# Switchgrass Production Decision Tool

*Background and Documentation for*

**AN EXCEL SPREADSHEET-BASED DECISION TOOL FOR POTENTIAL SWITCHGRASS PRODUCERS**

Bio-Based Energy Analysis Group
Department of Agricultural & Resource Economics
The University of Tennessee

Developed by Josh Qualls, former Graduate Research Assistant, Department of Agricultural and Resource Economics, The University of Tennessee.

## Introduction

Due to factors such as dependence on foreign oil and environmental concerns, there have been government policy initiatives dealing with alternative fuels that have far reaching impacts on the United States and world economies. An example of this type of policy is the Energy Independence and Security Act (EISA) of 2007, with its key provision being the Renewable Fuel Standard (RFS). The RFS has generated increased research into biomass production by mandating that by at least 36 billion gallons of ethanol for fuel be produced in the United States by 2022, with at least 16 billion gallons being ethanol that is derived from cellulose, hemi-cellulose, or lignin (U.S. Congress 2007).

Biomass accounts for over 3 percent of the energy consumed domestically and is currently the only source for liquid renewable fuels used in transportation (Perlack et al. 2005). There are many sources of biomass that can be used to make solid, liquid, and gaseous fuels including woody plants and their associated manufacturing waste and residues, aquatic plants, biological waste, and herbaceous plants such as grasses (Mckendry 2001). Biomass is promising because it allows us to take advantage of energy from the sun in a way that is compatible with current technologies and can be stored without technical problems allowing its energy to be used when needed and it could prove to be a clean energy source as the carbon that it releases during combustion is obtained from the atmosphere, potentially making it carbon neutral.

Generating sufficient biomass to meet the EISA's 16 billion gallon cellulosic ethanol quota will require the production of dedicated energy crops. Switchgrass (*Panicum virgatum*) is among the species of herbaceous plants being considered to help meet the expected demand generated for biomass. Switchgrass is a warm season perennial grass. The perennial nature of switchgrass separates it from more conventional annual crops because it does not have fixed annual establishment requirements. Its native habitat includes the prairies, open ground and wooded areas, marshes, and pinewoods of much of North America east of the Rocky Mountains (Stubbendieck et al. 1991). There are two distinct geographic varieties or ecotypes of switchgrass, lowland and highland (Porter 1966; Brunken and Estes 1975). Lowland types can be found on flood plains and other areas that may be subject to flooding and upland types can typically be found in areas that have a low potential to flood (Vogel 2004). Lowland types tend to be taller, coarser, and show the ability to grow more rapidly than upland types (Vogel 2004).

Many benefits could be seen through the planting of switchgrass as a biomass feedstock for fuel. Because it is a native species, it also has a natural tolerance to pest and diseases and can be grown successfully throughout a large portion of the United States with minimal fertilizer applications (Jensen et al. 2007), which would be cost efficient and less disruptive to the surrounding environment. Switchgrass has the capability to show high yields on soil that, due to low availability of nutrients or water, would not lend itself to the cultivation of conventional crops (Lewandowski et al. 2003) which means that the grass could add utility to land that may not be economically useful otherwise. It has the positive attribute of reducing erosion due to its extensive root system and canopy cover (Ellis 2006) and shows the potential ability to reduce the buildup of $CO_2$ by being a feedstock for a cleaner burning fuel than fossil fuels and through soil carbon sequestration due it is being a deep rooted crop (Ma et al.2000).

Despite these possible benefits that could be realized from the implementation of switchgrass as a dedicated energy crop, there are hurdles to overcome. One of the draw backs associated with switchgrass being produced for biomass used in energy production, being an innovative practice, is that there is unfamiliarity associated with the specific costs of its production. The decision of a farmer to adopt an innovation is based on its perceived ability to provide more utility than other viable options which may be more conventional and whose associated risk may be more known and understood.

Because of this, the distribution of knowledge related to the innovation, which for this study is the costs associated with the production of switchgrass, becomes imperative to the adoption of the practice. A productive way to disseminate this information in a manner that is readily understandable and adjustable to fit each individual farmer's operation is to apply it to a production decision tool in an excel workbook.

**Objective**

The objective of this paper is to explicate and present an interactive and adjustable excel spreadsheet-based decision tool for potential switchgrass producers that provides the user with detailed information on the costs incurred in each stage of a switchgrass operation in each year of its duration, which, for the purposes of this analysis, will be 10 years. The budget workbook is broken down into 13 different worksheets, including:

- welcome worksheet
- tutorial worksheet
- input-output worksheet
- cash flow worksheet
- cost distribution worksheet
- yearly cash flow worksheet
- accumulated cash flow
- planting and establishment worksheet
- stand maintenance worksheet
- harvest worksheet
- transportation worksheet

- storage worksheet
- biomass harvested worksheet

In the following chapters, the purpose of each worksheet, the source of the estimated figures in their adjustable cells, and the methods used in their calculating cells will be explained.

**Literature Review**

A significant portion of literature relating to switchgrass concerns the economic aspects of its production and delivery to a bio-refinery for the purpose of creating bio-energy. Many of these studies are regionally (e.g. Cundiff and Marsh 1996; Epplin 1996; Larson et al. 2010a; Larson et. al 2010b) or state (e.g. Sladden, Bransby, and Aiken 1991; Popp 2007) specific due to the variation in suitability of the crop and the focus on biomass production for alternative fuels in the area. Other studies focus on analyzing the cost of using switchgrass as a cellulosic biomass feedstock in comparison to other possible grass species options (e.g. Haque et al. 2008; Wilkes 2007). The results from these studies and others like them provide information used to compose budgets like those that create the foundation of this study.

Larson et al. (2010a), Larson et al. (2010b), Wang et al. (2009a), and Wang et al. (2009b) are examples of studies that consider the storage cost, among other costs, and biomass losses for different periods of storage time and methods. The data used in these studies came from a switchgrass harvest and storage study at the Milan Research and Education Center in Milan, Tennessee (English et al. 2008). The study analyzed many different storage options including whether the bails were round or square, if they were placed on bare ground or on a wooden pallet, the amount of time the bales were stored, and whether or not the bales were covered with a tarp. This data has been eminently valuable to this study by providing a base useable to calculate an estimate of the cost of storage given the type of bale used and the storage method as well as the loss in biomass given the duration of storage.

Fulton (2010) is a study that evaluated the impacts that introducing cellulosic ethanol plants in east Tennessee and west Tennessee would have on the economies of these two regions. In doing this, the study analyzed the costs of transporting the switchgrass from the farm to the bio-refinery. This information has been valuable in assembling the transportation cost section of this study.

The Woody Biomass Program ran by the College of Environmental Science and Forestry (ESF) at the State University of New York (SUNY) in 2008 created a Microsoft Excel based production decision tool for growing willow (Genus: *Salix*) for biomass energy production called “EcoWillow”. This willow decision tool assumed planting on marginal soils with low labor, machinery, fertilizer, and herbicide inputs compared to traditional crops. It details the costs associated with willow establishment, stand maintenance, harvesting, and the transportation of the biomass. It can have a stand life of 11 or 22 years, depending on which the user chooses. While it is useful in determining total cost estimates, it lacks the ability to estimate the cost of storage and the amount of biomass dry matter loss during storage, both of which can factor prominently in estimating whether or not a switchgrass stand will be a fortuitous endeavor.

Bransby et al. (2005) is a study that used Microsoft Excel to model a switchgrass budget. It allowed for alternative producing, harvesting, handling, and transporting methods. Similar to the Eco-Willow program created by the Woody Biomass Program at SUNY, it lacks the ability to calculate and account for the cost of and dry matter loss during storage.

