Will switchgrass as a bio-crop be adopted by the farmers?

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Abstract

Adoption of bio-crops has been suggested as a possible solution to reduce dependence on fossil fuels. Although switchgrass is a potential bio-crop, it is still not adopted by the farmers commercially for energy use. In this study, first an in-depth literature review has been done to analyze some of the important decisive factors which should be considered by farmers before adopting switchgrass as a bio-crop. Then an economic analysis has been done on the risks and returns to the farmers for including switchgrass in the farm mix. This study uses 21 years of experimental yield data for switchgrass, from a long term experiment in Alabama. For economic analysis, two hypothetical sample farms of 400 acres each, with and without switchgrass are compared. The yield and price data are simulated with 1000 iterations and return on investments for different cases are compared for final results. The results show that adoption of switchgrass as a bio-crop can be a viable addition to the farm mix which can both improve profitability as well as reducing profits variability in addition to other benefits.

Key Words: biofuels, producers, returns, risks, switchgrass

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Will switchgrass as a bio-crop be adopted by the farmers?

People across the world are seeing biofuels as a potential solution to global challenges: energy security, economic development and mitigation of climate change. Biofuels such as ethanol are renewable fuels and are produced from bio-crops such as corn, sugarcane, and switchgrass. They can be used as a substitute for fossil fuels, which are prone to depletion and contribute significantly to global warming. The U.S. and Brazil are major ethanol producers in the world and account for over 90% of the world's ethanol production (Worldwatch Institute 2006). Ethanol can be broadly classified into two categories based upon the raw material used for its production: grain ethanol and cellulosic ethanol. Grain ethanol is produced from sugar and starch from plants such as corn. On the other hand, cellulosic ethanol is produced from wood, crop residues and grass such as switchgrass. Most of the ethanol production in the USA is from corn. However, there have been concerns as corn grain can be used to feed people or animals. Cellulosic ethanol (such as from switchgrass) does not have a direct influence on food prices and food supply as compared to the ethanol made from corn grain (Runge and Senauer, 2007).

On December 19, 2007, the Energy Independence and Security Act set a goal of 36 billion gallons of renewable fuel use by 2022. It recommends that 21 billion gallons should be produced from feedstock other than corn. Cellulosic biomass demand is increasing and switchgrass is one of the promising bio crops due to its several agronomical, environmental, economic and other benefits. Switchgrass production may be a profitable alternative, but questions still remain as to its competitiveness with the other enterprise alternatives that farmers can adopt (James et al. 2010). A farmer will adopt production of switchgrass only when it will provide more advantages than other conventional options. On the other hand a farmer may prefer conventional options as associated returns and risks may be better known and understood.

Till today, most of the research on switchgrass is done from agronomical and environmental point of view. From agronomical point of view, studies have evaluated the effects of different variables such as weather, fertilizer applications, water requirements, soil type etc. on switchgrass yields. From environmental point of view, studies have focused mostly on issue of greenhouse gas reductions and carbon sequestration. To better understand the potential of switchgrass as a bio-crop, economic analysis is needed to evaluate profitability and risks associated with switchgrass relative to crops that farmers already choose to grow.

The economic characteristics of bioenergy perennials make them risky choices. From economic point of view, most studies have focused on doing production cost analysis, making enterprise budgets, ascertaining cost of producing ethanol from switchgrass, ascertaining farmers' willingness to grow switchgrass as a bio-crop etc. There are also few studies which have calculated the average profitability of different bio-crops (e.g. Heaton et. al.2004). Few studies have done breakeven analysis and have calculated the yields and prices at which a producer would cover costs of production (Mooney et al., 2009). Few studies also went one step ahead and did comparative breakeven analyses and calculated the yield or price required for a producer to earn profit at least equal to the return on a reference traditional crop (Jain et al., 2010).

In all these studies, one important point is to see that these studies relied mostly on secondary data, and they failed to account explicitly for risk. In the absence of adequate real yield data on bio-crops, usually studies have relied upon general crop growth simulation models (Dolginow et al., 2014). The other approach was to statistically estimate yields of bio-crops across time, using a one-period-lagged, linear and plateau function and using residuals to simulate the probability distribution of random variability around expected yields (Clancy et al., 2012). One study also relied on interview responses and recorded secondary data for short-term empirical distributions of bio-crop yields (Bocqueho & Jacquet, 2010).

The novel part of this paper is to use real yield data for switchgrass comprising of twenty one years of observations for actual biomass yields from a long term experiment on switchgrass in south-central Alabama, Macon County. As this study is trying to find the answer about adoption of switchgrass as a bio-crop by the farmers, therefore, it will also assess and review some of the important decisive factors, which can help farmers to understand various advantages/disadvantages, which may arise from adopting switchgrass as a bio-crop. So, by doing risks and returns analysis using the real yield data and analyzing the information gained from previous studies, this study offers much broader insights as compare to previous studies by explicitly accounting for risk factor in addition to comparative profitability analysis with respect to traditional crops.

