Comparative economic analysis of on-farm biodiesel production from summer oilseed crops

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Abstract

Soybean and sunflower are the major oilseeds crops that can be used as feedstock to produce biodiesel. This study investigates the comparative economic analysis of producing biodiesel from selected oilseed crops. The objective of this study is to advance research to provide knowledge needed for the feasible way of adaptation of oilseed crops for small scale on-farm production of biodiesel. The equipment, capital, acreage, and production costs needed for feedstock production, harvesting, and processing of these oilseed crops were identified and considered for the analysis. The annualized net revenue from the biodiesel production was calculated considering 15 years time period. After considering a price of seed meal and current selling price of biodiesel, the estimated range of net return of producing biodiesel from soybean and sunflower ranges from -$0.47 to $1.08/gallon and -$1 to $0.95/gallon respectively. The break-even price for the soybean biodiesel was $2.74/gallon and $2.71/gallon for sunflower. According to Monti Carlo simulation, the average profit generated across random samples for biodiesel production from sunflower and soybean was $21 and 11 /acre yr^{-1} respectively. The production of on-farm biodiesel from summer oilseed crops can be feasible however there need to be a government subsidy for small farmers.

Key words: oilseed crops, bio-diesel, benefit:cost analysis, Monti Carlo simulation

Introduction

Demand for petroleum oil including diesel has been increasing continuously while its global reserves are being depleted at an alarming rate. In the long-term one can expect, in relevant areas, a shift from petroleum- and gas-based raw materials to bio-based. The most feasible way to meet this growing demand is by using alternative fuels. One such fuel that exhibits great potential is biofuel, in particular biodiesel (Fernando *et al*., 2006). Among first generation biofuels, biodiesel production from oilseeds such as soybean, canola (a hybrid of rapeseed), sunflower and other vegetable oils is gaining popularity. Second generation biofuels, mainly cellulosic sources such as corn stover, rice and wheat straw, wood biomass, and perennial grasses, are equally gaining traction, albeit with a higher per unit production cost than ethanol production using corn (Yeboah *et al*., 2013). Reasons for using biofuels include energy security, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector (Reijnders, 2006). Many nations view biofuels as a simple, renewable alternative to fossil fuels that can reduce carbon and greenhouse gas emissions, increase farm income and promote rural development, and increase energy security (Rajagopal & Zilberman, 2007). In developed countries there is a growing trend towards using modern technologies and efficient bioenergy conversion with a range of biofuels, which are becoming cost-wise competitive with fossil fuels (Puhan et al., 2005).

Internationally, biofuel production and consumption is dominated by the United States and Brazil. Other countries, such as France, Germany, and China, contribute to global biofuel production and consumption as well (Gokianluy et al., 2014). The biodiesel industry is still in its infancy but is growing rapidly. The world total biodiesel production in 2007 was 8.4 million tons and it increased to 20 million tons in 2010; it is expected to reach 150 million tons by 2020 (Agra CEAS Consulting, 2010). However, variability in feedstock and fossil fuel price, as well as the production capacity of biodiesel, have given rise to instability within the industry (Sotoft et al., 2010). These factors have affected the economic viability of biodiesel at a global scale (Jayed et al., 2009). Costs of biofuel production are scale-dependent, with higher operating costs incurring in small-scale plants (CFC, 2007). On the other hand, small-scale decentralized biofuel plants in remote rural areas may offer an alternative to high-priced diesel and serving local communities as will have lower capital investments and transportation/ distribution costs (Bernesson et al., 2004). Relative to the large-scale plants, small-scale plants offer social returns on public investments. Experience in Brazil, France, Germany and United States has shown that biofuel production facilities that are small and locally owned tend to bring about higher local revenues and lower social spending (EUBIA, 2010).

Rational

Small farms, which are diverse, represent an important segment of the agricultural sector and rural communities (Rossett, 1999; Steele, 1997). The decline in farm income of limited resource farmers and the economic well-being of rural communities has been a focus of extensive study for the last three decades (Kebede & Gan, 1999). The main sources of farm income for small and limited resource farmers in the southern United States are livestock production, vegetables, and non-vegetable crops (Demissie, 1990; Dismukes et al., 1997). These farms are many in number contributing to agricultural output and controlling a substantial share of assets. Despite these facts, small farms have been facing a number of problems over the years that continue to challenge their viability (USDA, 1998; USDA-CSREES, 2002).

Processing of oil seeds is not common in Tennessee as well as most of southeastern region. Also, small-scale oilseed and on-farm biodiesel production remain largely unproven concepts (Stebbins-Wheelock et al., 2012). Farmers in the region generally have neither the necessary equipment nor experience to raise these crops, and processing oilseeds into biodiesel is an emerging area of knowledge. In 2010, U.S. companies used 4.1 million tons of plant oil for advanced biofuels and bio-based products, like plant-based chemicals and plastics (U.S. Census Bureau, 2011), with an estimated market value of $4.1 billion. Due to the climate, geography and rich farmland in the southeastern region there is a growing opportunity for farmers to produce feedstock for these markets. Regional crop production for these markets would provide economic benefits to participating farmers, as well as help the U.S. further reduce its dependence on petroleum and petroleum-based products.

The southeast region has great potential for producing plant feedstock that can be used to produce advanced biofuels and has the greatest relative need for increased research investment, especially in the development and deployment feedstock that can meet the needs of regional advanced biofuel facilities without displacing existing productive agricultural sectors (USDA-ARS, 2010). Because of small-scale farming throughout much of the Southern region, specific emphasis is needed on developing the approaches, practices and technologies that will allow small and medium size landowners to participate and contribute to the regional feedstock system.