For any business activity, an estimated budget is needed before it is started and there are multiple examples of budgets dealing with switchgrass operations (Wilkes 2007; Green and Benson 2008; UT Extension 2009; UT Extension 2007). Green and Benson (2008) is a budget put together at

North Carolina State University that gives the same values for the revenues and costs for each year of a switchgrass project. It mentions all important costs but lacks specificity with some of the more detailed expenses. Wilkes (2007) is a budget made for the Natural Resources Conservation Service Plant Materials Program. It estimates different costs associated with the establishment and subsequent years, with the subsequent years having the same costs projections. Because it covers three other grass budgets, it was not a relatively in depth analysis of switchgrass. The University of Tennessee Extension budget (2007) and (2009) serve as guidelines for establishing a switchgrass stand and up to ten years afterward. Most of the recommended values for input cost in this study have been drawn from these budgets.

**Case Study**

For illustrative purposes, the figures in this study will represent a specific case. This case will assume a 50 acre switchgrass stand with a mature yield of 6 dry tons of biomass per acre and that the producer will receive 75 dollars per dry ton at the plant gate. The biomass will be stored on farm for 200 days as round bales on pallets covered with a tarp. All other values to be used for the case study will be the suggested University of Tennessee Extension Budget values.

**Methods**

***Input – Output Sheet***

The input-output worksheet is the most integral worksheet in this excel workbook. It ties together the values from all of the other sheets in a way that is understandable to the user and has macros buttons that direct the user to each respective page. The two input sections of the worksheet are general data and startup loans. The output sections are financial analysis tools, production costs, and revenues and earnings.

*Input Section*

The general data section (Figure 1.) has six cells where the user can insert specific data. The interest rate for this workbook is determined in this section. The suggested interest rate is the current thirty year Treasury bond; however, the user has the ability to input any desired rate, as interest rates tend to fluctuate daily.

In this section, the user can input the cost of land, which includes taxes, leasing fees, and insurance. Internal administration fees are to be included in this section, as well. There are cells in this section that allow the user to include total acreage incentive payments they may receive from government agencies or any other organization and their duration. The last cell in this section gives the user the ability to insert the current price per dry ton of switchgrass at the plant gate. The suggested price per ton is $75.00 USD.

The startup loan section (Figure 1.) contains information regarding any loans that are taken out to establish the switchgrass stand. The three pieces of information to input are available equity, the amount of the loan, and the interest rate. This information will be used to determine the loan payments per period, assuming the loan is paid off over the life of the project which, in this case, is 10 years as according to Qin et al. (2006).

*Josh's Switchgrass Project*

## Input and Output

### Input data

| General Data | | | |
|---|---|---|---|
| interest rate | % | 3.47% | |
| Project size | acres | 50 | |
| Project life | yrs | 10 | 10 |
| Land costs (tax, lease) and insurance | $/acre/yr | 0 | 0 |
| Internal administration costs | $/acre/yr | 0 | 0 |
| Acreage Incentive payments | $/acre/yr | 0 | 0 |
| Total years of acreage incentive payment | yrs | 0 | 0 |
| Biomass price at plant gate | $/ton | 75 | 75 |

| Startup loans | | |
|---|---|---|
| Available equity | $ | |
| Loan amount | | 0 |
| Loan interest rate | % | 0% |

Yellow cells: insert numbers, insert "0" if not applicable

Grey cells: output from previous inputs

**Figure 1. The input section of the input-output sheet.**

*Output Section*

The financial analysis tools section (figure 2.) gives output that aides the user in understanding how the revenues and costs relate to each other over the life of the project. The analysis includes net present value with realistic revenues and costs, net present value with optimistic (+10% revenue and -10% costs) revenues and costs, net present value (NPV) with pessimistic (-10% revenue and +10% costs) revenues and costs, and also gives the internal rate of return (IRR). The formula for NPV following Ross, Westerfield, and Jaffe (2002) is as follows:

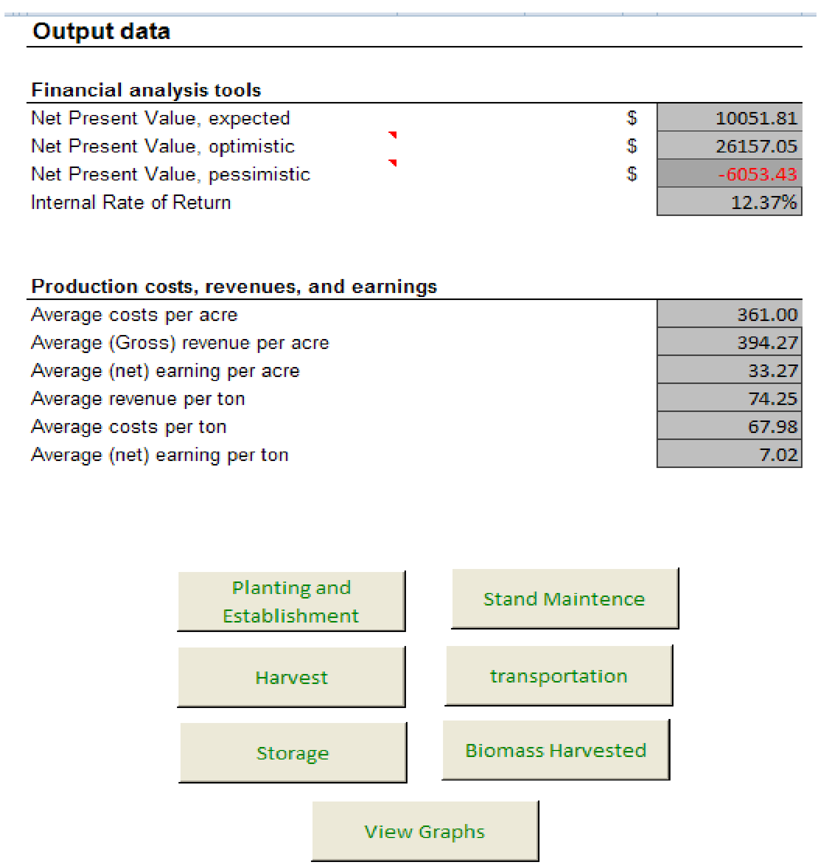
$$(1)\ NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

Where $C_0$ is initial costs, T is the number of time periods of the project, t is each time period, r is the discount rate, and $C_t$ is the cash flow for each time period. The net present values give the user an idea as to what the investment is worth in current terms after discounting each year's earnings back to the current period given that the project could go as planned, better than planned, or worse than planned. The IRR is the r where

$$(2)\ NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} = 0.$$

Basically, the IRR is the rate of return of a project where the NPV of the project is equal to zero.

The production costs, revenues, and earnings section (Figure 2.), like the financial analysis tools section, is meant to aid the user in understanding the revenues and costs associated with the project. This section contains average costs per acre, average gross revenue per acre, average profit per acre, average revenue per ton, average costs per ton, and average earning per ton. All of these reflect the average values over the total life of the project.



**Output data**

| Financial analysis tools | | |
| --- | --- | --- |
| Net Present Value, expected | $ | 10051.81 |
| Net Present Value, optimistic | $ | 26157.05 |
| Net Present Value, pessimistic | $ | -6053.43 |
| Internal Rate of Return | | 12.37% |

| Production costs, revenues, and earnings | |
| --- | --- |
| Average costs per acre | 361.00 |
| Average (Gross) revenue per acre | 394.27 |
| Average (net) earning per acre | 33.27 |
| Average revenue per ton | 74.25 |
| Average costs per ton | 67.98 |
| Average (net) earning per ton | 7.02 |

**Figure 2. The output section of the input-output sheet.**

***Cash Flow Sheet***

The cash flow worksheet documents the revenues and the expenditures for each year over the life of the operation. It shows the total and per acre and per acre revenues and expenditures in two separate diagrams. The expenditures per year include the following categories: land cost and insurance, administration cost, planting and establishment cost, storage cost, stand maintenance cost, harvest cost, and transportation cost. Planting and establishment costs apply only to the first year of the project while stand maintenance, which includes the cost of reseeding applies to years 2 through 9. Included in the revenues section is the amount of money received for the biomass and any sort of acreage incentive payments that the user might stand to receive. Finally, expenditures are subtracted from revenues to calculate profit before the subtraction of loans, labeled “Total Profit 1” in the table.

