**Feasibility Assessment of Biomass Harvesting Cooperative**


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Arjun Basnet and Philip Kenkel

**Abstract**

*The paper summarizes the harvesting and transportation costs of biomass in an individual producer's framework versus a cooperative framework using a feasibility template developed in MS Excel. The cost is compared between individual producer having 1000 acres of land and a cooperative with five members each having 1000 acres of land. The estimated total cost per ton for harvesting biomass and transporting it to a warehouse 20 mile far is $25.53 for individual producer and $18.00 for cooperative. The mowing, raking and baling cost per ton is estimated to be $5.71, $3.94 and $11.16 respectively for individual producer and $4.97, $2.00 and $5.85 respectively for cooperative.*

**Keywords: Biomass, Switchgrass, Harvesting, Transportation, Cooperative**

## 1. Introduction

The renewable fuel standard mandates 16 billion gallons of fuel to be derived from advanced biofuels such as lignocellulosic biomass by 2022 (U.S. Congress, 2007). This mandate has contributed to the continued growth of grain based ethanol plants. The first generation ethanol plants accessed grain feed stocks that could be easily purchased from the open market. Second generation biofuel industries will use dedicated energy crops like switchgrass for which a supply chain must be developed. Epplin *et al*, (2007) suggests three alternatives for supply of biomass to ethanol facility. One alternative is to have producers grow, harvest and store biomass and provide it to the biorefinery on the basis of spot market prices or long term contracts. Another alternative is for the biorefinery to lease land from landholders and operate a large scale integrated production, harvest and storage operation. The third alternative is for the producers to form a biomass harvesting cooperative.

The structure of the harvesting, storage and transportation aspects of biomass supply chain has implications for agricultural producers and rural communities. A study of the economic impact of farmer-owned ethanol plants concluded that the contribution of a farmer-owned plant to the local economy is over 50% larger than an absentee owned corporate plant (Urbanchuk, 2006). Miranowski *et al*, (2008) found that for each one percent reduction in ethanol plant ownership, one less job is created in a local community. In the early stages of the grain-based ethanol industry, projects were funded by local producers and rural investors (Kenkel, 2009). However, as the scale and capital requirements of ethanol projects increased the investment shifted to institutional investors and equity funds (Kenkel 2009). Second generation ethanol plants are projected to have a much higher capital cost per gallon of capacity relative to grain based projects (Taheripoor and Tyner, 2008). Participating in production, harvest and storage activities may be the best opportunities for producers and rural residents to benefit from the emerging cellulosic ethanol industry. The need to perform these activities under an efficient structure is critical. Larson *et al*, (2010) discuss substantial technical barriers related to the pre and post production of lignocellulosic feedstocks and emphasize the cost to harvest, store and transport switchgrass would affect the total cost of ethanol because of the bulkiness of switchgrass.

An efficient, coordinated biomass harvesting, transportation and storage infrastructural can be developed while maximizing benefits to agricultural producers and rural communities by the creation of biomass harvesting cooperatives. Farm equipment cooperatives have been common in Europe and Canada for many years and have been very successful in reducing machinery cost. Research done by Harris and Fulton (2000) in Saskatchewan found machinery cooperatives had expected machinery cost savings of 35% per acre relative to individual ownership. Similar research in the Southern Plains (Long and Kenkel, 2007) concluded that wheat producers could achieve machinery related cost savings of 23-54% through the formation of machinery cooperatives.

A recent national survey of farmers interested in growing switchgrass found that 77% were interested in participating in a farmer owned cooperative that harvests, stores and markets switchgrass (Jensen *et al*, 2011). In light of this apparent interest of producers in biomass cooperatives, there is a need to examine the structure and benefits of biomass supply through cooperatives. Researches who evaluated the costs of harvesting, storing and transporting lignocellulosic feedstock have not evaluated these costs in a cooperative framework (Thorsell *et al*, 2004; Bransby *et al*, 2005; Mapemba *et al*, 2007; Kumar and Sokhansanj, 2007; Popp and Hogan, 2007; Perrin *et al*, 2008 and Epplin, 1996).