The major objective of the proposed research is to investigate the options for farmers in investing for oilseed crop production and producing biodiesel in southern region of USA. The findings of the study are expected to help decide appropriate investment options for small scale biodiesel production. The study provides useful information needed for agricultural producers and entrepreneurs who are considering growing biodiesel feedstocks, processing oilseeds, or producing biodiesel as enterprises. The findings of this research will further improve the understanding of growing oilseed crops and on-farm processing of oil for local biodiesel production that could play vital role in improving farm income as well as sustainable and independent energy future for farmers.

Methodology and Data Collection

Conceptual Model

Farmers investing for oilseed crop production have several options. These include production of oilseed (feedstock) or processing feedstock to oil or biodiesel and bi-products production. This study will compare the profitability for soybean and sunflower production during summer months. Figure 1 represent conceptual model for a representative farm with three hundred fifty acres of soybean/ sunflower production. This includes investment for small scale biodiesel production (1,500 gallon of annual capacity). It is expected that farmers can produce biodiesel needed for the farm equipment on their own farm for self-sufficiency in energy.

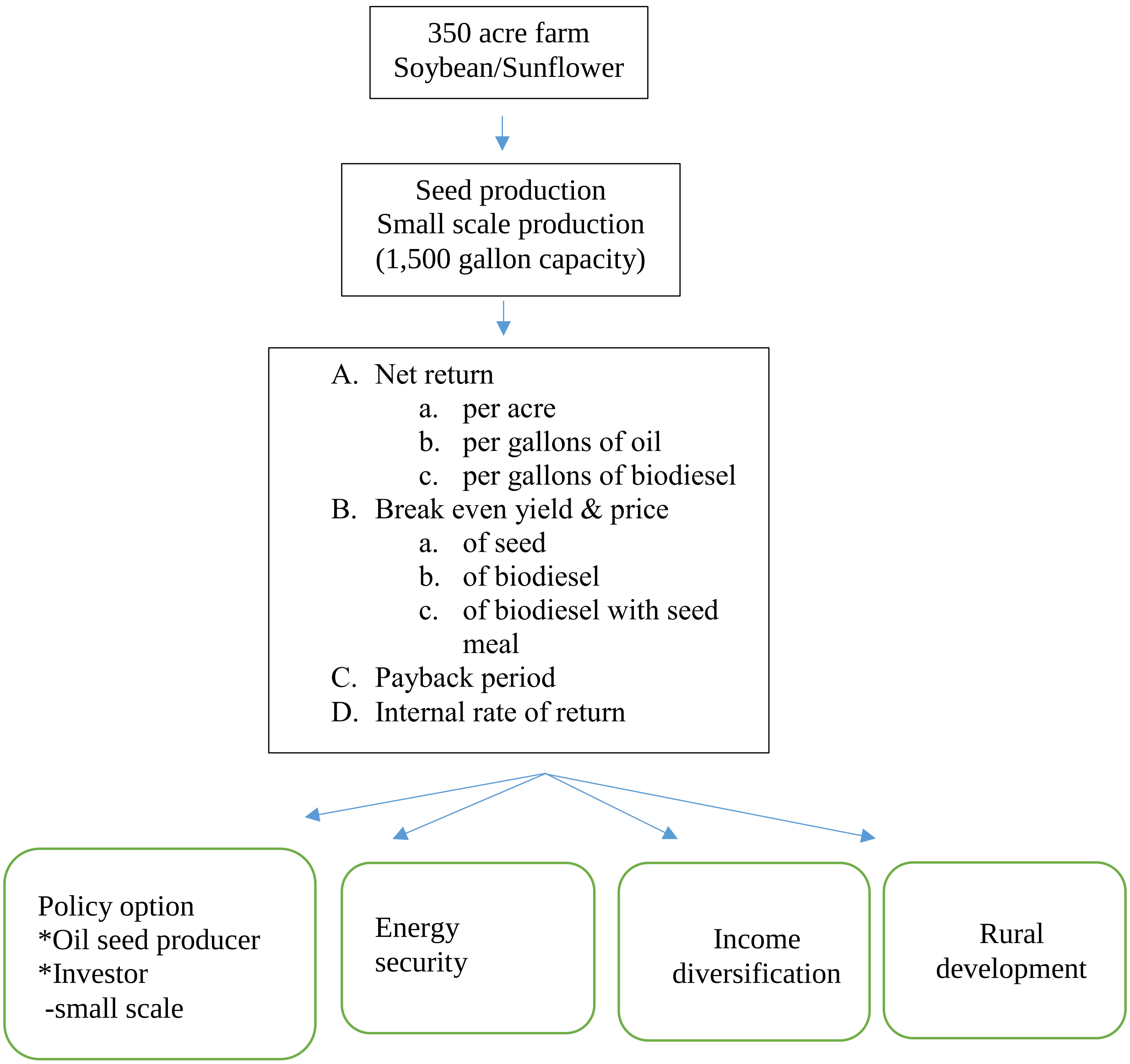


Figure 1 Opportunities for on-farm biodiesel production

Economic Model

In order to achieve the above objectives various methods and data sources were used. For example, full cost analyses were performed to determine the economic feasibility of oilseed crop production. Production costs data from various sources were used to identify various costs associate in various stages of production. A detail of variable costs and fixed costs was analyzed to identify source variation. Yield data was compared across national yield trials as well as information from farm data. Price data was based on USDA-ERS historical prices. The economic analysis relied on quantitative and qualitative data and in the three stages of biodiesel production from local feedstocks: (1) crop production, harvest, and storage; (2) oil and seed meal production by seed extrusion; and (3) biodiesel production. The total cost of implementing biodiesel production was estimated using the full cost accounting approach. The approach generally accounted for costs such as variable costs (e.g., land preparation, planting, fertilization, weed control, irrigation, transportation and marketing and processing) and fixed costs (structures, machinery, equipment for biodiesel processing unit, and rental cost).