To put this in equation form,

$$(3) \quad \text{TotalProfit } 1 = \text{Totalrevenues} - \text{Totalexpenditures excluding loan payments.}$$

In the other cost section, loan payments are calculated and subsequently subtracted from Total Profit 1 to get profit after loan payments, which is labeled “Total Profit 2”. In equation form, this is

(4) Total Profit 2= Total Profit 1 – loan payments

Total Profit 2 is then discounted back to the current time period for every year. This discounting is done for the realistic revenues and costs values, the pessimistic values, and the optimistic values. Total Profit 2 is also accumulated over each subsequent year for the realistic revenues and costs values, the pessimistic values, and the optimistic values.

**Cash Flow diagram (per Acre)** | Back to Input-Output | Next Graph

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Expenditures** | | | | | | | | | | |
| land costs and insurance | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Administration cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Planting and establishment cost | 175.53 | 35.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Storage Cost | 62.45 | 44.05 | 52.64 | 22.41 | 22.41 | 22.41 | 22.41 | 22.41 | 22.41 | 22.41 |
| Stand maintenance cost | 0 | 178.275 | 157.275 | 157.275 | 157.275 | 157.275 | 157.275 | 157.275 | 157.275 | 157.275 |
| Harvest Cost | 136.17 | 136.17 | 136.17 | 136.17 | 136.17 | 136.17 | 136.17 | 136.17 | 136.17 | 136.17 |
| Transportation Cost | 7.52 | 19.87 | 32.22 | 32.22 | 32.22 | 32.22 | 32.22 | 32.22 | 32.22 | 32.22 |
| Total Expendituеs | 381.67 | 413.47 | 378.30 | 348.07 | 348.07 | 348.07 | 348.07 | 348.07 | 348.07 | 348.07 |
| **Revenues** | | | | | | | | | | |
| Acreage incentive Payments | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Biomass | 103.95 | 274.725 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 |
| Total Revenue | 103.95 | 274.725 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 | 445.5 |
| **Total Profit 1** | -277.72 | -138.74 | 67.20 | 97.43 | 97.43 | 97.43 | 97.43 | 97.43 | 97.43 | 97.43 |
| **Other costs** | | | | | | | | | | |
| Loan Payments | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total Costs | 381.67 | 413.47 | 378.30 | 348.07 | 348.07 | 348.07 | 348.07 | 348.07 | 348.07 | 348.07 |
| **Total Profit 2** | -277.72 | -138.74 | 67.20 | 97.43 | 97.43 | 97.43 | 97.43 | 97.43 | 97.43 | 97.43 |
| **Total 2 per ton of biomass produced** | -198.36865 | -37.498184 | 11.1994801 | 16.237678 | 16.237678 | 16.237678 | 16.237678 | 16.237678 | 16.237678 | 16.237678 |
| **Total Profit 2 discounted** | -269.40 | -130.59 | 59.66 | 84.00 | 81.15 | 78.39 | 75.73 | 73.16 | 70.67 | 68.27 |
| **Total Profit 2 accumulated** | -269.40 | -408.15 | -340.95 | -243.52 | -146.10 | -48.67 | 48.76 | 146.18 | 243.61 | 341.03 |
| Total Profit 2 optimistic | -229.15 | -69.92 | 149.58 | 176.78 | 176.78 | 176.78 | 176.78 | 176.78 | 176.78 | 176.78 |
| Total Profit 2 optimistic, discounted | -222.47 | -66.31 | 134.03 | 153.24 | 148.06 | 143.06 | 138.23 | 133.56 | 129.05 | 124.69 |
| | | | | | | | | | | |
| Total Profit 2 optimistic, accumlated | -229.15 | -299.08 | -149.50 | 27.28 | 204.07 | 380.85 | 557.63 | 734.42 | 911.20 | 1087.98 |
| Total Profit 2 Pessimistic | -326.28 | -207.56 | -15.18 | 18.07 | 18.07 | 18.07 | 18.07 | 18.07 | 18.07 | 18.07 |
| Total Profit 2 Pessimistic, discounted | -316.34 | -194.87 | -14.71 | 14.76 | 14.24 | 13.72 | 13.23 | 12.75 | 12.29 | 11.85 |
| | | | | | | | | | | |
| Total Profit 2 Pessimistic, Accumulated | -326.28 | -533.84 | -549.02 | -530.96 | -512.89 | -494.82 | -476.75 | -458.68 | -440.61 | -422.54 |

**Figure 3. The per acre section of the cash flow sheet.**

***Cost Distribution***

The cost distribution worksheet is meant to show the user how the costs are spread out over the different activities associated with the production of switchgrass. It displays the land cost and insurance, administration cost, planting and establishment cost, storage cost, stand maintenance cost, harvest cost, and transportation cost per acre per year and in total per year. It then displays the percent of the total costs that each activity accounts for and shows this information in a pie chart.

Josh's Switchgrass Project

Cost distribution in %, undiscounted

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| Costs (per acre) | US$/acre | US$ total per year (avg.) | % of total |
|---|---|---|---|
| Planting and Establishment | 175.53 | 877.64 | 4.70% |
| Stand Maintenance | 159.61 | 7980.42 | 42.74% |
| Harvest | 136.17 | 6808.59 | 36.46% |
| Land cost and insurance | 0.00 | 0.00 | 0.00% |
| administration | 0.00 | 0.00 | 0.00% |
| Transportation (average per year) | 28.51225 | 1425.61 | 7.63% |
| Storage Cost | 3.160069 | 1580.03 | 8.46% |

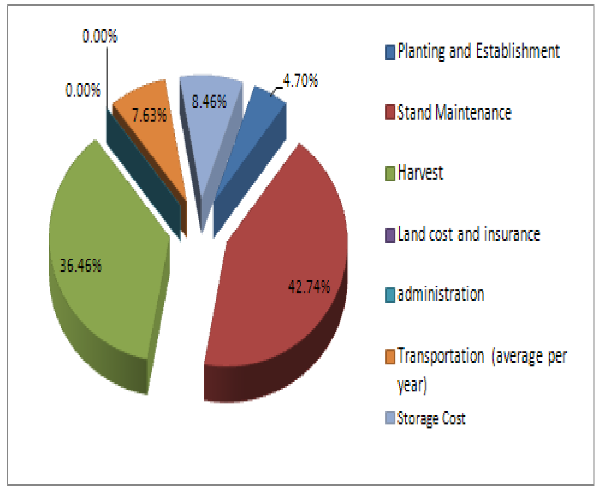


**Figure 4. The cost distribution sheet.**

***Yearly Cash flow***

The yearly cash flow worksheet is intended to give the user a visual concept of the yearly positive or negative undiscounted revenues. Two separate bar chart diagrams display per acre yearly undiscounted revenues and the total yearly undiscounted revenues.

