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Fueling America Through Renewable Resources

The Economics of Harvesting Corn Cobs for Energy

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Introduction

Biomass energy has received much attention in recent years. We now use about one third of the U.S. corn crop for biofuels. More recently, attention has focused on cellulosic resources—dedicated energy crops like switchgrass, miscanthus, and corn stover. Now the question has been raised concerning the economics of collecting just the corn cobs for energy instead of the stover. This publication provides information on the economics of corn cob harvest. What are the associated, additional costs of harvesting cobs? Will harvesting cobs generate extra revenue for the farming operation? To help answer the last question, we estimate the per ton payment farmers need to receive in order to take on the additional task of harvesting cobs during the corn harvest.

Cellulosic Ethanol Background

Cellulosic biofuels are liquid fuels that can be produced from wood, grasses, and non-edible parts of a plant. Corn stover, the non-grain residue left on the field after harvest, has been shown to have significant potential in Indiana as a biofuels feedstock (Brechbill and Tyner, 2008). In many cases, if the farm gate price of residues is $60 or higher, farmers could have an incentive to harvest, bale, and store residues for conversion to biofuels.

However, collecting the corn stover and removing the residue from the field may have implications for cropland and soil quality. The impact of removing corn stover varies from field to field, but removing corn stover from the field may result in a negative impact on maintaining or improving soil nutrient matter and organic matter. One possible feedstock that would not overly affect organic and nutrient content in the soil is corn cobs. But little or no work has been done on the economics from the farmer's perspective of harvesting and collecting just the cobs off the field.

Corn Cob Background

The primary use for cobs today is utilizing the nutrients and tilling them back into the ground. However, the nutrient content in cobs is relatively minimal. The ethanol company POET and Iowa State University are jointly studying the impact of removing only the cobs from the field during harvest. In the first year of the study (2008), researchers found that removing cobs had no substantial impact on the soil nutrient content. In fact, they concluded that fertilizer treatment for a field that has removed the cobs would be similar to that of a field in which the cobs were not removed (Research, 2009).

There is limited use of cobs today for energy. POET expects to use cobs in their cellulose conversion to ethanol at their Emmetsburg, Iowa plant. They had originally planned on producing 20 million gallons of cellulosic ethanol in 2011 (POET Project Liberty), but the project has been delayed a bit. The other user of cobs is Chippewa Valley Ethanol Company (CVEC), a co-op in Benson, Minnesota. CVEC gasifies the cobs to produce fuel for the corn ethanol plant, thereby displacing fossil fuels in corn ethanol production.

The EPA ruling on greenhouse gas (GHG) emissions for cobs and residue states that cellulosic biofuels will meet the Energy Independence and Security Act (EISA) standard and count towards the Renewable Fuel Standard (RFS). POET has a news release citing the EPA finding that residues reduce GHG more than the amount required in EISA (Research, 2009). CVEC sees the cobs-for-plant-fuel pathway as a means of making corn ethanol more attractive from a GHG perspective because much of the fossil energy in conversion of corn to ethanol is renewable in their plant.

During the 2009 corn harvest, the Minnesota farmers exclusively used the Vermeer CCX770 cob wagon to collect cobs. The cob wagon is designed as a pull-type wagon that hitches to the back of the combine.

The cob wagon is engineered to be self contained, with its own 4.1L engine. The idea of the cob harvester having a 4.1L engine is to minimize the added stress to the combine while maintaining the same operation combine speed used during normal harvest conditions. The cost of the cob wagon is on a rental basis for the entire harvest at $28,000 (Vermeer, 2009).

The Analysis

Methods

To obtain the most accurate results, we used real data provided by seven farmers who supplied cobs for CVEC during the 2009 corn harvest. We collected the data through two focus group sessions and a mailed questionnaire. Based on the information from these farmers, we created a cob harvesting activity for the Purdue B-21 PC-LP Farm Plan model (PC-LP) (Doster et. al., 2009) used in the Purdue Top Farmer Crop Workshop. Anonymous data for the 55 farm operations from the 2009 workshop provided real-world grounding for the research.