When overall plant cost estimation was required, inspecting the individual cost per year was not sufficient because some operations were not performed regularly and uniformly year after year and therefore, annual cost could differ over the crop life. From an economic point of view, the overall approach was to estimate the average annual cost and returns over the entire economic life of the crop, which allowed direct comparison among different crops. The financial feasibility was based on the Cost-Benefit Analysis (CBA) approach (Boardman et al., 2006). To calculate cost and revenue in annual equivalent terms, the present values of all costs and revenues over the useful life of the crop was transformed into an equivalent annuity. The following procedures were adopted in estimating annual equivalent cost and revenue (Monti et al., 2006).

In evaluating benefits and costs, the Net Present Value (NPV) of producing biodiesel was calculated. The NPV is the present worth of a stream of net benefits over time. The NPV was estimated as the difference between discounted benefits and costs for growing different organic products (options).

$$NPV = \sum_{j=0}^{n} (B_j - C_j)(1+r)^j \quad \text{where,}$$

j = year (15 year project period will be considered for investment for biodiesel processor)
B_j = revenue or cost savings for in year j
C_j = production cost in year j and
r = discount rate (%)

The overall approach was to estimate the average annual cost for biodiesel production for farmers. This approach included the initial investment cost and also takes into account the time value of money. Similarly, Annual Equivalent Revenues (AER) was also estimated. Also payback period, benefit: cost ratio and Internal Rate of Return (IRR) were assessed as investment evaluation criteria.

Investment Analysis Criteria

Investment analysis criteria include, payback period, benefit: cost ratio, Internal Rate of Return and Net Present Value. In addition, breakeven price for seed, seed meal, oil and biodiesel will be estimated. Also, breakeven yield will be useful to evaluate yield needed to recover costs in case of crop failure due to adverse climatic conditions or any other biological reason.

Distribution of net return

Since profitability analysis from average figures doesn't reflect accurate estimate, various uncertainty variables were identified and considered for possible range of net return from feedstock production. Monti Carlo simulation generates large number of random samples and estimate true mean, which is the average of net profit across large number of random samples. Therefore, the distribution of net return from oil seed, oil and biodiesel was performed using Monti Carlo simulation. The net return was simulated from possible combination of price, yield, and costs.

Data collection

In order to gather data for different stages of production and processing chain various sources were explored. The input data were collected from various technical sources such as biodiesel production experts, researchers, practitioners experienced in this field, technical notes and research papers as well as following the latest market prices.

a. Feedstock production data included production costs of sunflower and soybean. In order to capture the variability of production costs, various enterprise budgets were considered. Variation of estimated production costs were used to estimate sensitivity of costs to the key variables that were estimated.

b. Extensive search of yield data was conducted. These included national variety trials and variety trials conducted by regional centers. Studying variety trials were helpful to see the variability of yield. The yield variability was included in the sensitivity analysis.

c. Investment costs data for biodiesel processing include capital costs and variable costs. Capital costs include: a.) seed press b.) biodiesel processer and c.) methanol recovery system

The variables costs include: labor costs, potassium hydroxide, methanol, electricity and other miscellaneous costs. The capital costs were based on manufacture catalogs and variable costs were based on input required for various capacity of plants considered and market price in inputs.

Results and Discussion

Feedstock Production

Table 1 shows the annual production cost of Soybean and Sunflower. The total production cost of any given crop varies on location, cropping systems and in the fluctuation of the energy prices etc. The major expenditure of these two different crops heavily depends on planting, harvesting, seeds and pesticides used. Although soybean is a major crop grown throughout US and a major feedstock for production of biodiesel, the production cost of soybean is considerably higher than that of sunflower. The data for the production cost of these oilseed crops were taken into consideration from the various enterprise budgets from numerous university extension and outreach programs. The production cost comprises of variable and fixed costs.

The estimated variable and fixed costs were $243 and $85/acre for soybean and $118 and $11/acre for sunflower. Accordingly, the total production cost was $328 and $183/acre respectively for soybean and sunflower.

Table 1 Estimated oilseed production cost

Cost of Feedstock	Soybean		Sunflower	
Category	Average cost ($/acre)	AEC ($/acre)	Average cost ($/acre)	AEC ($/acre)
Seed	$45.73	$32.12	$24.82	$17.45
Chemicals	$102.94	$72.31	$36.8	$25.87
Fertilizers	$45.67	$32.08	$48.23	$33.91
Application cost	$30.52	$21.44	$10.53	$7.40
Cash rent	$43.83	$30.79	-	-
Irrigation	$9.25	$6.50	-	-
Harvesting cost	$5.83	$4.10	$13.69	$9.62
Hauling cost	$8.17	$5.74	$3.26	$2.29
Labor	$18.93	$13.29	$5.41	$3.80
Fuel	$10.03	$9.15	$10.04	$7.06
Repair& maintenance	$9.92	$6.96	$14.37	$10.10
Rent, Insurance and Insurance cost	$61.47	$43.18	-	-
Machinery & Equipments	$71.30	$50.08	$15.60	$10.97
Total Cost	$467	$328	$183	$129

Net returns from Feedstock Production

Table 2 shows the annual net return of soybean and sunflower grain production under 3 different yield scenarios. The ten year average inflation rate between 2006-2015 was taken in (i.e 0.02) consideration as the average annual inflation for future price projections. Similarly, to calculate the net present value, the average discount rate was used. The price of these both of the oilseed crops was estimated using the average price from the year 2011 to 2015.