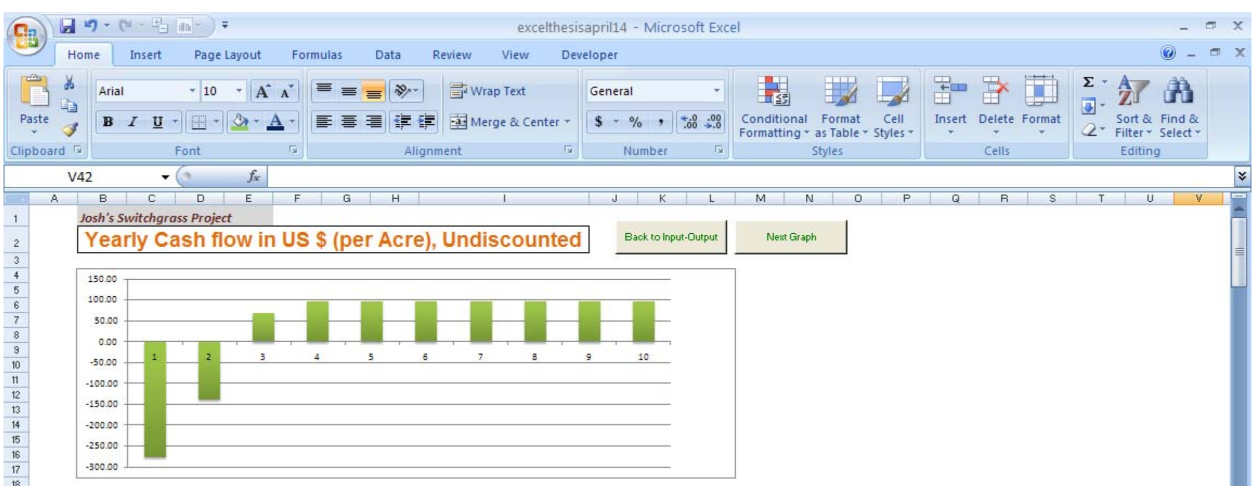


**Figure 5. The per acre yearly cash flow diagram.**

*Accumulated Cash Flow*

The accumulated cash flow worksheet is intended to give the user a visual idea of the accumulated cash flows for each successive year over the life of the project. Two separate line graphs show per acre accumulated cash flow and the total accumulated cash flow for each successive year over the life of the project.

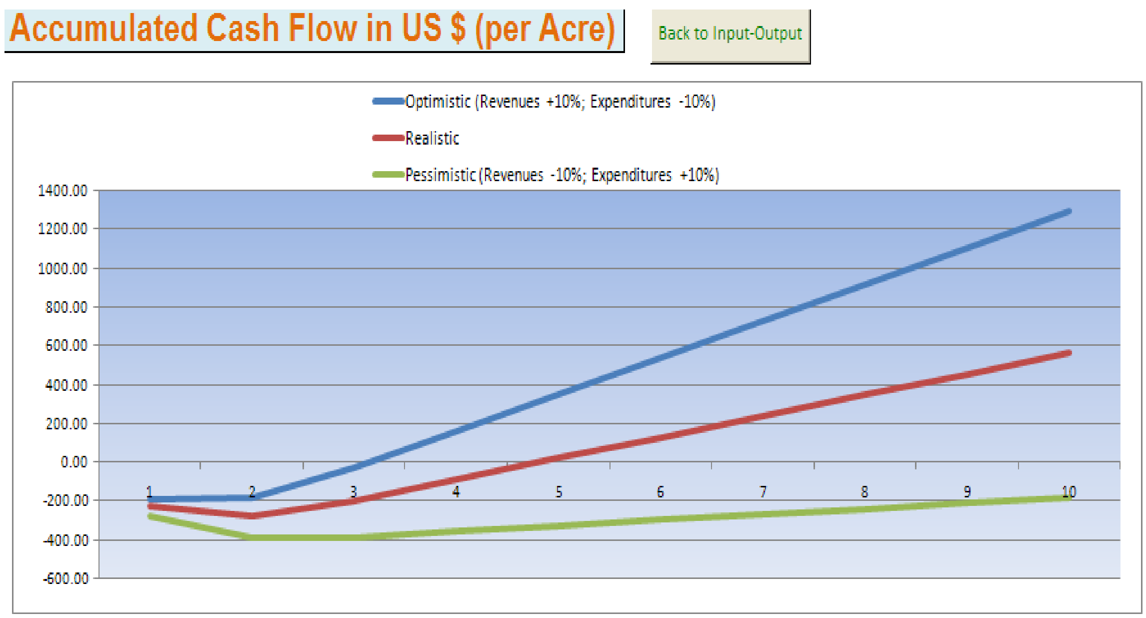


**Figure 6. The accumulated per acre cash flow diagram.**

| NPV Sensitivity Analysis | | | | | | |
|---|---|---|---|---|---|---|
| Price/dry ton | 60 | 65 | 70 | 75 | 80 | 85 |
| Mature yield | | | | | | |
| 5 | -37723.11 | -28586.33 | -19440.65 | -10294.92 | -1149.19 | 7996.54 |
| 6 | -22158.67 | -11421.84 | -685.02 | 10051.81 | 20788.64 | 31525.46 |
| 7 | -6585.23 | 5742.69 | 18070.62 | 30398.54 | 42726.4 | 55054.39 |
| 8 | 8988.2 | 22907.23 | 36826.23 | 50745.27 | 64664.3 | 78593.32 |

| | |
|---|---|
| Price where NPV is zero | 70.32 |

**Figure 7. NPV sensitivity analysis and NPV breakeven price.**

***Planting and Establishment Sheet***

This sheet is designed to give the user the cost of planting and establishing his or her switchgrass stand during the first year of the project. There are six different sections of this worksheet including: general data, labor, travel costs, equipment, supplies, and a totals section. The general data section includes acres to be planted, planting time in hours per acre, and total planting time in hours. The number of acres to be planted comes from the value given in the welcome sheet. Planting time is an estimate value that comes from the University of Tennessee Extension (2009) switchgrass budget. The user has the option to change this value if a more accurate figure is known. Total planting time is found by multiplying total acres to be planted by planting time in hours per acre.

The labor section contains the following values: number of crew on site, laborers per crew, laborer wage rate, hours at site per crew, indirect labor cost, the total labor cost, and the total labor cost per acre. The number of crews on site, laborers per crew, and laborer wage rate have values that are suggested by the University of Tennessee Extension (2009) switchgrass budget. These values may be adjusted by the user if more accurate figures are known. The number of hours spent at the site per crew is found by multiplying the planting time by the acres to be planted. The total labor cost is found by multiplying the number of crews at the site, total planting time, laborers per crew, laborer wage rate, and one plus the indirect labor cost percentage.

The travel cost section consists of the following subsections: number of vehicles, vehicle cost, distance, total nights, hotel cost per person per night, meal cost per day per person, and the total travel costs. The number of vehicles, vehicle cost, distance, total nights, hotel cost per person per night, and meal cost per person per day are adjustable values and can be altered by the user if more accurate figures are known. The travel cost section is borrowed from the State University of New York's poplar excel workbook.

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**Planting and Establishment Submodel**

| General data | | | | |
|---|---|---|---|---|
| Acres to be planted | acre | 50 | | |
| Planting time | hrs/acre | 0.68 | 0.68 | Equipment Delivery |
| total planting time | hrs | 34 | | |

| Labor | | | | |
|---|---|---|---|---|
| No. of crews at site | | 1 | 1 | |
| Labors/crew | | 1 | 1 | |
| Laborer rate | $/hr | 9.75 | 9.75 | Tractor |
| hours at site/crew | Hrs | 34 | | |
| Indirect labor costs | % | 0 | 0 | |
| Total | $ | 331.5 | | |
| Per acre | | 6.63 | | |

| Travel costs | | | |
|---|---|---|---|
| No. of vehicles | | 1 | |
| Vehicle costs | $/mi | 0.4 | No-till drill |
| Distance | Mi | 0 | |
| total nights | | 0 | |
| Hotel | $/night/person | 0 | |
| Meals | $/day/person | 0 | |
| Total | $ | 0 | |

Yellow cells: insert numbers, insert "0" if not applicable

Grey cells: output from previous inputs

Sprayer 60" boom

**Figure 8. The general data, labor, and travel costs subsections of the planting and establishment sheet.**

The equipment section of this worksheet is divided up into 5 subsections. These subsections are equipment delivery, tractor costs, not-till drill costs, sprayer costs, and mower costs. The recommended values in the adjustable cells in the section come from the University of Tennessee Extension (2009) switchgrass budget. The equipment delivery subsection contains value cells to represent transport cost per mile for the drill, tractor, sprayer, mower, distance to be transported, all of which are cells that allow adjustments by the user, and the total delivery costs. The total delivery cost is determined by summing all of the transport cost per mile and multiplying this figure by the distance both ways.