In section 'Descriptive Analysis', first an in-depth literature review has been done to analyze some of the important decisive factors which should be considered by farmers before adopting switchgrass as a bio-crop. Then for the economic analysis, after building a theoretical model in section 'Conceptual framework', analysis for risks and returns to the farmers has been done for including switchgrass in farm-mix in the 'Methodology' section. For this, study has compared two hypothetical sample farms of 400 acres each i.e. one sample farm with 200 acres each for two conventional crops i.e. corn and cotton, and, second sample farm with one additional crop of switchgrass taking 30 acres away from each conventional crops. The yield and price data are simulated with 1000 iterations to calculate profit/loss and return on investments (ROI) for different options. Then on the basis of analysis of these sections, this study will try to offer useful insights on adoption of switchgrass as an energy crop.

Descriptive Analysis

To address the question of adoption of switchgrass, only economic analysis is not sufficient for the farmers. A farmer may consider some other important decisive factors, which can play an equally important role in deciding on the adoption of switchgrass as a bio-crop. So, in this section, we will assess and review few such factors.

For this, first we will analyze the future of ethanol production in USA, specifically the future of cellulosic ethanol. As, if future does not seems good for it, then there is no point in discussing adoption of switchgrass as a cellulosic biofuel feedstock. Next, we will analyze the potential of switchgrass as a cellulosic bio-crop by evaluating its agronomical, environmental, economic and other benefits. Technical and economic feasibility to convert switchgrass into ethanol will also be carefully analyzed. Lastly, current subsidies and various policy regimes will be studied to throw light on the support program/subsidy for the farmers, which can really influence the farmers' decision.

Future of ethanol production in USA

Every year in the last decade ethanol production has increased in the United States. In 2014 the U.S. produced 14.3 billion gallons of ethanol which accounted for 58% of global ethanol production (Renewable Fuels Association, 2015). Ethanol could replace 30% or more of U.S. gasoline demand by 2030 (US Department of Energy, 2009). Several policies to promote the use of renewable sources of energy including cellulosic ethanol have been implemented in the USA (Zegada et al 2013). We should remember that there is a goal of 36 billion gallons of renewable fuel use by 2022, set by Energy Independence and Security Act of 2007 (EISA).

Renewable Fuel Association (2015) has stated that the production of 14.3 billion gallons of ethanol in 2014 had substantial economic impacts including 83,949 direct jobs, 295,265 indirect and induced jobs, $53 billion contribution to GDP, and $27 billion in household. These figures are impressive, and don't yet take into account other potential benefits such as enhanced energy security, improved environmental amenities such as water quality, wildlife habitat, and decreased greenhouse gas emissions. From these facts, future of ethanol production seems promising in USA.

Future of cellulosic ethanol in USA

As we know that ethanol can be broadly classified into two categories based upon the raw material used for its production: grain ethanol (such as from corn) and cellulosic ethanol (such as from switchgrass). Cellulosic ethanol offers an attractive bio based alternative to conventional gasoline (Ragauskas et al., 2006; Schemer, 2008). Cellulosic ethanol has lower green-house gas emissions and higher energy efficiency as compared to ethanol made from corn grain (Farrell et al., 2006). Commercial production of cellulosic biofuels at a cost that is competitive with fossil fuels could occur within the next five years (Solecki et al., 2012). Using food crops (such as corn) for ethanol production raises concerns of food security (Mitchell, 2008) and environmental degradation (Pimentel and Patzek, 2005). Therefore, majority of the petroleum importing countries (including U.S.) are interested in utilizing cellulosic biomass as a feedstock for ethanol production. U.S. has a large cellulosic biomass production base and production of ethanol from cellulosic feedstock and utilizing it as a substitute for gasoline could help in promoting rural development, reducing greenhouse gases, and achieving energy independence (Perlack et al., 2005).

In the USA, the development of cellulosic ethanol is being driven in large by Energy Independence and Security Act of 2007 (EISA). The Energy Independence and Security Act have set a goal of 21 billion gallons of cellulosic ethanol production by 2022. Federal government has provided a funding of $1 billion for promoting research in developing a commercial viable conversion technology for producing cellulosic ethanol (Curtis, US Department of Energy 2008). It is expected that the successful demonstration of at least one conversion technology on a commercial scale will help in increasing the confidence of investors in cellulosic ethanol production and thus, will help in achieving the policy target of producing 21 billion gallons of cellulosic ethanol by the year 2022.

These facts clearly state that the biofuels (ethanol) will contribute significantly to future fuel consumption and the government is focusing on cellulosic bio-crops such as switchgrass.

Switchgrass: a potential bio-crop for cellulosic ethanol

Among the many agricultural crops screened as potential biofuels, the herbaceous bio-crop switchgrass has been identified as a promising feedstock for conversion to biofuels (Sanderson et al. 1996; McLaughlin et al. 2002; Parrish and Fike 2005). Switchgrass has been evaluated as a biofuel crop in parts of the USA, Canada and Europe (Adler et al. 2006; Berdahl et al. 2005; Madakadze et al. 1999; Mclaughlin et al. 2002). According to the Parrish and Fike (2005), a variety of lowland and upland cultivars of switchgrass are available and cultivars of both ecotypes are being considered for biofuels. Switchgrass can be used to produce biofuel and is viewed as a potential long-term biofuel feedstock to replace corn (Keshwani and Cheng 2009).