The market price obtained for soybean and sunflower was $0.216 and $0.227/lbs respectively. The annual equivalent gross revenue from soybean grain production under three different yield scenarios (high, medium and low) were $437, $400 and $346/acre, and that of sunflower was $276, $233, and $145/acre. As the average initial cost for the feedstock production of soybean was $328/acre, the net revenue for each yield scenario was $109, $72 and $18/acre. Similarly, based on the average initial cost for the feedstock production of sunflower as $128, the net revenue for each yield scenario were $148, $105 and $17/acre yr^{-1}. Accordingly, farmers could generate a reasonable amount of net profit under high and medium yield scenarios. According to the result generated, the higher yield is associated with higher net revenue hence oilseed yield is a one of the key factors in determining farm profitability The estimated break-even yield for soybean and sunflower was 2158 and 805 lbs/acre respectively.

Table 2 Net return from soybean and sunflower under different yield scenarios

Category	Unit	Yield Scenarios (high-low)					
		Soybean			Sunflower		
Production cost	$/acre	$328	$328	$328	$128	$128	$128
Yield	lbs/acre	2,880	2,633	2,280	1,732	1,457	908
Grain price	$/lbs	$0.216	$0.216	$0.216	$0.227	$0.227	$0.227
Gross revenue	$/acre	$437	$400	$346	$276	$233	$145
Net revenue	$/acre	$109	$72	$18	$148	$105	$17

Oil processing

For the processing of oil, 3 different operating rates for seed pressing (high, medium and low) were considered. Based on the amount of oil content in seed and the efficiency of the seed press given its speed, the amount of the oil that can be extracted varies. Accordingly, the seed press operating in high, medium and low speed has the efficiency of 53.6%, 55.10% and 68.50% respectively. The total number of hours required to process the grain into oil and total hours needed for labor to process oil depends on the efficiency of the seed press used. The hourly seed processing/pressing capacity of the small scale biodiesel unit was 11.5, 6.74 and 2.13 lbs for high, low and medium speed respectively. The processing of crude vegetable oil under 3 different yields and processor operating speeds are given in table 3.3. The amount of oil content of soybean is approximately 18 to 20%, which is around half the oil content of sunflower which contains about 43% of oil. Based on the annual average oil price during past five years, the soybean and sunflower oil prices were taken as $0.39 and that $0.72/lbs respectively.

The amount of oil that can be produced under low operating rate is high hence can fetch higher revenue compared to medium and high operating rate categories. In medium operating rate, revenue collected from three different yield scenarios (high to low) were $249, $228 and $197/acre yr^{-1} for soybean. For sunflower, the expected net return was $551, $465 and $289/acre yr^{-1} for high, low and medium operating rate scenarios respectively. According to the analysis, compared with soybean oil production sunflower oil production generates higher net return to farmers.

Meal Production

Table 4 shows the revenue that is generated from marketing of soybean and sunflower meal. The amount of meal that can be obtained during the process of pressing seed is based on the operating seed of the oil press. The amount of meal that can be obtained under low, medium and high operating speed of the seed press (with efficiency of 68.5%, 55.1% and 53.6% respectively), were 1.55, 5.25, 9.03 lbs/hr respectively for soybean and 0.97, 3.76 and 6.56 lbs/hr for sunflower. The difference in the total amount of meal extracted between these two oilseed crops is due to the difference in the amount of oil content as mentioned. The seed processor with high efficiency (lower operating rate) produces high amount of oil and low amount of seed meal and vice-versa.

Table 3 Net return form producing vegetable oil from soybean and sunflower

Category	Average yield scenario					
	Soybean			Sunflower		
	HRP[1]	MRP[2]	LRP[3]	HRP	MRP	LRP
Efficiency rate	53.60%	55.10%	68.50	53.60%	55.10%	68.50
Seed processed per hour (lbs)	11.5	6.74	2.13	11.5	6.74	2.13
Days to process	10	16	52	5	9	28
Oil yield (lbs/hr)	2.47	1.49	0.58	4.94	2.98	1.16
Oil yield (lbs/acre)	565	582	717	626	644	793
Oil price ($/lbs)	$0.392	$0.392	$0.392	$0.72	$0.72	$0.72
Revenue ($/acre)	$222	$228	$281	$452	$465	$573

1.-High Rate Processor, 2- Medium Rate Processor and 3- Low Rate Processor

For soybean, the estimated meal yield under three different yield scenario (high-low) and medium operating rate were 1.12, 1.02 and 0.89 ton/acre respectively. The average price of soybean meal was taken as $413.12 based on the price data from USDA- oil crops outlook 2016 during the period of 2011-2015. Accordingly, the total revenue obtained from the soybean meal under three different yield scenarios and medium operating rate are $463, $424 and $367/acre respectively.

For sunflower, the total amount of meal produced under three different scenarios (high-low) and medium operating speed were 0.48, 0.40 and 0.25 ton/acre respectively. Based on the annual price data from USDA- oil crops outlook 2016 during the period of 2011-2015, the price of sunflower seed meal was taken as $231/ton. Hence the total revenue obtained under three different yield scenarios and medium operating rate were $112, $94 and $59/acre yr^{-1}.

According to the analysis, the potential revenue from marketing soybean meal is almost four times than that of sunflower meal. This difference is mostly due to the high grain yield of soybean, less oil content in the seed and high market price of the soybean meal.

Although the amount of oil content in soybean grain is lower compared to sunflower, the higher price of soybean meal due to its higher nutrient value (i.e protein) fetches higher prices that can be offset the disadvantages due to lower meal, hence generate higher revenue/acre compared to sunflower meal.

