mooney et al. 2009) to 1.1 in Nebraska (Perrin et al. 2008) with an average of 4.0 across all these studies. This summary of the breakeven prices adjusts all reported prices to 2012 dollars using the CPI. With yields of 1.1 tons per acre, Perrin et al. (2008) calculated a breakeven cost of $97 per ton. The lowest estimate is $28.05 per acre in 2012 prices (Popp 2007). The average of all these is $58 per ton.



3.2: Summary from 10 independent switchgrass studies showing the breakeven cost in dollars per acre versus yield in tons per acre

Fewer studies have analyzed the costs of growing miscanthus and a native polyculture of grasses. Khanna, Dhungana, and Clifton-Brown (2008) found that breakeven costs of miscanthus to range from $41 to $58 per ton in 2008 dollars in Illinois assuming an average yield of 14.5 tons per acre. Another study found that if miscanthus rhizomes cost as much in the United States as they do in Europe, the breakeven costs would be close to $42 per ton (James, Swinton, and Thelen 2010). A native polyculture had a much higher breakeven cost at $522 per ton assuming a yield of almost 1.9 tons per acre (James, Swinton, and Thelen 2010).

Establishing enterprise budgets on a per acre basis is the most common method for calculating profitability of perennial grasses. Estimates of costs, revenue, and net returns are made based on a series of assumptions, which subsequently can be changed in order to analyze different scenarios (CIMMYT 1988). These budgets normally have a base unit, which is normally one acre for any crop and follow the basic equation for calculating profit:

$$(Price * Yield) - Costs = Net\ Profit$$

Since the methods are mostly the same, the variations resulted from the assumptions researchers make. The assumed yield described above and shown in figure 3.2 has a great influence on the final breakeven price as it is a component of revenue. The higher breakeven costs occur when yields are relatively low. Perrin et al. (2008) gathered actual data over a five year period on a field in Atkinson, Nebraska and found a breakeven price of $97 per ton including establishment years. That same study found that a different field in Munich, North Dakota had a lower breakeven cost of $43 per ton despite similar costs bases. The difference between those two sites was yield. Input costs such as fertilizer rate and land rental rate also affect yield (Popp 2007).

For miscanthus and native prairie, there is less actual agronomic data published and more uncertainty in the yields. In the absence of such data, researchers use crop growth modeled data. Several different crop modeling interfaces exist including EPIC, APEX, and POLYSIS. Prior studies of bioenergy cropping systems have used Agricultural

Land Management Alternatives with Numerical Assessment Criteria (ALMANAC) to predict yields (Landers et al. 2012; McLaughlin et al. 2006; Kiniry et al. 2013). This interface has proven capable of simulating switchgrass and miscanthus yields north of Arkansas where drought intensity is not as high (Kiniry et al. 2013). Yields for native prairie are more difficult than miscanthus or switchgrass. Research has reported a range of possibilities depending on the productivity of the land and mix of grasses and legumes grown. James, Swinton, and Thelen (2010) estimated native grass mix to yield 0.5 tons per acre less than switchgrass but acknowledges the range of yields as high as 2.7 tons per acre on fertile soils and 2.4 tons per acre on average cropland.

Another assumption affecting the breakeven costs is the time horizon. Perennial cropping systems are multiyear investments with the little revenue during the establishment phase. In order to account for those years, researchers used a time horizon and net present value. Although studies could use a range from 5 to 40 years, they normally have used a 10 year (James, Swinton, and Thelen 2010; Perrin et al. 2008; Walsh et al. 2003). For example, Walsh (2003) used a 10 year time horizon for switchgrass and a 40 year time horizon for short rotation woody crops to compare their profitability.

Shorter or longer time horizons change profitability. Longer time horizons allow farmers to amortize establishment costs over more years lowering those costs on a per year basis. Evidence suggested a miscanthus stand could last decades meaning a 10 year time horizon would underestimate profits (Anderson et al. 2011). However, if the stand only lasts five years, then profits would be overestimated using a 10 year time horizon.

Future profits are discounted and variations exist in the rate that they are discounted. The practice of discounting helps allow for better comparison of current and future profits. Using a positive discount rate weighs current profits more than future profits. Thus, profits 15 years in the future are less valuable than profits next year. Discounting adjusts those future profits for three factors: time value of money, inflation rate, and a risk premium. The time value of money largely depends on the opportunity cost. In bioenergy production, Perrin et al. (2008) assumed that the opportunity cost is the "average historic rate of return to land [or] a real rate of 10 percent". Other studies used a percentage between four and ten following the logic that farmers typically earn a five percent return on capital (Popp 2007; Landers et al. 2012; James, Swinton, and Thelen 2010; Jain et al. 2010). Perrin et al. (2008) discussed how farmers will need extra compensation for growing perennial grasses as opposed to corn-soybeans as these grasses were riskier due to undeveloped markets, which partially explained the higher rate in that study. Since prices were normally held constant, researchers assumed an inflation rate of zero (James, Swinton, and Thelen 2010). Jain et al. (2010) conducted analysis finding miscanthus to be much more sensitive to changes in the discount rate than switchgrass presumably because of higher establishment costs. While the exact impact and magnitude is subject to many assumptions, any differences in the discount rate and time horizon will ultimately change the profitability of a cropping system.

Beyond differences in the time horizon and discount rate, researchers typically have relied on local data to establish input costs. That local data varies from state-to-state and source-to-source. In Arkansas, Popp (2007) gathered input cost data from

University of Arkansas Cooperative Extension Service and a local agronomist. Similarly, Landers et al. (2012) used custom rates from University of Missouri Extension, average prices from the National Agricultural Statistics Service, and local seed prices.

Storage and transportation costs are among the most influential costs in these production systems. Biomass in the form of 1,200 to 1,500 pound bales must be moved from the field to processing plant, incurring expense. Densification technology which could be used at the field is currently not readily available. Thus, calculating and minimizing transportation costs are important in a successful bioenergy production system. Storage is also important as biomass is harvested once per year but energy is produced every day. Brechbill, Tyner, and Klein (2011) included estimates of transportation to the costs for power plants in Indiana which raises the overall breakeven cost. That study reported transportation costs as using the custom rate for hauling biomass in dollars per metric ton which was equal $1.52 for loading and unloading and $2.28 per kilometer traveled. However, a number of studies ignored these costs focusing on the farm-gate breakeven to limit the number of assumptions made and focused on costs producers are likely to incur (Jain et al. 2010).

Land rental rates are another cost that vary among these studies and explain differences in the final breakeven costs. Rental rates on productive cropland are significantly higher as expected returns from land are higher; poor cropland or pastureland typically are less expensive (Plain and White 2011). Duffy (2007) assumed land charge of $80 per acre in Iowa but does not specify what type of land. Similarly, Busby et al. (2007) study included a land charge of $45 per acre. Two studies (James, Swinton, and Thelen 2010; Popp 2007) ignored land prices in order for better comparison across cropping systems.

Assumptions about land are critical in studies about bioenergy production. Land assumptions go beyond just rental rate seen in the budgets; they affect the opportunity cost of any alternative crop and the willingness-to-grow a dedicated perennial bioenergy crop (James, Swinton, and Thelen 2010). Furthermore, these assumptions can affect yield because more productive land has higher rents versus less productive lands (Mooney et al. 2009).

Yet, profitability studies do not fully explore the land component. James, Swinton, and Thelen (2010) simply assumed that land is “medium- to high-quality land in Southern Michigan”. Other studies do not mention the productivity of the land (Duffy 2007; Haque et al. 2008). Mooney et al. (2009) explored how landscape soil and drainage affect production comparing switchgrass profitability in flood plains and upland locations. Yet, the Mooney study does not fully account for the opportunity costs associated with growing corn or soybeans on that land.

Properly accounting for the opportunity costs is important in a profitability study of any bioenergy cropping system. Producers consider opportunity costs in their decision-making process, and bioenergy production can seem more or less attractive based on the opportunity costs. Landers et al. (2012) considered opportunity costs in a comparative break even analysis. That research builds on findings that corn and soybean yield and profitability relate to amount of topsoil (Massey et al. 2008; Thompson, Gantzer, and Hammer 1992). Because certain landscape soils are less profitable, the opportunity cost of growing corn and soybeans is lower and could be more suitable for bioenergy production.

3.2 Crop Insurance and Decision-Making

Relative profitability of cropping may be an important factor in the decision about what crop to grow, but relative risk is also important. Research in Europe has discussed this aspect of bioenergy crops (Bocquého and Jacquet 2010), yet profitability studies of bioenergy crops in the United States largely ignore the effect of risk focusing only on the net present value of the mean of profit. Currently, producers of commodity crops, including corn and soybeans, benefit from subsidies to insurance programs allowing them to transfer production risk. Such programs do not exist for bioenergy crops like switchgrass, miscanthus, or native prairie.

Federally subsidized programs like crop insurance can have distortionary effects on behavior, including planting decisions. There is no literature discussing the relationship between the discussion to plant bioenergy crops and crop insurance. However, academics and risk management experts have concluded that crop insurance does cause distortions. Goodwin and Smith (2013) argue:

> In the case of subsidized crop insurance, the answer is clear—subsidizing risk leads agents to assume more risk. This may take the form of changes in production patterns (i.e., the quantity and allocation of acreage to individual crops) and changes in production practices (i.e., moral hazard).

There are two ongoing debates about distortionary effects of crop insurance: one described above as changes in production practices but more commonly known as intensity of cultivation (Goodwin, Vandeveer, and Deal 2004) and the second about quantity and allocation.

For the purposes of this thesis, the questions of quantity and allocation of acreage, known in the literature as extensiveness, is more important. Simulations conducted by Goodwin, Vandeveer, and Deal (2004) showed that producers buying crop insurance plant more corn but that increase is small ranging from 0.2 to 1.1 percent. Their study uses simulation changing insurance premiums and seeing how those different premium rates affected planting decisions between corn and soybeans. These simulations were meant to mimic the increase in federal subsidies and decrease in premium cost that occurred during the 1980s and 1990s. Young, Vandeveer, and Schnepf (2001) modeled the impacts of subsidizes crop insurance using POLYSYS in the United States finding results very similar Goodwin, Vandeveer, and Deal (2004). A partial equilibrium model of the agricultural sector in the United States in LaFrance, Shimshack, and Wu (2001) had a different finding. It "concludes that under reasonable conditions subsidized crop insurance creates incentives to utilize greater quantities of marginal land". That study implied that crop insurance results in corn and soybeans being planted on more marginal lands; however, it relied exclusively on a theoretical model.

These studies tend to focus on insurable crops. The Goodwin, Vandeveer, and Deal (2004) explored only two alternative cropping systems corn and soybeans or wheat and barley. Similarly, Young, Vandeveer, and Schnepf (2001) considered eight different row crops including corn, grain sorghum, oats, barley, wheat, soybeans, cotton and rice. These studies do not explore viable alternative crops such perennial grasses grown for bioenergy that could grow on marginal lands, generate returns, and offer ecosystem benefits and the effect crop insurance may have on those alternatives.

4 THEORETICAL FRAMEWORK

4.1 Expected Utility Maximization Model

Producers weigh many factors when deciding whether or not to plant perennial grasses for bioenergy purposes. Profits are normally an important and often pivotal factor although others such as ecosystem benefits or diversification are considered. Expected utility analysis has been used in research on planting decisions (Woodard et al. 2012). This analysis uses the uncertainty and preferences of a producer to explain his/her decision. Here, the focus is on a risk-averse producer or a producer who will actively reduce uncertainty. The model constructed for this thesis assumes a producer has the liquidity to afford to plant perennial grasses and forgo income on those acres for at least two years during the establishment phase. The model also assumes bounded rationality of the producer because he/she does not have perfect information about all potential outcomes. The framework presented here also relies on the assumptions that a producer can integrate bioenergy crops into his/her operations without excessive labor and equipment costs. The model deals with utility rather than a monetary value because of the assumption of diminishing marginal utility of greater wealth or income. The following expected utility (E(U)) function is used:

Max E(U)= f(Profit)

$$Profit = (price)(yield) - costs$$

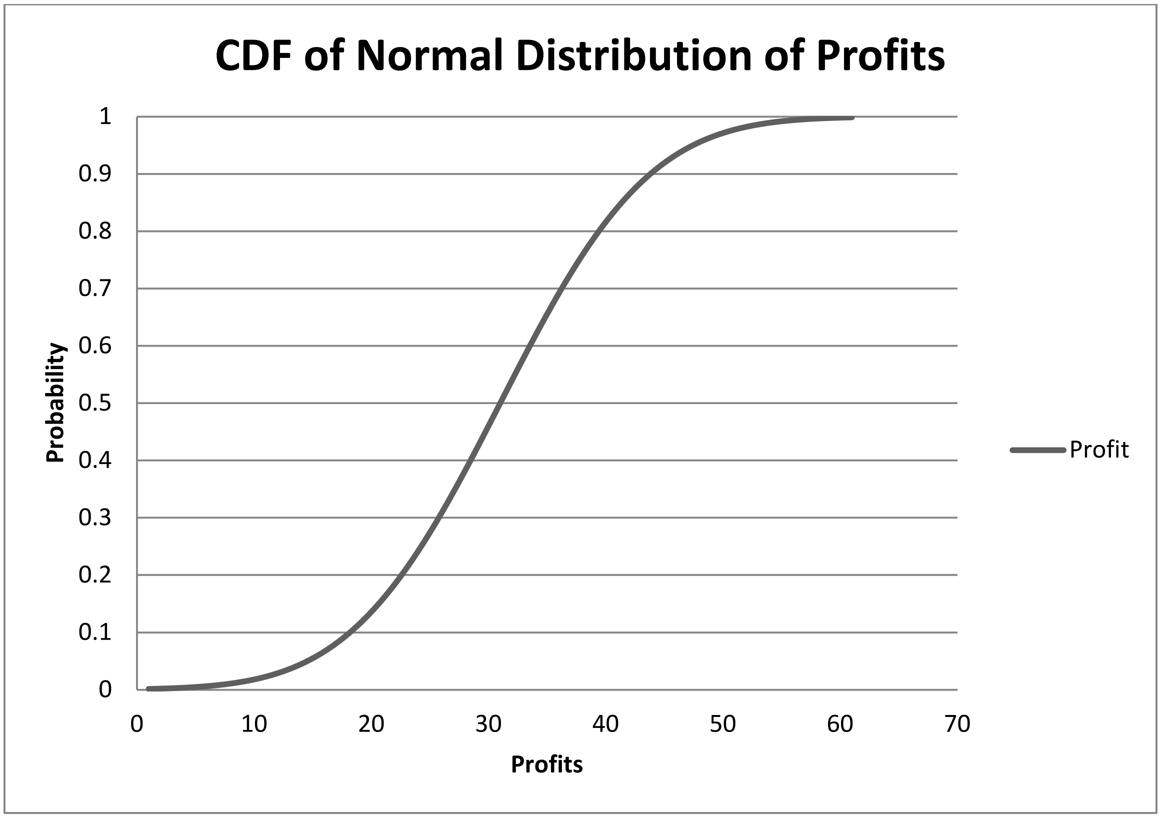
Subject to uncertainty in grain prices, grain yields, and biomass yields

The singular goal of this model is to maximize utility based on the profits per acre of production. Profits from the four different cropping systems are considered in three different landscape soils: upland and non-eroded represented by a Putnam silt loam, upland and eroded represented by an Armster or Armstrong loam, and flooded represented by a Belknap silt loam. The grain crops, corn and soybeans, are evaluated both with and without crop insurance. In this model, the decision about what crop to plant depends on a producer's belief about three uncertain variables, grain prices, grain yields and biomass yields.

An important consideration is the instability of grain incomes relative to perennial grasses. Grain income depends on fluctuating market prices, unpredictable yields, and higher annual production costs. Perennial grasses, however, have more consistent yields and are assumed to have a contractually fixed price for a set number of years due to the need for a consistent supply of cellulosic material to meet RFS and the need to amortize high establishment expenses over many years. The grasses may not have maximum profits level as great as row crops but also do not have the loss potential that grains do.

The widespread availability and low cost of grain crop insurance in the United States limits the opportunity for bioenergy crops. Revenue protection insurance allows producers to reduce the uncertainty in both prices and yields by transferring that risk to a third party. When that risk is transferred, planting corn and soybeans still has the relatively unstable prices and yields but now has a minimum profit that is much more certain. If the average returns are similar, a risk averse producer who is maximizing utility and operating under the assumptions above would favor corn and soybeans which has guaranteed a minimum profit and still has potential for a high maximum versus more stable returns offered by perennial grasses.

4.2 Relevant Decision making tools



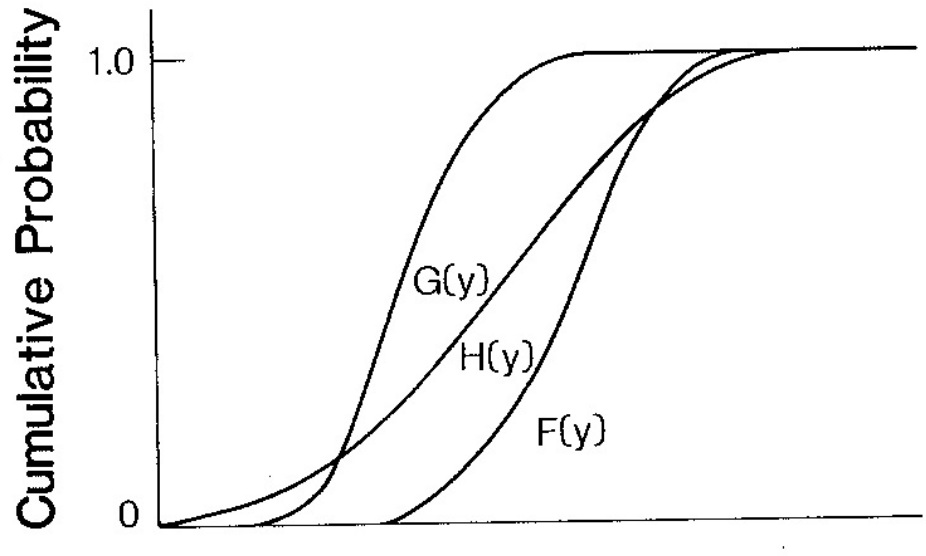
4.1: Sample CDF of a normal distribution.

Cumulative distributions functions (CDFs) are used in the analysis of the effects of random or uncertain variables. A CDF is a non-decreasing, monotonic function made from all the simulated outcomes ordered from smallest to largest. Figure 4.1 is an example of the CDF for a normal distribution function. Like the figure shows, the Y-axis is the probability of a certain outcome occurring from 0 to 1, and the X-axis is the outcomes. In this thesis and in figure 4.1, an outcome is the profit determined by one simulation.

CDFs illustrate information about the probability of an outcome. In figure 4.1, the greatest profit which is 60 has a probability of 1 meaning that 100 percent of the profits are less than or equal to 60. Similarly, a profit of 30 corresponds with a probability of 50 percent meaning that 50 percent of the profits are below 30. Such interpretation can be completed on any level of profit or for any probability.

CDFs can also be useful when comparing more than one activity. Figure 4.2 shows CDFs for multiple activities or, in the case of this thesis, multiple cropping systems. These CDFs are not only useful by showing the probability associated with various outcomes of just the one activity but also in decision-making among a set of activities. One plot could contain multiple activities for ease of comparison.

Based on the assumption of this thesis that the producer is risk averse, there are four pertinent rules used in deciding which activity to choose: two types of stochastic dominance, maxi-min, and safety-first. Each rule assumes more is better, meaning that curves situated farther from the Y-axis in the positive direction are more desirable.



4.2: Sample CDF to illustrate different decision-making rules.

Stochastic dominance has two forms. First degree stochastic dominance is when all outcomes for a particular activity are preferred. Figure 4.2 from King and Robison (1984) graphically illustrates stochastic. The three curves in Figure 4.2 each show a different activity. F(y) has first order stochastic dominance over G(y) because all the outcomes resulting from that activity are greater. However, F(y) is not first order stochastic dominant over H(y). Even though most of F(y) is greater at a high probability of .8 or .9 H(y) is greater. Thus, some outcomes of H(y) are more desirable than F(y) (King and Robison 1984). In the case of this thesis, if the profits from one cropping system are always greater than the profits from the others, then that cropping system has first order stochastic dominance. In the event of first degree stochastic dominance, a producer's risk preferences are unimportant as one cropping system is always preferable over the others.

Only risk averse producers care about second order stochastic dominance. In second order, two activities could have curves that cross; however, the area underneath one is less than the other (King and Robison 1984). F(y) is second degree stochastic dominance over H(y) because:

$$\int_{-\infty}^{y} F(y)dy \leq \int_{-\infty}^{y} H(y)dy$$

An integral of the curve from negative infinity to a specific outcome Y measures the area underneath the curve. Since more is better, the curve with less area underneath is more desirable because its outcomes are greater. Visually, the curve with less area is also the curve farther away from the Y-axis in the positive quadrant.

Maxi-min is when a producer selects the crop that has the greatest minimum profit. This rule ignores every other outcome except the minimum. In figure 4.2, F(y) has the highest minimum meaning that a producer following this strategy would select that activity.