Whether switchgrass is a potential bio-crop for cellulosic ethanol or not, can be analyzed by understanding its following benefits:

1. *Agronomical benefits*

Bransby (1998) found that switchgrass is well-adapted to grow in a large portion of the United States with low fertilizer applications and high resistance to naturally-occurring pests and diseases. Switchgrass requires less water than most crops currently cultivated because of a deep and extensive root system (Bransby et al., 1989). Switchgrass requires about 25 inches or less of water per season, compared to 26 inches for corn and 39 inches for cotton (Brouwer and Heibloem, 1986; Stroup et al., 2003; Smith, 2007). Thus, switchgrass is more drought resistant than other crops (Bransby et al., 1989) and may provide higher yields than many annual crops in drought years. In addition, switchgrass requires less pesticides and fertilizers than most crops currently grown in the United States (Bransby et al., 1989; Rinehart, 2006).

Switchgrass has high yields and is tolerant of water deficiency and needs low soil nutrient concentrations (Sanderson et al. 1999). Switchgrass is a high potential bio-crop with advantages such as cost effectiveness, broad adaptability, better tolerance of wet and dry soil, freeze tolerance, efficient use of water and nutrient, and high yield (McLaughlin 2002; Parrish and Fike 2005). Bransby and Huang (2014) determined long term biomass yields of eight switchgrass cultivars in Alabama and evaluated the effects of weather variables on annual yields of switchgrass grown at a single location. They concluded that under similar soil, environmental and management conditions, stands of switchgrass should be productive for 20 years or more. Their results showed that switchgrass is considerably more tolerant to drought than most of the other annual crops. Lot of other research work has also talked about its comparative better agronomical benefits as a bio-crop.

2. *Environmental benefits*

McLaughlin (2005) established that studies of soil carbon storage under switchgrass indicate significant carbon sequestration will occur in soils, improving soil productivity and nutrient cycling and substantially augmenting greenhouse gas reductions. Bai et al. (2010) conducted a study to analyze the environmental sustainability of using the switchgrass plant material as a feed stock for ethanol production. They took air and water emissions into account that are associated with growing, managing, processing and storing switchgrass crop. They even considered transportation of stored switchgrass to an ethanol plant and found that using switchgrass for ethanol production can reduce global warming potential by 5% and 65% for E10 and E85 respectively. Ethanol produced from switchgrass, either alone or by co-firing with other fossil fuels has a potential of reducing Green House Gas (GHG) emissions (Tillman 2000). Thus, positive environmental impacts make switchgrass more likely to be adopted as a bio-crop.

3. *Economic benefits*

Switchgrass has economic advantages due to its unique features such as being a perennial crop meaning that it does not need to be planted each year and can survive 20 years or more. There is no establishment cost in subsequent years to planting year. Unlike many other bio-crops, it can grow on marginal land. 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) so for economically not useful lands, it can prove to be a very profitable enterprise. Switchgrass can be high yielding on marginal land (Fuentes &Taliaferro, 2002), so it could potentially be introduced into the feasible product mix by the farmers to increase their overall profitability.

Larson et al. (2005) developed a farm-level risk programming model based on yield and price variability to evaluate the risk management potential of including biomass crops as a diversification strategy for a grain farm. Their results indicate that adding biomass crops to the farm enterprise mix could reduce net revenue variability and improved mean net revenues.

4. *Other benefits*

Farmers can also acquire other benefits such as ecosystem services benefits from the production of switchgrass. These benefits can be in the form of increased soil organic matter that retains moisture and maintains fertility, reduction in soil erosion and fertilizer runoff and provision of wild life habitat. There are some studies that have tried to quantify these benefits. Debnath et al. (2013) estimated that these intangible benefits could raise the value of a switchgrass crop by $13 to $46 per ton relative to intangible benefits from no-till wheat. Liebig et al. (2008) measured increases in soil carbon sequestration under switchgrass and found an average increase of 1.1 Mg C/ha, which at the value the U.S. Environmental Protection Agency places on carbon emission reductions, would be worth $54 per acre (around $15 per ton). These benefits are difficult to quantify, but play an important role in decision making.

Feasibility for conversion of switchgrass into ethanol: refineries' perspective

This is really an important aspect in relation to future of switchgrass as a potential biomass feedstock. In 2014, a genetically altered form of 'bacteriu caldicellulosiruptor bescii' was created which can cheaply and efficiently turn switchgrass into ethanol (Chung, 2014). Without mandates, at current prices for fossil fuels cellulosic ethanol is not competitive with gasoline. Currently the Food, Conservation and Energy Act of 2008 (H.R. 2419) includes a tax credit of US$ 1.01/gallon for cellulosic biofuel refineries (sec 15321), and a cost sharing program matching up to US$ 45/ton for collection, harvest, storage and transportation of biomass crops (section 9011). Yu et al. (2011) evaluated the potential value of including preprocessing in the biomass feedstock supply chain for a bio refinery in East Tennessee using a spatial oriented mixed-integer mathematical programming model. The results showed that stretch-wrap bale reprocessing technology could reduce the total delivered cost of switchgrass for large scale bio refineries.

There is a considerable variability in the expected quantity of ethanol that can be produced from per dry ton of switchgrass. Schmer et al. (2008) used conversion rate of 91 gallons per dry ton. The USEPA (2010) reports conversion rates of 72 gallons per dry ton (p. 721), 90 gallons per dry ton (p. 285), and 92.3 gallons per dry ton (p. 286), depending on system and maturity of the system. For a given size of bio-refinery, total feedstock requirements, acres required, transportation distances, and feedstock cost would lead to different conversion rates. Because there are no commercial-scale cellulosic ethanol plants in operation, it is quite difficult to determine what will be the variable cost of converting switchgrass to ethanol. The average conversion cost for the farm bill period of 2008 to 2012 is $1.10 per gallon.