Table 4 Production and processing of oilseed meal

Category	Average yield scenario					
	Soybean			Sunflower		
	HRP	MRP	LRP	HRP	MRP	LRP
Meal yield (lbs/hr)	9.03	5.25	1.55	6.56	3.76	0.97
Processing time (hr/acre)	229	391	1236	127	216	684
Meal yield (lbs/acre)	2067	2051	1916	831	813	663
Meal yield (ton/acre)	1.034	1.025	0.96	0.42	0.41	0.33
Meal price ($/ton)	$413.12	$413.12	$413.12	$231.38	$231.38	$231.38
Revenue ($/acre)	$427	$423	$396	$96	$94	$77

Biodiesel Processing

Generally, biodiesel is produced through chemical reaction of vegetable oil or animal fat mixing with methanol and potassium hydroxide. The processing cost of biodiesel includes investment for equipment and variable costs for chemicals (potassium hydroxide and methanol), electricity and labor etc. The annual equivalent cost for each of the category was estimated for processing of soybean and sunflower oil into biodiesel.

During biodiesel processing, the major types of equipment used were categorized into three different types. The unit consist of seed press, biodiesel processor and methanol recovery system. For this analysis, we have used seed press of model 'M70' of year 2013 with power capacity of 2HP/ 1.5 kWh. The initial purchasing cost for the seed press was $8,240. Similarly, a biodiesel processor named Mega Ester with power capacity of 120V/30 amp and initial investment of $2,800 was used for converting oil into biodiesel. With the purpose of removing toxic and flammable methanol from biodiesel and glycerin, methanol recovery system was taken into consideration with initial cost of $3,495. Beside these major costs, cost of installation of the machinery and equipment was taken as $2,100. After deducing 25% government subsidy on the machinery and equipment, the total cost for buying and installing the biodiesel processing equipment for farmer was $12,476. The straight line method was used to calculate the annual depreciation of the fixed assets for 15 years of lifetime. Thus, the annual depreciation cost obtained was $832. The variable costs incurred during processing of vegetable oil into biodiesel is given in table 5 and 6.

The amount of biodiesel extracted from three different yield scenarios of soybean (high-low) under medium operating speed of the biodiesel processor was 74, 68 and 59/gallons respectively. The annual depreciation cost for the biodiesel processor was $41, $37 and $32 respectively under three different yield scenarios.

For extraction of biodiesel from unprocessed soybean oil, the cost for the chemicals (potassium hydroxide and methanol) and electricity were $45 and $39/acre of produce under high grain yield scenario; $41 and $36/acre in medium grain yield scenario and, $35 and $31/acre in low grain yield scenario. The cost of labor for processing was $30/acre. Accordingly, the estimated total annual equivalent operational cost for the extraction of biodiesel was $107, $100 and $89/ acre under high, medium and low yield scenarios respectively.

Table 5 Processing cost of Soybean seed to biodiesel

Category	Yield Scenario/ Processing under medium speed of operation					
	High yield		Medium yield		Low yield	
	Average Cost	AEC	Average Cost	AEC	Average Cost	AEC
Depreciation ($/acre yr^{-1})	$40.57	$28.50	$37.09	$25.68	$32.12	$22.23
Potassium Hydroxide ($/acre)	$17.69	$12.25	$16.18	$11.20	$14.01	$9.70
Methanol ($/acre)	$26.79	$18.55	$24.49	$16.95	$21.21	$14.68
Electricity ($/acre)	$39.42	$27.29	$36.03	$24.95	$31.21	$21.60
Labor ($/acre)	$30.00	$20.77	$30.00	$20.77	$30.00	$20.77
Total processing cost ($/acre)	$154.47	$106.94	$143.79	$99.54	$128.54	$88.99

For sunflower, the amount of biodiesel extracted from three different yield scenarios (high to low) under medium operating speed was 90, 75 and 47 gallons/acre respectively. The annual depreciation cost for the biodiesel processor was $24, $21 and $13/acre. Under the above mentioned different grain yield scenarios, the processing costs of chemicals and electricity were $78, $65 and $40 respectively. The cost of labor for processing of sunflower into biodiesel was $30/acre. Thus the total annual equivalent processing cost to process biodiesel was $91, $80 and $58/acre the above yield scenarios as shown in table 6. The comparative analysis shows that the overall processing cost for soybean is higher than that of sunflower due to higher grain yield of soybean.

Table 6 Processing cost of Sunflower seed to biodiesel

Category	Yield Scenario - Processing under medium speed of operation					
	High yield		Medium yield		Low yield	
	Average Cost	AEC	Average Cost	AEC	Average Cost	AEC
Depreciation($/yr)	$24.40	$17.11	$20.52	$14.20	$12.79	$8.85
Potassium Hydroxide ($/acre)	$21.28	$14.73	$17.90	$12.39	$11.16	$7.72
Methanol ($/acre)	$32.22	$22.30	$27.10	$18.75	$16.89	$11.69
Electricity ($/acre)	$23.71	$16.40	$19.94	$13.80	$12.43	$8.60
Labor ($/acre)	$30.00	$20.77	$30.00	$20.77	$30.00	$20.77
Total processing cost ($/acre)	$131.61	$91.07	$115.47	$79.90	$83.27	$57.62

Net Return from Biodiesel Production

Table 7 shows the net return of producing biodiesel under medium processing speed from three various yield scenarios of soybean. The estimated gross return of producing biodiesel under three different yield scenarios (high-low) was $247, $225 and $195/acre yr^{-1} respectively. The estimated gross return from marketing of soybean meal under the above yields scenarios were $463, $424 and $367/acre yr^{-1}respectively. The total production cost (feedstock and processing cost) of biodiesel under the various yield scenarios was $621, $610 and 595/acre respectively. Accordingly, the annual equivalent net return on producing biodiesel was $62, $29 and -$21/acre yr^{-1} in respective to three different yield scenarios considered for the analysis.