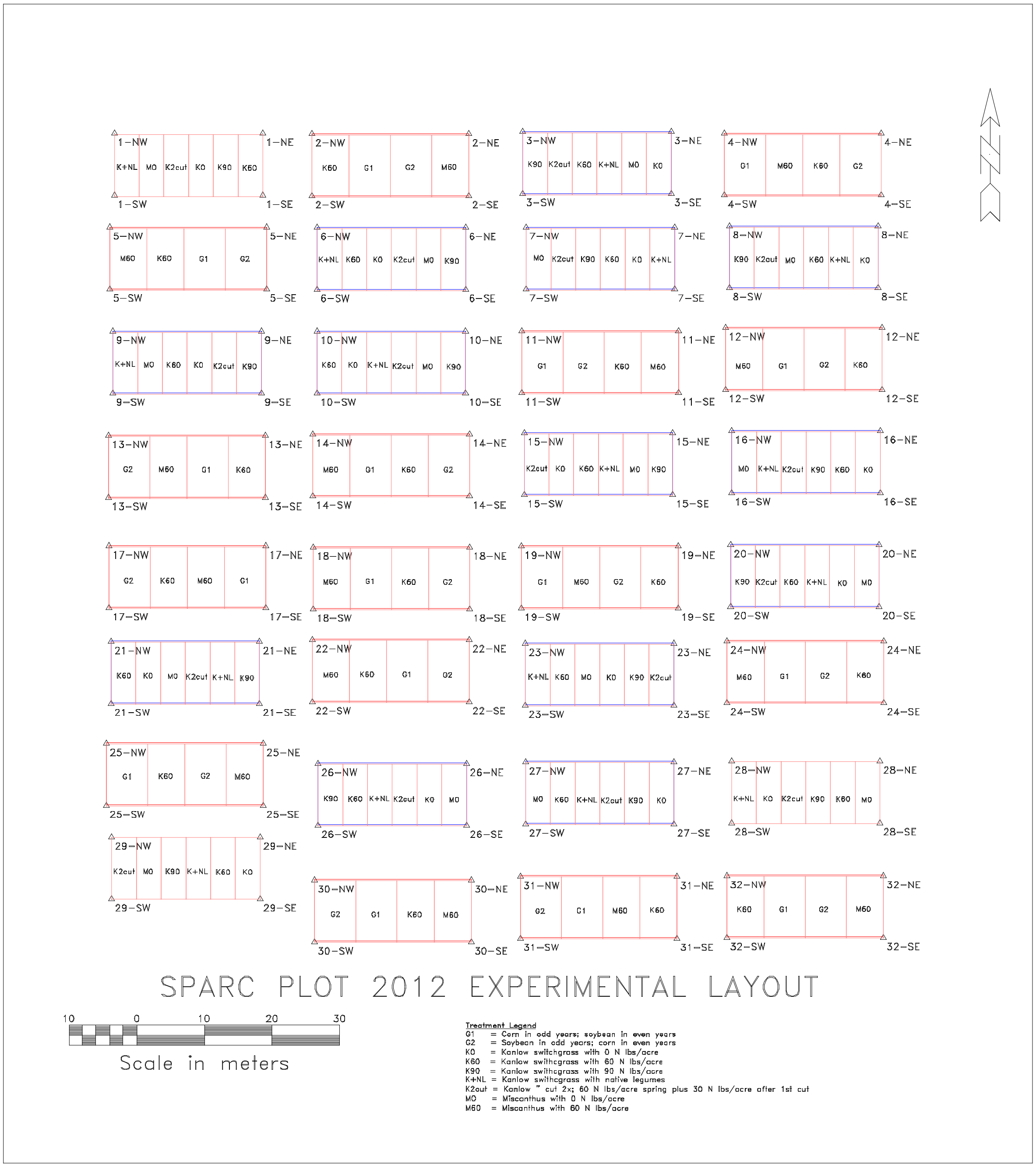
Safety-first is a more general version of the maxi-min. In safety-first, a producer will select an outcome Y that is a personal minimum. Then, based on that outcome, the producer selects the activity which has the greatest probability of obtaining it (Selley 1984). For example, a producer needs a profit of at least $100 per acre. He/she would select the cropping system that gives $100 most frequently. This strategy, like the maxi-min, ignores the potential upside but does give the producer the greatest likelihood of receiving that minimum profit needed.

5 DATA AND METHODS

The results of this thesis are based on cumulative distribution functions of simulated profits. This section details how those CDFs were made. The data and subsequently the main focus of this research are from northeast Missouri. Thus, models and simulations are meant to represent fields and conditions in that region. Even though forage crops, grain sorghum, and wheat are grown in northeast Missouri, corn and soybeans are used as the comparison.

5.1 Ongoing Agronomic Studies

Ongoing agronomic research at the Soil Productivity and Resource Conservation (SPARC) plots has informed this thesis. The SPARC plots are located at University of Missouri South Farms southeast of the city of Columbia, Missouri in Boone County. These plots were originally constructed in 1982 to simulate corn and soybeans production on landscape positions with different levels of topsoil erosion. There are 32 blocks with four or six plots per block. Each block measuring approximately 30 feet by 82 feet has had topsoil either artificially removed or added. The soil is a Mexico silt loam with slopes of 1% to 3%. From 1982 to 1993, corn and soybeans were planted. Thompson, Gantzer, and Hammer (1992) explains more about the plots during the 1980s and 1990s in a study of corn and soybean production.

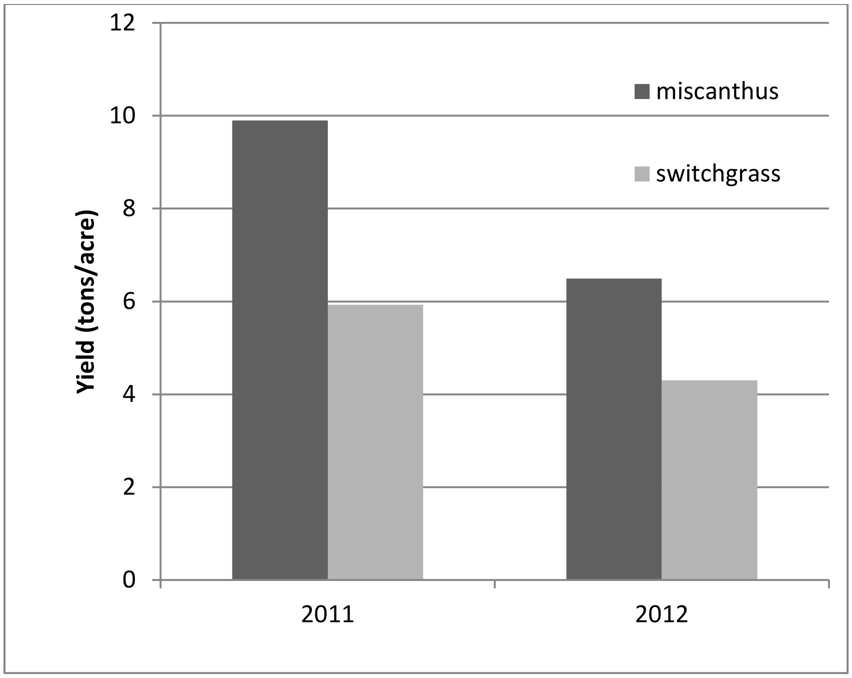


5.1: Layout of SPARC plots at South Farms.

5.1: Explanation of 2012 layout and breakdown of each experiment at the SPARC plots.

Experiment	Treatment	Description
1	G1 and G2	No till corn and soybeans rotation
	M60	Miscanthus with 60 lbs per acre of nitrogen
	K60	Kanlow switchgrass with 60 lbs per acre of nitrogen
2	K + NL	Switchgrass and native legumes
	M0	Miscanthus without any added nitrogen fertilizer
	K2cut	Switchgrass harvested 2 times per year and 60 lbs per acre of nitrogen
	K0	Kanlow switchgrass without any added nitrogen fertilizer
	K60	Kanlow switchgrass with 60 lbs per acre of nitrogen
	K90	Kanlow switchgrass with 90 lbs per acre of nitrogen

Agricultural production ceased on the plots until 2009 when a study comparing switchgrass to annual grain cropping systems was initiated by USDA Agricultural Research Service (ARS) and the University of Missouri. The main goal of the study is to evaluate how switchgrass and miscanthus grows on eroded claypan soils similar to those found in northeast Missouri. The study is arranged via split-block, completely randomized design. The area has been divided into two experiments. The first compares annual no-till corn and soybeans grain production to switchgrass with different nitrogen treatments. The second compares management practices for switchgrass varying in fertility treatments and harvesting strategies. In 2012, the study was altered to include miscanthus. Figure 5.1 is a current layout of the SPARC plots. Table 5.1 explains the SPARC experiment and indicates the meaning of the plot labels in figure 5.1.



5.2: Actual yields from 2011 and 2012 for miscanthus and switchgrass from SPARC and Jefferson Farms

In addition to the research at SPARC, there is one block of established miscanthus albeit not the variety considered here. That block is located adjacent to South Farms at Jefferson Farms. It was planted in June of 2007 into a field previously managed in fescue. The block received 50 lbs per acre of nitrogen fertilizer in the years 2007 to 2010, but no other amendments were added. The block was mowed each year from 2008 to 2010 but burned in early 2011. Yield was not measured during these years. In 2011, ARS began coordinating studies on this site including experimenting with sequential harvest dates and varying rates of nitrogen fertilizer. Figure 5.2 shows average actual yields from miscanthus at Jefferson Farms and Switchgrass at SPARC on comparable soils for the years 2011 and 2012.

5.2 Data and Methods

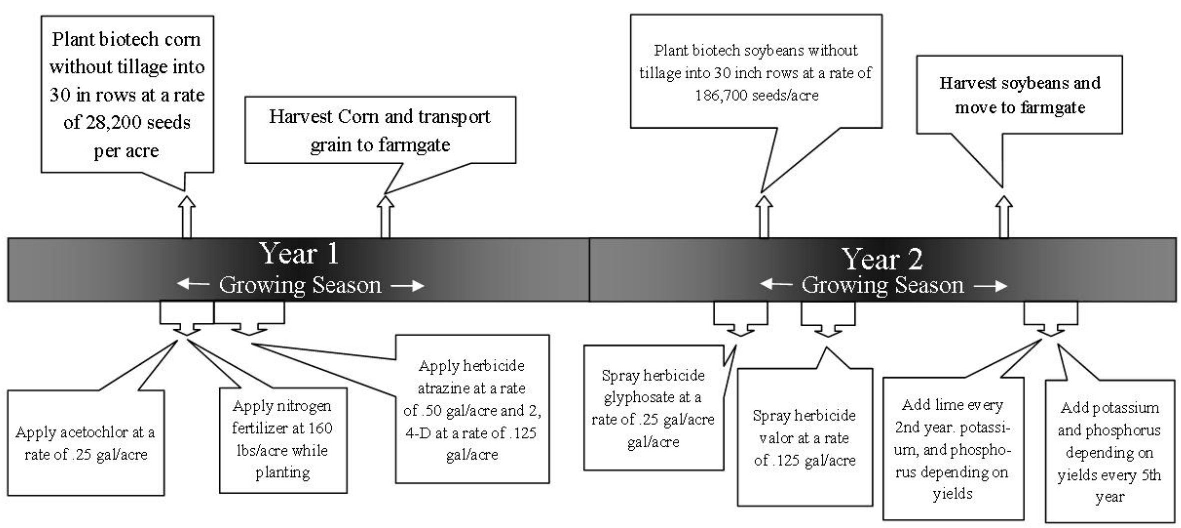
An empirical model illustrates the theoretical model previously described. Partial enterprise budgets are at the heart of the empirical model. Each crop has its own budget based on typical management practices. These budgets follow similar ones explained in the literature review and ones created by University of Missouri Extension. CIMMYT (1988) explains the method in more detail and sets the standard used by researchers in the analysis of partial enterprise budgets for crops.

One cost that is not included for any of the cropping systems is transitioning out from perennial grasses to another cropping system. For example, the costs of eradicating an established stand of miscanthus to plant corn or soybeans are not included. Converting from corn or soybeans is easy because they are annuals. The cost of removing a perennial grass is difficult to know exactly but presumably more expensive than any annual. These perennial grasses do respond to herbicides as seen at SPARC; however, the exact amounts and tillage required are not published information and depend on a variety of conditions. Beyond the costs of removal, production of the next crop could be reduced for the subsequent year. Further complicating the issue is the outcome that perennial grasses rejuvenate soil quality by enhancing more soil organic carbon (Blanco-Canqui 2010). Those improvements could result in improved productivity for the future crop. Thus, because of the uncertainty in removal costs and in potential soil benefits, costs of transitioning out of perennial grass cropping systems are ignored, even though producers will consider them when deciding to plant a new cropping system.

This analysis focuses on the producer and does not account for transportation costs fully. Any cellulosic material will need to be transported from the field to an aggregator or processing facility. These costs are important but require assumptions about distance of the field to the plant as well as about the cost of fuel. Thus, in an effort to limit the number of assumptions and focus the analysis, the incomes calculated are for the farm-gate.

5.2.1 Management Assumptions

5.2.1.1 Corn and Soybeans

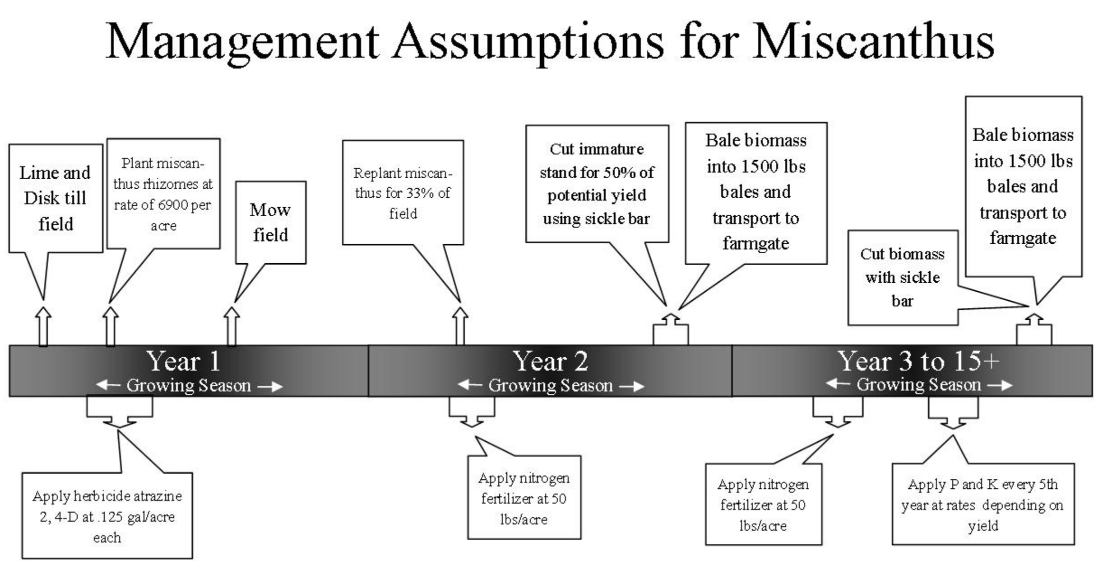


5.3: Management assumptions for corn and soybeans

Figure 5.3 displays the management assumptions used in this thesis for corn and soybeans. Corn is planted in the first year in 30 inch rows into a field without tillage. Dry fertilizer is added at a rate of 160 pounds of nitrogen per acre around the planting date. The herbicide acetochlor is applied as pre-emergent after the fertilizer and at the labeled rate. Then, the post emergent herbicides, 2,4-D and atrazine, are applied again at their labeled rates. This field is dryland, so there is no irrigation. Finally, the corn grain is harvested and transported to the farm-gate.

Soybeans are planted the following season. Much like the corn, they are planted into 30 inch rows without tillage. Glyphosate and then Valor are sprayed to kill weeds. Once the beans are ready, they are harvested and transported to the farm-gate. Lime, potassium, and phosphorus are added after the harvest. For production years, those costs are divided equally between corn and soybeans. Lime is added every second year, and potassium and phosphorus are added every fifth.

5.2.1.2 Miscanthus



5.4: Management assumptions for miscanthus

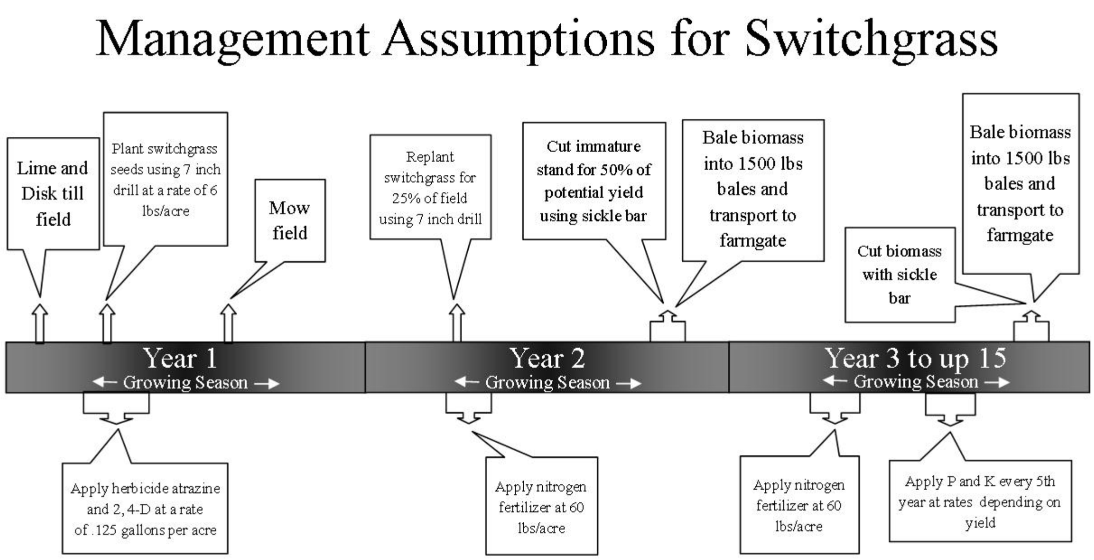
Figure 5.4 is a depiction of the management assumptions used in this thesis for growing miscanthus. Producers vary management practices for all crops but, as a new crop for the United States and the state of Missouri, management practices are even more debatable. Producers will handle weeds differently and apply fertilizer at different rates. For this thesis, assumptions follow the recommendation of researchers (Kitchen and Wilmes 2013).

Growing miscanthus begins with a disk tilled field that has been limed. The rhizomes require good soil contact. Good establishment is important for the profitability of the cropping system. The rhizomes are planted at a rate of approximately 6,900 per acre. The producer sprays for weeds at labeled rates and applies dry fertilizer. What biomass does grow that first year is mowed at the end of the season and after the plant has senesced.

The second year begins with some miscanthus replanting. The exact amount will vary depending on many factors. Fields may not need any replant whereas others may require some. There is no set percentage for the replant; however, this thesis assumes 33 percent replant. Again, a limited amount of herbicide is applied as well as another 50 pounds per acre of dry fertilizer. At the end of the season and after senescence, an immature stand is harvested yielding approximately 50 percent of its maximum potential yield. That biomass is transported to the farm-gate in large bales which weigh 1,500 pounds.

In the third year going forward to at least 15 years in total, the miscanthus is established. Fifty pounds per acre of nitrogen fertilizer is applied each year after the first year. The biomass is harvested after senescence allowing most of the nutrients to cycle back into the root system. The harvest occurs most likely in December; however, the exact day would depend largely on the end user and suitable field conditions. All the biomass is baled into large bales and moved to the farm-gate. Every fifth year potassium and phosphorus are added to the soil.

5.2.1.3 Switchgrass



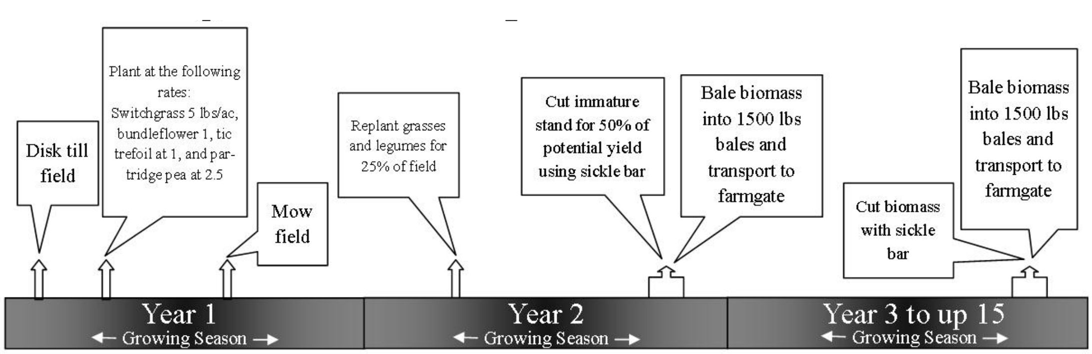
5.5: Management assumptions for switchgrass

Figure 5.5 shows the management assumptions for a switchgrass cropping system. The management practices are similar to miscanthus with the first two years as establishment phase and remaining years as a mature stand. The field is disked prior to planting and limed. Switchgrass seed is drilled using 7 inch rows. One acre is planted with 6 pounds of seed (Douglas, Lemunyon, and Wynia 2009). Herbicides atrazine and 2,4-D are applied at the labeled rates, and nitrogen fertilizer at 60 pounds per acre is added to deter competitive weeds and stimulate switchgrass growth. After senescence, the field is mowed leaving the biomass in the field.

In year two, switchgrass is replanted but at a rate less than miscanthus. Again, nitrogen fertilizer and herbicide at labeled rates are applied. An immature stand is harvested after senescence yielding approximately 50 percent of potential yield. The biomass is gathered in 1,500 pound bales and transported to the farm-gate.

After the second year, the stand is considered mature and may last up to 15 years total. The established stand requires fewer inputs. Early in the season, nitrogen fertilizer is applied at the rate of 60 pounds per acre after the first year. After senescence, the grass is harvested, baled, and transported to the farm-gate.

5.2.1.4 Native Prairie



5.6: Management assumptions for native prairie

The management assumptions used in this thesis for native prairie are similar to both miscanthus and switchgrass. The distinction is that native prairie does not require any chemical inputs. Herbicides are not applied in any year. Chemical fertilizers are forgone in favor of nitrogen fixing legumes. Figure 5.6 shows the management practices broken down by year. The stand is assumed to last as long as the switchgrass in a monoculture and requires the same two years to full yield potential. The seeds are planted in the first year into a tilled field. Switchgrass is sowed at a rate of 5 pounds per acre, Illinois bundleflower at 1 pound per acre, tic trefoil at one pound per acre, and partridge pea at 2.5 pounds per acre (Douglas, Lemunyon, and Wynia 2009; Houck 2006; Anonymous 2011b, 1997). After senescence, the field is mowed. During the second year, 25 percent of the field is replanted and an immature stand is harvested. For the remaining years represented in the figure 5.6 by “Year 3 up to 15”, the grasses grow and are harvested, baled and transported to the farm-gate after senescence.

5.2.2 Budgets

5.2.2.1 Deterministic Factors

Each budget consists of three cost sections: operations, materials, and financial costs. Even though these costs may vary among producers, for the purposes of the model, they are deterministic meaning they do not have uncertainty associated with them. The operation section is activities performed on the land including the following: any tillage or field preparation, planting and seed costs, application of any chemicals, mowing or harvesting and baling, and transporting harvest to farm-gate. For all budgets, these costs are taken from 2012 Missouri Custom Rates published by University of Missouri Extension (Plain and White 2012). The budgets use the average rate except for harvesting miscanthus, which uses the high rate because it is more difficult to bale than most forage crops. The planting activity includes the cost of seeds, which has been added to the custom rate of actually sowing the seeds. These rates assume the rate for a “normal” job thus could vary slightly in the field (Plain and White 2012).