In order to fully capture the cob economics objectives, the analysis added a new activity that encompassed simultaneous corn and cob harvest. In other words, in the model there was a choice between the normal corn rotations and corn rotations including cob harvest. In that way, we could estimate the relative attractiveness of the cob operation over a range of cob prices. In addition, we did sensitiv-

Table 1. *Base Case*

55 farms	Corn Harvest (w/o Cobs)	Corn Harvest w/Cobs ($40/ton)	Corn Harvest w/Cobs ($60/ton)	Corn Harvest w/Cobs ($80/ton)	Corn Harvest w/Cobs ($100/ton)	Corn Harvest w/Cobs ($120/ton)
Farm Participation for Cobs	-	-	3	14	22	22
Total Corn Only Acres	100,264	100,264	96,839	60,074	51,480	49,308
Total Corn + Cob Acres	-	-	4,296	43,560	60,363	65,800
Total Corn Acres	100,264	100,264	101,135	103,634.0	111,843.0	115,108.0
% Cob + Corn Acres in Corn Rotation	0.0%	0.0%	4.2%	42.03%	53.97%	57.16%
% Change in Corn Acreage	0.0%	0.0%	0.9%	3.36%	11.55%	14.80%
Estimated Profit From Resources	$ 43,361,364.00	$ 43,361,364.00	$ 43,404,663.00	$ 43,857,706.00	$ 44,723,807.00	$ 45,766,278.00
Estimated Profit Change Induced by Cobs ($/acre)	$ -	$ -	$ 10.08	$ 11.39	$ 22.57	$ 36.55

ity analyses for a range of factors, including a yield shock representing the risk of a poor harvest. Sensitivity analysis investigates how key variables affect the variability of the overall outcome. For this study, key harvest variables (decreasing working rate, price of the cob wagon, and the amount of cobs in the stover) were altered to test whether they had much effect on the breakeven price for harvesting cobs during the corn harvest.

Base Case Scenario & Interpretation at $100 per Ton

In the preliminary analysis, we found that the results were particularly sensitive to the percent of cobs in the stover, the cost of the cob wagon, and the reduction in corn harvest time due to the cob operation. Thus, we did sensitivity analysis on those variables. In the base case scenario, the amount of cobs in the overall stover is 20%. The rental cost of the cob wagon is $28,000. Each farm experienced a 10% decreasing working rate due to the added operation of harvesting cobs during the corn harvest. Table 1 shows the base case of the 55 farms from PC-LP.

From Table 1, the two optimization scenarios for the 55 farms in PC-LP are represented in the first row (the corn harvest without the cobs and the corn harvest with the corn plus cob activity). The 55 farms harvested 100,264 corn acres without the added operation of harvesting cobs. At $40 per ton, no farms participated in the corn plus cob activity due to the inability to offset the cost of the $28,000 lease of the cob wagon. As the price for cobs increased, a higher percentage of the corn acres were used for harvesting corn and cobs simultaneously. At $100 per ton, 54% of the 55 farms' corn acres harvested were used for the corn plus cob activity.

We assume that over 50% of corn acres used for the simultaneous activity of corn and cob harvest suggests that significant potential for cob harvest exists. From Table 1, the higher price received for cobs also causes an increase in total corn acreage. This was due to the farms receiving a higher payment for their overall corn enterprise, while holding other planting enterprises (soybeans, wheat, etc.) constant at their original prices. Finally, the higher payment for cobs caused profits to increase. At $60 per ton, profit change induced by cobs was estimated at $10 per acre of corn. At $120 per ton, the profit change induced by cobs was approximately $37 per acre of corn plus cobs.