Thus, the objective of this study is to assess the potential cost savings of a harvesting and transportation of biomass of a cooperative relative to the individual operations. Switchgrass which was identified as a model energy crop by the U.S. Department of Energy for ethanol production (Caddel *et al*, 2010) will be considered as a biomass in this study. The study examines the capital investment requirement, optimal machinery compliments for both the producer and various scales of cooperative operations. It also investigates alternative structures for the cooperative including the minimum size needed to capture scale economies and the harvesting and transportation costs of an optimal (least cost) scaled cooperative. Sensitivity analysis is conducted to examine the impact of field size, impact of distance between producers, impact of biomass yield, impact of equipment operating speeds and impact of labor rate.

## 2. Data and Methods

A feasibility template was developed in MS Excel to model the operations and costs of a biomass harvesting cooperative. While the template is designed as a decision tool for producers investigating the formation of a harvesting cooperative, it also provides a convenient platform to project harvesting and transportation costs under a cooperative structure. The template has 12 worksheets with several input cells to enter values and in-built formulas to perform calculations. Online resources (Edwards, 2009; Stiles and Griffin) are extensively used to collect the baseline data used in the template. The template allows users to model the costs of harvesting and transporting biomass for storage to a warehouse at both the producers and cooperative level. The template can be used to model biomass transportation directly from an infield stacks to a refinery as can be the case suggested by Thorsel *et al*, 2004. The template does not model the costs of producing biomass (switchgrass) such as the cost of seed, fertilizer, pesticides, labor, machinery or land charges etc. All costs calculations are the post production activities of producing switchgrass which includes the cost for harvesting switchgrass (mowing, raking and baling) and transporting it to the warehouse. Variable costs include costs for fuel and lube, hired labor, repair and maintenance, equipment transportation and hauling costs. Fixed costs include insurance and housing, interest, property tax and depreciation.

The cost projections were based on a set of base-line assumptions. The cooperatives are assumed to have five members with 1000 acres of land each with field size of 100 acres. The biomass yield is assumed to be 2 tons per acre and each bale is assumed to contain 1/2 tons of biomass. Only one cutting (harvest) per year is assumed. Switchgrass can be harvested using traditional hay swathers and balers (Caddel *et al*, 2010). The baseline assumptions reflect the use of a high speed rotary mower and side delivery rake and round baler for the individual producer scale of operations. The cooperative scale compliment of equipment includes a self-propelled windrower,   side delivery rake and large rectangular baler (4 ft * 4 ft * 6 ft). In order to harvest the production of all five members, the cooperatives are assumed to use 2 windrowers, 2 rakes and 2 balers. The details of equipment complements are presented in table 1 and table 2.

**Table 1: Equipments Complement for Individual Producers**

| Equipments | Width | Speed | Value | Capacity | HP | Field Eff. (%) |
|---|---|---|---|---|---|---|
| Tractor (2WD, 80-149 HP) | | | $ 58,000 | | 85 | |
| Mower, Rotary | 9 ft | 6 mph | $ 20,000 | | | 80 |
| Rake, Side Delivery | 9 ft | 6 mph | $ 6,000 | | | 80 |
| Baler, Round | 9 ft | 5 mph | $ 39,500 | | | 65 |
| Wagon | | 6 mph | $ 5,000 | 10 bales | | 65 |
| Skid Steer Loader | | 6 mph | $ 7,500 | | | 80 |