Owning equipment may cause even more variation in costs for activities. Producers who own their own equipment could perform these activities at greater or lesser costs, depending how intensively the equipment is used. However, custom rates allow for a relatively fair comparison across cropping systems. Furthermore, these costs avoid difficulties comparing costs for larger and small operations, ones financed with more debt versus capital, producers using different equipment brands, and differences in auxiliary costs associated with operations such as fuel. Those differences can significantly change costs for machinery per acre. For these reasons, using custom rates is not unique to this research (Landers et al. 2012; James, Swinton, and Thelen 2010).

The operations are mostly quoted in costs per acre. Thus, for most operations the “Number of Operations” is one or the work is completed on one acre. For example, the custom rates for field preparation and herbicide application are costs per acre. This thesis is doing a comparative analysis, and it is sufficient to compare just one acre of each cropping system. Thus, the “Number of Operations” is one. For replanting which is completed in the second year of the perennial grass cropping systems, the assumed replanting proportions, 33 percent for miscanthus and 25 percent for switchgrass and native prairie, are entered as decimals. The cost of two operations, baling biomass and transporting both grain and biomass to the farm-gate, are a function of the amount of yield. Baling biomass costs $11.25 per 1,500 pound bale. Moving grain to the farm-gate is $0.12 per bushel whereas moving a large biomass bale is $3.18 per bale.

Because miscanthus is a new crop and is propagated through rhizomes, few producers or custom operators own equipment to plant and harvest it. Debate exists about the exact price to plant an acre of miscanthus. James, Swinton, and Thelen (2010) elaborates more on this price and chooses to use two different prices for miscanthus rhizomes, which is the most expensive aspect of planting. Because of government assistance in paying for the establishment of bioenergy crops, Farm Service Agency (FSA) published an approximation of how much it would cost to plant an acre of miscanthus. They use $803 per acre to plant miscanthus including costs for rhizomes (Anonymous 2012a). Though that cost is most likely higher than what can be expected if miscanthus is planted on a large-scale and costs of rhizomes drops with more supply, it is used in this analysis.

Seed prices for the other cropping systems are also included in the operations section of the budget under “Planting and Seed”. Corn and soybean seeds are calculated using data from USDA National Agricultural Statistics Service (NASS). Both prices are averages of national prices paid for the years 2012, 2011, and 2010. The seeds are hybrid biotech seeds. Switchgrass and native prairie seed prices came from Hamilton Native Outpost LLC, a seed vendor in southwest Missouri.

The materials section of the budgets is next and includes costs of chemical inputs and lime. The cost for the herbicides atrazine, 2,4-D, acetochlor, and glyphosate are averages of NASS prices paid by producers from the years 2012, 2011, and 2010 (NASS 2013). The price of Valor, an herbicide used to spray resistant weeds when growing soybeans, is from a national retailer (Anonymous 2012b). The rates at which they are applied are the labeled rates. For atrazine, that rate is 0.50 gallon per acre (Anonymous 2013a). Glyphosate and acetochlor are applied at two pints per acre (Smeda 2013). Both 2-4D and Valor are applied at one pint per acre or .125 gallon (Smeda 2013).

Fertilizer inputs, including nitrogen in the form of dry urea, DAP, and potash, are also averages from NASS of prices paid by producers from 2012, 2011, and 2010 (NASS 2013). The application rate depends largely on the crop. Nitrogen is assumed to be applied every year at the rates of 50 pounds per acre for miscanthus, 60 pounds per acre for switchgrass, and 160 pounds per acre for corn. Soybeans and native prairie do not receive any nitrogen.

5.2: Phosphorus and potassium removal rates for each cropping system

P & K Removal Rates	**lb-P2O5/bu**	**lb-K2O/bu**
Corn	0.34	0.20
Soybean	0.82	1.01
P & K Removal Rates	**lb-P2O5/ton**	**lb-K2O/ton**
Miscanthus	2.53	6.10
Switchgrass	2.53	6.10
Native Prairie	Nutrients not added	

Table 5.2 lists the cropping system nutrient removal rates for P_2O_5 and K_20, and serves as the basis for the amount of potassium and phosphorus removed. The nutrient removal rates for miscanthus are assumed to be the same as switchgrass. The corn and soybean removal rates are taken from Tichnor (1992) and switchgrass is taken from

Yang et al. (2009). Potassium and phosphorus are added once every five years, and nitrogen is added every year. The budgets have a dry fertilizer application rate of a total 1.2 (one for nitrogen application each year and 0.2 for the potassium and phosphorus added every fifth year). Native prairie receives no inputs meaning its rate is zero, and soybeans receive only potassium and phosphorus every fifth year, which means its rate is 0.2.

The final cost section of the budget is financial. This section includes insurance, land rental, and interest. Corn and soybeans are insurable, and producers pay premiums for that insurance. That premium is calculated using FARMDOC from the University of Illinois for 2013 for a producer in Audrain County, Missouri on a non-irrigated field. The model assumes a producer enrolls in revenue protection covering 75 percent of their APH without trend adjustments. The producer selects enterprise unit. The mean of the distribution is the APH. The premium of level of insurance for corn is \$11.40 and for soybeans is \$5.46. RMA Summary of Business data suggests this insurance package for corn and soybeans is the most common in Missouri (Anonymous 2013b). Insurance is not commonly purchased for the other crops, so there are no premiums.

Any indemnity payments are entered as revenues. Those payments occur when revenue is less than the certain guaranteed level. That level is calculated as:

$$Guaranteed\ revenue = (APH * coverage\ percent * \max(guaranteed\ price, market\ price)$$

Thus, if revenue is below that level, the producer will receive indemnity payout. The calculation for indemnity is as follows:

$$Indemnity = guaranteed\ level - market\ price * yield$$

If yields are lower than APH or the market prices drops significantly, producers receive an indemnity payout, which will bring their income to guaranteed level. For the purposes of this thesis, APH is average yield from the distributions of corn and soybeans data, which are explained below. Coverage level is 75 percent. The guaranteed price is average price from price distributions which is $5.18 for corn and $11.49 for soybeans. The market price and yield are stochastic variables explained below.

Rent is included as a cost. Because it is the same for every cropping system, the rent payment does not ultimately affect the comparison among cropping systems; however, including that payment makes the final profits in the analysis more realistic. Since lands with different productivity are analyzed, three different rental rates are used corresponding to average yields. Plain and White (2011) surveyed cash rental rates in Missouri and reported their rental rate findings based on productivity. Their average rates are used. For the upland and non-eroded land, $165 per acre is used because that cropland is presumably the most productive. The next most productive is floodplain cropland, and a rental rate of $147 per acre is used. Upland but eroded cropland is considered the least productive and has a rental rate of $115 per acre.

The final financial cost in the budgets is interest. Rates are assumed to be 7.5 percent, which is approximately what other studies use (Brechbill, Tyner, and Klein 2011). Producers use the financing to cover their operation and materials costs for a six month period. Interest is included in every cropping system and each year, even though it is possible, producers of perennial grasses would not need financing after establishment years.

Two deterministic factors in these budgets affect revenues of perennial grass cropping systems: the price of biomass and BCAP payments. As discussed above, markets for cellulosic bioenergy crops are not well developed. Estimates vary and studies which address it (James, Swinton, and Thelen 2010; Landers et al. 2012) present multiple price scenarios. For this thesis, a farm-gate price for biomass is estimated. That price assumes producers and end-users are contractually bound to selling and buying all their biomass from each other at a predetermined price. These contracts can be renegotiated for changes in the market and can be indexed to price fluctuations in inputs like fuel. However, only the base price is considered here.

Currently in Missouri, the most viable market for biomass is power plants where it can be co-fired with coal. Power plants buy heat units to produce electricity. Thus, the price of biomass is approximately equal to the price of coal for equivalent amount heat units.

5.3: Calculation of a power plant's willingness to pay

Calculation	**Value**
BTUs in one pound of biomass	7,600
Pounds in one ton	2,000
BTUs produced per ton of biomass	15,200,000
MMbtu produced by one ton of biomass	15.2
Price of coal per MMbtu	$2.90
Approximation of power plant's willingness to pay per ton	$44.08

Table 5.3 estimates the willingness to pay. British Thermal Units (BTUs) in one pound depend on the heat content of the biomass. For miscanthus, switchgrass, and native prairie, that value is between 7,400 and 7,800 (Wright et al. 2006). That number is converted into millions of BTUs (MMbtus) in one ton; the middle value 7600 BTU/lb of the high and low BTUs per pound is used in this thesis. The University of Missouri is paying $2.90 per MMbtu of coal meaning their willingness to pay for biomass is almost $44 per ton based on a calculation of only buying BTUs (Coffin 2013). Coal does have an ash removal cost which drives up its price although the exact amount depends on the overall size of the power plant and their system for ash removal. For this thesis, $50 per ton is used based on its price as a substitute. Alternative prices could easily be justified including those used in James, Swinton, and Thelen (2010) and would change the results. However, given the uncertainty and lack of a developed market, $50 per ton is a possible price. There are possibilities for more income from the bioenergy crops through credits for offsetting GHG emissions and providing other ecosystem benefits; however, those possibilities are ignored because those systems are not prevalent.

BCAP is modeled based on the projects in Missouri. There are two types of payments included. First, 75 percent of establishment costs are paid through the program. Second, a land payment of $65 per acre is included. The figures below show the production budgets for each cropping system on a Putnam soil. The only difference between the budgets for Putnam and the other two soils considered is the land rental rates.

	Corn			Soybeans		
Revenue	**Yield/Acre**	**$/bu.**	**Total/Acre**	**Yield/Acre**	**$/bu.**	**Total/Acre**
Grain in bushels	116.00	5.18	$ 600.88	57.00	9.75	$ 555.75
Insurance Indemnity			$ -			$ -
Government Support						
Total Revenue			**$ 600.88**			**$ 555.75**
Operations	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Field Prep	0.00	15.80	$ -	0.00	15.80	$ -
Planting and seed	1.00	108.08	$ 108.08	1.00	81.18	$ 81.18
Dry Fertilizer Application	1.20	5.34	$ 6.41	0.20	5.34	$ 1.07
Herbicide Application	2.00	5.98	$ 11.96	2.00	5.98	$ 11.96
Cut Biomass	0.00	20.04	$ -	0.00	20.04	$ -
Harvesting/Baling	1.00	28.59	$ 28.59	1.00	27.87	$ 27.87
Transport to Farmgate	116.00	0.12	$ 13.92	57.00	0.12	$ 6.84
Mowing	0.00	16.38	$ -	0.00	16.38	$ -
Operations Subtotal			**$ 168.96**			**$ 128.91**
Materials	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Nitrogen (lb-N)	160	$ 0.55	$ 88.58	0	$ 0.55	$ -
Phosphorus (lb-P_2O_5)	40	$ 0.45	$ 17.81	47	$ 0.45	$ 21.00
Potassium (lb-K_2O)	117	$ 0.47	$ 55.51	58	$ 0.47	$ 27.27
Lime (ton)	0.0	$ 18.55	$ -	1.0	$ 18.55	$ 18.55
Herbicide-Atrazine	1.00	$ 9.00	$ 9.00	0.00	$ 9.00	$ -
Herbicide-Glysophate/Valor	0.00	$ 4.78	$ -	1.00	$ 15.77	$ 15.77
Herbicide-Acetochlor	1.00	$ 17.72	$ 17.72	0.00	$ 17.72	$ -
Herbicide-2,4-D	1.00	$ 2.30	$ 2.30	1.00	$ 2.30	$ 2.30
Materials Subtotal			**$ 190.91**			**$ 84.90**
Financial						
Insurance	1.00	$ 11.40	$ 11.40	1.00	$ 5.46	$ 5.46
Rental Rate per acre	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00
Operating Interest	@ 7.5%	$ 179.93	$ 13.49	@ 7.5%	$ 106.91	$ 8.02
Financial Subtotal			**$ 193.89**			**$ 182.48**
Total Costs/Acre			**$ 553.76**			**$ 396.29**
Income Over Total Costs/Acre			**$ 47.12**			**$ 159.46**

5.7: Production budget for corn and soybeans on Putnam soils

	Miscanthus Year 1			Miscanthus Year 2			Miscanthus Year 3-5			Miscanthus Year 5-15+		
Revenue	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**
Biomass in tons	0.00	$ 50.00	$ -	7.00	$ 50.00	$ 350.00	13.00	$ 50.00	$ 650.00	13.00	$ 50.00	$ 650.00
Land Payment Subsidy			$ 65.00			$ 65.00			$ 65.00			
Establishment Subsidy			$ 602.25			$ 198.74						
Total Revenue			**$ 667.25**			**$ 613.74**			**$ 715.00**			**$ 650.00**
Operations	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Field Prep	1.00	15.80	$ 15.80	0.00	15.80	$ -	0.00	15.80	$ -	0.00	15.80	$ -
Planting and Rhizomes	1.00	803.00	$ 803.00	0.33	803.00	$ 264.99	0.00	803.00	$ -	0.00	803.00	$ -
Dry Fertilizer Application	0.20	5.34	$ 1.07	1.20	5.34	$ 6.41	1.20	5.34	$ 6.41	1.20	5.34	$ 6.41
Herbicide Application	1.00	5.98	$ 5.98	0.00	5.98	$ -	0.00	5.98	$ -	0.00	5.98	$ -
Cut Biomass and swath	0.00	20.04	$ -	1.00	20.04	$ 20.04	1.00	20.04	$ 20.04	1.00	20.04	$ 20.04
Harvesting/Baling	0.00	11.25	$ -	9.33	11.25	$ 105.00	17.33	11.25	$ 195.00	17.33	11.25	$ 195.00
Transport to Farmgate	0.00	3.18	$ -	9.33	3.18	$ 29.68	17.33	3.18	$ 55.12	17.33	3.18	$ 55.12
Mowing	1.00	16.38	$ 16.38	0.00	16.38	$ -	0.00	16.38	$ -	0.00	16.38	$ -
Operations Subtotal			**$ 842.23**			**$ 426.12**			**$ 276.57**			**$ 276.57**
Materials	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Nitrogen (lb-N)	0	$ 0.55	$ -	50	$ 0.55	$ 27.68	50	$ 0.55	$ 27.68	50	$ 0.55	$ 27.68
Phosphorus (lb-P_2O_5)	0	$ 0.45	$ -	18	$ 0.45	$ 7.90	33	$ 0.45	$ 14.67	33	$ 0.45	$ 14.67
Potassium (lb-K_2O)	0	$ 0.47	$ -	43	$ 0.47	$ 20.18	79	$ 0.47	$ 37.48	79	$ 0.47	$ 37.48
Lime (ton)	1	$ 18.55	$ 18.55	0	$ 18.55	$ -	0	$ 18.55	$ -	0	$ 18.55	$ -
Herbicide-Atrazine	1.00	$ 9.00	$ 9.00	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -
Herbicide-Glysophate/Valor	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -
Herbicide-Acetochlor	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -
Herbicide-2,4-D	1.00	$ 2.30	$ 2.30	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -
Materials Subtotal			**$ 29.85**			**$ 55.77**			**$ 79.84**			**$ 79.84**
Financial	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Insurance Premium	0.00		$ -	0.00		$ -	0.00		$ -	0.00		$ -
Rental Rate per acre	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00
Operating Interest	@ 7.5%	$ 436.04	$ 32.70	@ 7.5%	$ 240.94	$ 18.07	@ 7.5%	$ 178.20	$ 13.37	@ 7.5%	$ 178.20	$ 13.37
Financial Subtotal			**$ 201.70**			**$ 187.07**			**$ 182.37**			**$ 182.37**
Total Costs/Acre			**$ 1,073.78**			**$ 668.95**			**$ 538.77**			**$ 538.77**
Income Over Total Costs/Acre			**$ (406.53)**			**$ (55.21)**			**$ 176.23**			**$ 111.23**

5.8: Production budgets for miscanthus on Putnam soils

	Switchgrass Year 1			Switchgrass Year 2			Switchgrass Year 3-15			Switchgrass Year 3-15		
Revenue	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**
Biomass in tons	0.00	$ 50.00	$ -	3.50	$ 50.00	$ 175.00	6.50	$ 50.00	$ 325.00	6.50	$ 50.00	$ 325.00
Land Payment Subsidy			$ 65.00			$ 65.00			**$ 65.00**			
Establishment Subsidy			$ 60.71			$ 15.18						
Total Revenue			**$ 125.71**			**$255.18**			**$ 390.00**			**$ 325.00**
Operations	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Field Prep	1.00	15.80	$ 15.80	0.00	15.80	$ -	0.00	15.80	$ -	0.00	15.80	$ -
Planting and Seed	1.00	80.95	$ 80.95	0.25	80.95	$ 20.24	0.00	80.95	$ -	0.00	80.95	$ -
Dry Fertilizer Application	0.20	5.34	$ 1.07	1.20	5.34	$ 6.41	1.20	5.34	$ 6.41	1.20	5.34	$ 6.41
Herbicide Application	1.00	5.98	$ 5.98	0.00	5.98	$ -	0.00	5.98	$ -	0.00	5.98	$ -
Cut Biomass and swath	0.00	20.04	$ -	1.00	20.04	$ 20.04	1.00	20.04	$ 20.04	1.00	20.04	$ 20.04
Harvesting/Baling	0.00	11.25	$ -	4.67	11.25	$ 52.50	8.67	11.25	$ 97.50	8.67	11.25	$ 97.50
Transport to Farmgate	0.00	3.18	$ -	4.67	3.18	$ 14.84	8.67	3.18	$ 27.56	8.67	3.18	$ 27.56
Mowing	1.00	16.38	$ 16.38	0.00	16.38	$ -	0.00	16.38	$ -	0.00	16.38	$ -
Operations Subtotal			**$ 120.18**			**$ 114.03**			**$ 151.51**			**$ 151.51**
Materials	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Nitrogen (lb-N)	0	$ 0.55	$ -	60	$ 0.55	$ 33.22	60	$ 0.55	$ 33.22	60	$ 0.55	$ 33.22
Phosphorus (lb-P_2O_5)	0	$ 0.45	$ -	9	$ 0.45	$ 3.95	16	$ 0.45	$ 7.34	16	$ 0.45	$ 7.34
Potassium (lb-K_2O)	0	$ 0.47	$ -	21	$ 0.47	$ 10.09	40	$ 0.47	$ 18.74	40	$ 0.47	$ 18.74
Lime (ton)	1	$ 18.55	$ 18.55	0	$ 18.55	$ -	0	$ 18.55	$ -	0	$ 18.55	$ -
Herbicide-Atrazine	1.00	$ 9.00	$ 9.00	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -
Herbicide-Glysophate/Valor	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -
Herbicide-Acetochlor	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -
Herbicide-2,4-D	1.00	$ 2.30	$ 2.30	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -
Materials Subtotal			**$ 29.85**			**$ 47.26**			**$ 59.30**			**$ 59.30**
Financial												
Insurance Premium	0.00		$ -	0.00		$ -	0.00		$ -	0.00		$ -
Rental Rate per acre	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00
Operating Interest	@ 7.5%	$ 75.01	$ 5.63	@ 7.5%	$ 80.64	$ 6.05	@ 7.5%	$ 105.40	$ 7.91	@ 7.5%	$ 105.40	$ 7.91
Financial Subtotal			**$ 174.63**			**$ 175.05**			**$ 176.91**			**$ 176.91**
Total Costs/Acre			**$ 324.65**			**$ 336.33**			**$ 387.71**			**$ 387.71**
Income Over Total Costs/Acre			**$ (198.94)**			**$ (81.16)**			**$ 2.29**			**$ (62.71)**

5.9: Production budget for switchgrass on Putnam soils

	Native Prairie Year 1			Native Prairie Year 2			Native Prairie Year 3-5			Native Prairie Year 5-15		
Revenue	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**	**Yield/Acre**	**Price/Ton**	**Total/Acre**
Biomass in tons	0.00	$ 50.00	$ -	1.75	$ 50.00	$ 87.50	3.25	$ 50.00	$ 162.50	3.25	$ 50.00	$ 162.50
Land Payment Subsidy			$ 65.00			$ 65.00			$ 65.00			
Establishment Subsidy			$ 188.29			$ 47.07						
Total Revenue			**$ 253.29**			**$ 199.57**			**$ 227.50**			**$ 162.50**
Operations	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Field Prep	1.00	15.80	$ 15.80	0.00	15.80	$ -	0.00	15.80	$ -	0.00	15.80	$ -
Planting and Seed	1.00	251.05	$ 251.05	0.25	251.05	$ 62.76	0.00	251.05	$ -	0.00	251.05	$ -
Dry Fertilizer Application	0.00	5.34	$ -	0.00	5.34	$ -	0.00	5.34	$ -	0.00	5.34	$ -
Herbicide Application	0.00	5.98	$ -	0.00	5.98	$ -	0.00	5.98	$ -	0.00	5.98	$ -
Cut Biomass and swath	0.00	20.04	$ -	1.00	20.04	$ 20.04	1.00	20.04	$ 20.04	1.00	20.04	$ 20.04
Harvesting/Baling	0.00	11.25	$ -	2.33	11.25	$ 26.25	4.33	11.25	$ 48.75	4.33	11.25	$ 48.75
Transport to Farmgate	0.00	3.18	$ -	2.33	3.18	$ 7.42	4.33	3.18	$ 13.78	4.33	3.18	$ 13.78
Mowing	1.00	16.38	$ 16.38	1.00	16.38	$ 16.38	1.00	16.38	$ 16.38	1.00	16.38	$ 16.38
Operations Subtotal			**$ 283.23**			**$ 132.85**			**$ 98.95**			**$ 98.95**
Materials	**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**		**Quantity**	**Cost/Unit**	
Nitrogen (lb-N)	0	$ 0.55	$ -	0	$ 0.55	$ -	0	$ 0.55	$ -	0	$ 0.55	$ -
Phosphorus (lb-P_2O_5)	0	$ 0.45	$ -	0	$ 0.45	$ -	0	$ 0.45	$ -	0	$ 0.45	$ -
Potassium (lb-K_2O)	0	$ 0.47	$ -	0	$ 0.47	$ -	0	$ 0.47	$ -	0	$ 0.47	$ -
Lime (ton)	0	$ 18.55	$ -	0	$ 18.55	$ -	0	$ 18.55	$ -	0	$ 18.55	$ -
Herbicide-Atrazine	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -	0.00	$ 9.00	$ -
Herbicide-Glysophate/Valor	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -	0.00	$ 4.78	$ -
Herbicide-Acetochlor	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -	0.00	$ 17.72	$ -
Herbicide-2,4-D	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -	0.00	$ 2.30	$ -
Materials Subtotal			**$ -**			**$ -**			**$ -**			**$ -**
Financial												
Insurance Premium	0.00		$ -	0.00		$ -	0.00		$ -	0.00		$ -
Rental Rate per acre	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00	1.00	$ 169.00	$ 169.00
Operating Interest	@ 7.5%	$ 141.62	$ 10.62	@ 7.5%	$ 66.43	$ 4.98	@ 7.5%	$ 49.48	$ 3.71	@ 7.5%	$ 49.48	$ 3.71
Financial Subtotal			**$ 179.62**			**$ 173.98**			**$ 172.71**			**$ 172.71**
Total Costs/Acre			**$ 462.85**			**$ 306.83**			**$ 271.66**			**$ 271.66**
Income Over Total Costs/Acre			**$ (209.56)**			**$ (107.26)**			**$ (44.16)**			**$ (109.16)**

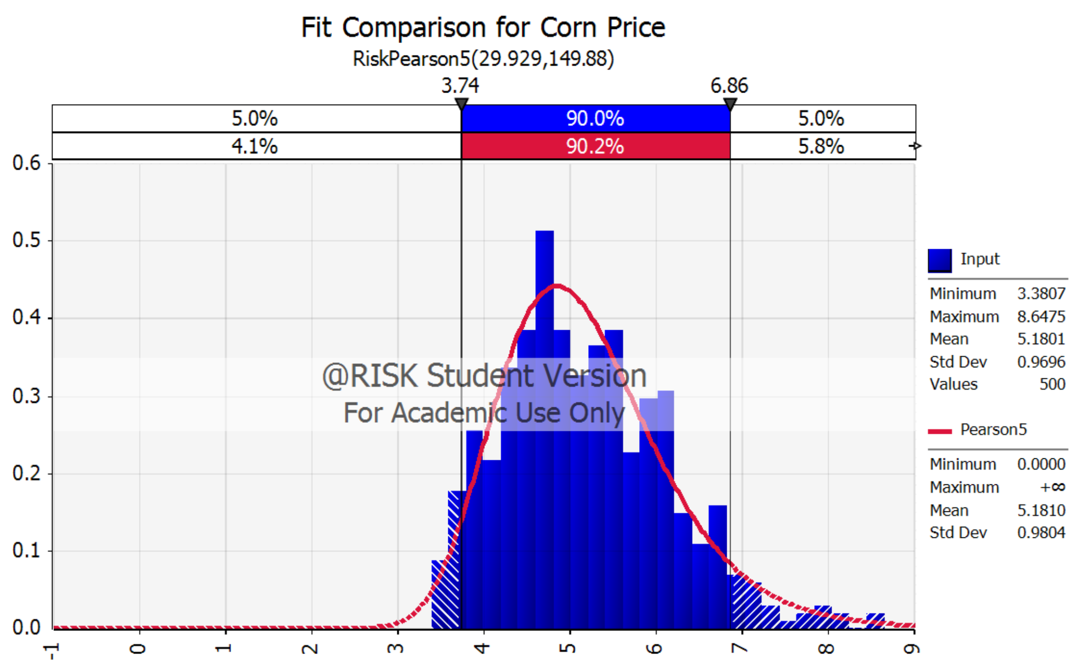
5.10: Production budget for native prairie on Putnam soils

5.2.2.2 Stochastic Factors

The model incorporates uncertainty into the following variables: corn price, soybean price, corn yield, soybean yield, miscanthus yield, switchgrass yield and native prairie yield. @Risk simulation model in Decision Tools Suite (Palisade Corporation 2007) to create distribution functions and provided statistical analysis of the stochastic data.