At $100 per ton, 22 out of the 55 farms participated in cob harvest. The $100 per ton price for cobs caused more cobs to be harvested, thus "Total Corn Only Acres" decreased to 51,480 acres. However, "Total Corn Plus Cob Acres" increased to 60,363 acres, which resulted in an overall increase in "Total Corn Acres" to 111,843 acres. Because total corn plus cob acres increased, cobs harvested during the corn harvest also increased. The $100 per ton price increased corn acres by 12%. Finally, the profit change induced by cobs at $100 per ton was approximately $23 per acre of corn plus cobs. Having looked at price changes for cobs, we assessed three factors critical to the economics of cob harvesting: 1) Changing the harvest working rate; 2) Less expensive cob wagon rental at $14,000; and 3) Different percentages of cobs in residue.

Decreasing Harvest Working Rates

One of the major concerns from the Minnesota farmers harvesting cobs during the corn harvest was how much this activity would slow down the harvest. The base case analyzed the farms at a 10% decreasing harvest working rate. To test this impact, 5 percentage points were added and subtracted from the 10% decreasing harvest working rate from the base case. The 5% decreasing working rate

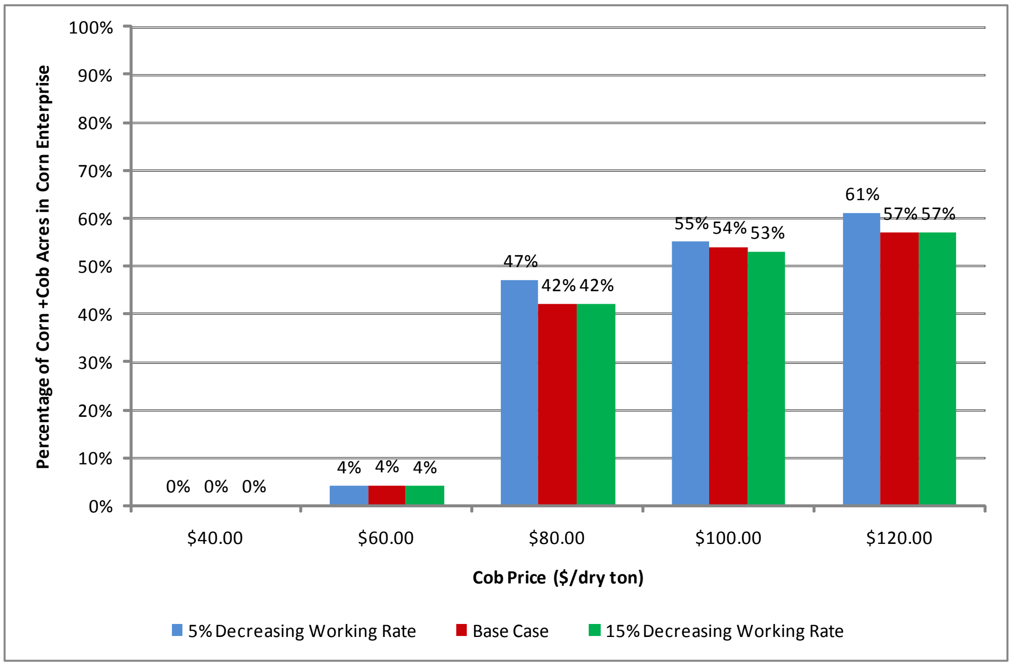

Figure 1. *Base Case vs. Decreasing Harvest Working Rates*

indicated the least amount of time to complete the corn harvest and vice versa for the 15% decreasing working rate. All other costs associated with the base case and the two sensitivity decreasing working rate cases did not change. Figure 1 shows the percentage of corn plus cob acres harvested in the overall corn harvest enterprise between the three decreasing working rates.

From Figure 1, the higher price received for cobs indicated a higher percentage of corn plus cob acres in the corn enterprise. Because no farms participated at a cob price of $40 per ton for all three decreasing working rates, none of the total corn acres harvested by the 55 farms were used for the corn plus cob harvest activity. At $60 per ton, 4% of the corn acres harvested by the 55 farms were used for the corn plus cob harvest activity for all three decreasing working rates. Moving to $100 per ton, all three decreasing working rates harvested over 50% of their total corn acres for the corn plus cob harvest activity.