The tractor subsection of the equipment section contains the following value cells fixed costs per hour, variable costs per hour, hours per acre, fixed costs per hour, variable costs per hour, repair costs per acre, fuel costs per acre, and total tractor costs. Fixed costs per hour, variable costs per hour, hours per acre, repair costs per acre, and fuel costs per acre are all adjustable cells. The value for the fixed cost per acre is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre is found by multiplying the variable cost per hour by the hours per acre. Total tractor cost is found by multiplying the fixed cost and the variable cost by the total acres to be planted and then adding them together.

The remaining 3 subsections in the equipment section; no-till drill cost, sprayer cost, mower costs, have the same costs categories: fixed cost per hour, variable costs per hour, hours per acre, fixed cost per acre, variable cost per acre, repair costs per acre, and total costs for each respective piece of equipment. Fixed costs per hour, variable costs per hour, hours per acre, and repair costs per acre for each respective piece of equipment are all adjustable cells. The value for the fixed cost per acre for each piece of equipment is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre for each piece of equipment is found by multiplying the variable cost per hour by the hours per acre. Total cost for each piece of equipment is found by multiplying the fixed cost and the variable cost by the total acres to be planted and then adding them together. At the end of the equipment section the total cost of all the equipment is calculated. This is done by adding all of the individual equipment costs together. This total cost figure is then divided by the number of acres planted to give total equipment costs per acre.

Submodel

Back to Input-Output

| | Equipment | | | |
|---|---|---|---|---|
| Equipment Delivery | transport for drill | $/mi | 0 | |
| | Transport for tractor | $/mi | 0 | |
| | Transport for sprayer | $/mi | 0 | |
| | Tranport for mower | $/mi | 0 | |
| | Distance | mi | 0 | |
| | Total delivery costs | $ | 0 | |
| Tractor | Fixed cost per hour | $/hr | 8.21 | 8.21 |
| | Variable cost per hour | $/hr | 29.04 | 29.04 |
| | Hours per acre | hr/acre | 0.54 | 0.54 |
| | Fixed cost per acre | $/acre | 4.43 | |
| | Variable cost per acre | $/acre | 15.68 | |
| | Repair cost per acre | $/acre | 4.38 | 4.38 |
| | Fuel cost per acre | $/acre | 11.31 | 11.31 |
| | **Total tractor costs** | $ | 1005.75 | |
| No-till drill | Fixed cost per hour | $/hr | 11.49 | 11.49 |
| | Variable cost per hour | $/hr | 8.5 | 8.5 |
| | Hours per acre | hr/acre | 0.24 | 0.24 |
| | Fixed cost per acre | $/acre | 2.76 | |
| | Variable cost per acre | $/acre | 2.04 | |
| | Repair cost per acre | $/acre | 2 | 2 |
| | **Total drill costs** | $ | 239.88 | |
| Sprayer 60" boom | Fixed cost per hour | $/hr | 5.78 | 5.78 |
| | Variable cost per hour | $/hr | 3.92 | 3.92 |
| | Hours per acre | hr/acre | 0.14 | 0.14 |
| | Fixed cost per acre | $/acre | 0.81 | |
| | Variable cost per acre | $/acre | 0.55 | |
| | Repair cost per acre | $/acre | 0.55 | 0.55 |
| | **Total sprayer costs** | $ | 67.9 | |
| Rotary mower 15' | Fixed cost per hour | $/hr | 5.78 | 5.78 |
| | Variable cost per hour | $/hr | 3.92 | 3.92 |
| | Hours per acre | hr/acre | 0.1 | 0.1 |
| | Fixed cost per acre | $/acre | 0.58 | |
| | Variable cost per acre | $/acre | 0.39 | |
| | Repair cost per acre | $/acre | 1.14 | 1.14 |
| | **Total mower costs** | $ | 48.50 | |
| | **Total equipment cost** | $ | 1362.03 | |
| | **Total equipment cost per acre** | $/acre | 27.24 | |

**Figure 9. The equipment costs subsection of the planting and establishment sheet.**

The supplies section of the planting and establishment worksheet contains three subsections: seed costs, fertilizer costs, and burndown costs. All of the recommended values in this section come fromthe University of Tennessee Extension (2009) switchgrass budget. The seed costs subsection contains the price of seed per pound and the number of pounds of seed needed per acre. The fertilizer subsection contains the phosphorus pentoxide price per pound and pounds per acre as well as the potassium oxide price per pound and pounds per acre values. The burndown subsection contains the price per quart and the quarts per acre values for the fall burndown glycophosate.

| | Supplies | | | |
|---|---|---|---|---|
| ***Seed*** | Seed Price | $/pound | 8.25 | |
| | Pounds Seed Per Acre | pounds/acre | 6 | 6 |
| ***Fertilizer*** | Fertilizer P205 Price | $/pound | 0.8 | 0.8 |
| | Fertilizer P205 Pounds per Acre | pounds/acre | 40 | 40 |
| | Fertilizer K20 Price | $/pound | 0.75 | 0.75 |
| | Fertilizer K20 Pounds per Acre | pounds/acre | 80 | 80 |
| **Burndown and Herbici** | Fall Burndown Glycophosate Price | $/qt. | 7.87 | 7.87 |
| | Fall Burndown Glycophosate Qt per Acre | Qt./acre | 1 | 1 |
| | Other supplies | $/acre | | |
| | Establishment grant | $/acre | 0 | 0 |
| | Total | $/acre | 7082.87 | |
| | Total including grant | $/acre | 7082.87 | |
| | Total including grant per acre | $/acre | 141.66 | |

| TOTALS | | |
|---|---|---|
| Labor | $ | 331.50 |
| Travel | $ | 0.00 |
| Equipment | $ | 1362.03 |
| Supplies | $ | 7082.87 |
| **Total** | **$** | 8776.40 |
| **Total per acre** | **$/acre** | 175.53 |

**Figure 10. The supplies costs and the total cost subsections of the planting and establishment sheet.**

After the burndown cost section, the values for other supplies, the establishment grant, total supply cost, total supply cost including grant. The other supplies and establishment grant values are variable cells that can be changed by the user. The total supplies cost is found by multiplying the unit per acre amount of each item by the price per unit amount and then adding the other supplies cost. The total including grant is found by multiplying the establishment grant per acre figure by the number of acres to be planted then subtracting that amount from the total supplies cost. The total cost including grant per acre is found by dividing the total cost including grant by the number of acres to be planted.

The last section of the worksheet is the total costs section. In this section the total cost of the planting and establishment of the project is calculated. This is done by adding the total labor, total travel, total equipment, and total supplies costs together. The total cost per acre is found by dividing the overall total cost by the acres to be planted.

***Stand Maintenance***

The stand maintenance worksheet is designed to determine the cost of maintaining the stand of switchgrass for each year of the life of the stand after the first planting year. It contains the following values: project size, the pounds per acre of nitrogen, the price per pound of nitrogen, the pounds per acre of phosphorus pentoxide, the price per pound of phosphorus pentoxide, pounds per acre of potassium oxide, price per pound of potassium oxide, spring burndown quantity per acre, spring burndown price per acre, fall burndown quantity per acre, fall burndown price per acre, broadleaf herbicide quantity per acre, broadleaf price per quantity, grass herbicide quantity per acre, grass herbicide price per quantity, total stand maintenance cost, and total stand maintenance cost per acre. All of these values, with the exception of project size, total stand maintenance cost, and total stand maintenance cost per acre come from the University of Tennessee Extension switchgrass budget (2007).