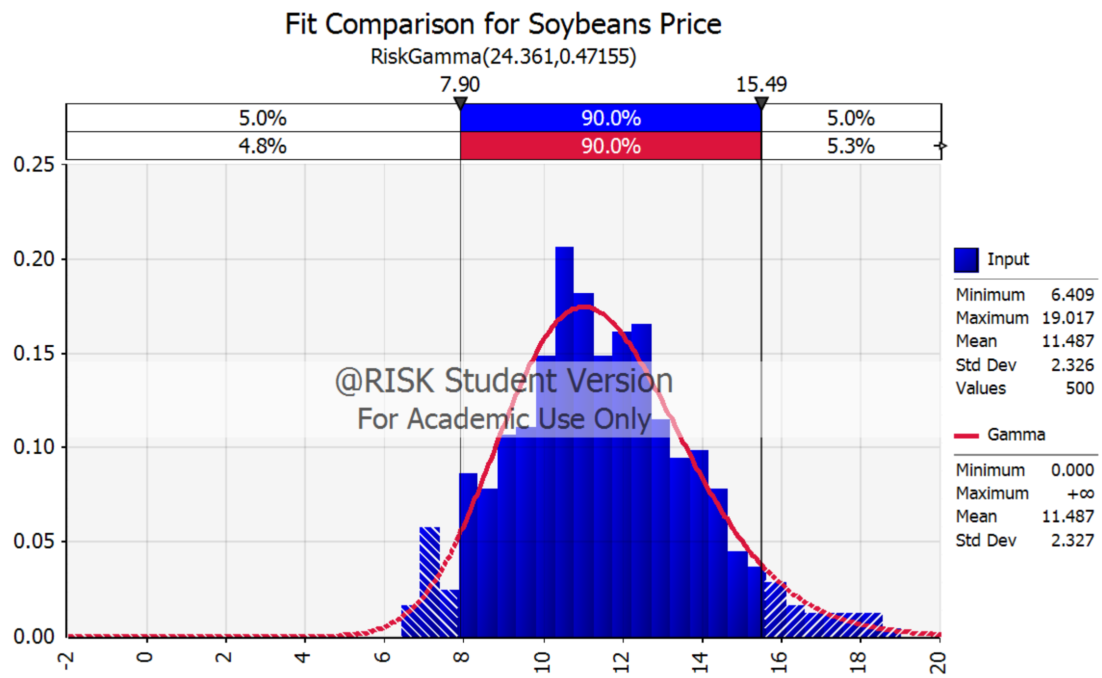
5.2.2.3 Prices of Corn and Soybeans

The Food and Agriculture Policy Research Institute (FAPRI) at the University of Missouri supplied simulated corn and soybeans prices. This thesis uses a distribution produced from 500 simulated national corn and soybean prices for 2013.



5.11: Histogram of corn prices with fitted distribution and summary statistics.

Each year FAPRI produces baseline projections of agricultural markets and commodities (Westhoff and Brown 2013). Commodity prices are one part of those projections; they are correlated and based on an array of assumptions about macroeconomic conditions, policies, and production. No adjustments are made to those prices despite that Missouri producers can receive a premium or a discount on national prices (Dhuyvetter 2013).

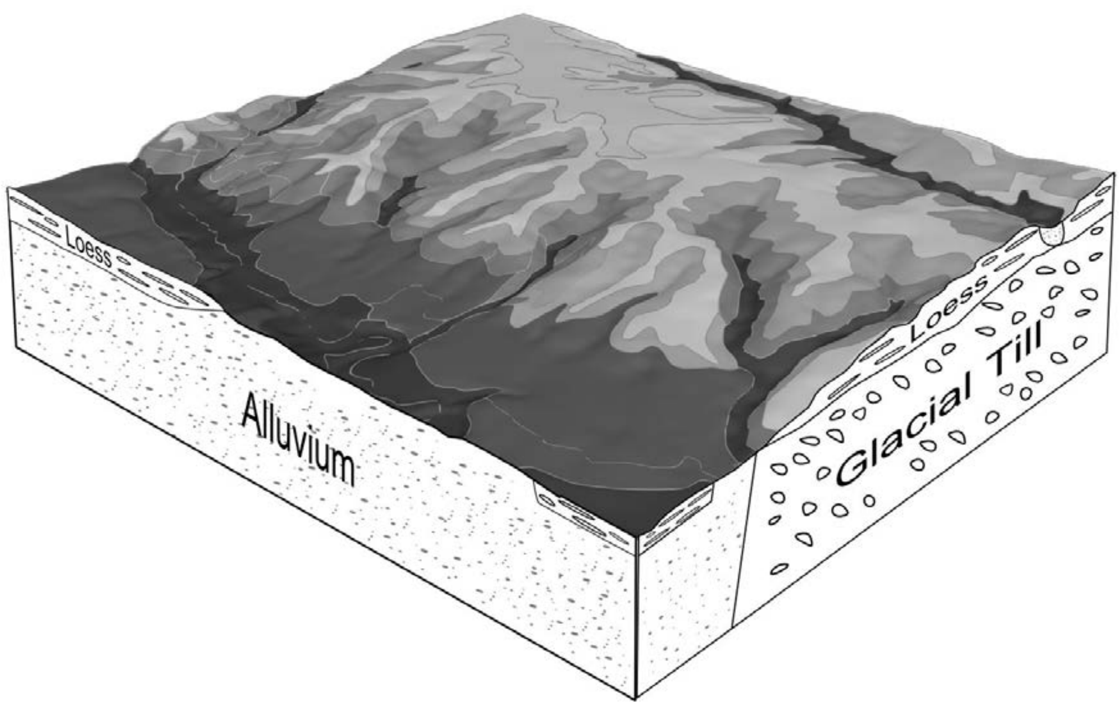


5.12: Histogram for soybean prices with fitted distribution and summary statistics.

Figure 5.11 and figure 5.12 show the distributions of corn and soybean prices, respectively. To the right of each figure are the summary statistics and description of the distribution. The X-axis is the prices in dollars and the Y-axis is the frequency. The line is the distribution fitted for both of the sets of data. @Risk gives options about the distribution to use. The minimum X-value is presumed to be zero since prices cannot be negative. An empirical distribution would have been more appropriate; however, it was unavailable in @Risk. Instead, this thesis uses the distribution with the lowest Akaike information criterion (AIC), a statistical indicator of goodness of fit.

5.2.2.4 Yield

As previously discussed, the perennial grasses have the lowest breakeven costs where corn and soybeans have the lowest average yields. Numerous factors contribute to yield including weather, management practices, and soil conditions. This thesis compares the profitability of cropping systems on three different landscape soils. In Northeast Missouri, two soil landscape factors greatly impact grain crop productivity: erosion and flooding. Thus, the relative profitability of perennial grasses to corn and soybeans will be the highest in landscape soils susceptible to those conditions.



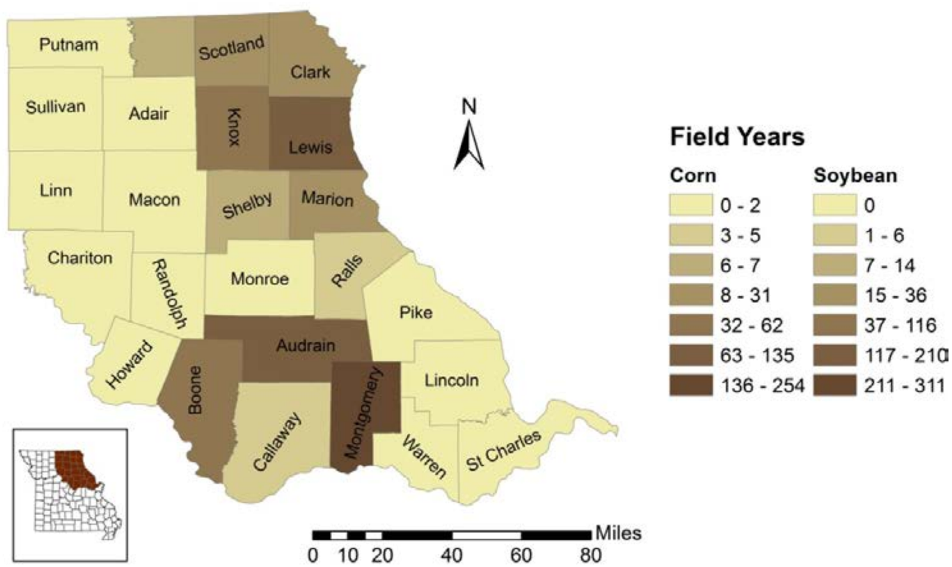
5.13: A diagram of landscape soils in Missouri illustrating the floodplain soils, upland eroded soils, and upland non-eroded soils

Three different landscape soils are analyzed for each cropping system: a baseline soil which is upland and non-eroded, a floodplain soil, and an upland and eroded soil. Figure 5.13 is a diagram of landscape soils. The darkest areas are floodplains, which have productive alluvium soils; however, as their name suggests, they are prone to flooding in years of more than average rain washing out not only nutrients but also the actual crop. This thesis uses a Belknap Silt Loam to represent a floodplain soil.

Landscape soils subject to erosion are represented by the second lightest gray Figure 5.13. These positions are found on the back slopes and are especially prone to soil loss, nutrient runoff, and have limited water holding capacity, commonly losing their topsoil to lower landscape positions like the toe-slopes or floodplains. Two very similar soils Armstrong Loam and Armster Loam with 5 to 9 percent slopes are analyzed in this thesis.

The remaining areas are the higher yielding corn and soybeans cropland and consist of lightest gray colors in figure 5.13. They are upland and non-eroded landscapes. The lightest gray areas are summit positions where topsoil stays. In this thesis, a Putnam Silt Loam with 0 to 1 percent slope is analyzed as a soil that does not flood or is especially prone to erosion.

5.2.2.4.1 Corn and Soybeans



5.14: Location and amount of data by county in northeast Missouri where yield data was obtained

Myers, Kitchen, and Sudduth (2012) collected actual gridded yield data from northeast Missouri. The data comes either directly from producers or through their precision ag-service providers with the calibrations made by the producer during the harvest season. Yield maps were processed using Yield Editor 1.02 to eliminate bad data points and systematic error, such as thresher delay (Myers, Kitchen, and Sudduth 2012). The raw dataset contains over 13 million records but was aggregated and sampled for more convenient analysis. Yields from irrigated fields and near field edges were removed. The mean of yield data points were calculated within grid areas of one arc second by one arc second, or about 0.20 acres. Yield data were stratified by field and year and 50 gridded yield data points were randomly sampled from within each field-year strata. The yields date back to 1996. Figure 5.14 from Myers, Kitchen, and Sudduth

(2012) shows the county in northeast Missouri where the corn and soybean yields were obtained.

Each data point contains information about the yield. This information includes a code for producer and name of the specific field as well as the year that the yield occurred. More importantly for this study, the data contains information about the soil series, a grouping for eroded and flooded fields, and information about the landscape position.

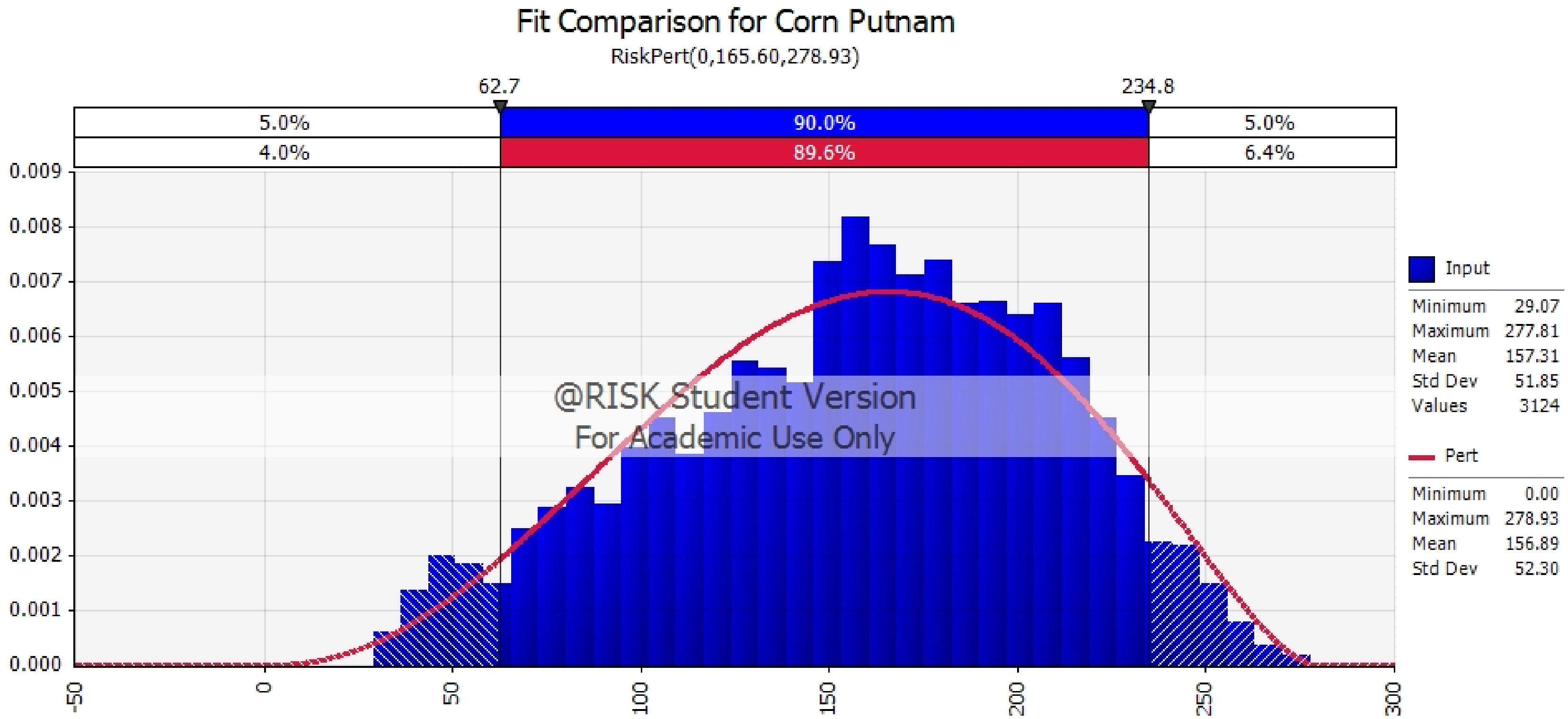
This empirical data of corn and soybeans yields includes bias. Producers deem fields too marginal or unproductive for corn and soybean and have taken those fields out of corn and soybean production before yield mapping data was available. Thus, those fields are ignored in this analysis. This point is important as those fields can be converted into perennial grasses grown for bioenergy. Thus, the interpretation of this analysis should only be in the context of replacing currently cropped corn and soybeans fields with the perennial grass cropping systems grown for bioenergy.

These groupings allow the data to be divided into three categories based on the different landscape soils that limit productivity discussed above. The first group is eroded soils from the Armstrong or Armster series. Since the soil series and site specific information come from soil map units, the definition of erosion is from the Natural Resource Conservation Service (NRSC) who originally created the soil maps. They designate a subfield to be eroded based on the “estimated % loss of the original combined A + E horizons or the estimated loss of the upper 20 cm” (Schoeneberger et al. 2002). That percentage is classified based on degree of erosion: none, class 1 with 0-

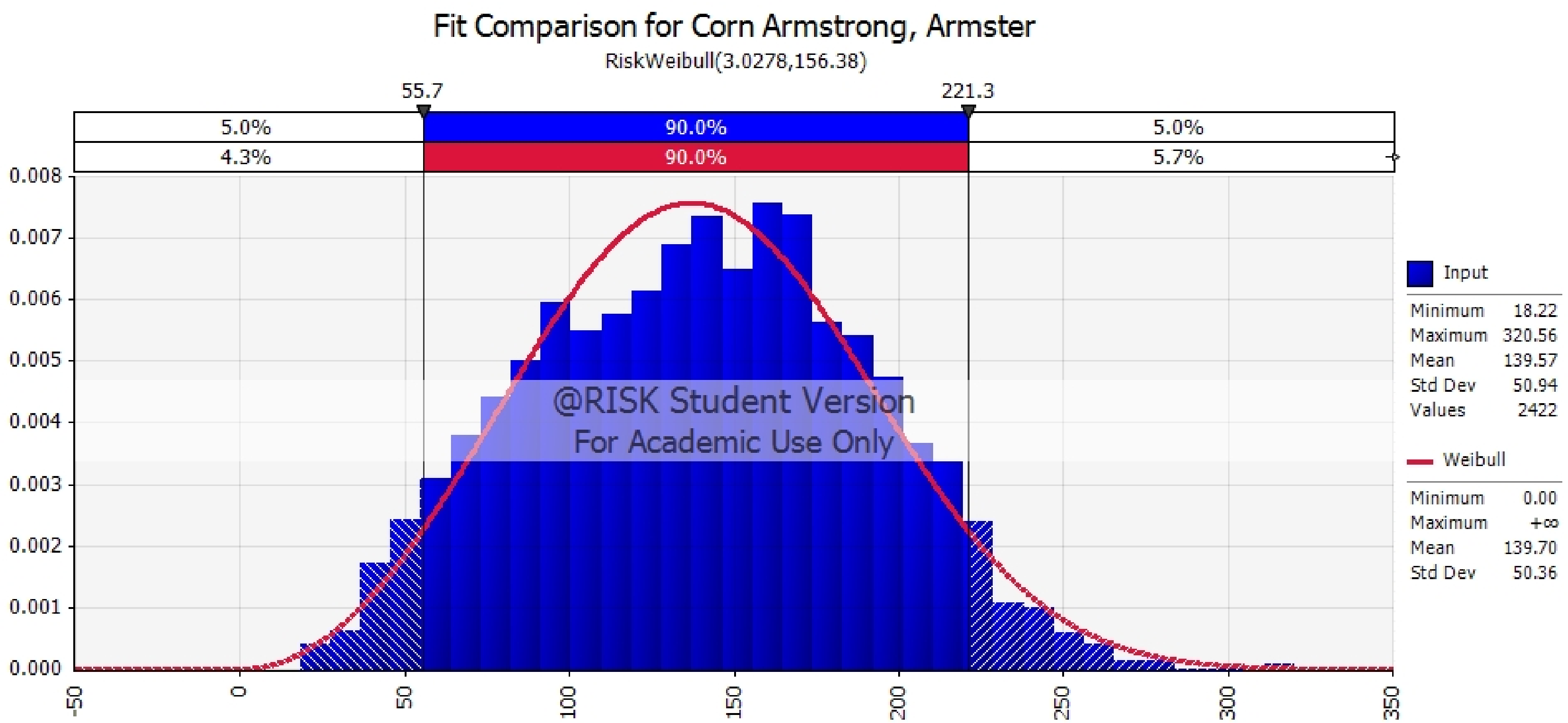
25 percent loss, class 2 with 25 to 75 percent loss, class 3 with 75 to 100 percent, and class 4 with 75 percent and total removal of the A horizon. For this thesis, any yield taken from a subfield with class 3 or class 4 erosion as classified by NRCS is considered eroded.

The second group is landscapes prone to flooding and fall into the Belknap series. NRCS designation of flooded soils is used to distinguish these landscapes. NRCS defines flooding of cropland by frequency it floods, duration it is flooded, and months it floods. The definition is for land in its current state; thus, if new levies are built decreasing the frequency of flooding, the land will be reclassified. The scale for frequency ranges from none to very rare and rare to occasional and frequent and very frequent. The duration scale begins at extremely brief and goes to very long based on the amount of time the area is flooded for a single flood event. The months flooding occurs in a given year are simply listed (Schoeneberger et al. 2002).