This indicated that at $100 per ton, the three decreasing working rates showed significant potential in harvesting cobs in their corn enterprise. The bottom line for this sensitivity analysis is that the change in working rate was not a major driver of the cob results. However, this result holds for a normal year, and it could be very different for difficult harvest years like 2009.

Less Expensive Cob Wagon Rental at $14,000

Another major concern from the Minnesota farmers harvesting cobs was the rental price of the cob wagon. The rental price of the cob wagon for the entire harvest period was $28,000, regardless of the acres harvested. The base case used a rental cost of $28,000 for the cob wagon for each combine. The base case was tested against a reduced rental price of the cob wagon to $14,000 for each combine. All other costs associated with the base case did not change. Figure 2 shows the percentage of corn plus cob acres harvested in the overall corn harvest enterprise between the base case and the $14,000 rental cost case.

At $60 per ton, 4% of the corn acres harvested by the 55 farms were used for the corn plus cob harvest activity for the base case. Reducing the rental price of the cob wagon to $14,000 increased the percentage of corn plus cob acres in the corn enterprise to 38%. At $80 per ton, the $14,000 rental cob wagon case harvested over 50% of their total corn acres for the corn plus cob harvest activity. However, the base case did not reach the 50% benchmark until $100 per ton. Clearly, the cob wagon cost is a major determinant of the economics of cob harvest.

Different Percentages of Cobs in Residue

The next sensitivity case was motivated by industry press releases versus prior research studies. POET is benchmarking cobs in the overall stover at 18% to 20% (POET, 2007), whereas recent research studies are ranging cobs between 15% and 20% (Varvel and Wilhelm, 2008; Halvorson and Johnson, 2008). From the farmers' perspective, there is no indication of exactly whether there are 15% or 20% cobs in the residue. However, testing this range can determine how sensitive the amount of cobs in the residue is on the breakeven price for cob harvest. The base case analyzed the 55 farms assuming 20% cobs. In this sensitivity test, we assumed 15.7% cobs. All other costs associated with the base case did not change. Figure 3 shows the percentage of corn plus cob acres harvested in the overall corn harvest enterprise between the base case and the 15.7% cobs in stover case.