The values for the pounds per acre of nitrogen, the price per pound of nitrogen, the pounds per acre of phosphorus pentoxide, the price per pound of phosphorus pentoxide, pounds per acre of potassium oxide, price per pound of potassium oxide, spring burndown quantity per acre, spring burndown price per acre, fall burndown quantity per acre, fall burndown price per acre, broadleaf herbicide quantity per acre, broadleaf price per quantity, grass herbicide quantity per acre, grass herbicide price per quantity are variable and can be changed by the user. The estimated figures used come from the University of Tennessee Extension (2007) switchgrass budget. The total stand maintenance cost per acre is found by multiplying the quantity per acre together with the price per quantity of each item in the stand maintenance section. The total stand maintenance cost is found by multiplying this number by the number of acres to be planted.

*Josh's Switchgrass Project*

**Stand Maintenance Submodel**

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| General input data | | | |
|---|---|---|---|
| Project Size | | 50 | |
| Nitrogen | Pounds/acre | 60 | 60 |
| Nitrogen Price | $/pound | 0.76 | 0.76 |
| $P_2O_5$ | Pounds/acre | 40 | 40 |
| $P_2O_5$ Price | $/pound | 0.8 | 0.8 |
| $K_2O$ | Pounds/acre | 80 | 80 |
| $K_2O$ Price | $/pound | 0.75 | 0.75 |
| Spring burndown | Quantity/acre | 1.5 | 1.5 |
| Spring burndown Price | $/quantity | 7.87 | 7.87 |
| Fall burndown | Quantity/acre | 1 | 1 |
| Fall burndown price | $/quantity | 7.87 | 7.87 |
| broadleaf herbicide | Quantity/acre | 2 | 2 |
| broadleaf herbicide price | $/quantity | 2.5 | 2.5 |
| grass herbicide | Quantity/acre | 2 | 2 |
| grass herbicide price | $/quantity | 8 | 8 |
| Total stand maintenance cost second year | | 8913.75 | |
| Total stand maintenance cost second year per acre | | 178.275 | |
| Total stand maintenance cost after second year | | 7863.75 | |
| Total stand maintenance cost after second year per acre | | 157.275 | |
| Total stand maintence cost second year per ton | | 48.18243 | |
| Total stand maintence cost after second year per ton | | 26.2125 | |

**Figure 11. The stand maintenance sheet.**

### *Harvest Sheet*

The harvest sheet is intended to determine the total cost associated with harvesting activities for each year of the life of the project. This sheet is broken down into five subsections that include: general input data, labor costs, travel costs, equipment costs, totals, and costs per ton per year. The general data section has cells for the acres to be harvested and the harvest speed in hours per acre. The number of acres to be harvested comes from the project acres cell in the welcome sheet. The harvest speed in hours per acre cell is an adjustable cell that allows the user to insert his or her estimation if a more accurate one is known. The suggested value for this cell comes from the University of Tennessee Extension (2007) switchgrass budget.

*Josh's Switchgrass Project*

**Harvest Submodel**

| General Input Data | | | |
|---|---|---|---|
| Acres to be harvested | acres | 50 | |
| Harvest speed | hr./acre | 1.48 | 1.48 |

| Labor | | | |
|---|---|---|---|
| no. crews at site | | 1 | 1 |
| Laborer/ crew | | 1 | 1 |
| Foreman/crew | | 1 | 1 |
| Laborer rate | $/hr | 9.75 | 9.75 |
| Foreman rate | $/hr | 9.75 | 9.75 |
| Hours at site/crew | | 74 | |
| indirect labor costs | % | 0 | 0 |
| total | $ | 1443 | |
| Total per acre | $/acre | 28.86 | |

| Travel Costs | | | |
|---|---|---|---|
| No of Vehicles | | 1 | 1 |
| Vehicle costs | $/mi | 0.4 | 0.4 |
| Distance (one way) | mi | 50 | 50 |
| Total nights | | 0 | 0 |
| Hotel costs | $/night/perso | 0 | 0 |
| Meal costs | $/night/perso | 0 | 0 |
| Total crew travel costs | $ | 20 | |

Yellow cells: insert numbers, insert "0" if not applicable
Grey cells: output from previous inputs

**Figure 12. The general input, labor, and travel costs subsections for the harvest sheet.**

The labor section of the harvest sheet contains nine value cells. These cells include: number of crew on site, labors per crew, foreman per crew, laborer wage rate, foreman wage rate, hours at site per crew, indirect labor cost, the total labor cost, and the total labor cost per acre. The number of crews on site, labors per crew, foreman per crew, laborer wage rate, and the foreman wage rate have values that are suggested by the University of Tennessee Extension (2007) switchgrass budget. These values may be adjusted by the user if more accurate figures are known. The number of hours spent at the site per crew is found by multiplying the planting time by the acres to be planted. The total labor cost is found by multiplying together the number of crews at the site, total planting time, laborers per crew, laborer wage rate, and one plus the indirect labor cost percentage.

The travel costs section of the worksheet contains seven value cells including: number of vehicles, vehicle cost, distance, total nights, hotel cost per person per night, meal cost per day per person, and the total travel costs. The number of vehicles, vehicle cost, distance, total nights,hotel cost per person per night, and meal cost per person per day all has adjustable values and can be altered by the user if more accurate figures are known.

The equipment section of this worksheet is divided into six subsections. These subsections are delivery cost, tractor costs, mower costs, rake costs, bailer costs, and loader costs. The recommended values in the adjustable cells in the section come from the University of Tennessee Extension (2007) switchgrass budget. The equipment delivery subsection contains value cells to represent transport cost per mile for the drill, tractor, sprayer, mower, distance to be transported; of which all are cells that allow adjustments by the user, and the total delivery costs. The total delivery cost is found by summing all of the transport cost per mile and multiplying this figure by the distance both ways.

The tractor subsection of the equipment section contains the following categories fixed costs per hour, variable costs per hour, hours per acre, fixed costs per acre, variable costs per acre, fuel costs per acre, and total tractor costs. Fixed costs per hour, variable costs per hour, hours per acre, and fuel costs per acre are all adjustable cells. The value for the fixed cost per acre is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre is found by multiplying the variable cost per hour by the hours per acre. Total tractor cost is found by multiplying the fixed cost and the variable cost per acre by the total acres to be planted and then adding them together.

The four remaining subsections in the equipment section; mower costs, rake costs, bailer cost, and loader costs, have the same costs categories: fixed cost per hour, variable costs per hour, hours per acre, fixed cost per acre, variable cost per acre, repair costs per acre, and total costs for each respective piece of equipment. Fixed costs per hour, variable costs per hour, hours per acre, and repair costs per acre for each piece of equipment are all adjustable cells. The value for the fixed cost per acre for each piece of equipment is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre for each piece of equipment is found by multiplying the variable cost per hour by the hours per acre. Total cost for each piece of equipment is found by multiplying the fixed cost and the variable cost by the total acres to be planted and then adding them together. At the end of the equipment section, the total cost of all the equipment is calculated. This is done by adding all of the individual equipment costs together. This total cost figure is then divided by the number of acres planted to give total equipment costs per acre.

Below the equipment section of the harvest worksheet is the total cost section. In this section, the total cost of the planting and establishment of the project is calculated. This is done by adding the total labor, total travel, and total equipment costs together. The total cost per acre is found by dividing the overall total cost by the acres to be planted.