Table 7 Net return from biodiesel production from Soybean

Category	Yield Scenario/ Medium Rate Processor					
	High		Medium		Low	
	Average Cost	AEC	Average Cost	AEC	Average Cost	AEC
Biodiesel Revenue ($/acre)	$247.06	$171.03	$227.96	$157.81	$197.41	$136.66
Meal Revenue ($/acre)	$463.38	$320.78	$423.61	$293.25	$366.84	$253.95
Total Revenue ($/acre)	$710.44	$491.81	$651.57	$451.06	$564.26	$390.61
Total Cost ($/acre)	$621.05	$429.93	$610.37	$422.54	$595.12	$411.98
Net Return ($/acre)	$89.39	$61.88	$41.20	$28.52	-$30.87	-$21.37

The estimated gross return from producing biodiesel under medium speed from high, medium and low yield scenarios was $297, $250 and $156/acre yr^{-1} respectively. The added revenue from marketing sunflower seed meal was $112, $94 and $59/acre yr^{-1} respectively.

As shown above, the estimated total production cost of biodiesel from sunflower was $314, $298 and $266/acre yr^{-1} respectively. Thus, the estimated annual equivalent net return of producing biodiesel from sunflower was $66, $32 and -$36/acre yr^{-1} under high, medium and low grain yield respectively (Table 8). As in soybean, the net return from producing biodiesel from sunflower gives positive return in high and medium grain yield while gives negative return in low grain yield. Here the net return obtained after from producing biodiesel from both of the oilseed gave almost the same results.

Table 8 Net return from biodiesel production from Sunflower

Category	Yield Scenario/ Medium Rate Processor					
	High		Medium		Low	
	Average Cost	AEC	Average Cost	AEC	Average Cost	AEC
Biodiesel Revenue ($/acre)	$297.16	$205.63	$249.95	$172.96	$155.79	$107.80
Meal Revenue ($/acre)	$111.78	$77.35	$94.02	$65.06	$58.60	$40.55
Total Revenue ($/acre)	$408.94	$282.98	$343.97	$238.01	$214.39	$148.35
Total Cost ($/acre)	$314.35	$217.52	$298.20	$206.35	$266.00	$184.07
Net Return ($/acre)	$94.60	$65.46	$45.76	$31.67	-$51.62	-$35.72

Analysis of Net Return per Volume Basis

Table 9 shows the net return from producing a gallon of biodiesel from soybean and sunflower under medium operating speed and different yield scenarios. Accordingly, the total cost for producing a gallon of biodiesel from soybean was $8.35/gallon, $8.97/gallon and $10.10/gallon respectively. Accounting the production of seed meal worth of $6.23/gallon of biodiesel and the selling price of selling a gallon of biodiesel as $3.32/gallon, an estimated net return from production of biodiesel was $1.08, $0.55 and -$0.47/gallon respectively. Accordingly, the production of biodiesel is profitable only under high and medium yield scenarios.

The total production costs of biodiesel from sunflower under the above yield scenarios was $3.51, $3.96 and $5.66/gallon respectively. Production of each gallon of biodiesel yields a seed meal worth of $1.25 as a by-product. Taking the market price of biodiesel as $3.32/gallon, the net return from producing biodiesel was $0.95, $0.5 and -$1/gallon respectively.

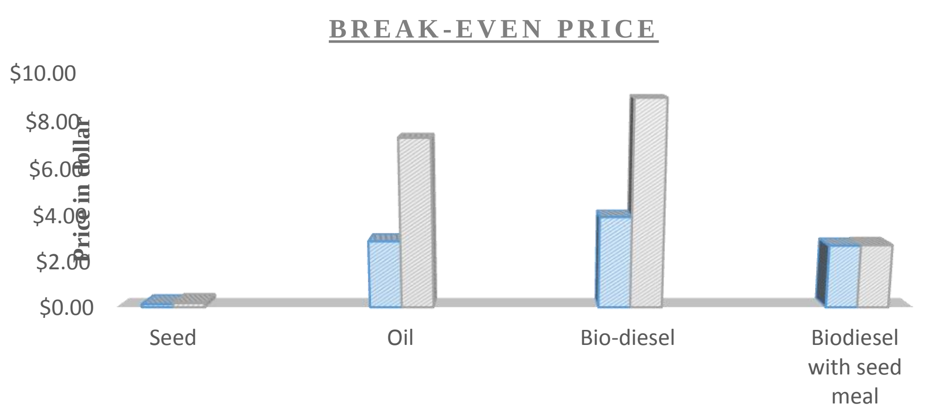
According to the results generated from this study, the production of biodiesel from soybean shows better profits to the producer compared with sunflower under high and medium yield scenarios. Although net return from producing a gallon of biodiesel was negative for both crops under low yield scenario considered in this analysis, the amount of loss from from soybean was less compared with sunflower.

Table 9 Analysis of net return per gallon from oilseeds crops

Category	Yield Scenario/ Medium Rate Processor					
	Soybean			Sunflower		
	High	Medium	Low	High	Medium	Low
Feedstock production cost ($/gal)	$6.27	$6.86	$7.92	$2.04	$2.43	$3.89
Processing cost ($/gal)	$2.07	$2.11	$2.18	$1.47	$1.53	$1.77
Total Production cost ($/gal)	$8.35	$8.97	$10.10	$3.51	$3.96	$5.66
Meal revenue ($/gal)	$6.23	$6.23	$6.23	$1.25	$1.25	$1.25
Revenue from biodiesel	$3.32	$3.32	$3.32	$3.32	$3.32	$3.32
Net return ($/gal)	$1.08	$0.55	-$0.47	$0.95	$0.5	-$1.0

Break-even Analysis

The break even analysis was performed for both of the oilseed crops under average yield and medium processing speed scenario. In case of soybean, the estimated break-even price for grain was $0.18/lbs, raw oil was $7.32/gallon, bio-diesel was $8.97/gallon and for bio-diesel with accounting seed meal price was $2.74/gallon. Similarly, in case of sunflower, the break even price for grain was $0.13/lbs, raw oil was $2.90/gallon, bio-diesel was $3.96/gallon and that for bio-diesel with seed meal was $2.71/gallon respectively as shown in figure 2. Here the break-even analysis shows that the production of sunflower as a bioenergy feedstock is equally or more competent than that of soybean.