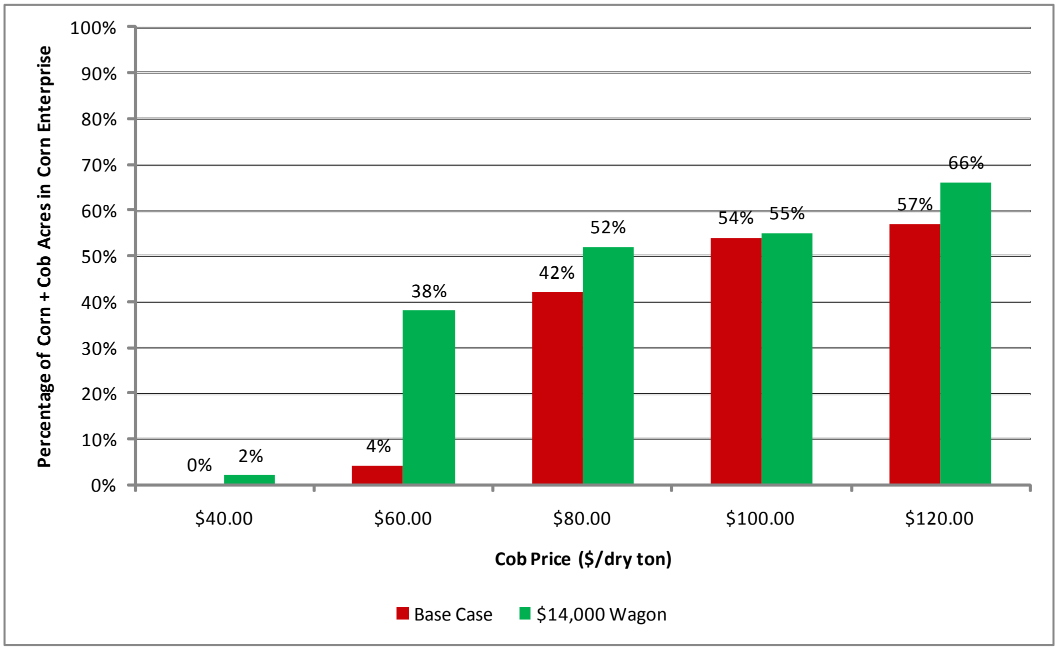

Figure 2. *Base Case vs. $14,000 Cob Wagon Rental Case*

At $60 per ton for both cases, 4% of the corn acres harvested by the 55 farms were used for the corn plus cob harvest activity. At $80 per ton, the difference in corn plus cob acres became apparent. The base case contained 42% corn plus cob acres in the corn enterprise, while the 15.7% case contained only 29%. At 15.7% cobs, farms harvested fewer cobs on the field, which made it harder to offset the costs associated with cob harvest at lower per ton prices. At $100 per ton, the base case reached the 50% benchmark. Meanwhile, the 15.7% case did not reach the 50% benchmark until $120 per ton. This indicated that farms need to receive a higher payment for less quantity of cobs on the field in order to cover all the associated costs for harvesting cobs during the corn harvest.