**Table 2: Equipments Complement for Cooperative**

| Equipments | Width | Speed | Value | Capacity | HP | Field Eff. (%) |
|---|---|---|---|---|---|---|
| Tractor (2WD, 80-149 HP) | | | $ 58,000 | | 85 | |
| Windrower, Self-propelled | 20 ft | 5 mph | $ 100,000 | | 85 | 80 |
| Rake, Side Delivery | 30 ft | 6 mph | $ 19,891 | | | 80 |
| Baler, Large Rectangular | 30 ft | 5 mph | $ 100,000 | | | 80 |
| Stacker | | 6 mph | $ 150,000 | 15 bales | 100 | 80 |

The procedure followed to calculate the distance travelled by the equipments in our study is in some way similar to the procedure applied by Kumar and Sokhansanj, 2007. We first calculated the infield transport distance which is the total distance travelled by the equipment (mower, rake and baler) in the field during mowing, raking and baling. This distance depends on the distance between the bales and the total number of bales in the field. The distance between the bales was calculated assuming the field as a grid and bales distributed uniformly over it as also followed by Kumar and Sokhansanj, 2007. Then for example, if the total area of the field is 100 acres and there are 400 bales or 4 bales per acre, the distance between the bales would be 104.35 ft. The infield transport distance would be total no. of bales times the distance between the bales. Second, we calculated the distance travelled by the loading and unloading equipment. In the cooperative scenario, stacker is assumed to collect and load the produced bales and stack them on the edge of field for future hauling to the warehouse. Wagon and skid steer loader are assumed to do this job in the individual producers. This distance travelled by the stacker and wagon/skid steer loader was calculated by assuming that the equipment would travel from the center of the field somewhere to the middle of either side of the field. For example, if the total area of the field is 100 acres then this distance would be 1043.55 ft which represents the distance traveled by the stacker or wagon/skid steer loader to move the bales to the field edge. Infield transportation costs depend on this distance, capacity of the stacker or loader and the total no. of bales in the field. The final category of transportation cost modeled is transportation from the field edge to a centralized warehouse. An average distance of 5 miles between field and warehouse was used in the baseline assumptions.

The machinery days for the equipments are based on the annual hours the equipments are used in the field with the assumption of 10 working hours per day. The annual hours of the equipments however depend on the total acres, yield, field size and field speed of the equipment. Fuel and lube cost are calculated with the assumption of $2.50 per gallon of diesel. The repair and maintenance cost for tractors and equipments are based on the American Society of Agricultural Engineering (ASAE) methods. The annual repair cost is calculated by using the price of the equipment, annual hours used in the operation and the repair factors. The hired labor rate is assumed to be $20 per hour for the cooperative and $10 per hour for the individual producers. The labors are based on the no. of tractors used and equipments that need tractor and equipments that do not need tractor. Modified straight line method of depreciation is used in the study with a depreciation rate of 10% and inflation rate of 1%. The insurance rate is modeled at 2% of the equipment value per year.

In the cooperative structure, the members share the equipments compliment which must be transported from one producer's location to another. The costs associated with this kind of transportation are included in the trucking cost and equipment operation costs. The self propelled equipment was assumed to be driven from one producer location to another with the travel operation included in the total annual hours of operation. The baler and rake were assumed to be trucked to the next location with the costs reflected in the trucking costs. The remainder of the trucking costs reflected the costs of transporting the bales from the stacks at the field edge to the warehouse. It was calculated by multiplying the no. of trips the truck has to make with the average distance from the stacking to the warehouse and the trucking cost per mile. The number of trips depends on the total yield and the capacity of the trucks per load. For trucking and hauling cost assumption see Appendix A.

Fifty percent of the investment is assumed to be financed with a loan term of 5 years and long term interest rate of 6 %. The loan amount is exactly the same as the total investment as half of the investment was financed. The baseline structure of the cooperative was five members each having a 20% share of ownership and 1,000 acres of production. The total investment for the baseline situation was estimated to be $368,391 for the cooperative and $61,750 for the producers. All these investments are made for the purchase of harvest and transport equipments (Table 1 and 2). No costs for lands and buildings were assumed.