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| | | | | |
|---|---|---|---|---|
| | **Equipment** | | | |
| **Tractor** | Fixed cost per hour | $/hr | 8.21 | 8.21 |
| | Variable cost per hour | $/hr | 29.04 | 29.04 |
| | Hours per acre | hr/acre | 2.03 | 3.14 |
| | Fixed cost per acre | $/acre | 16.6663 | |
| | Variable cost per acre | $/acre | 58.9512 | |
| | Fuel cost per acre | $/acre | 42.56 | 42.56 |
| | **Total tractor costs** | $ | 3780.875 | |
| **Mower** | Fixed cost per hour | $/hr | 3.3 | 3.3 |
| | Variable cost per hour | $/hr | 4.88 | 4.88 |
| | Hours per acre | hr/acre | 0.26 | 0.26 |
| | Fixed cost per acre | $/acre | 0.858 | |
| | Variable cost per acre | $/acre | 1.2688 | |
| | **Total mower costs** | $ | 106.34 | |
| **Rake** | Fixed cost per hour | $/hr | 1.37 | 1.37 |
| | Variable cost per hour | $/hr | 0.72 | 0.72 |
| | Hours per acre | hr/acre | 0.17 | 0.29 |
| | Fixed cost per acre | $/acre | 0.2329 | |
| | Variable cost per acre | $/acre | 0.1224 | |
| | **Total rake costs** | $ | 17.765 | |
| **Baler** | Fixed cost per hour | $/hr | 14.62 | 14.62 |
| | Variable cost per hour | $/hr | 13.8 | 13.8 |
| | Hours per acre | hr/acre | 0.75 | 0.75 |
| | Fixed cost per acre | $/acre | 10.965 | |
| | Variable cost per acre | $/acre | 10.35 | |
| | **Total baler costs** | $ | 1065.75 | |
| **Loader** | Fixed cost per hour | $/hr | 7.27 | 7.27 |
| | Variable cost per hour | $/hr | 3 | 3 |
| | Hours per acre | hr/acre | 0.73 | 1.07 |
| | Fixed cost per acre | $/acre | 5.3071 | |
| | Variable cost per acre | $/acre | 2.19 | |
| | **Total loader costs** | $ | 374.855 | |
| | **Total equipment costs** | $ | 5345.585 | |
| | **Total equipment costs per acre** | $/acre | 106.9117 | |
| | | | | |
| | **TOTALS** | | | |
| | Labor | $ | 1443 | |
| | Travel | $ | 20 | |
| | Equipment | $ | 5345.585 | |
| | **Total** | $ | 6808.585 | |
| | **Total per Acre** | $/acre | 136.1717 | |

**Figure 13. The equipment costs and total costs subsections of the harvest sheet.**

The cost per ton of harvesting per year section is the last section of the harvest worksheet. It is intended to give the user an idea of how much of the cost per ton in each year is represented by the cost of harvesting the biomass. The value for each year is found by dividing the total harvest cost per year by the amount of biomass harvested in tons for each respective year.

| Cost per ton by year | |
| --- | --- |
| Year | Harvest cost per ton |
| 1 | 97.27 |
| 2 | 36.80 |
| 3 | 22.70 |
| 4 | 22.70 |
| 5 | 22.70 |
| 6 | 22.70 |
| 7 | 22.70 |
| 8 | 22.70 |
| 9 | 22.70 |
| 10 | 22.70 |

**Figure 14. The harvest cost per ton by year.**

***Transportation Worksheet***

The transportation worksheet is intended to show the user the transportation costs for each year over the life of the project. The worksheet has 13 sections that include: general data, labor costs, equipment costs, costs in year one, costs in year two, costs in year three, costs in year four, costs in year five, costs in year six, costs in year seven, costs in year eight, costs in year nine, and costs in year ten.

The general data section of the worksheet contains 9 value cells including: project size highway speed, field road speed, distance on highway (one way), distance on field road (one way), total driving time roundtrip, loading time, unloading time, and total time per trip. Highway speed, field road speed, distance on highway (one way), distance on field road (one way), loading time, and unloading time are all adjustable cells that the user can change. The suggested values for the adjustable cells in this section come from the eco-willow spreadsheet. Total driving time round trip is calculated by multiplying the distance on the highway and the distance on the field road by two, dividing each by the highway speed and the field road speed respectively, and then adding these two values together. Total time per trip is found by adding the loading time and the unloading time to the total driving time.

The labor costs section includes three value cells: driver wage per hour, indirect labor costs, and average loading and unloading costs. These cells may be adjusted by the user. The estimated value for the wage of the driver comes from Fulton (2009) and the value for the average loading and unloading cost comes from Wang (2009).

The equipment section includes four value cells: tractor-trailer costs per mile, fuel consumption in miles per gallon, fuel price, and maximum capacity in tons. Tractor-trailer costs per mile, fuel consumption in miles per gallon, and fuel price are cells that allow adjusting by the user. The estimated values for the tractor-trailer costs and fuel consumption come from Fulton (2009). The fuel price per gallon fluctuates daily and should be changed accordingly. The maximum capacity in tons is dependent on the type of bale used. If round bales are used, 36 bales with an average density of 0.4 tons/bale can be loaded onto each trailer. If rectangular bales are used, 24 bales with an average density of 1 ton/bale can be loaded on a trailer. These figures are taken from Wang (2009).

Each year of the project has a cost section to itself. Each year has the same value cells and the values are figured in the same manner, however, different values are used for different years. Each yearly cost section contains seven different value cells including: total trips, total time, labor, equipment, total per acre, and total per ton. The number of total trips is calculated by dividing the capacity of the tractor trailer by the amount of biomass mass harvested in each respective year. Total time is found by multiplying the total number of trips by the total time per trip. Total labor costs are found by adding average loading and unloading cost multiplied by total trips with the product of total time and the value found by adding driver wage with driver wage multiplied by indirect labor costs. The total equipment costs is found by multiplying together the product of distance on field road and distance on highway, the number two, and the product of the summation of tractor-trailer costs and the quotient of fuel consumption and fuel price and total trips. Total cost is the summation of total labor and total equipment costs. Total cost per ton is total cost divided by the tons of biomass harvested in each respective year.

*Josh's Switchgrass Project*

**Transportation Submodel**

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**General Input Data**

| | | | |
|---|---|---|---|
| Project size | acres | 50 | |
| Highway Speed | mi/hr | 50 | 50 |
| Field road speed | mi/hr | 20 | 20 |
| Distance on highway (one way) | mi | 25 | 25 |
| Distance on field road (one way) | mi | 1 | 1 |
| Total driving time roundtrip | hrs | 1.1 | |
| Loading time | min | 5 | 5 |
| unloading time | min | 15 | 15 |
| Total time per trip | hrs | 1.43333333 | |

**Labor**

| | | | |
|---|---|---|---|
| Driver wage | $/hr | 9.5 | 9.5 |
| Indirect Labor costs | % | 0% | 0 |
| Average Loading and unloading cost | $ | 16.2 | 16.2 |

**Equipment**

| | | | |
|---|---|---|---|
| Tractor-trailer costs | $/mi | 0.5 | 0.5 |
| Fuel consumption | mi/g | 7 | 7 |
| Fuel price | $/g | 3 | 3 |
| Maximum capacity | tons | 14.4 | |

| | |
|---|---|
| Yellow cells: insert numbers, insert "0" if not applicable | |
| Grey cells: output from previous inputs | |

**Figure 15. The general data, labor costs, and equipment costs subsections of the transportation sheet.**

| **Cost in year 1** | | |
|---|---|---|
| Total trips | | 4.81 |
| Total time | hrs | 6.90 |
| Labor | $ | 143.49 |
| Equipment | $ | 232.38 |
| Total | $ | 375.87 |
| Total per acre | $/acre | 7.52 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 2** | | |
|---|---|---|
| Total trips | | 12.72 |
| Total time | hrs | 18.23 |
| Labor | $ | 379.23 |
| Equipment | $ | 614.13 |
| Total | $ | 993.36 |
| Total per acre | $/acre | 19.87 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 3** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 4** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 5** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 6** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 7** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 8** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 9** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

| **Cost in year 10** | | |
|---|---|---|
| Total trips | | 20.63 |
| Total time | hrs | 29.56 |
| Labor | $ | 614.97 |
| Equipment | $ | 995.89 |
| Total | $ | 1610.86 |
| Total per acre | $/acre | 32.22 |
| **Total per ton** | $/odt | 5.42 |

**Figure 16. The yearly transportation costs of the transportation worksheet.**

### *Storage Worksheet*

The storage worksheet is designed to cover the main issues associated with the storage of biomass. It gives the user the total loss of biomass, the total biomass that makes it to the plant gate, and the cost of storage per ton per year. The storage worksheet contains seven sections including: general data, bailing method, storage time, dry matter loss schedule by year in tons, total biomass making it to the plant, and cost of storage per ton per year.