	Seed	Oil	Bio-diesel	Biodiesel with seed meal
Sunflower	$0.13	$2.90	$3.96	$2.71
Soybean	$0.18	$7.31	$8.97	$2.74

Figure 2 Break-even price for seed, oil and biodiesel

Monti Carlo Simulation

The analysis based on average figures does not reflect range of outcome, therefore various uncertainty variables need to be identified and consider for possible range of net return from various scenarios for various stages of biodiesel production from soybean and sunflower. Monti Carlo simulation was performed to obtain true average based on random samples generated. The estimated true mean is the average of net profit across large number of random samples.

Sensitivity analysis for sunflower and soybean seed production

Tornado chart (figure 3 and 4) shows how net profit could change with changes in uncertainty variables. Grain yield is positively correlated with net profit while feedstock production costs are negatively correlated with net profit. More over negative correlation with net profit how we make lower profit under low yield though receive higher price. The typical selling price is high at low yield, but decreased yield does not make up to recover the losses.

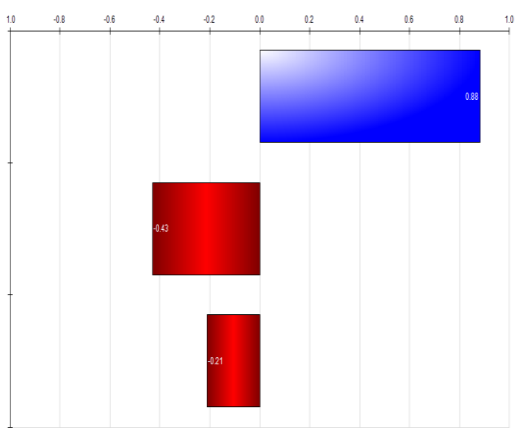


Figure 3. Tornado chart for sensitivity analysis of sunflower seed production

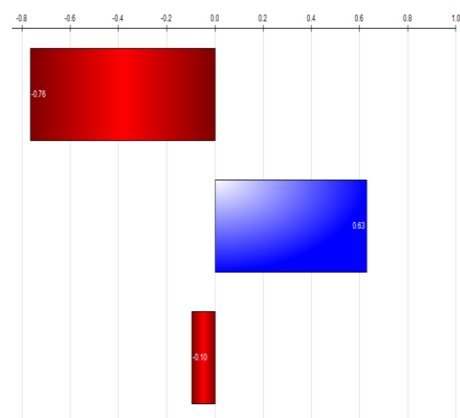


Figure 4. Tornado chart for sensitivity analysis of soybean seed production

Net Return from biodiesel production

In terms of biodiesel production from sunflower, as illustrated in figure 5 the net return could range from -\$72 to \$97/acre of sunflower, with a standard deviation of \$28. The average profit generated across random samples for biodiesel production from sunflower was \$21/acre yr^{-1} with 5% chance of outcome of -\$26/acre yr^{-1} or below and 95th percentile shows outcome of \$65/acre yr^{-1} or above Similarly, from figure 6, true average obtained was \$11/acre yr^{-1} for biodiesel production from soybean with 5% chance of outcome of -\$85/acre yr^{-1} or below and 95th percentile outcome of \$107 /acre yr^{-1} or above. The net return could range from -\$154 to \$208/acre, with standard deviation of \$59.

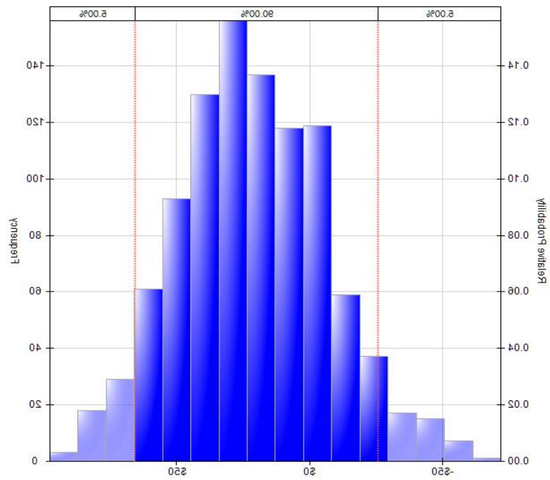


Figure 5. Relative probability for net return from biodiesel production from sunflower

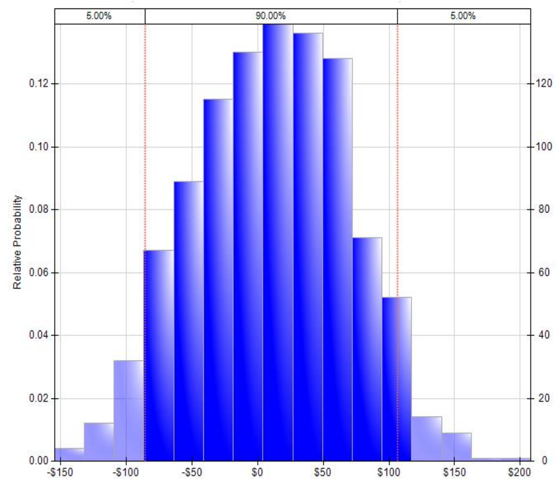


Figure 6. Relative probability for net return from biodiesel production from soybean

Sensitivity analysis for biodiesel production

Sensitivity analysis (figures 7 and 8) shows how net profit could change with changes in uncertainty variables. Biodiesel yield from soybean is positively correlated with net profit. Feedstock production and processing costs of biodiesel production is negatively correlated with net profit.