**Table 3: Capital Requirements for Cooperative and Producer**

| | Cooperative | Producer |
|---|---|---|
| Total Investment | $368,391 | $61,750 |
| Long Term Interest Rate | 6 % | 6 % |
| Percent Financed | 50 % | 50 % |
| Loan Amount | $368,391 | $61,750 |
| Loan Term | 5 Years | 5 Years |
| Total Plant, Property & Equip | $736,782 | $123,500 |

## 3. Results and Discussion

The results provide interesting insights into the structure of the cooperatives to harvest and transport biomass. Preliminary results indicate that even small scale (3-5 members) biomass harvesting cooperatives could have substantial cost savings versus individual member operations. The total cost was estimated to be $18.00 per ton for the cooperative and $25.53 per ton for the individual producers (Table 4). The harvesting cost per ton was $15.42 in the cooperative and $23.13 in the individual producers. The transportation cost was $2.40 per ton for both the scenarios.

**Table 4: Itemized Cost/Dry Ton**

| | **Cooperative** | **Producer** |
|---|---|---|
| Fuel & Lube | $ 1.35 | $ 4.22 |
| Hired Labor | $2.50 | $3.96 |
| Repair & Maintenance | $ 1.03 | $ 4.61 |
| Equipment Transportation | $0.18 | - |
| Hauling Cost | $2.40 | $2.40 |
| **Total Variable Costs** | **$ 7.47** | **$ 15.19** |
| Insurance & Housing | $ 1.54 | $ 1.42 |
| Interest | $ 0.82 | $ 1.38 |
| Property Tax | $ 0.39 | $ 0.36 |
| Depreciation | $ 7.79 | $ 7.19 |
| **Total Fixed Costs** | **$ 10.53** | **$ 10.34** |
| **Total Cost** | **$ 18.00** | **$ 25.53** |

The harvest cost estimates for individual producers are very close to the estimates made by Duffy and Nanhou, 2001 who estimated the total harvesting cost of $26.05 per ton in Iowa. A similar study by Kumar and Sokhansanj, 2007 estimated the total cost of $24.10 per ton for square bales and $22.62 per ton for round bales. This cost estimates included the cost to swathing, raking, baling, road siding, stacking and tarping. In another study by Thorsell *et al*, 2004 the cost of mowing, raking, baling, gathering and stacking in-field was estimated from $11.26 to $14.01 per Mg depending upon the biomass yield. Both of these studies do not include the hauling costs. Our study assumes that the bales would be transported to a storage site which is 20 miles away from the field and estimates this cost to be $2.40 per ton in both the scenarios. The University of Kentucky (U.K.) Extension, 2009 estimates the hauling cost of $11.50 per ton for a distance of 50 miles. Brechbill and Tyner, 2008 in their study estimate a series of transportation costs for a range of 5 miles to 50 miles for field size of 500 acres, 1000 acres, 1500 acres and 2000 acres. Their cost estimates for 20 miles is $5.27 for 500 acres, $4.74 for 1000 acres, $4.56 for 1500 acres and $4.47 for 2000 acres. The per ton cost in their study increases almost by $0.10 to $0.20 as the field size increase by 500 acres and almost by a dollar if the distance to the plant increases by 5 miles. The hauling cost in our study shows a uniform change of $0.60 per ton for a change of 5 miles in the transportation distance.