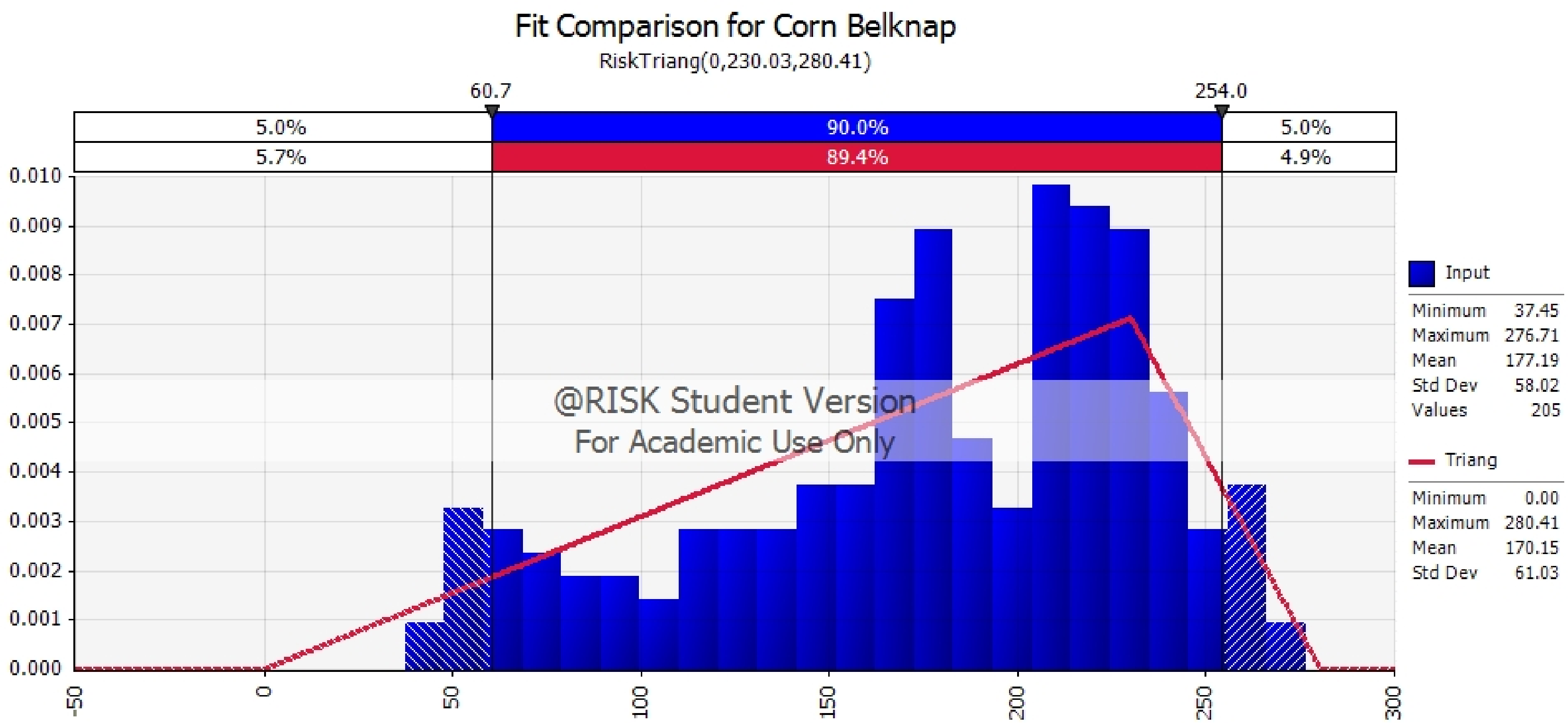
The figures below show the yield data from 1996 to 2009 for corn on Putnam soils, eroded Armstrong or Armster soils, and flooded Belknap soils. Following the distributions of corn yields are the distributions for soybeans. The bars are a histogram of yields, and the line is the fitted distribution functions with lowest AIC developed by @Risk. Since yields cannot be negative, the minimum is zero. The summary statistics of the yield data and fitted distribution function are on the right. Each figure includes a description of the distribution used below its title listing the type of distribution used and input numbers @Risk used. Similar to prices, an empirical distribution would be better suited; however, @Risk did not easily offer that feature.



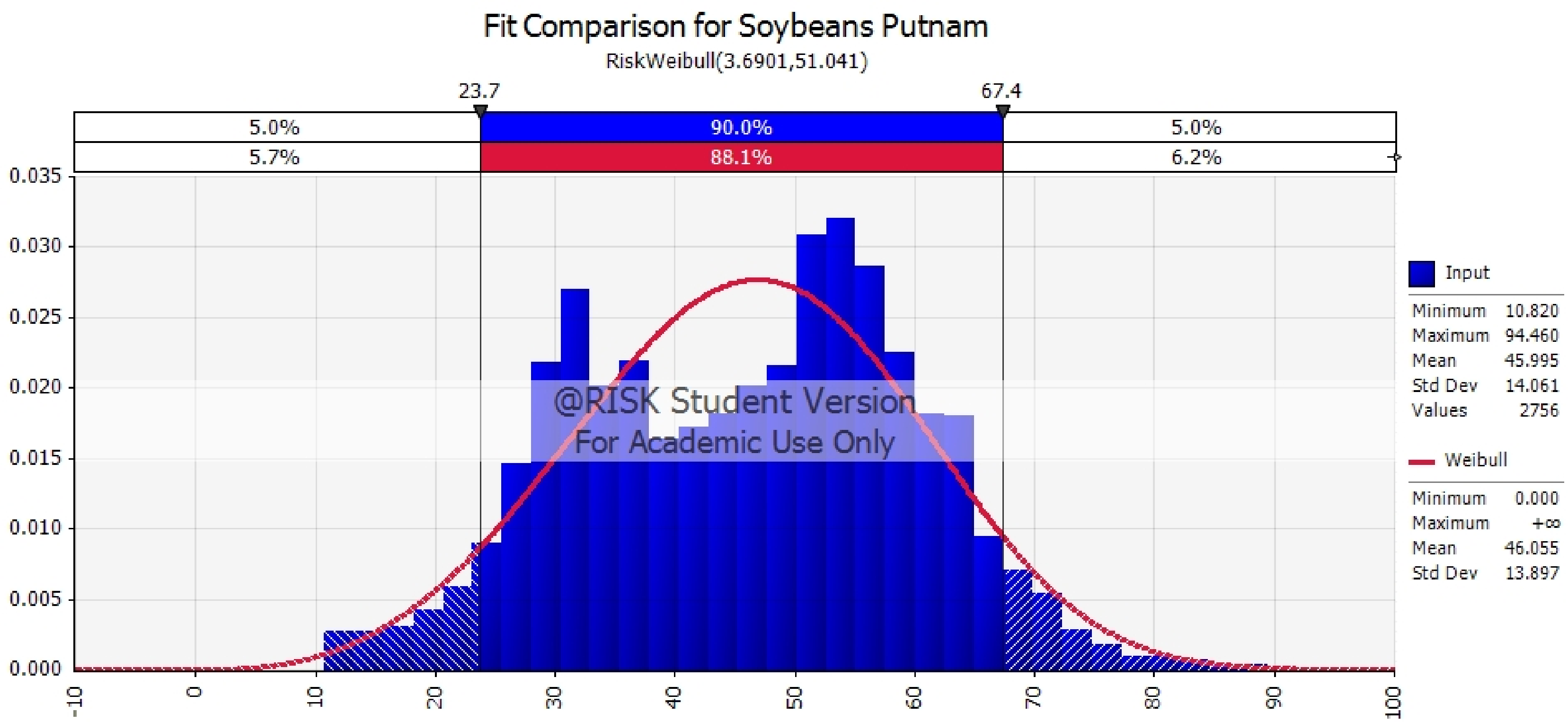
5.15: Distribution of corn yields on Putnam soils



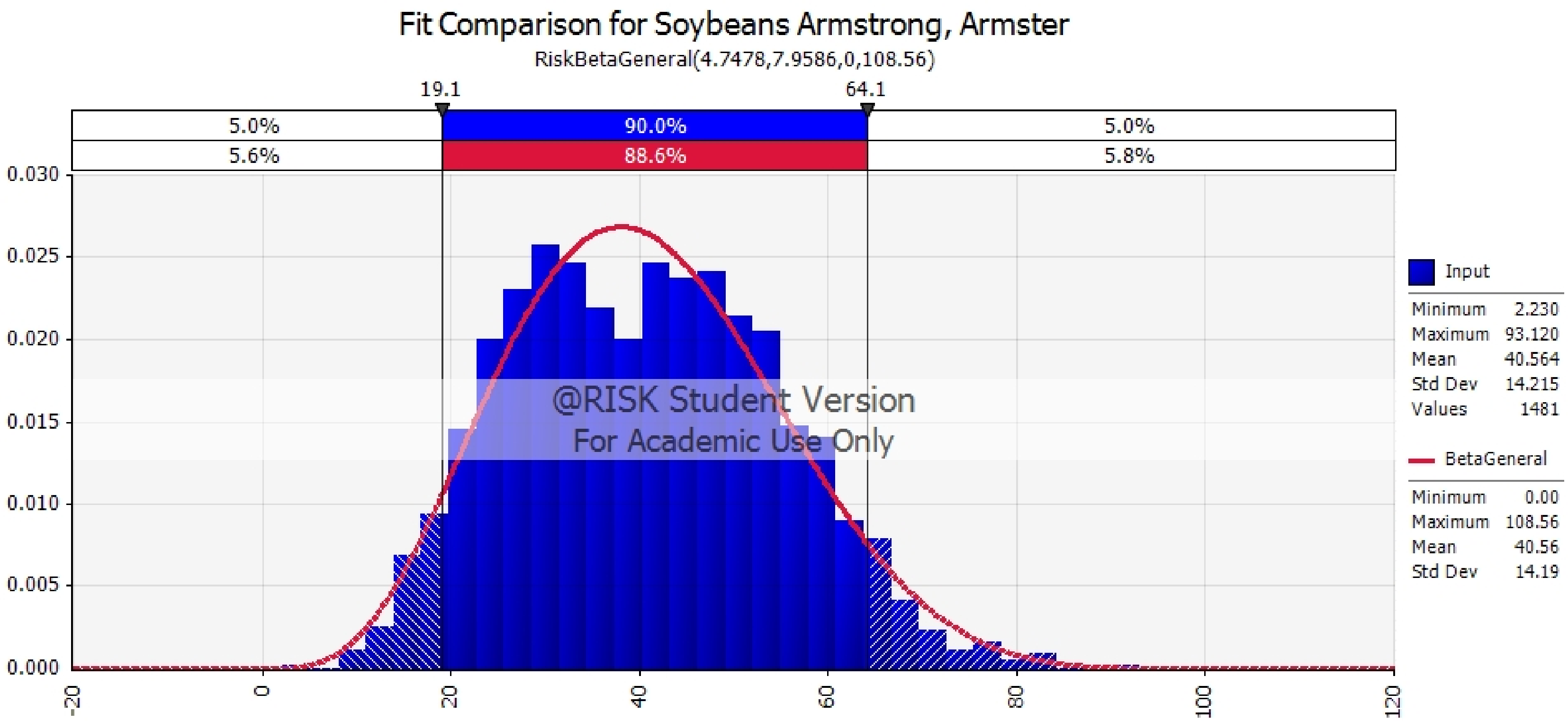
5.16: Distribution of corn yields on Armstrong or Armster soils



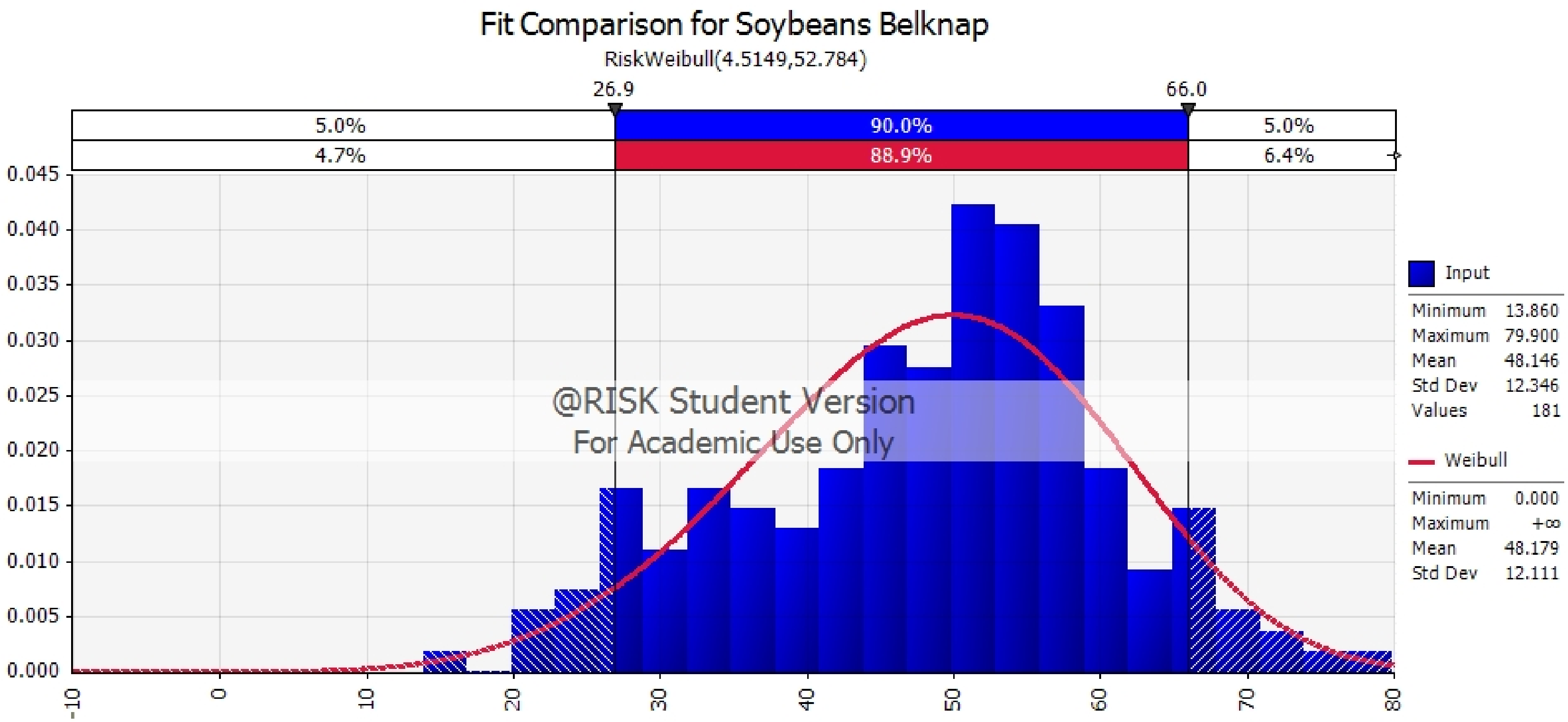
5.17: Distribution of corn yields on Belknap soils



5.18: Distribution of soybean yields on Armstrong or Putnam soils



5.19: Distribution of soybean yields on Armstrong or Armster soils



5.20: Distribution of soybean yields on Belknap soils

5.2.2.4.2 Miscanthus, Switchgrass, and Native Prairie

The yields for switchgrass and miscanthus are simulated using ALMANAC over a 30 year period from 1970 to 2000. The yields for a native prairie are assumed to be one half of the simulated yields for monoculture switchgrass. All the simulations are run for a field in Audrain County, Missouri using weather data from Moberly AP. ALAMANAC is unable to model establishment years, so the 30 yields modeled are for mature stands. Similar to the 10 years of corn and soybean data, the 30 years modeled incorporate a range of weather including different levels of precipitation, temperature, etc.

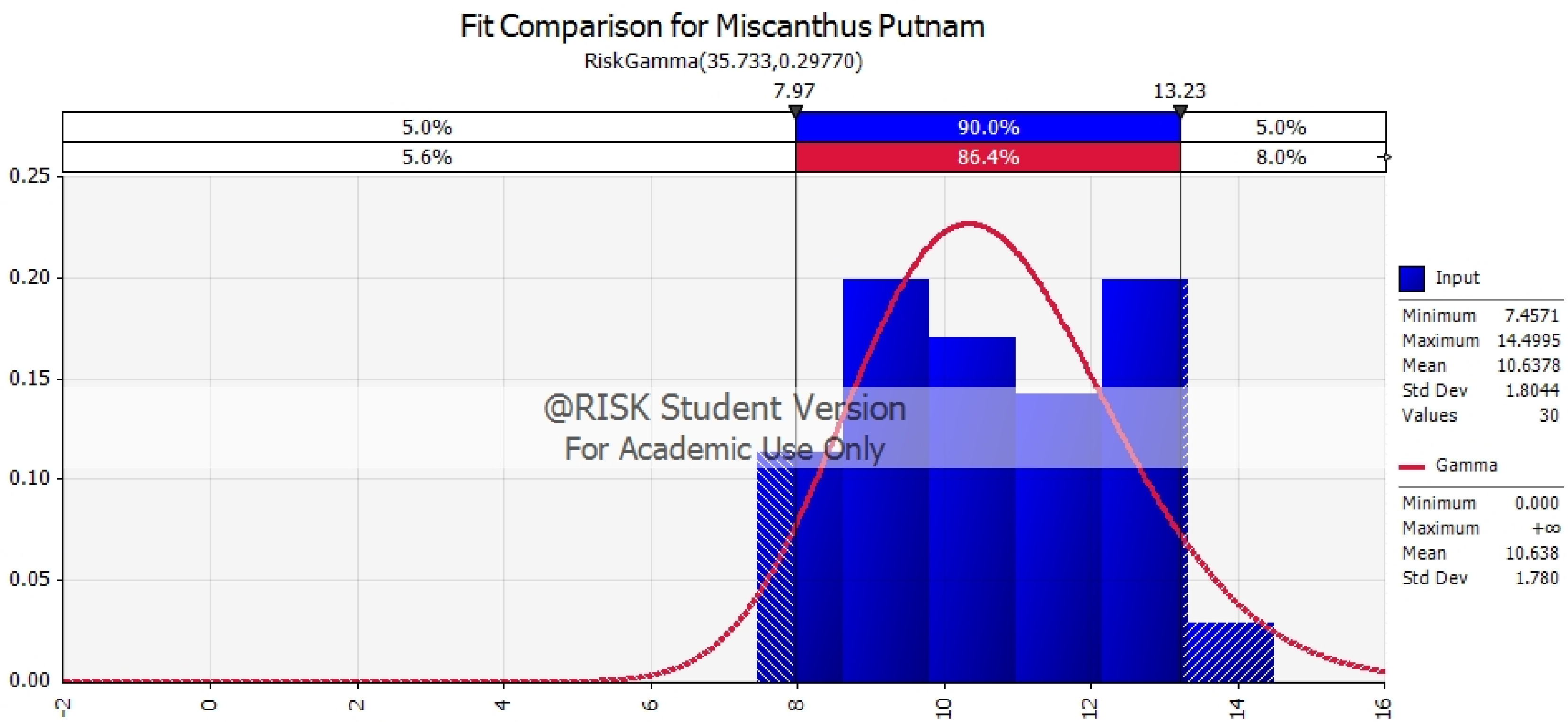
ALMANAC required that both of the crops receive more nitrogen fertilizer than actual experiments at SPARC and Jefferson Farms to obtain the yields similar to SPARC and Jefferson Farms. Nitrogen fertilizer rates of 125 pounds per acre for switchgrass and 312 pounds per acre for miscanthus were used. Field experience indicates that a stand can produce similar yields at rates of 60 pounds per acre for switchgrass and 50 pounds per acre for miscanthus, which are the rates used in the budget analysis. At those lower rates, ALMANAC modeled significant nitrogen deficiency approximately every third year resulting in an unrealistic yield.

The crop parameters for switchgrass and miscanthus were preset according to prior research but were slightly altered to simulate yields calibrated to ongoing research at SPARC and Jefferson Farms. Switchgrass is a default crop in ALMANAC meaning most of its parameters are preloaded. The potential heat units (PHUs) for switchgrass was 1320. Miscanthus has mostly similar parameters being that both crops are C4 perennial grasses; however, the maximum leaf area index and maximum canopy height were altered according to Parajuli (2012). The PHUs for miscanthus was set at 1,500. Lastly, the potential unstressed growth rate was increased to 67 for miscanthus to obtain representative yields.