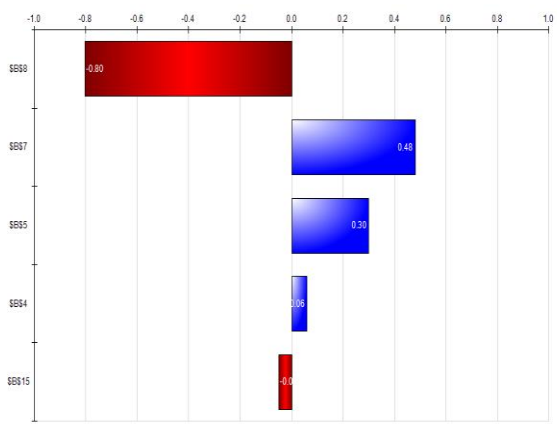


Figure 7. Sensitivity analysis for biodiesel production from soybean under different cost, price, and yield scenarios

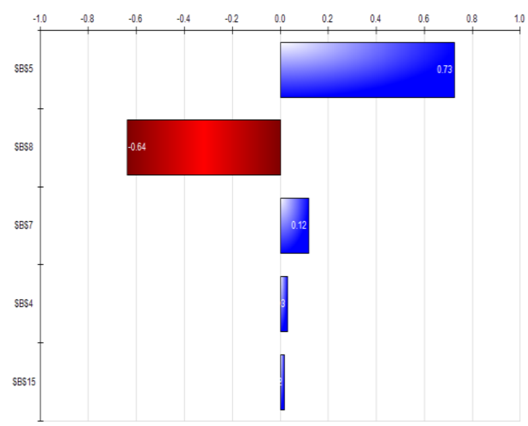


Figure 8. Sensitivity analysis for biodiesel production from soybean under different cost, price, and yield scenarios

Moreover, negative correlation with net profit shows we make lower profit under low biodiesel yield though lower production is theoretically associated with higher product price. The typical selling price is high at low yield, but decreased yield does not make up to recover the losses.

Conclusion

This research was focused on the comparative feasibility study of two potential oilseed crops, soybean and sunflower as bioenergy crops. Beside soybean, the number one oilseed crops in terms of its production and a major biofuel feedstock, oilseed sunflower is gaining popularity as a feedstock crop for biodiesel as it shares many positive agronomic characters with other common oil crops. The major objectives of this research are to evaluate production costs and returns of seed, oil and seed meal production from soybean and sunflower, estimate investment costs for biodiesel plants with small to medium scales and assess the profitability of producing biodiesel from oil seed crops, and perform sensitivity analysis of key production variables on profitability of on-farm production of biodiesel.

For performing economic analysis, secondary data were collected for the model estimation. Annualized net revenue from feedstock production was calculated considering 15 year of time period and this information is important to the producers to determine the potential revenue from soybean and sunflower. The estimated gross revenue and net revenue from producing sunflower feedstock is $331 and $148/acre and that for soybean is $569 and $103/acre respectively. The feedstock thus produced was processed under three different processing rate with various efficiency. Under medium rate processor and three different yield scenario, the amount of biodiesel produced from sunflower was 90, 75 and 47 gallons/acre fetching $297, $250 and $156/acre to producers, and that of soybean was 74, 68 and 59 gallons/acre which fetches $247, $226 and $196/acre to producers respectively. From this information, we were able to predict that sunflower is competent enough with soybean and could be used as prominent biodiesel feedstock. The amount of meal produced makes it the key component of the analysis. Since byproduct obtained from processing seed is an important output which could impact the net revenue from production of soybean and sunflower, we have taken it into consideration. The estimated revenue obtained from selling sunflower seed meal under medium rate processor and three different yield scenarios were $112, $94 and $59/acre and that of soybean were $463, $424 and $367/acre respectively. This difference in the revenue from these two different oilseed crops are mainly due to the high yield of soybean seed and high market price of soybean seed meal. After considering the estimated price obtained through marketing of seed meal, the net return from producing biodiesel ranges $1.08 - -$0.47/gallon and $0.95 - -$1.0/gallon from soybean and sunflower respectively.

From break-even analysis, after considering the price fetched by seed meal ($6.23 and $1.25/gallon of biodiesel produced from soybean and sunflower), the break-even price for the soybean biodiesel was $2.74/gallon and $2.71/gallon, in case of sunflower. From Monti Carlo simulation, simulation results of net profit for seed and biodiesel production from soybean was lower compared to that of sunflower.

The average profit generated across random samples for seed production from sunflower was $95/acre yr^{-1} and from soybean was -$42/acre yr^{-1} and, biodiesel production from sunflower was $21/acre yr^{-1} and from soybean was $11/acre yr^{-1} respectively.

The results from break even analysis and Monti Carlo simulation shows that the producing sunflower as energy feedstock crops is as efficient as producing soybean for small scale on-farm setting. The medium to high yield scenarios give positive return whereas the low yield gives negative return on producing these two oilseed crops as energy feedstock. Here the returns gained are highly sensitive to the farm level values (prices) of biodiesel, seed meal and value placed on the crop. Furthermore, the results presented are subject to 25% subsidy on machinery used in biodiesel processing and the removal of this subsidy will lead the investment on biodiesel unprofitable. The results of this research further improve the understanding of different options for growing bio-energy crops and on-farm processing of those crops for local biodiesel production.

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