The total fixed cost in our study is almost the same in both the cooperative and the individual producers. The total variable cost is almost twice in the individual producers than in the cooperative. The costs for fuel and lube, hired labor and repair and maintenance costs were all significantly higher for the individual producers than the cooperative. Perlack *et al*, 2011 estimated fixed and variable costs for switchgrass production and harvesting in the southeast U.S. with average dry yield of 6.1 tons per acre. The fuel and lube cost per acre were estimated as $9.09, $12.22 and $16.48 for year-1, year-2 and year-3 which appear significantly higher than what we have estimated ($1.33 and $4.17). Similar estimates for year-1, year-2 and year-3 are $12.39, $16.91 and $23.63 for repairs, $6.10, $12.20 and $18.30 for twine, $2.95, $2.18 and $2.86 for insurance, housing, taxes, $5.04, $2.45 and $2.48 for interest (operating loan), $60.0, $60.0 and $60.0 for land rent and $21.56, $15.17 and $18.62 for labor. The estimates for repairs, housing and insurance, interest and labor were all higher than our estimates. The U.K. Extension (2009) have estimated total fixed costs of $12.5 for full switchgrass production (years 3 to 6) and yield of 6 tons/acre which is higher than our estimates of $10.53 and $10.34 for cooperative and individual producers respectively. Their estimates of labor cost per ton of $5.66 were also higher than the estimates of our labor cost of $2.47 and $3.91 for cooperative and individual producers respectively.

**Table 5: Itemized Cost/Dry Ton by Activities**

| | Cooperative | | Producer | |
|---|---|---|---|---|
| **Operation** | **Cost Per Ton** | **Machinery Days** | **Cost Per Ton** | **Machinery Days** |
| Mowing | $ 4.97 | 26 | $ 5.71 | 28 |
| Raking | $ 2.00 | 14 | $ 3.94 | 19 |
| Baling | $ 5.85 | 17 | $ 11.16 | 19 |
| In-field Transport | $ 2.60 | 5 | $ 2.33 | 5 |
| Hauling | $ 2.40 | | $ 2.40 | |

The breakdown of costs by field activities shows that most of the cost would go for baling for both the cooperative ($5.85 per ton) and individual producer's ($11.16 per ton) and least cost would be for raking ($2.00 per ton) in cooperative and for in-field transport ($2.33 per ton) in the individual producers. The cost per ton for baling and raking in the individual producer scenario was almost twice the cost in the cooperative scenario.  The cost per ton for mowing was almost a dollar higher in the individual producer than the cooperative. The infield transport cost was higher in the cooperative (stacker) than in the individual producers which were because the equipments were not fairly being utilized for the acres it should have covered. Duffy and Nanhou, 2001 have estimated the cost for mowing ($2.18), raking ($1.03), staging and loading ($6.51) per ton in Iowa which are lower than our estimates but their baling cost ($16.34) estimates are higher.

The estimated days of machinery operation show that the harvesting and transporting of biomass in the cooperative structure could be achieved in fewer days compared to the individual producer's scenario. Under the cooperative structure, raking could be accomplished in 5 fewer days relative to operations by the individual producers. Likewise mowing and baling could be completed 2 fewer days but the infield transport of the loading/unloading equipment would be same (5 days) for both the scenarios. The fewer machinery days in the cooperative structure would lower the overall variable costs compared to individual producer and help achieve economies of scale.

## 4. Sensitivity Results

Sensitivity analysis is important to see the impacts on total costs due to changes in any factors considered important in the study. This study evaluates and compares the changes in the total cost per ton because of these factors between the individual producers and the cooperative. The sensitivity analysis performed in this study are for the impacts on total costs due to changes in yield of the crop, field size, distance between the producers, field operation speed and labor rate per hour.

One ton per acre change in the yield of the crop had a significant impact on the total cost per ton. Increasing the yield from one ton/acre to two tons/acre would lower the cost by approximately 50% but this rate would not be consistent as we increase the yield. In both the cooperative and individual producer's scenario, with the increase in yield the total cost per ton would decrease in decreasing rate (Table 6). The field size did not have as much effect on the total cost per ton. An increase in the field size from 50 acres to 200 acres would increase the total cost just by $0.10 for cooperative and by $0.44 for the individual producers.