Thus, gradual development of technology is bringing attention of bio refineries towards switchgrass as a potential biomass feed stock.

Subsidies and different policy regimes

It's important to understand all current subsidies and policies in relation to biofuels to analyze whether there is any push from the government to farmers for adoption of switchgrass as a bio-crop. Tyner, W.E. 2008 claimed that today's boom in ethanol industry is an unintended consequence of a fixed ethanol subsidy. He points out that the current government policy toward biofuels combines a fixed subsidy of 13.5 cents per liter (51 cents per gallon). In future, the policy chosen will be critical in determining the growth of both corn and cellulose ethanol. Using cellulose for ethanol production would reduce the problems associated with using corn — namely, food insecurity, reduced corn exports and higher costs for animal feed. According to him, the government should provide a tax credit to cellulose processors for each dry ton of cellulose converted into fuels in order to assist in launching the cellulose based industry. Babcock et al 2007 suggested that subsidies should be directly targeted at biomass production rather than ethanol production or biofuels production because new ethanol production subsidies would simply increase the demand for corn, not switchgrass, despite the potentially significant environmental advantages of expanded switchgrass production.

After doing an in-depth literature review in section "Descriptive Analysis", we can say that there are reasonable grounds for promoting more research on switchgrass and taking first step towards thinking of adoption of switchgrass as a bio-crop more seriously.

After considering all these points, if farmers think about adoption of switchgrass as a bio-crop, then first they will require information about switchgrass profits and risk estimates to compare with of alternative farm enterprises. As mentioned earlier, previous studies doing economic analysis on bio-crops, relied mostly on secondary data for yields of bio-crops, and they failed to account explicitly for risk. This study uses real yield data for switchgrass and offers much broader insights as compare to previous studies by explicitly accounting for risk factor in addition to profitability analysis.

Conceptual framework

Rational economic decision-makers are assumed to make crop production decisions by choosing crop i to maximize their profits in light of their risk preferences. The farm model used in this study is based on a risk-neutral farmer, who is a profit maximizer deciding whether or not to include switchgrass as a bio-crop in his/her crop-mix. The farmer is assumed to grow two traditional crops of corn and cotton and has the choice of replacing a part of these both crops with switchgrass. The farmer's overall objective is to maximize profit, which is the net return from selected crop mix. The profit function (π) is represented by:

$$\pi_j = \sum_i [(Y_i . P_i) - VC_i - FC_i] \qquad (1)$$

Where π_j represents profit of farm j, Y_i represents yield of crop i which is stochastic, P_i represents selling price of crop i which is stochastic except for switchgrass, VC_i represents total variable cost for crop i and FC_i represents total fixed cost for crop i. Profits will be calculated based on 1000 draws obtained from yield-price joint distribution (using 21 years real yield and price data) with the help of stochastic simulation. These profits will be used to analyze the risks and returns for including switchgrass in the crop-mix.

Next, in the 'Methodology' section, as there is still no market for switchgrass, this study will analyze the economic risks and returns at different expected switchgrass prices

Methodology

This section describes data used in the study and simultaneously points out all methods and steps undertaken in order to analyze risks and returns to farmers adopting the switchgrass cultivation as a bio-crop.

For this analysis, two hypothetical sample farms, each of 400 acres size are created. The sample farm 1 (base farm) is created with 200 acres each of two traditional crops i.e. corn and cotton (this equal division is arbitrary). The sample farm 2 is created where 30 acres from each traditional crop are replaced with switchgrass, resulting in 60 acres of switchgrass cultivation (this division is also arbitrary) and 170 acres each of corn and cotton cultivation. The study has chosen corn and cotton specifically because, as per United States Department of Agriculture, corn and cotton are the two of the most important and commonly grown field crops in Alabama, a state for which actual real yield and price data for 21 years are used in this study. Moreover the major crops of Macon County (place of switchgrass experimental Center) by planted acreage are cotton and corn. For switchgrass real yield data, the data used in this study include twenty one years of observations for biomass yields from a long term experiment on switchgrass at the Auburn University's E.V. Smith Research and Extension Center in south-central Alabama, Macon County. As novel part of this paper is using real yield data for switchgrass in Alabama for

21 years (1989-2009), therefore, yield and price data for corn and cotton is also collected for these same 21 years for the Alabama. The study has used state-level yields data for corn and cotton as experimental yield data for corn and cotton is unavailable both at state-level and at county-level.

This study has considered this period as a 21-year framework during which switchgrass can finish one life cycle. Return on investment (ROI) will be calculated and compared for both farms based on 1000 draws obtained from yield-price joint distribution (with the help of simulation) to analyze the risks and returns for including switchgrass in the crop-mix.

If a farmer, who is growing traditional crops, introduces switchgrass in a crop-mix, then definitely such farmer will like to earn at least the same earlier ROI, and, preferably with reduced profit variability. A critical factor in adopting new crops, such as bio-crops, is their profitability relative to that of existing cropping systems. Most farmers will allocate land to bio-crops only if the economic returns from these crops are at least equal to returns from the most profitable conventional alternatives (Jain et al., 2010).