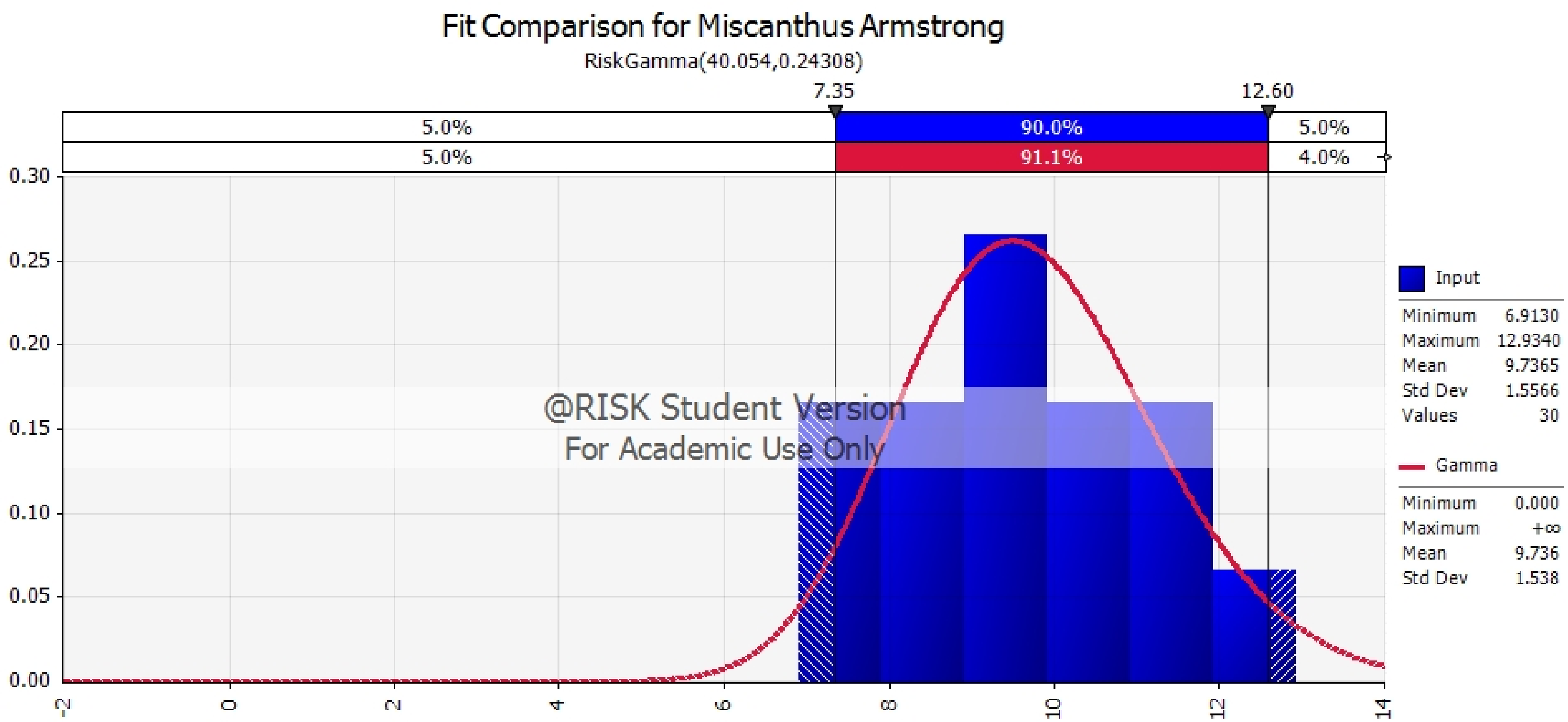
Much like the corn and soybeans, the yields are simulated for three different soil landscape scenarios. The first is a situation with Putnam Silt Loam with 0 to 1 percent slope meant to replicate an upland and non-eroded field. The second scenario keeps the same runoff curve but changes the soil to a Belknap Silt Loam with 0 to 2 percent slope that floods frequently. For both of these landscape soils, the runoff curve was adjusted down to 70 from 79 to give the grasses more plant available water. The last scenario is with an eroded Armstrong Silt Loam with 5 to 9 percent slope. The runoff curve was raised to the default of 79 decreasing plant available water. The maximum root depth was also changed from the 1.5 meters to 0.75 meter to simulate the claypan.

Statistical distributions of the 30 simulated yields for each cropping system in each scenario, nine distributions total were calculated using @Risk. The distributions were selected because they had the lowest AIC relative to other types of distributions. These distributions are not as certain as the corn and soybeans because the yields are simulated, and there are only 30 observations from which a distribution can be made; however, they are calibrated to ongoing research.

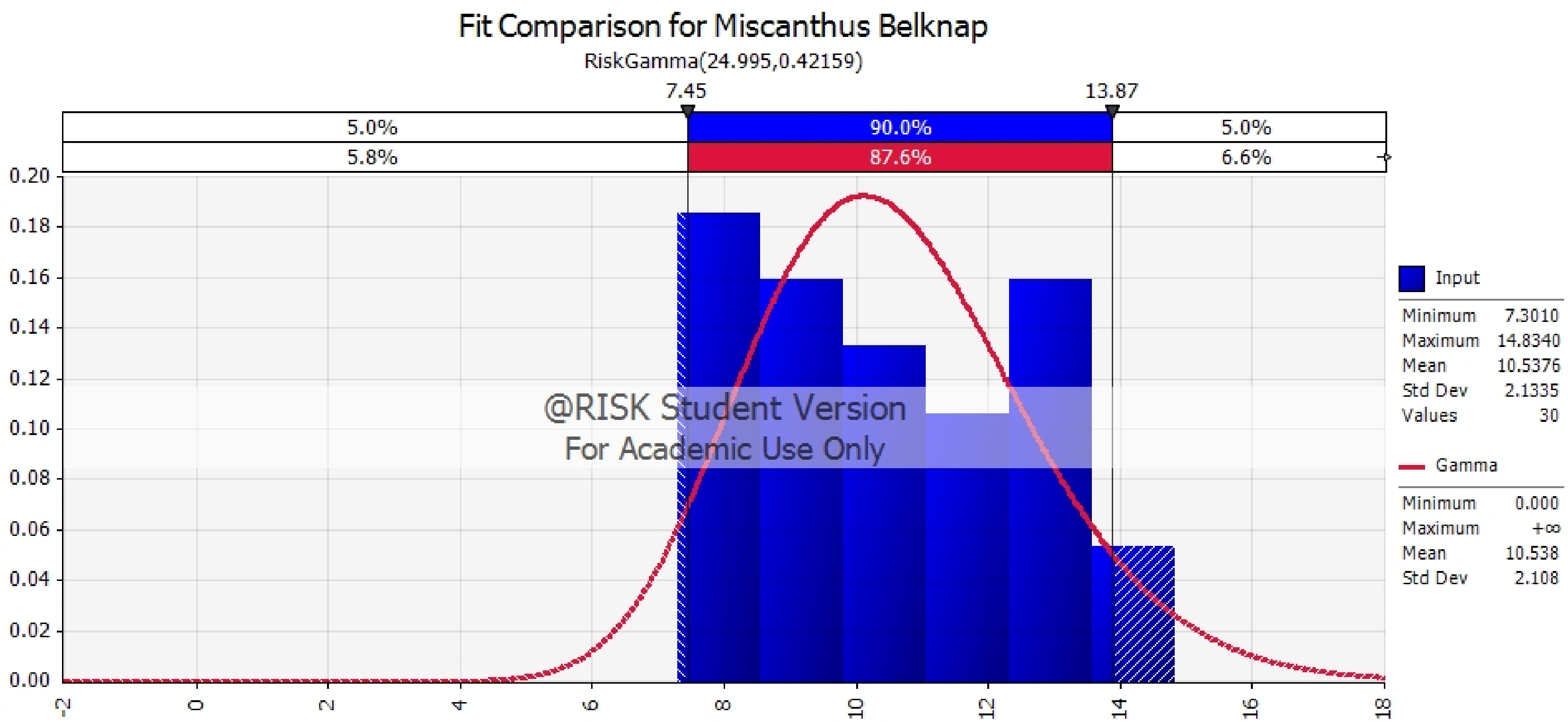
The following figures are the distributions of miscanthus, switchgrass, and native prairie. The simulated data have histograms and a line as the fitted function. The X-axis is yields in tons per acre, and the Y-axis is the frequency each yield occurs. The summary statistics, including a minimum and maximum for each crop, are listed to the right.



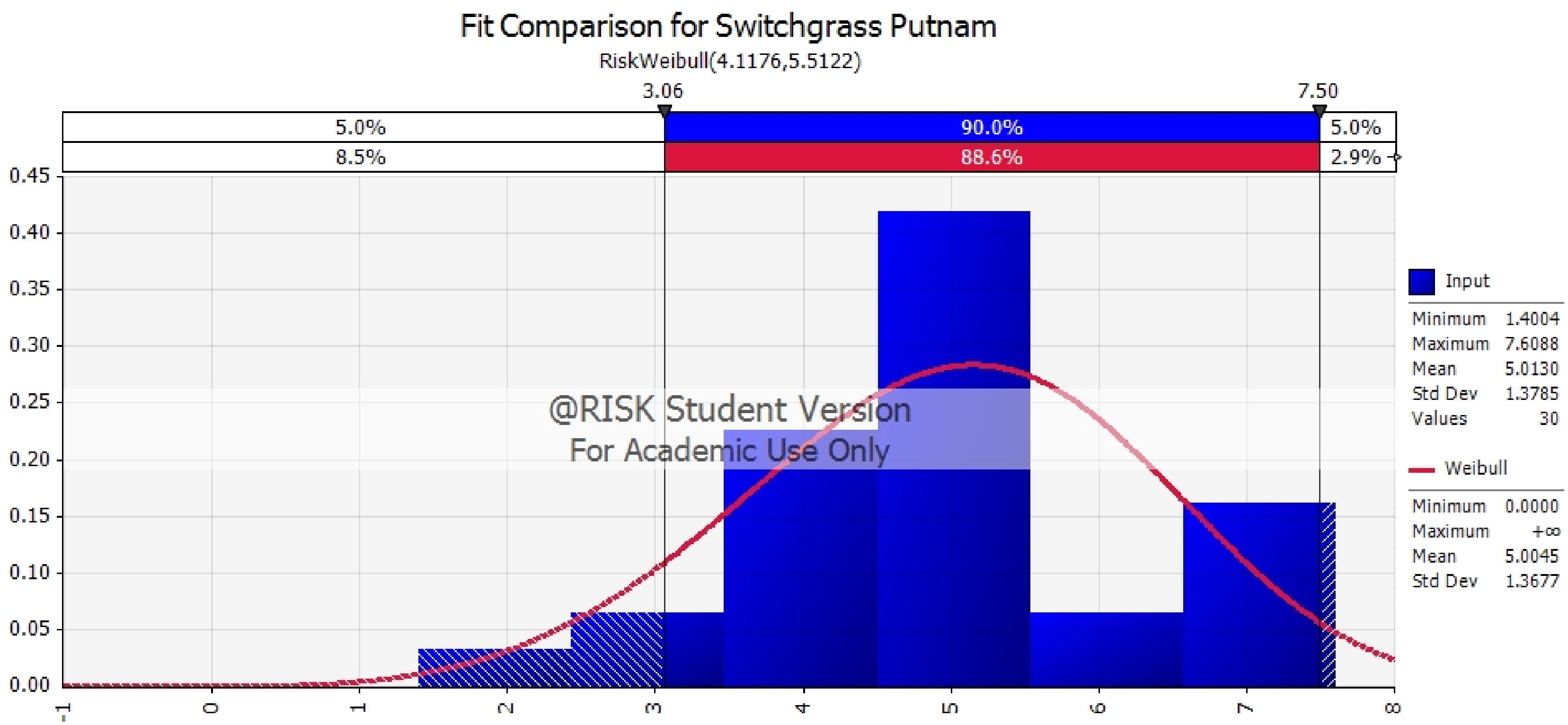
5.21: Distribution of miscanthus yields on Putnam soil



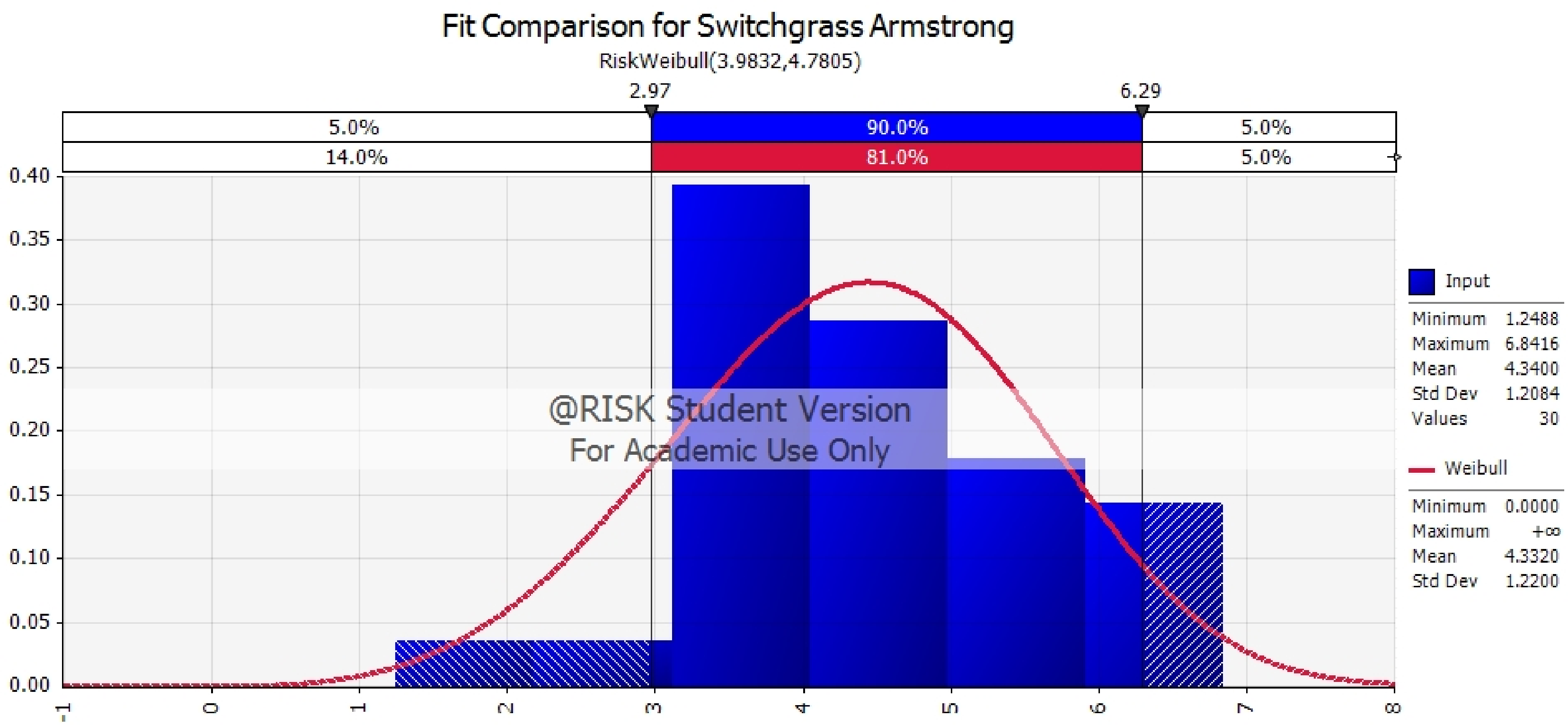
5.22: Distribution of miscanthus yields on Armstrong soil



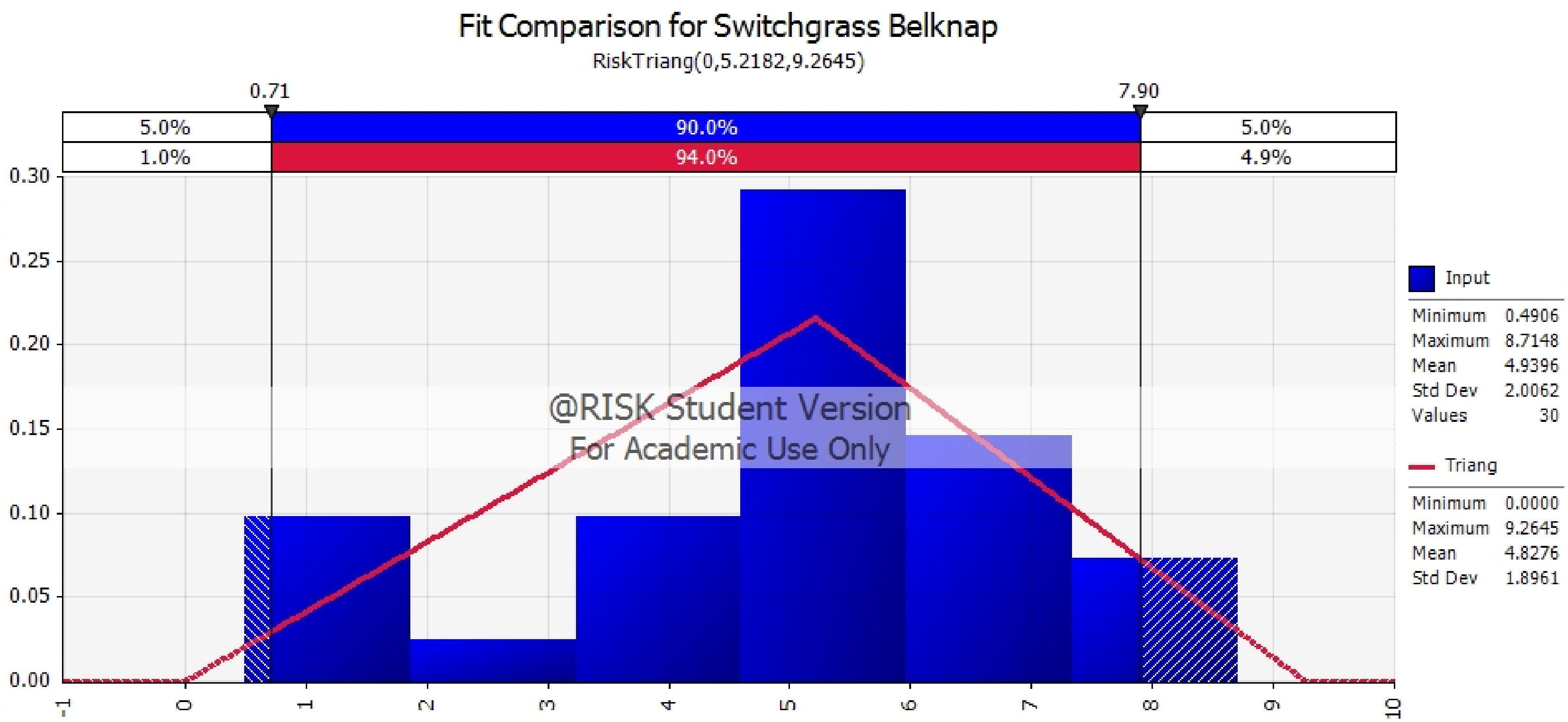
5.23: Distribution of miscanthus yields on Belknap soil



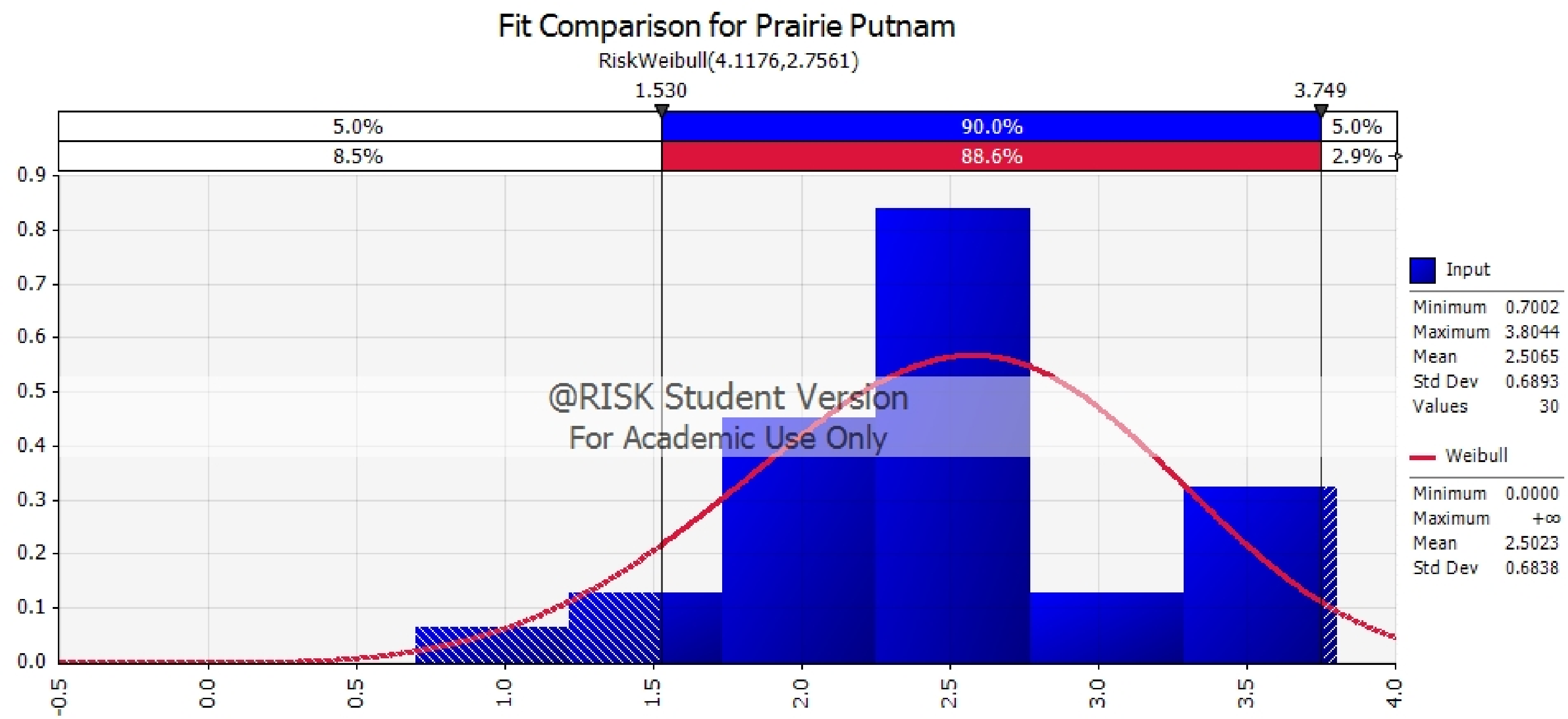
5.24: Distribution of switchgrass yields on Putnam soil



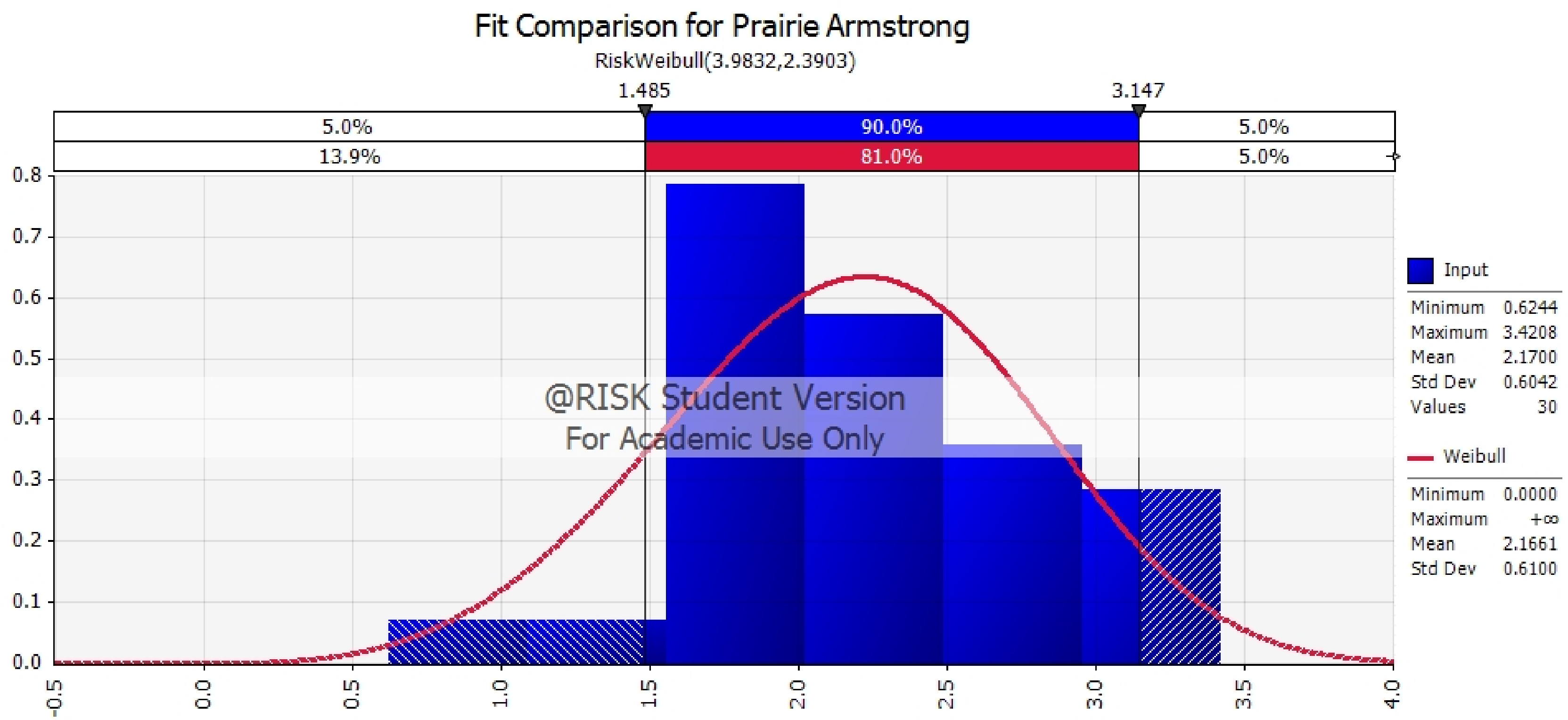
5.25: Distribution of switchgrass yields on Armstrong soil