**Table 6: Sensitivity Analysis**

| | **Total Cost/Ton** | |
|---|---|---|
| | **Cooperative** | **Producers** |
| *Impact of Yield* | | |
| 1 ton/acre | 33.41 | 47.63 |
| 2 ton/acre* | 18.00 | 25.53 |
| 3 ton/acre | 12.86 | 18.16 |
| 4 ton/acre | 10.29 | 14.48 |
| 5 ton/acre | 8.75 | 12.26 |
| *Impact of Field Size* | | |
| 50 acre | 17.96 | 25.35 |
| 100 acre* | 18.00 | 25.53 |
| 150 acre | 18.03 | 25.67 |
| 200 acre | 18.06 | 25.79 |

* Baseline yield and field size.

The results were also not sensitive to the distance between the producers. The total cost per ton would increase just by $0.24 if the distance between the producers would increase from 10 miles to 40 miles. The field speeds of the stacker also did not have a major impact on the total cost per ton. When the field speed was increased from 10 mph to 30 mph the total cost decreased only by $0.33 per ton. There were two different labor rates use in the study- one for the cooperative and one for the individual producers.  However, wage rates did not have a significant impact on the total cost per ton. When compared to their individual impacts, the labor rates in the individual scenario were more than the cooperative scenario. An increase in labor rate from $16 to $24 per hour in the cooperative increased the total cost by almost $1.00 and increase of labor rate from $8 to $12 in the individual producers increased the total cost by $1.58.

**Table 7: Sensitivity Analysis**

| | **Total Cost/Ton** | |
|---|---|---|
| | **Cooperative** | **Producers** |
| *Impact of distance between producers* | | |
| 10 miles | $17.93 | |
| 20 miles* | $18.00 | |
| 30 miles | $18.08 | |
| 40 miles | $18.17 | |
| *Impact of field operation speed (Stacker)* | | |
| 10 mph | $18.25 | |
| 15 mph | $18.08 | |
| 20 mph* | $18.00 | |
| 25 mph | $17.95 | |
| 30 mph | $17.92 | |
| *Impact of Hired Labor Rate (Coop.)* | | |
| $16 | $17.50 | |
| $18 | $17.75 | |
| $20* | $18.00 | |
| $22 | $18.25 | |
| $24 | $18.50 | |
| *Impact of Hired Labor Rate (Producers)* | | |
| $8 | | $24.74 |
| $9 | | $25.14 |
| $10* | | $25.53 |
| $11 | | $25.93 |
| $12 | | $26.32 |

* Baseline distance between the producers; field speed of the stacker; hired labor rate for cooperative and producer.

## 5. Conclusion

The renewable fuel standard mandate has resulted in a continued growth of ethanol plants in recent years. Unlike first generation ethanol plants, second generation will require a dedicated source of feedstock supply to meet the mandates of the renewable fuel standards and second generation ethanol plants are forecasted to cost 3-4 times more than grain based ethanol. This may limit farmer ownership of the actual processing plant. The best avenue for farmer participation and value-added returns may be farmer ownership in the supply chain. A commonly suggested structure for the biomass supply chain is an integrated business model owned by the biorefinery. Producer ownership of harvesting operations generates increased economic impact for producers and rural communities. However, this structure fails to capture the economies of scale in equipment ownership and operations. Another alternative is the formation of biomass harvesting and transportation cooperatives. This paper has attempted to model the cost of harvesting and transporting biomass (switchgrass) in this type cooperative structure. A cost comparison with equipment ownership and operations by individual producers is provided. The results show that even small scale biomass harvesting cooperative could have substantial cost savings versus individual member operations. For a five member cooperative the total cost of harvesting and transporting biomass was estimated to be $18.00 per ton and it was estimated to be $25.53 per ton for the individual producers. The harvesting cost per ton was $15.42 in the cooperative and $23.13 in the individual producers. Sensitivity analysis indicated that biomass yield, had the most significant impact on per ton cost while minimal impacts were observed for field size, distance between producers, labor rates and field speed of the bale pick up equipment. Sharing of equipments and forming a cooperative to harvest and transport biomass allows spread of costs among producers and helps achieve economies of scale. Similar cost savings could therefore be achieved and wider economic impact could be made by involving local producers and forming cooperative rather than harvesting and transporting biomass individually.