Data

For this study, yield, price and cost data is required for corn, cotton and switchgrass. This data section will explain the sources of data collection and any processing of data to make it fit for running simulation and for calculating ROI.

Yield data

To start with the data collection, first of all data related to yield is collected. For switchgrass yield data, the data used in this study include twenty one years of observations for biomass yields, rainfall and age from a long term experiment on switchgrass. Plots were planted in 1989 at the Auburn University's E.V. Smith Research and Extension Center in south-central Alabama, Macon county, on a Wickham sandy loam (fine-loam, mixed, semi active, thermic Typic Hapludult) soil. Precipitation occurs throughout the year, averaging 1,335 mm on an annual basis. They were planted in a randomized complete block small-plot experiment with four replicates. The plots were 1.5 m wide and 6.0 m long and they were planted with a seed drill with 0.2 m between rows. Nitrogen fertilizer was applied at a rate of 84 kg n ha-1 annually. No P and K fertilizer, irrigation, or herbicides were applied over complete experiment period. Biomass harvested from each plot was weighted immediately after harvesting and subsamples taken out of it were weighted before and after drying to determine dry matter content. Annual yields were determined by harvesting plots twice each year from 1989 to 2009 (Table 1). Average yield for all four replicates are taken as final yield data for the analysis.

The state data (Alabama data) for yields related to corn and cotton is taken from the database of United States Department of Agriculture (Quick stats, USDA) for same years 1989 to 2009 (Table 2). Detrending – a statistical or mathematical operation is frequently applied in crop yield risk assessment as risk analysis yields better insight once trend is removed. In yield data, a significant trend is found only with respect to corn. The simplest way to "detrend" a time series would be to fit a straight line through the data, using a least square procedure and then a simple linear trend in mean can be removed by subtracting this least-squares-fit straight line. Application of this approach produced following regression equation which is used to calculate predicted yields for corn (figure 1):

$$y = 1.6636x + 70.271 \qquad (2)$$

These predicted yields are subtracted from actual yield data to get error terms (Table 3). For yield data of cotton and switchgrass, simple mean was found and subtracted from actual yield data to get errors around the mean. Thus, error terms for all three yields are calculated to be used in finding correlation matrix later on in order to run simulations.

Price Data

The state data (Alabama data) for prices related to corn and cotton is taken from the database of United States Department of Agriculture (Quick stats, USDA) for same years 1989 to 2009 (Table 2). The crop prices data is indexed with base year 2014 using Producer Price indexes (Table 4). The Producer Price Indexes (PPI) measure the average change in selling prices over time from the perspective of the seller. For further analysis these indexed prices are used everywhere. For prices, after adjusting for inflation, mean was found and subtracted to get errors around the mean to be used in finding correlation matrix later on in order to run simulations.

Thus, a set of five error terms (three for yields for corn, cotton, switchgrass and two for prices for corn, cotton) will be used to find the correlation matrix. Thus data was detrended before running any simulation.

Due to unavailability of switchgrass market price, it has been taken as $30, $45 and $60 per ton for doing calculations in different scenarios. U.S. Department of Energy (2011) suggested that a switchgrass price of $60 per ton can attract a sufficient supply of biomass feedstock to replace 30% of transportation fuel use by 2030.

Simulations

Data related to five variables i.e. yield data for all three crops and price data for two traditional crops (there is no market price for switchgrass) will be used for this simulation. By generating 1000 iterations for these variables, study has included randomness through properly identified distributions taken directly from actual data. Remember, averages of the raw data will not be able to accurately capture the variability that exists in reality.

In this study, simulations are run to obtain 1000 draws from yield-price joint distribution with the help of Cholesky decomposition which is widely used in generating correlated random numbers (RN). A set of uncorrelated variables can be transformed into variables with given covariance with the help of Cholesky transformation.

A well-known fact from linear algebra is that any symmetric positive-definite matrix, K, may be written as:

$$K = U^T DU \tag{3}$$

Where U is an upper triangular matrix and D is a diagonal matrix with positive diagonal elements. Since a variance-covariance matrix Σ is a symmetric positive-definite matrix, therefore one can write:

$$\Sigma = U^T DU \tag{4}$$

$$= \left(U^T . \sqrt{D}\right) \left(\sqrt{D} . U\right) \tag{5}$$

$$= (\sqrt{D} . U)^T \, (\sqrt{D} . U) \tag{6}$$

The matrix $C = \sqrt{D}U$ therefore satisfies $C^T C = \Sigma$.

It is called the Cholesky Decomposition of Σ.

Thus, Cholesky transformation is represented by a matrix that is square root of the correlation matrix of actual data. To get the correlated random numbers with the given covariance, matrix of uncorrelated random numbers is multiplied with the Cholesky matrix.

This study has specifically used this approach as Cholesky decomposition is easier to understand intuitively and has numerical stability as compare to some other methods. It also preserves the variance observe in the data, instead of just the mean value (Table 5). This stochastic approach simply allows calculation of many equally probable situations, which further can be processed to quantify and assess uncertainty.

Cost data

Data related with variable costs and fixed costs of producing switchgrass is taken from database of Alabama Cooperative Extension System (Table 6). Data related with variable costs and fixed costs of producing corn and cotton is taken from enterprise planning budget summaries – 2015 for Alabama, from the database of Alabama Cooperative Extension System (ACES, 2015).