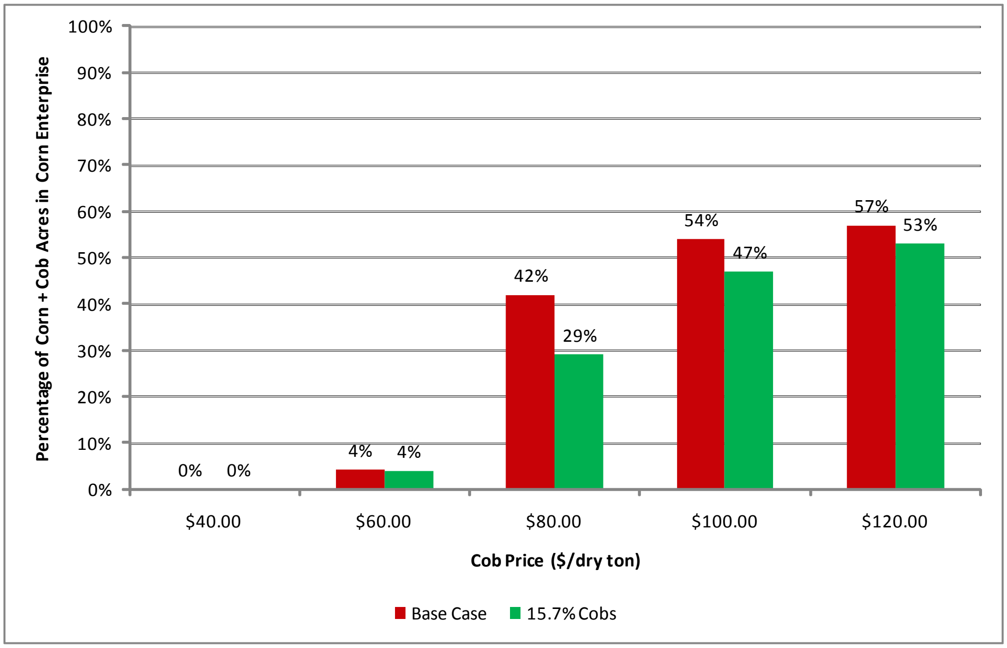

Figure 3. *Base Case vs. 15.7% Cobs Case*

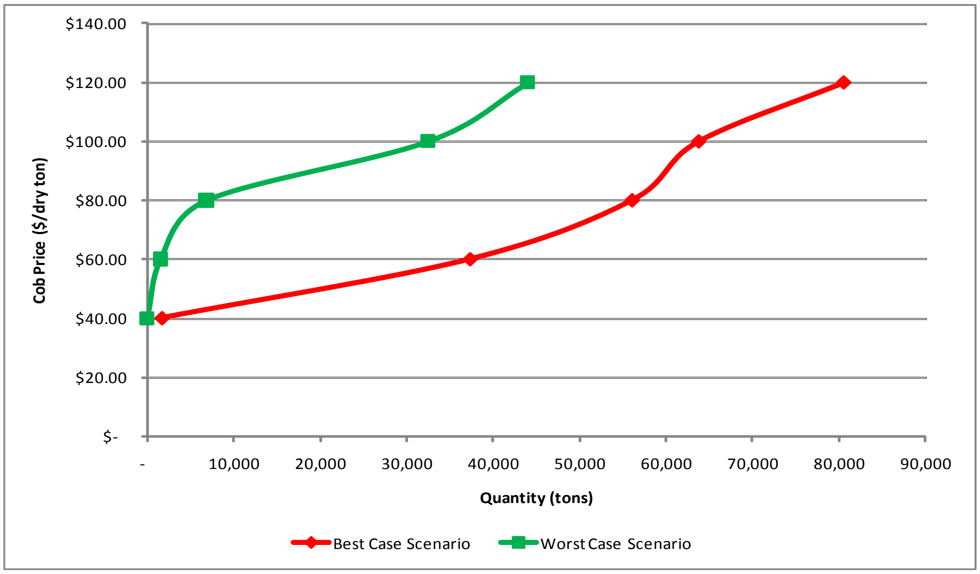

Figure 4. *Best Case vs. Worst Case Scenario*

Best Case vs. Worst Case Scenario

One important consideration to test was the best case versus the worst case scenario. Planning budgets and configuring ideas for decisions often plan for the best case and/or the worst case scenario. The best case scenario for the 55 farms contained 20% cobs, a $14,000 rental cost for each cob wagon, and a 5% decreasing harvest working rate. The worst case scenario contained 15.7% cobs, a $28,000 rental cost for each cob wagon, and a 15% decreasing harvest working rate. Figure 4 shows the price-quantity relationships of the total tons of cobs harvested between the best case and worst case scenarios.

From Figure 4, the higher price received for cobs resulted in a higher quantity of cobs harvested. As expected, the best case scenario (red line) harvested more cobs than the worst case scenario (green line) between $40 and $120 per ton. At $100 per ton for cobs, there was a 96% difference in the amount of cobs harvested. At $120 per ton for the best case, 33 farms participated in the corn plus cob activity and harvested approximately 80,477 tons of cobs. This is equivalent to approximately 5.6 million gallons of ethanol production. For the worst case scenario, 21 farms participated in the corn plus cob activity and harvested approximately 43,997 tons of cobs. This is equivalent to approximately 3.1 million gallons of ethanol production.

Types of Farms for Which Cob Harvesting Is Feasible

Farms across the country contain many different characteristics that make each farm unique. This section was motivated by the idea of finding which farms are harvesting cobs during the corn harvest. Intuitively, larger farms have more resources to better cover the costs associated with harvesting cobs than do smaller farms. For this analysis, we broke down the 55 farms from the base case into three corn acreage categories. There were 14 farms with fewer than or equal to 1000 corn acres, 28 farms between 1000 and 2000 corn acres, and 13 farms with greater than or equal to 2000 corn acres. Figure 5 shows the 55-farm sample broken down into the three corn acreage categories and the percentage of corn plus cob acres harvested in the overall corn harvest enterprise.

From Figure 5, farms that contained more than 2000 corn acres better established cob harvest in their corn enterprise from $80 to $120 per ton. The 13 farms that contained 2000 corn acres or more were better able to cover the costs associated with cob harvest than farms with less than 2000 corn acres. In fact, all 13 farms with 2000 corn acres or more had to cover an additional rental wagon cost of $28,000. At $80 per ton received for cobs, the farms with 2000 or more corn acres harvested 71% of their corn acres for the corn plus cob activity. From the 14 farms with 1000 corn acres or fewer, only three farms harvested cobs. The three farms that harvested cobs had expected corn yields of 210 bushels per acre, which resulted in higher cob yields. In fact, the three farms harvested 100% of their corn acres for the corn plus cob harvest activity at $120 per ton. Thus, the three farms that harvested cobs generated 35% of the corn acres for the corn plus cob harvest activity at $100 per ton, and 41% at $120 per ton.