## References


ASAE, 2004. Standard 48th Edition. ASAE D497. American Society of Agricultural Engineers, St, Joseph, MI.

Bochtis, D.D., C.G. Sorensen, O. Green, T. Bartzanas and S. Fountas. 2010. "*Feasibility of a Modelling Suite for the Optimised Biomass Harvest Scheduling.*"

Brechbill, S.C and W.E. Tyner. 2008. "*The economics of biomass collection, transportation, and supply to indiana cellulosic and electric utility facilities*." Working Paper #08-03. Department of Agricultural Economics, Purdue University.

Caddel, J., N. Walker, G. Kakani, J. Warren, D. Porter, Y. Wu, D. Redfearn and H. Zhang. 2010. "*Switchgrass Production Guide for Oklahoma*". E-1012 Oklahoma Cooperative Extension Service. Division of Agricultural Sciences and Natural Resources. Oklahoma State University.

Duffy, M. and V.Y. Nanhou. 2001. "*Costs of Producing Switchgrass for Biomass in Southern Iowa*". Iowa State University Extension.

Eddwards, W. 2009. "*Estimating Farm Machinery Cost*". Ag Decision Maker. Iowa State University Extension. Avaiable at http://www.extension.iastate.edu/publications/pm710.pdf

Epplin, F.M. 1996. "*Cost to Produce and Deliver Switchgrass Biomass to an Ethanol-Conversion Facility in the Southern Plains of the United States*".

Epplin, F.M., C. Clark, R. Roberts and S. Hwang. 2007. "Challenges to the Development of a Dedicated Energy Crops." *American Journal of Agricultural Economics 89(5):1296-1302.*

Ginder, R.G. 2007. "Potential Infrastructure Constraints on Current Corn-Based and Future Biomass Based U.S. Ethanol Production."

Harris, A., and M. Fulton. 2000. Farm Machinery Cooperatives: an Idea Worth Sharing." Centre for the Study of Cooperatives, University of Saskatchewan, Saskatoon, SK, CA. ISBN 0–88880–415–6

Jensen, K. L., C. D. Clark, B. C. English and R. J. Menard. 2011. Preferences for Marketing Arrangements by Potential Switchgrass Growers. Journal of Cooperatives, Volume 25, Page 16-43. Available at http://www.agecon.ksu.edu/accc/ncera210/JOC%20pdfs/V25/MarketingArrangementsSwitchgrass.pdf

Kumar, A. and S. Sokhansanj. 2006. "Swithgrass (*Panicum vigratum,* L.) Delivery to a Biorefinery Using Integrated Biomass Supply Analysis and Logistics (IBSAL) Model."

Larson, J. A., T-H Yu, B.C. English and D. F. Mooney. 2010. "Cost Evaluation of Alternative Switchgrass Producing, Harvesting, Storing, and Transporting Systems and their Logistics in the Southeastern USA."

Long, G., and P. Kenkel. 2007. "Feasibility of Machinery Cooperatives in the Southern Plains Region." Selected paper presented at the 2007 Southern Agricultural Economics Association meetings in Mobile, AL, Feb. 4-7, 2007.

Miranowski, J., D. Swenson, L. Eathington, and A. Rosburg. 2008. "Biofuel, the Rural Economy, and Farm Structure." *Risk, Infrastructure and Industry Evolution*, B.C. English, R.J. Menard, and K. Jensen, eds. Farm Foundation Press, Washington, D.C.

RFA, 2011. Renewable Fuel Association. Building Bridges to a More Sustainable Future. 2011 Ethanol Industry Outlook. Available at http://www.ethanolrfa.org/pages/annual-industry-outlook

Perlack, R.D., A.F. Turnhollow and L.M. Eaton. 2011. "Switchgrass Production in the USA". Promising Resources and Systems for Producing Bioenergy Feedstocks. IEA Bioenergy Task 43:2011:03.