All the costs are adjusted with current prices. Fixed costs per acre given in the budgets are taken as it is in our calculation of final costs. All variable costs excluding good management expenses such as crop insurance and cover crop establishment expenses are taken as it is in our calculation of final costs. These good management expenses are totally excluded from variable costs.

Average variable and fixed costs for both sample farms are shown in table 7.

Calculation of risks and returns

By using the costs, yields and prices data of 1000 draws, first profits/losses for farm 1 are calculated by using equation (1). Then with the help of these figures, return on investment (ROI) for farm 1 is calculated with the following formula:

$$ROI = \frac{\pi}{C} * 100 \qquad (7)$$

Where π is the profits function as is mentioned in equation (1) and C is the cost function. The cost function (C) is represented by:

$$C = VC + FC \qquad (8)$$

Where VC is the total variable cost of farm and FC is the total fixed cost of farm.

Then in similar way, profits for farm 2 are calculated with three different switchgrass prices i.e. \$30, \$45 and \$60 per ton. Then with the help of these profit figures, return on investments (ROI) with above formula for all three cases are calculated. Mean ROI with standard deviation for each case is calculated along with frequency for different ranges of ROI.

Results

The results show that adoption of switchgrass as a bio-crop can be a viable addition to the farm mix as it can reduce profits variability and can also improve profitability to the farmers. To compare risk for different cases, a chart showing different ROI under different cases is created (Figure 2). The frequencies of different ranges of ROI are depicted in this chart. The red and yellow shaded area in each bar represents the frequency of a negative ROI. The green area represents the frequency of a positive ROI. The results shows that the sample farm 1 of 400 acres size with 200 acres each of 2 traditional crops i.e. corn and cotton provides 4.23% return on investment (ROI) on an average with a standard deviation of 20.66%. The median ROI is 4.31%. The farmer expects to incur losses for 41% of cases (Table 8 and Table 9).

In the sample farm 2, with switchgrass price at \$30, \$45 and \$60, the mean ROI ranged between 4.62% and 23.38%, which is considerable higher than mean ROI for farm 1. Even the median ROI for farm 2 is higher in all three cases. Median ROI for farm 2 ranges between 4.56 and 23.65. For switchgrass prices \$45 and \$60 per ton, there is significant reduction in number of years of losses. In these scenarios, farmer expects to incur losses ranged between 28% and 8%, which are considerable lower as compare with farm 1. An important observation was the reduction in risk in case of farm 2 as measured by the standard deviation. The standard deviation in all three scenarios of farm 2 was less than the farm 1 indicating reduction in variability in ROIs to the farmer.

Conclusion

In addition to risks and returns analysis using stochastic simulation, this paper also provides a valuable overview about some crucial factors influencing switchgrass adoption decision. By assessing the competitiveness of switchgrass as a bio-crop relative to two most common traditional crops i.e. corn and cotton, this study concludes that switchgrass can be a viable addition to the farm mix which can increase the profitability and can reduce variability to the farmer. It will be interesting to consider how much this positive impact can be increased using policies that provide farmers with payments for environmental benefits of switchgrass, as it should be remembered that in addition to economic gains, there are many important agronomical and environmental benefits also. Moreover, the lower corn and cotton yields on poorer soils will definitely increase this advantage gap. At low market prices, switchgrass can turn out to be a poorer investment than corn and cotton, but their lower opportunity cost for marginal lands clearly indicates the potential for comparative advantage at lesser productive sites. Here, one thing is really important to mention that absence of an established market for switchgrass is an important factor affecting variability in profits (i.e. risk), so risk minimization solutions to farmers e.g. by means of contacting, insurance options etc. can really motivate the adoption of switchgrass.

An in-depth literature review of some previous studies has also helped in assessing and reviewing information in order to increase the knowledge concerning the economies of switchgrass adoption and in understanding some of the important decisive factors, which can help farmers to understand various advantages/disadvantages which may arise from adopting switchgrass as a bio-crop. This review has revealed that there are reasonable grounds to consider switchgrass as a potential bio-crop and taking first step towards thinking of adoption of switchgrass as a bio-crop more seriously.

Further research needs to be conducted to explore the feasibility of using switchgrass partly as forage and partly as a biofuel feedstock. As per the news published by Mississippi State University Extension service in August, 2008, there is some part (usually first 24 inches of growth) which has high protein and can be harvested for forage). Producers have the option to grow switchgrass as a “dual-purpose” crop. Biomass production will be lower under this scenario, but, due to high forage prices, it can significantly raise the profits of producers.

Further research is needed to find the right mix of crops. Additionally, a deeper investigation of different national and transnational policies promoting different kinds of bio-crops can be conducted to encourage more farmers to adopt switchgrass as a bio-crop. These future research efforts will lead to creation of favorable circumstances for adoption of switchgrass as a bio-crop by the farmers and thus will contribute to meet the cellulosic ethanol targets set by Energy Independence and Security Act.