The general data section has only one data cell, which is acres planted. The value of this cell comes from the welcome sheet. Likewise, the bailing method only has one data cell, the type of bailing method to be used. This cell may be adjusted by the user, but can only take on the value of rectangular bales or round bales. The storage time section contains three value cells, including storage time up to 200 days, percentage going directly to plant gate, and percentage being stored for up to 200 days. All three of these cells may be adjusted by the user by the user.

The storage method section gives the user the ability to choose which biomass storage method he or she will be using. There are 10 storage options that include: storing large round bales with a tarp and pallet, tarp and gravel, tarp on bare ground, pallet with no tarp, gravel with no tarp, bare ground no tarp, storing large rectangular bales using tarp and pallet, tarp and gravel, pallet and gravel, pallet with no tarp, and gravel with no tarp. With this spreadsheet, only one storage option may be chosen.

***Josh's Switchgrass Project***

**Storage Submodel**

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| General data | | |
|---|---|---|
| Acres planted | acres | 50 |

| Bailing method^ | | |
|---|---|---|
| | Choose one | Round bales |

| Storage time^ | | |
|---|---|---|
| Storage time up to 200 days | days | 200 |
| Percentage going directly to plant gate | % | 0% |
| Percentage being stored for up to 200 days | % | 100% |

| Storage method^ | 1 if yes, 0 if no | Dry matter loss after 200 days* |
|---|---|---|
| **Large round bale** | | |
| Tarp and Pallet | 1 | 1.0% |
| Tarp and gravel | 0 | 8.5% |
| Tarp on bare ground | 0 | 7.0% |
| Pallet no tarp | 0 | 18.2% |
| Gravel no tarp | 0 | 16.6% |
| Bare ground no tarp | 0 | 12.8% |
| **Large rectangular bale** | | |
| Tarp and pallet | 0 | 13.7% |
| Tarp and gravel | 0 | 28.0% |
| Pallet no tarp | 0 | 48.0% |
| Gravel no tarp | 0 | 57.1% |

*Calculated from unpublished work by Burton English, James Larson and Don Tyler at Milan Research and Education Center.
^ Only one storage method and baling type may be used for storage loss calculation in this worksheet.

**Figure 17. The general data, bailing method, storage time, and storage method subsections of the storage sheet.**

The dry matter loss schedule by year in tons is intended to show the amount of dry matter the user can expect to lose due to weathering and decomposition. The amount of loss incurred is calculated by taking into consideration the percent of overall harvest that will be stored and the amount of time that it will be stored with the amount of dry matter loss to be expected with each storage type. The dry matter loss for each storage type comes from Wang (2009). The total amount of biomass making it to the plant is found by subtracting the amount of loss due to storage from the total amount harvested.

| Dry matter loss schedule by year in tons | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Storage method | | | | | | | | | | |
| Large round bale | | | | | | | | | | |
| Tarp and Pallet | 0.7 | 1.85 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Tarp and gravel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tarp on bare ground | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pallet no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gravel no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bare ground no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Large rectangular bale | | | | | | | | | | |
| Tarp and pallet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tarp and gravel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pallet no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gravel no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 18. The dry matter loss schedule of the storage worksheet.**

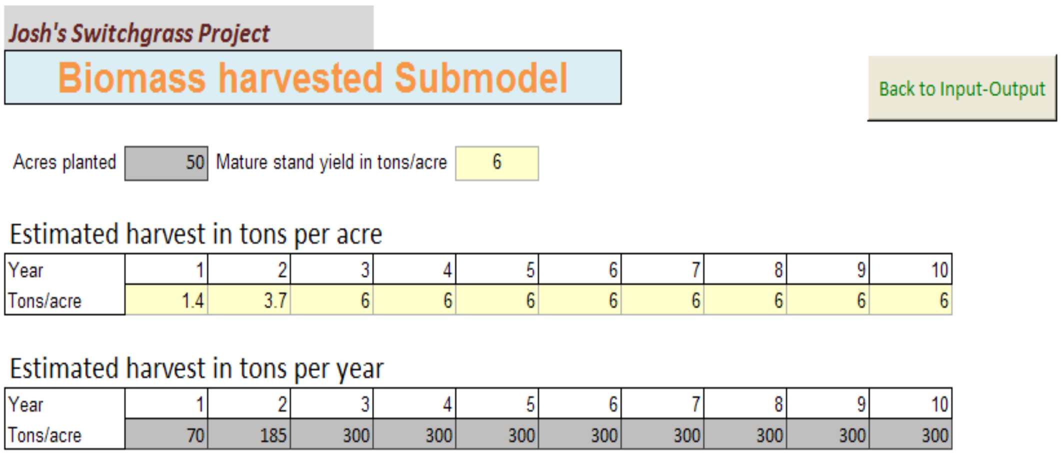
The total cost of storage by year section gives the total cost of storage for each year and the total cost of storage for each year per ton. The total cost for each year has to take into account the amount of storage materials that are still usable from the previous year in determining the amount of material that have to be bought in each current year. Tarps, pallets, and gravel all have different expected rates of replacement, so different storage types will have different material rollover percentages. The amount of materials that roll over from the previous year is subtracted from the amount that is needed in the current year to get the amount that has to be bought is the current year.

| Storage costs per year | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **Storage method** | | | | | | | | | | |
| **Large round bale** | | | | | | | | | | |
| Tarp and Pallet | 3122.453 | 2202.434 | 2631.959 | 1120.5 | 1120.5 | 1120.5 | 1120.5 | 1120.5 | 1120.5 | 1120.5 |
| Tarp and gravel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tarp on bare ground | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pallet no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gravel no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bare ground no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Large rectangular bale** | | | | | | | | | | |
| Tarp and pallet | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tarp and gravel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pallet no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gravel no tarp | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Figure 19. The storage costs per year in the storage sheet.**

***Biomass Harvested Worksheet***

The biomass harvested worksheet is designed to tell the user how much biomass he or she can expect to get from the project in each year in total and per acre. The tons per acre value cells may be adjusted by the user. The values used are estimates that come from the UT switchgrass budget. With any crop, the weather and soil conditions of the region it is grown can have a great impact on how well it performs. Therefore, it is advisable that the user tries to find the estimated switchgrass yield for his or her area.



Josh's Switchgrass Project

Biomass harvested Submodel

Back to Input-Output

Acres planted 50 Mature stand yield in tons/acre 6

Estimated harvest in tons per acre

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Tons/acre | 1.4 | 3.7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

Estimated harvest in tons per year

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Tons/acre | 70 | 185 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |

**Figure 20. The biomass harvested sheet.**

**Conclusions**

This paper explained how an adjustable excel spreadsheet decision tool for potential switchgrass producers was made. It shows where values for costs incurred at each level of production are derived from as well as the costs for storage and transportation of the final baled switchgrass. A major hurdle to overcome with the production of switchgrass, as with any innovation, is the lack of knowledge that potential adopters have about it and consequentially the sense of risk that may accompany its implementation. This paper and the associated decision tool have aimed at and hopefully succeeded in reducing this lack of knowledge.

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