Stiles, S and T. Griffin. "Estimating Farm Machinery Costs". Agricultural and Natural Resources. University of Arkansas, Division of Agriculture. Available at http://www.uaex.edu/Other_Areas/publications/PDF/fsa-21.pdf

Thorsell, S., F.M. Epplin, R.L. Huhnke and C.M. Taliaferro. 2004. "Economics of a Coordinated Biorefinery Feedstock Harvest System: Lignocellulosic Biomass Harvest Cost."

Tiffany, D.G., B. Jordan, E. Dietrich and B. Vargo-Daggett. 2006. "Energy and Chemicals from Native Grasses: Production, Transportation and Processing Technologies Considered in the Northern Great Plains."

Urbanchuk, J.M. 2006. "Economic Impact on the Farm Community of Cooperative Ownership of Ethanol Plants" National Corn Growers Association, September 2006. http://www.ncga.com/ethanol/pdfs/2006/FarmerOwnedEthanolEconomicImpact

U.S. Congress, House of Representatives. 2007. Section 111, Subtitle A, Renewable Fuels, Consumer Protection and Energy Efficiency Act of 2007, H.R. 6 (EAS).

U.K. Extension. 2009. "*Switchgrass for Biomass*", University of Kentucky, College of Agriculture, Cooperative Extension Service.

## Appendix:

| Producer/Member description | Producer | Cooperative |
|---|---|---|
| Acres | 1000 | 5000 |
| Field Size (Acres) | 100 | 100 |
| Yield (Tons/acre) | 2 | 2 |
| Tons/bale | 0.5 | 0.5 |
| No. of Cuttings | 1 | 1 |
| Share of Machinery Cooperative | 20% | 100% |

| Input capital structure & expense information | Producer | Cooperative |
|---|---|---|
| Percent Financed | 50% | 50% |
| Long Term Interest Rate | 6% | 6% |
| Loan Term | 5 | 5 |
| Equipment Replacement Cycle | 5 | 5 |
| Total Plant Property & Equip | $ 123,500.00 | $ 736,782.00 |
| Loan Amount | $ 61,750.00 | $ 368,391.00 |
| Current Equity Investment Individually | $ 61,750.00 | $ 368,391.00 |
| Current Equity Investment Per Acre | $ 61.75 | $ 73.68 |
| Required Investment in Cooperative | $ 73,678 | $ 368,391 |
| Net Annual Fee in Cooperative | $ 89,975 | $ 449,876 |

| Cooperative assumptions | |
|---|---|
| **Input Costs** | |
| Hired Labor Rate/Hour (Coop.) | $20.00 |
| Hired Labor Rate/Hour (Producers) | $10.00 |
| Fuel Price/Gallon (Diesel) | $2.50 |
| Insurance Rate % of Property Value | 2% |
| Cooperative Fee Per Acre | $105.00 |
| **Tax Information** | |
| Property Tax as % of Property Value | 0.5% |
| Income Tax Rate | 50% |
| **Profit Allocation**(all percentages relate to before tax income) | |
| Percentage to Cash Patronage Refund | 20% |
| Percentage to Stock Patronage Refund | 75% |
| Percentage Retained | 5% |
| **Trucking (Equipment Transportation)** | |
| Avg distance between producers (mi) | 20 |
| Avg trucking speed (mph) | 40 |
| Trucking Cost/Mile | $3.00 |
| Setup Time (Hrs) | 4 |
| No. of trips required | 3 |
| Total trucking hours | 5.5 |
| **Trucking (Hauling)** | |
| Avg distance from stacking to warehouse (mi) | 20 |
| Capacity of trucks (Tons/Load) | 25 |
| **Other** | |
| Inflation Rate | 1% |
| Total Working Hours / Day | 10 |