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Table 1: Switchgrass yield (Tons per acre) (Year 1989-2009)

Randomized complete block design with four replications					
Year	Rep 1	Rep 2	Rep 3	Rep 4	Avg. Yield
1989	8.943	9.065	6.091	6.219	7.580
1990	17.170	16.577	14.693	13.292	15.430
1991	15.520	12.418	10.799	11.760	12.620
1992	11.327	11.332	10.002	10.593	10.810
1993	12.152	10.001	7.385	10.905	10.110
1994	12.892	6.769	6.680	8.495	8.710
1995	7.649	7.054	8.101	7.419	7.560
1996	7.784	6.086	6.765	7.535	7.040
1997	6.409	6.854	7.358	6.509	6.780
1998	11.172	8.186	8.753	9.608	9.430
1999	11.240	9.367	9.252	11.662	10.380
2000	12.673	11.381	12.848	16.230	13.280
2001	17.900	10.400	13.108	13.315	13.680
2002	16.393	7.490	10.659	11.730	11.570
2003	10.006	6.780	13.118	13.324	10.810
2004	11.605	5.878	9.909	11.482	9.720
2005	12.146	6.551	11.139	11.556	10.350
2006	13.777	7.076	11.890	12.355	11.270
2007	11.270	3.934	9.596	11.192	8.990
2008	12.066	6.364	8.438	10.207	9.270
2009	15.645	7.314	8.993	12.753	11.180

Table 2: Yield and Price Data for Corn and Cotton (Year: 1989-2009)

Year	Prices		Yields	
	Corn	Cotton	Corn	Cotton
	$/BU	$/LB	BU/Acre	LB/Acre
1989	2.75	0.637	81	571
1990	2.69	0.69	58	476
1991	2.6	0.566	80	655
1992	2.35	0.562	94	731
1993	2.64	0.571	55	524
1994	2.5	0.691	96	766
1995	3.5	0.729	75	409
1996	3.45	0.709	82	734
1997	2.82	0.673	87	597
1998	2.31	0.606	63	559
1999	2.26	0.478	103	535
2000	2.16	0.528	65	492
2001	2.35	0.277	107	730
2002	2.72	0.435	88	507
2003	2.36	0.596	122	772
2004	2.48	0.406	123	724
2005	2.5	0.487	119	747
2006	2.91	0.446	72	579
2007	4.54	0.597	78	519
2008	5.26	0.449	104	787
2009	3.89	0.657	108	662

Table 3: Detrending corn yield - Estimation Results

Year	Obs.No.	Actual yield	Predicted yield	error terms
1989	1	81	71.9346	9.0654
1990	2	58	73.5982	-15.5982
1991	3	80	75.2618	4.7382
1992	4	94	76.9254	17.0746
1993	5	55	78.589	-23.589
1994	6	96	80.2526	15.7474
1995	7	75	81.9162	-6.9162
1996	8	82	83.5798	-1.5798
1997	9	87	85.2434	1.7566
1998	10	63	86.907	-23.907
1999	11	103	88.5706	14.4294
2000	12	65	90.2342	-25.2342
2001	13	107	91.8978	15.1022
2002	14	88	93.5614	-5.5614
2003	15	122	95.225	26.775
2004	16	123	96.8886	26.1114
2005	17	119	98.5522	20.4478
2006	18	72	100.2158	-28.2158
2007	19	78	101.8794	-23.8794
2008	20	104	103.543	0.457
2009	21	108	105.2066	2.7934

Table 4: Indexed Prices with Base Year 2014

Year	Corn	Cotton
1989	4.85	1.12
1990	4.52	1.16
1991	4.28	0.93
1992	3.82	0.91
1993	4.24	0.92
1994	3.99	1.10
1995	5.48	1.14
1996	5.27	1.08
1997	4.29	1.02
1998	3.54	0.93
1999	3.41	0.72
2000	3.14	0.77
2001	3.35	0.39
2002	3.92	0.63
2003	3.30	0.83
2004	3.35	0.55
2005	3.22	0.63
2006	3.64	0.56
2007	5.46	0.72
2008	5.95	0.51
2009	4.52	0.76

Table 5: Mean and standard deviations before and after simulations.

	Prices		Yields		
Before (i.e. of actual data)	Corn	Cotton	Corn	Cotton	Switchgrass
Mean	4.17	0.83	105.21	622.67	10.31
S.D.	0.84	0.23	18.30	115.95	2.24
After (i.e. of 1000 draws)					
Mean	4.15	0.83	105.31	623.79	10.35
S.D.	0.85	0.23	18.76	118.31	2.29

Table 6: Establishment and maintenance Budget for Switchgrass

Item	Unit	Amt/Acre	Quantity	Price or Cost/Unit	Total Cost
1. Variable costs					
Soil Test	each	0.03	0.0250	7.00	0.1750
Fertilizer					
Nitrogen	lbs.	50.00	50.0	0.58	29.00
Phosphate	lbs.	40.00	40.0	0.43	17.20
Potash	lbs.	40.00	40.0	0.43	$17.20
Interest on op. cap.	dol.		$31.79	5.5%	$1.75
Total variable cost					$65.32
2. Fixed costs					
Estab. cost amort.	dol.		$19.79	1.00	$19.79
General overhead	dol.		$65.32	4.0%	$2.61
Total fixed costs					$22.41
3. Total of all specified costs					$87.73