Analyzing the farms between 1000 and 2000 corn acres, the corn plus cob activity begins at $60 per ton. Many farms categorized between 1000 and 2000 corn acres had two combines for a total fixed cost of the rental cob wagon of $56,000. This increase in the rental fixed cost of the cob wagon created a further cost that needed to be covered in order to achieve profits from cob harvest. The added addition of one cob wagon caused farms in this category to harvest fewer cob acres in their corn enterprise than the farms with less than or equal to 1000 corn acres. The farms that harvested cobs at $100 per ton generated 25% of their corn acres for the corn plus cob harvest activity and 31% at $120 per ton received for cobs. We were not able to test the possibility that these farmers would lease one cob wagon to use with one of the combines.

Impacts of a Corn Yield Shock

The last sensitivity test is estimation of the impact of an unexpected decrease in corn yields of 17%. Because all farms have different production practices and managerial decisions, we selected five farms from PC-LP that harvested cobs at $100 per ton with differing expected corn yields and farm size ranging between 686 and 5,897 corn acres. At $100 per ton, the change in corn plus cob total costs from the yield shock were similar for the five farms, so the case of the 686 corn acre farm is presented here. By collecting the costs and benefits of harvesting cobs from the literature and from PC-LP, we created a spreadsheet to determine the original cost for harvesting cobs. Once the original cost for harvesting the corn plus cob enterprise was determined, the original corn yield from PC-LP was decreased by 17%. This created the new cost for harvesting the corn plus cob enterprise. The spreadsheet containing the costs for the 686 corn acre farm is in Appendix A.

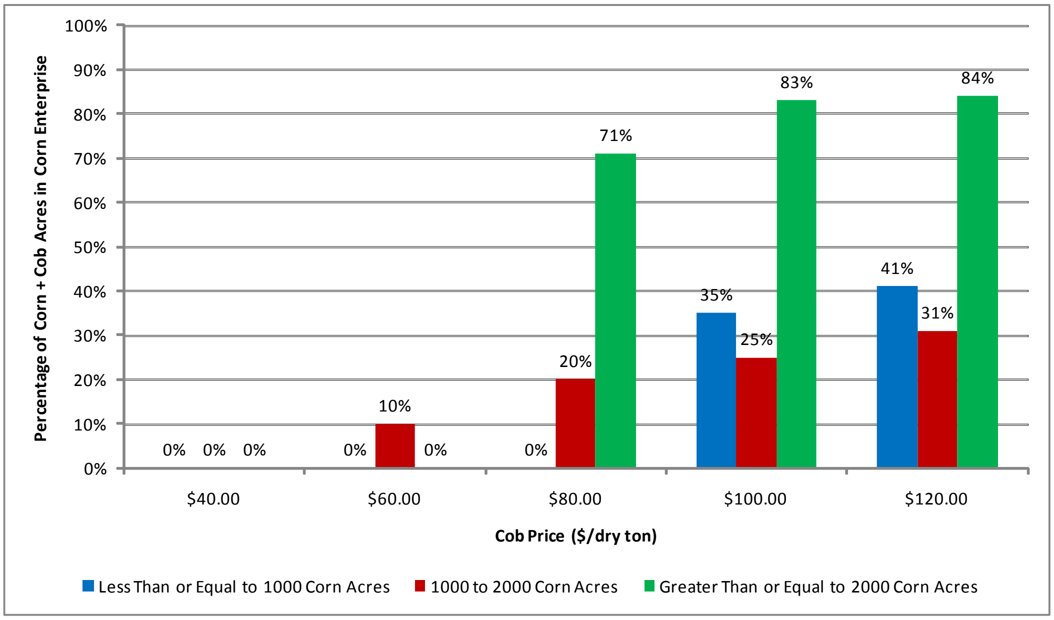

Figure 5. *55-Farm Sample Broken Down into Three Corn Acreage Categories*

Table 2. *Total Cob Costs for 686 Corn Acre Farm With and Without the 17% Yield Shock*