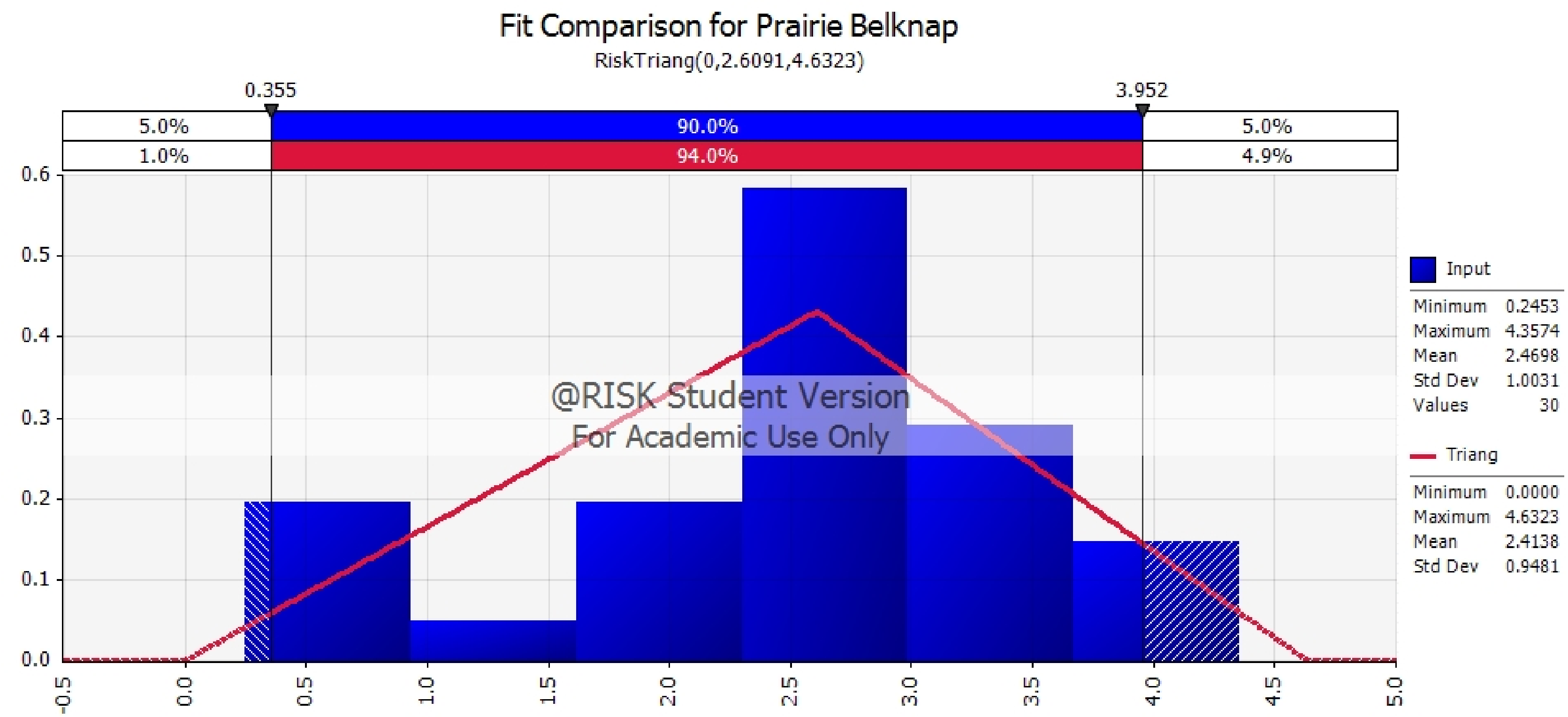
5.26: Distribution of switchgrass yields on Belknap soil



5.27: Distribution of native prairie yields on Putnam soil



5.28: Distribution of native prairie yields on Armstrong soil



5.29: Distribution of native prairie yields on Belknap soil

5.3 Simulations

With the budgets explained above and fitted distributions of stochastic variables, 1000 simulations were run using @Risk in Microsoft Excel. The software randomly selects a price for corn and soybeans, and yields for each cropping system plugging those variables into the budgets. With those 1000 different input scenarios, a profit is outputted.

The stochastic variables are only inputted into budgets that assume a fully established stand for the perennial grasses. The establishment costs of perennial grasses including the costs for planting, seeds, and related materials are prorated over 14 production years. This timeframe assumes a stand lasts 15 years even though 10 years is the normal assumption in breakeven studies. Anderson et al. (2011) discusses the longevity of a miscanthus stand to emphasize a stand in Denmark that is over 25 years old, meaning that 15 years is certainly possible. Similarly, Rinehart (2006) indicates that a stand of switchgrass can last longer than 15 years. Table 5.4 shows the prorated establishment costs for all perennial grass cropping systems. The top of the table is without BCAP. The bottom of the table is with BCAP and includes the land payment of $65 per year for the first five years.

5.4: Establishment costs with and without BCAP for perennial grass cropping systems

Without BCAP	**Miscanthus**	**Switchgrass**	**Native Prairie**
Establishment costs in 1st and 2nd years	$(1,137)	$(459)	$(526)
Amortized over 15 years	$(81)	$(33)	$(38)
With BCAP	**Miscanthus**	**Switchgrass**	**Native Prairie**
Establishment costs in 1st and 2nd years with BCAP	$(292.52)	$(104.98)	$(131)
BCAP and Amortized over 15 years	$(9)	$(8)	$(9)
Land Payments	$65	$65	$65
Total Amortized BCAP Award Less Amortized Establishment Expenses	$44	$57	$56

The stochastic variables are correlated. While the simulation draws randomly from the variables, some of the variables have a relationship meaning that it is unlikely for certain scenarios to occur. For example, if the corn yield is especially low, then soybean yield is most likely below average as well. The correlation in this example could be caused by drought conditions including hot temperatures, lack of rain, and wind on all the cropland.

Correlation coefficients are between negative one (-1) and positive one (1). Zero signifies no correlation. As the absolute value of the correlation coefficient increases, the strength of the correlation whether it be negative or positive also increases. Perfect negative correlation (-1) means that as one variable increases while the other decreases. Perfect positive correlation means as two variables increase or decrease at the same magnitude and in the same direction.

Table 5.5 shows the correlation values and their source. The values used in this thesis are calculated from the distributions data using the Microsoft Excel function. Calculating correlation values from FAPRI data and ALMANAC is straightforward, and that data are explained above. Some correlation functions could not be calculated because they have significant differences in the number of observations. Of those values that could not be calculated, most are assumed to be zero or have no correlation. For example, the relationship between corn price and switchgrass yields from Putnam soils is assumed to be zero. However, there should be some positive correlation between yields on the same type of soil landscape. For example, if corn yields are above average one year on eroded landscape soils, then switchgrass yields on that same cropland will most likely be higher as well. The correlation coefficients for these situations are listed as “ESTIMATE” in table 5.5 and are assumed to be 0.330.

@Risk outputs a profit from each simulation for each cropping system. Those profits are then sorted from smallest to largest and graphed as cumulative distribution functions (CDFs). The CDFs can then be analyzed according to the decision-making tools discussed in the Theoretical Framework section on page 37.

5.5: Correlation values and sources used in the simulations

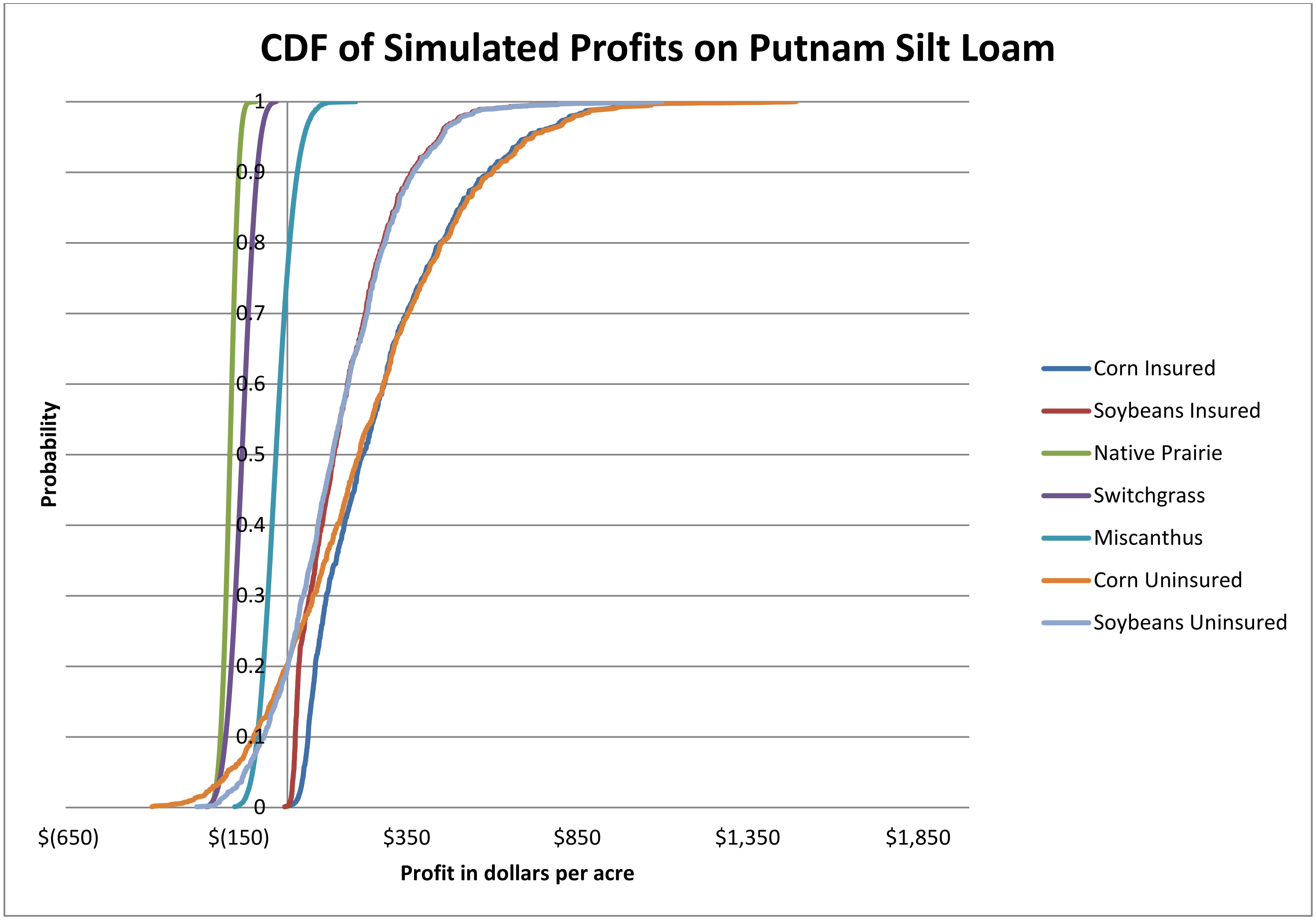
@RISK Correlations	Corn Price in $	Soybeans Price i	Miscanthus Good in	Miscanthus Flood in	Miscanthus Eroded i	Switchgrass Good i	Switchgrass Eroded i	Switchgrass Flood i	Prairie Good i	Prairie Eroded i	Prairie Flood i	Soybeans Good i	Soybeans Eroded i	Soybeans Flooded i	Corn Good i	Corn Flood i	Corn Eroded i
Corn Price in D7	1																
Soybeans Price in D8	0.7365811	1															
Miscanthus Good in D9	0	0	1														
Miscanthus Flood in D10	0	0	0.2908309	1													
Miscanthus Eroded in D11	0	0	0.2924639	0.2983017	1												
Switchgrass Good in D12	0	0	0.05215549	0.07485171	0.07017097	1											
Switchgrass Eroded in D13	0	0	0.01943122	0.04430424	0.04248752	0.289013	1										
Switchgrass Flood in D14	0	0	0.02210763	0.0507705	0.05215609	0.2602829	0.2677647	1									
Prairie Good in D15	0	0	0.05215549	0.07485171	0.07017097	0.3016644	0.289013	0.2602829	1								
Prairie Eroded in D16	0	0	0.01943122	0.04430424	0.04248752	0.289013	0.3016644	0.2677638	0.289013	1							
Prairie Flood in D17	0	0	0.02210763	0.0507705	0.05215609	0.2602829	0.2677638	0.3016644	0.2602829	0.2677638	1						
Soybeans Good in D18	0.1175814	-0.07738049	0.3304994	0	0	0.3304994	0	0	0.3304994	0	0	1					
Soybeans Eroded in D19	0.1175814	-0.07738049	0	0.3304994	0	0	0.3304994	0	0	0.3304994	0	0.2262483	1				
Soybeans Flooded in D20	0.1175814	-0.07738049	0	0	0.3304994	0	0	0.3304994	0	0	0.3304994	0.2262483	0.2262483	1			
Corn Good in D21	-0.08403224	-0.07109479	0.3304994	0	0	0.3304994	0	0	0.3304994	0	0	0.2534332	0.2534332	0.2534332	1		
Corn Flood in D22	-0.08403219	-0.07109471	0	0.3304994	0	0.3304994	0	0.3304994	0	0	0.3304994	0.2534332	0.2534332	0.2534332	0	1	
Corn Eroded in D23	-0.08403219	-0.07109471	0	0	0.3304994	0	0.3304994	0	0	0.3304994	0	0.2534332	0.2534332	0.2534332	0	0	1

@RISK Correlations	Corn Price in $	Soybeans Price i	Miscanthus Good in	Miscanthus Flood in	Miscanthus Eroded i	Switchgrass Good i	Switchgrass Eroded i	Switchgrass Flood i	Prairie Good i	Prairie Eroded i	Prairie Flood i	Soybeans Good i	Soybeans Eroded i	Soybeans Flooded i	Corn Good i	Corn Flood i	Corn Eroded i
Corn Price in D7	1																
Soybeans Price in D8	FAPRI	1															
Miscanthus Good in D9	0	0	1														
Miscanthus Flood in D10	0	0	ALMANAC	1													
Miscanthus Eroded in D11	0	0	ALMANAC	ALMANAC	1												
Switchgrass Good in D12	0	0	ALMANAC	ALMANAC	ALMANAC	1											
Switchgrass Eroded in D13	0	0	ALMANAC	ALMANAC	ALMANAC	ALMANAC	1										
Switchgrass Flood in D14	0	0	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	1									
Prairie Good in D15	0	0	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	1								
Prairie Eroded in D16	0	0	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	1							
Prairie Flood in D17	0	0	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	ALMANAC	1						
Soybeans Good in D18	FAPRI	FAPRI	ESTIMATE	0	0	ESTIMATE	0	0	ESTIMATE	0	0	1					
Soybeans Eroded in D19	FAPRI	FAPRI	0	ESTIMATE	0	0	ESTIMATE	0	0	ESTIMATE	0	FAPRI	1				
Soybeans Flooded in D20	FAPRI	FAPRI	0	0	ESTIMATE	0	0	ESTIMATE	0	0	ESTIMATE	FAPRI	FAPRI	1			
Corn Good in D21	FAPRI	FAPRI	ESTIMATE	0	0	ESTIMATE	0	0	ESTIMATE	0	0	FAPRI	FAPRI	FAPRI	1		
Corn Flood in D22	FAPRI	FAPRI	0	ESTIMATE	0	ESTIMATE	0	ESTIMATE	0	0	ESTIMATE	FAPRI	FAPRI	FAPRI	0	1	
Corn Eroded in D23	FAPRI	FAPRI	0	0	ESTIMATE	0	ESTIMATE	0	0	ESTIMATE	0	FAPRI	FAPRI	FAPRI	0	0	1

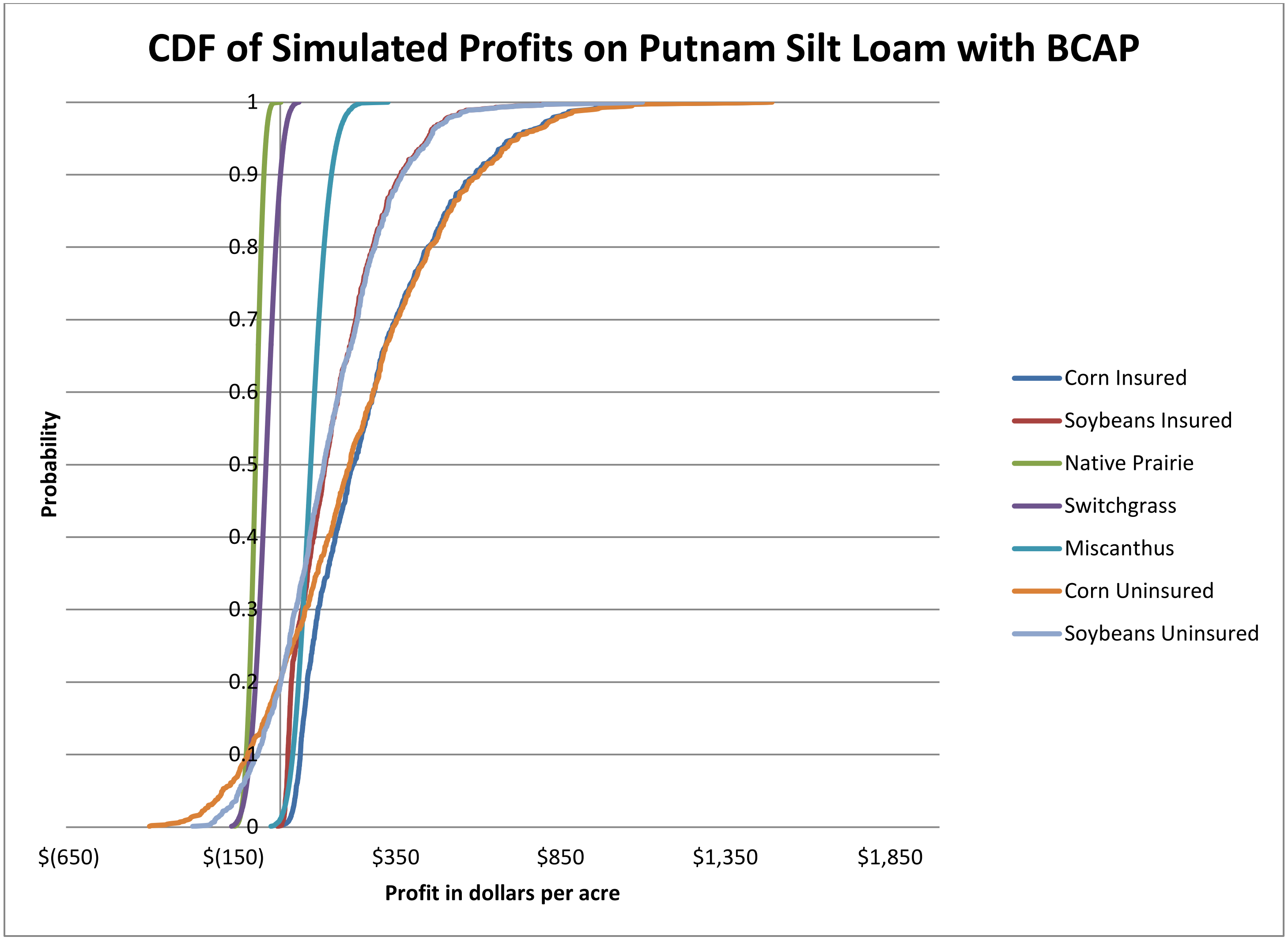
6 RESULTS AND DISCUSSION

Six figures below show the CDFs of this analysis. Every CDF consists of seven curves, one for native prairie, one for switchgrass, one for miscanthus, and two for both corn and soybeans illustrating what happens with crop insurance and in the absence of it. Figure 6.1 and figure 6.2 are CDFs of Putnam soils. Figure 6.3 and figure 6.4 are CDFs of the cropping systems on eroded Armstrong or Armster soils. Figure 6.5 and figure 6.6 are results from flooded Belknap soils. The Y-axis the probability from 0 to 1 of any given profit level. The X-axis is the different profit levels ranging from negative $650 per acre to $2,000 per acre. The vertical line is where profit is zero, thus to the right of that line the cropping systems earn money and to the left they lose money.