Harvest & Transport Budget for Switchgrass

Item	Unit	Amt/Acre	Quantity	Price or Cost/Unit	Total Cost
1. Variable costs					
Harvest cost (1 or 2)	acre	1.00	1.0	$59.06	$59.06
Tractor & equipment	acre	1.00	1.0	$65.58	$65.58
Total variable cost					$124.63
2. Fixed costs					
Tractor & equipment	acre	1.00	1.0	$19.45	$19.45
General overhead	dol.		$124.63	4.0%	$4.99
Total fixed costs					$24.43
3. Other costs					
Labor(wages &fringe)	hour	3.80	3.8	$12.50	$47.46

Table 7: Average variable and fixed costs per farm (in $)

	Farm 1	Farm 2
Average Variable Costs	145200	138180
Average Fixed Costs	36400	33760

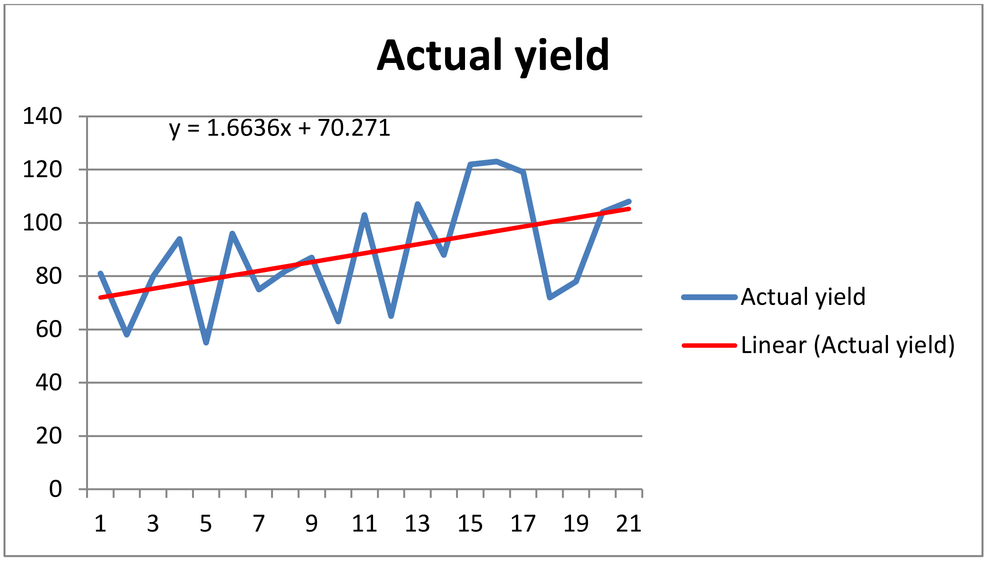
Table 8: ROI for different cases

	Farm 1 ROI	Farm 2 ROI (at 30 sg price)	Farm 2 ROI (at 45 sg price)	Farm 2 ROI (at 60 sg price)
Mean	4.23	4.62	10.12	23.38
Standard Deviation	20.66	18.34	17.83	16.94
Median	4.31	4.56	10.16	23.65

Table 9: Frequency Table for ROI

	Farm 1 ROI	Farm 2 ROI	Farm 2 ROI	Farm 2 ROI
		(at 30 sg price)	(at 45 sg price)	(at 60 sg price)
Losses more than 20%	124	92	45	8
Losses less than 20%	285	307	240	75
Profits up to 20%	373	405	436	335
Profits more than 20%	218	196	279	582

Figure 1: Detrending of Corn Yield data



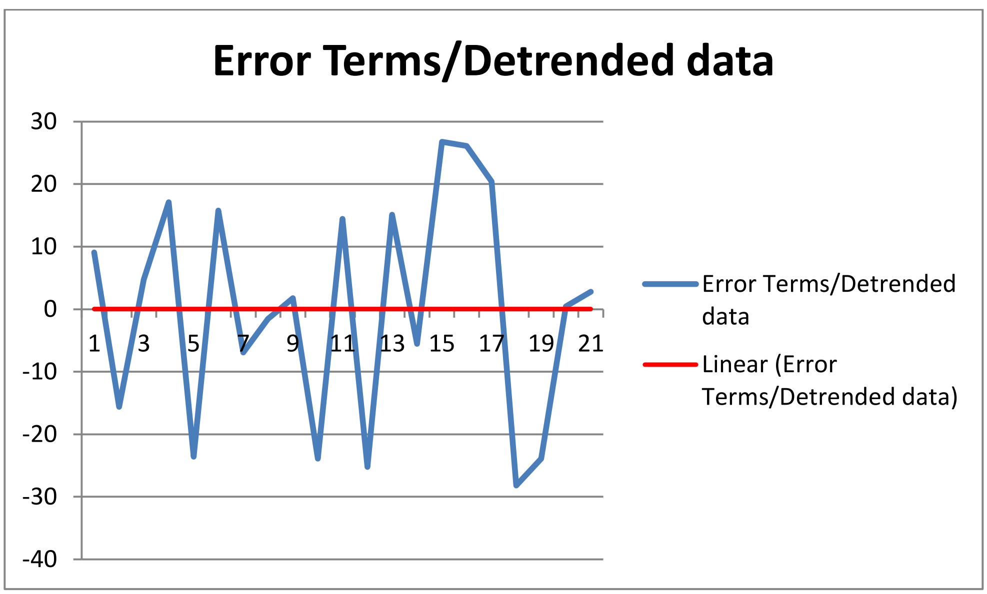


Figure 2: Graph showing different ROI under different scenarios