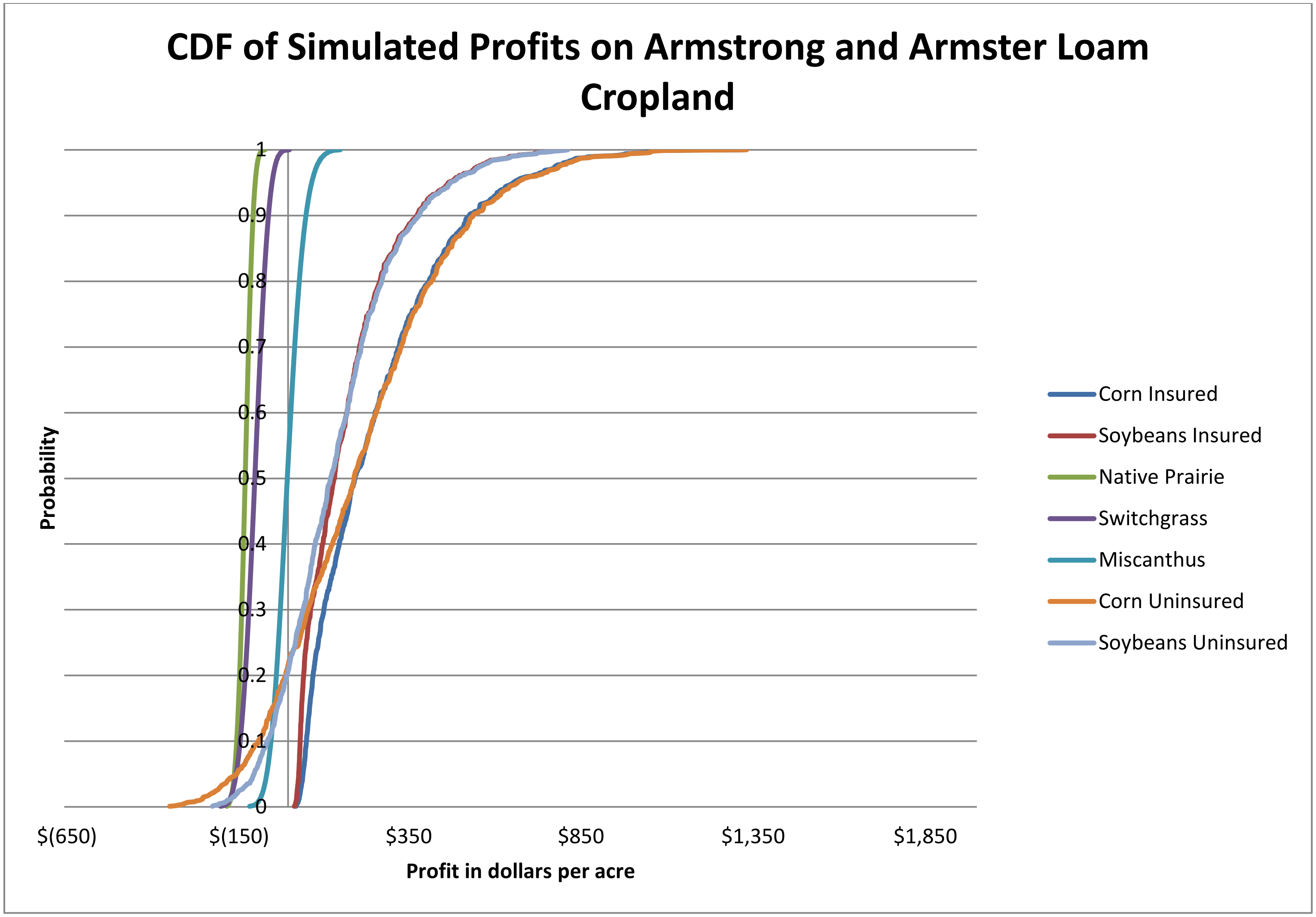
Corn both with and without insurance tends to be the most profitable cropping system in all scenarios. Corn with insurance has first degree stochastic dominance over all the bioenergy cropping systems in every scenario except when miscanthus is grown on an eroded Armstrong soil with BCAP. Expected profitability of soybeans with insurance is second to corn (both with and without insurance), but miscanthus with BCAP is competitive with soybeans in every scenario. Soybeans is never first degree stochastically dominate over miscanthus. The profitability of native prairie and switchgrass are relatively close to each other; however, switchgrass is more profitable a majority of the time. Because of its significantly higher yields, miscanthus is first degree stochastically dominant over the other two energy crops in all scenarios.



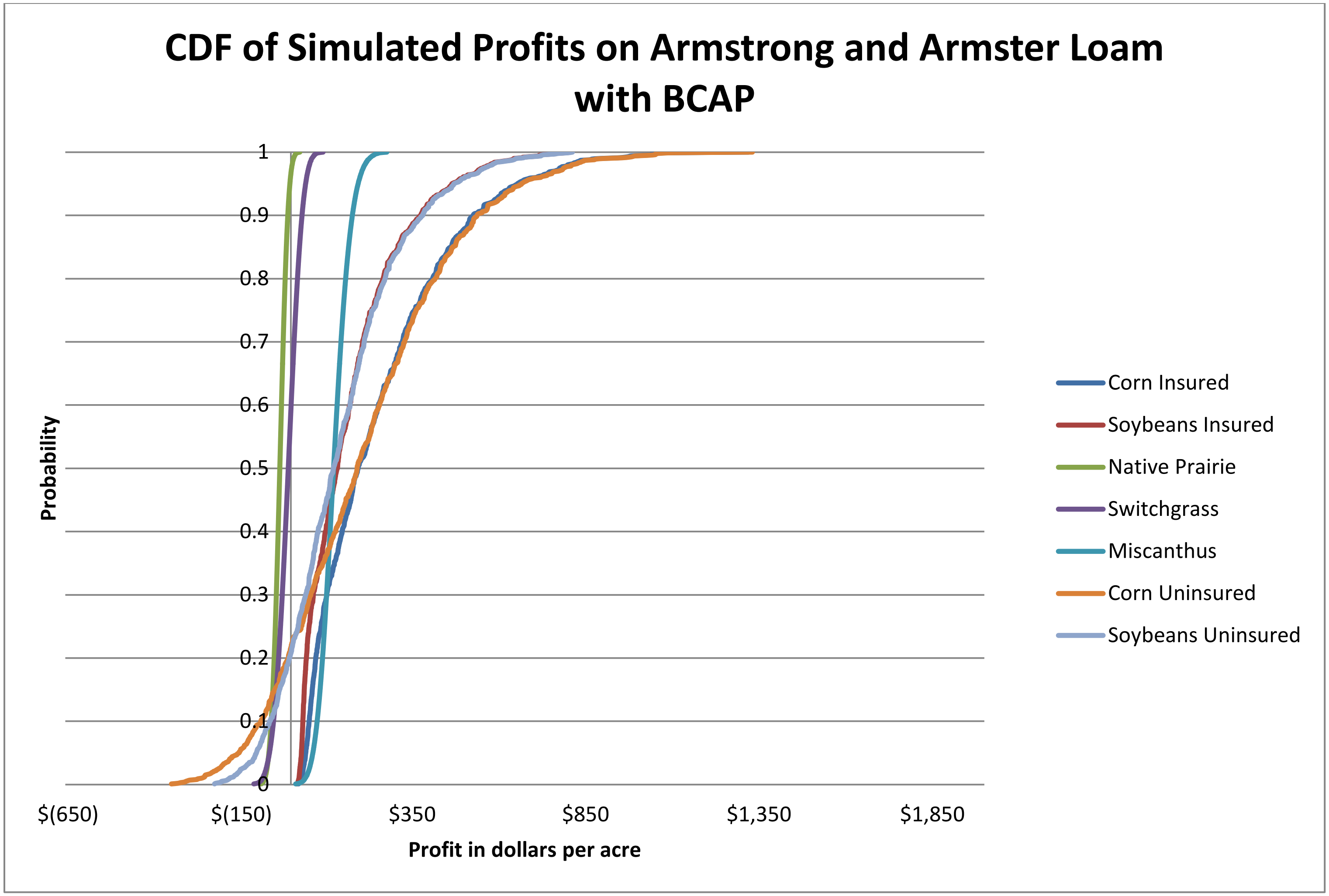
6.1: CDFs of each cropping system on Putnam soils



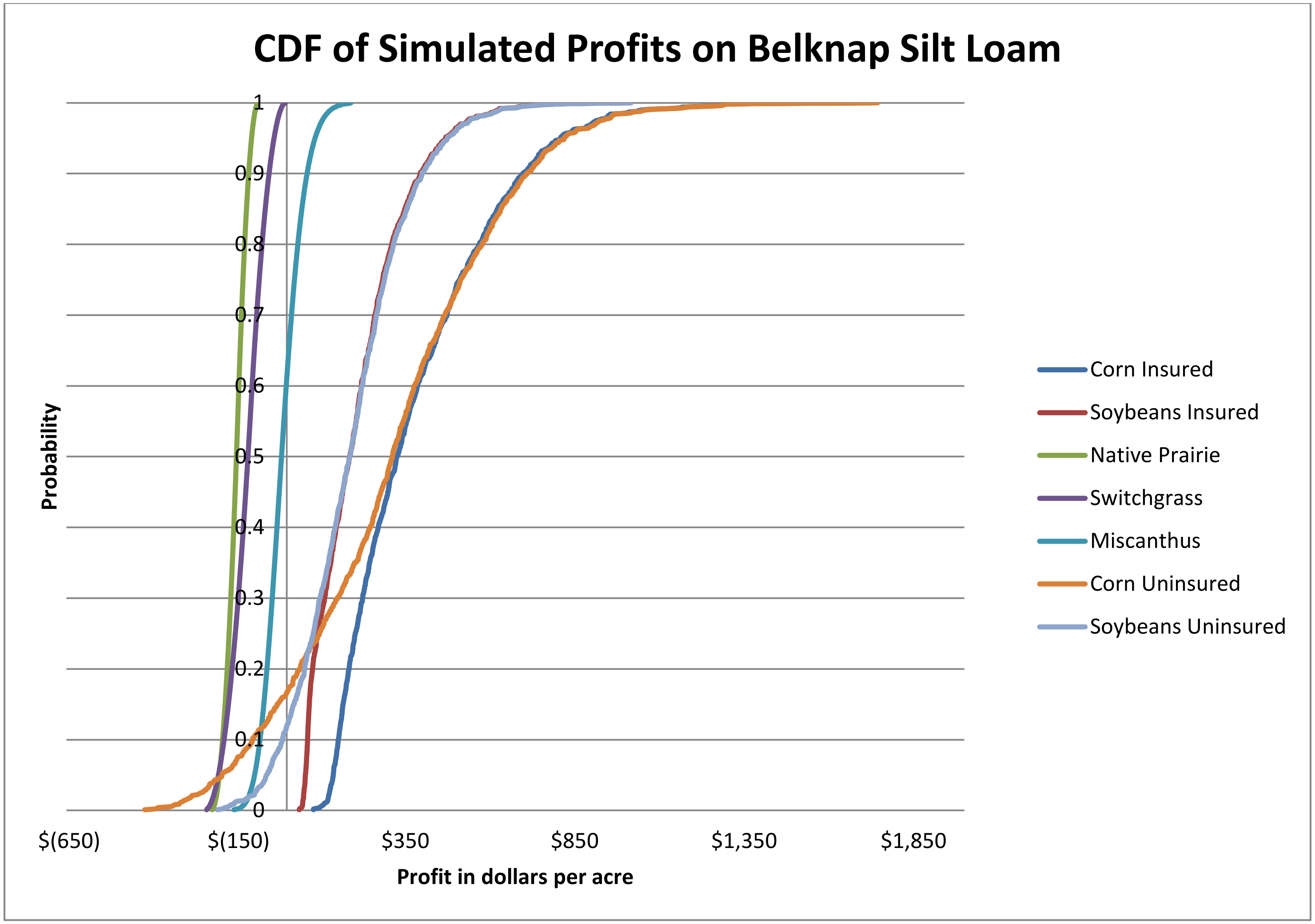
6.2: CDFs of each cropping system on Putnam soils with BCAP



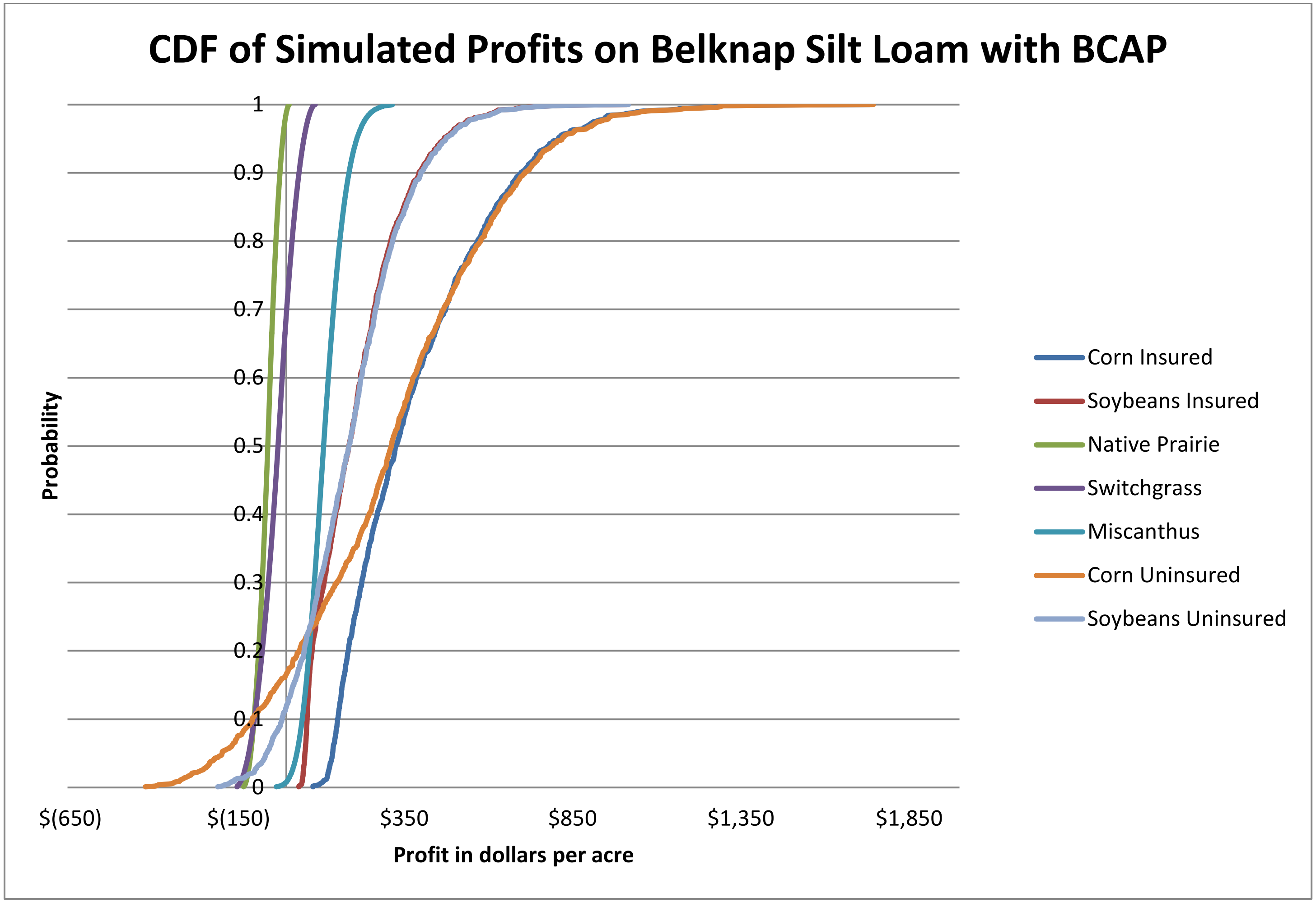
6.3: CDFs of each cropping system on Armstrong and Armster soils



6.4: CDFs of each cropping system on Armstrong and Armster soils with BCAP



6.5: CDFs of each cropping system on Belknap soils



6.6: CDFs of each cropping system on Belknap soils with BCAP

6.1 Landscape Soils

Jain et al. (2010) showed that miscanthus and switchgrass have the lowest breakeven in Missouri relative to other Corn Belt states because of lower opportunity costs. Results here indicate that even though Missouri has the lowest breakeven costs, the profit of miscanthus and switchgrass are not as high as corn and soybeans. Table 6.1 shows the mean, maximum, and minimum from the simulated profits of corn and soybeans with insurance. Like James, Swinton, and Thelen (2010), the opportunity cost here is represented by the mean profit.

6.1: Mean, maximum, and minimum of simulated profits of corn and soybeans with insurance for each type of soil.

	Putnam		**Armstrong and Armster**		**Belknap**	
	Corn	**Soybeans**	**Corn**	**Soybeans**	**Corn**	**Soybeans**
Mean	$278	$170	$253	$170	$384	$209
Max	$1,481	$1,093	$1,320	$807	$1,733	$1,011
Min	$(7)	$(8)	$22	$18	$79	$37

Based on that information, the opportunity cost is the lowest on fields growing soybeans with Putnam or Armstrong or Armster soils. If perennial grasses replace corn, the opportunity cost is the lowest on the eroded Armstrong or Armster soil. The best opportunity for profitably growing miscanthus on currently cropped land is to replace soybeans on an eroded Armstrong or Armster soil.

Corn with insurance and soybeans with insurance are first degree stochastically dominant over all the bioenergy cropping systems without BCAP in every landscape soil. Figure 6.1, figure 6.3, and figure 6.5 show corn and soybeans CDFs to the positive side of every bioenergy cropping system. Despite Missouri having a relatively low breakeven price compared to other potential growing regions, the profits from corn and soybean are still greater, meaning a utility maximizing producers will grow insured corn and soybeans.

6.2 BCAP and Pricing

In all three landscape soils, producers are more inclined to plant bioenergy crops if BCAP is available. The government subsidy shifts the CDFs for the perennial bioenergy crops to the positive side making them more desirable to grow. Figure 6.3 and figure 6.4 compare the bioenergy crops on the eroded Armstrong and Armster soils. Without BCAP, the CDFs at the median or 50 percent point all the biomass cropping systems return negative profits. With BCAP, miscanthus returns a profit above $100 per acre. Switchgrass and native prairie still have negative returns although that return is nearly $0 per acre.

Furthermore, in the presence of BCAP, a safety-first or maxi-min producer may choose to plant miscanthus on an eroded Armstrong or Armster field. The returns for miscanthus on Armstrong or Armster soils are greater at the minimum than any other cropping system including corn with insurance. On all other soils modeled, corn with insurance is the maxi-min selection. Miscanthus could also be selected if the producer is deciding using safety-first. Miscanthus is the most profitable cropping system almost 30 percent of the time or up until a profit of $100 per acre (see figure 6.4).

In the other landscape soils, corn and soybeans are always more profitable despite BCAP subsidies. In figure 6.2, corn with insurance grown on Putnam soils still has first degree stochastic dominance over miscanthus although miscanthus with BCAP is more profitable than soybeans about 25 percent of the time. In Belknap soils, corn and soybeans with insurance are both first degree stochastically dominant even with BCAP (see figure 6.5 and figure 6.6).

While BCAP did improve the profitability of these bioenergy crops, the subsidy is currently insufficient to stimulate large-scale production of bioenergy from these perennial grasses. On eroded Armstrong and Armster soils where the opportunity is the best for these perennial grasses, an increased subsidy of at least $60 per acre per year is needed. At that level, a producer would be indifferent between corn and miscanthus at the median; soybeans would have a lower expected profit than miscanthus. However, at the higher BCAP payment, the maximum profit for corn and is approximately four times greater than miscanthus; soybeans are two times greater. One benefit of miscanthus is that the profit is much less variable or, stated another way, more stable.

The additional income or subsidy to induce producers to plant perennial grass cropping systems could come in two forms. The establishment subsidy is important because those costs are difficult for an operation to finance. The additional subsidy discussed here is for production years (years 3-15). First, the government could increase the land payments to correspond with actual rental rates. This increased payment would provide the best safety-net for producers growing these biomass crops because that money does not depend on yields. Another option is to increase the price of biomass. Current BCAP matching payments for biomass delivered to a liquid fuel processing facility is an example of a change in the price of biomass. One of the negative aspects of price adjustment is that future payments are less certain because of uncertainty with governmental appropriations.

Rather than subsidizing the production of perennial grasses, the price of biomass could increase. That price change would then provide producers with the additional income and incentive to plant these perennial grass cropping systems. The RFS with its mandated levels of cellulosic ethanol may cause that price increase and, in effect, subsidize the production of perennial grasses to a level where its profits are similar to that of corn and soybeans. Another possibility is developing a green market where consumers who value the ecosystem benefits of perennials and the carbon sequestration pay a higher price for energy which would increase the profitability of the grasses.

6.3 Crop Insurance

The CDFs offer insight into the variation in profits and about the effect of crop insurance. Corn and soybeans have a much greater range of profits on all cropping systems. Table 6.2 shows numeric information about the effect crop insurance has and summarizes information from the Belknap CDFs in figure 6.6.

6.2: Mean, median, range, and coefficient of variation for miscanthus, corn, and soybeans both with and without insurance on Belknap soils.

	Corn Insured	Corn Uninsured	Insurance Effect	Soybean Insured	Soybean Uninsured	Insurance Effect	Miscanthus
Mean	$384	$314	$70	$209	$191	18	$114
Median	$325	$312	$13	$186	$186	0	$111
Range	$1,654	$2,163	$(509)	$974	$1,220	$(246)	$345
CV	.59	.98		.66	.86		.48

Crop insurance effectively increases the profitability of corn and soybeans by mitigating the risk. It decreases the range of profits by eliminating the possibility for extreme losses. Corn and soybeans without insurance have potential for large losses. The distribution of profit is skewed towards the negative side as indicated in table 6.2 by the mean being greater than the median. There is also much more variation in their profits as indicated by the higher coefficients of variation, which is .98 for corn without insurance and .86 for soybeans without insurance. The range is also relatively large. Contrasting that variation, miscanthus profits are much more stable. The mean and median are relatively close indicating a less skewed distribution, and coefficient of variation is half of corn and nearly half of soybeans. The CDFs show this decreased variance by the relative steepness of curve. All the perennial grass curves in every landscape soil are steeper than corn or soybeans.

The implications are that without insurance a risk averse producer would be more inclined to plant these grasses. Without the extreme loss potential associated with uninsured corn and soybeans, a maxi-min or safety-first producer is more inclined to plant perennial grasses, especially miscanthus.

However, the crop insurance program takes away that inclination. The range of profits for corn and soybeans decreases with crop insurance as indicated in table 6.2. Extreme negative profits which occur when the price falls or crop fails are no longer realized by insured corn and soybeans, as shown by their CDF. With insurance, a producer making decisions using safety first or maxi-min would be grow corn or soybeans.

6.4 Conclusions

The implications for this research are twofold. First, there is disagreement in academic literature about whether crop insurance increases the extensiveness of a particular crop. This research demonstrates a scenario in which crop insurance increases the extensiveness. In the absence of crop insurance, a risk averse producer may select the perennial grasses if the market develops.

Second, federal government agricultural policies have two objectives. The government seeks to provide a safety-net to farmers with crop insurance and seeks to stimulate the production of biomass with BCAP. These two objectives are competing and need to be balanced so that each can better achieve their aim.

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