	Cost for Harvesting Cobs @ $100/ton Cob Payment ($/ton)	
	No Yield Shock	With 17 % Yield Shock
5% Decreasing Working Rate	$ 48	$ 55
10% Decreasing Working Rate	$ 52	$ 60
15% Decreasing Working Rate	$ 54	$ 63

The cob costs were run against six scenarios for 20% cobs. The six scenarios included a run with and without the 17% yield shock for the three decreasing harvest working rates of 5%, 10%, and 15%.

Due to the 17% yield shock, the total per ton cost for the corn plus cob enterprise increased by $7 to $9 for the 686 corn acre farm at $100 per ton. Table 2 indicates the total per ton cost for cobs for the three decreasing working rates for the 686 corn acre farm. The higher the decreasing working rate resulted in higher total costs, thus the higher the total per ton cost to harvest cobs.

For all five farms the breakeven price with the yield shock increased $6-$9 per ton.

Conclusions

Overall, cobs are more expensive to harvest for energy than originally thought. In fact, harvesting cobs generally became attractive at approximately $100 per dry ton. If ethanol plants are unable to pay $100 per dry ton for cobs in the near future, a potential subsidy program would be required to cover the differential payment and make cobs "economic."

It was evident that the cob operation is more attractive for farms greater than or equal to 2000 corn acres. Farms containing 2000 corn acres or more were better able to offset the associated total costs of harvesting cobs, thus reducing per unit costs of cob harvest. For smaller farms, the rental cost of the wagon at $28,000 was a barrier to entry. The ability to offset the rental cost of the $28,000 wagon and the other associated cob costs appeared challenging for small farms. However, decreasing the rental cost of the wagon to $14,000 allowed for higher farm participation by including more moderate to small farms.

Every farm is unique. The results of this analysis demonstrate that the breakeven prices for cobs can differ substantially among farms depending on corn yield, farm size, and other factors. However, the major conclusion is that cobs will be more expensive than previously believed—maybe too expensive to be used for energy production unless the public is willing to further subsidize such activities.

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Appendix A

686 Corn Acre Farm With and Without 17% Corn Yield Shock

Harvest Working Rate Scenarios	5%	5% (w/ Yield Shock)	10%	10% (w/ Yield Shock)	15%	15% (w/ Yield Shock)
Nitrogen ($/acre)	$ 2.04	$ 1.70	$ 2.04	$ 1.70	$ 2.04	$ 1.70
Phosphorus ($/acre)	$ 0.93	$ 0.78	$ 0.93	$ 0.78	$ 0.93	$ 0.78
Potassium ($/acre)	$ 5.65	$ 4.71	$ 5.65	$ 4.71	$ 5.65	$ 4.71
Storing and Piling ($/acre)	$ 4.72	$ 3.94	$ 4.72	$ 3.94	$ 4.72	$ 3.94
Nutrient Replacement and Storage Total (per acre)	**$ 13.34**	**$ 11.13**	**$ 13.34**	**$ 11.13**	**$ 13.34**	**$ 11.13**
Harvest Working Rate (Total Cost)	$1138 ($1.66/acre)	$1138 ($1.66/acre)	$1,593 ($2.32/acre)	$1,593 ($2.32/acre)	$1,972 ($2.88/acre)	$1,972 ($2.88/acre)
Diesel Fuel ($/acre) @ $2.73	$2.00	$2.00	$2.12	$2.12	$2.24	$2.24
Lubrication ($/acre)	$0.30	$0.30	$0.32	$0.32	$0.34	$0.34
Labor ($/acre)	$2.59	$2.59	$2.87	$2.87	$3.17	$3.17
Labor Hours per Machine Hour (Benchmark of 3.5)	$4451 ($6.49/acre)	$4451 ($6.49/acre)	$4451 ($6.49/acre)	$4451 ($6.49/acre)	$4451 ($6.49/acre)	$4451 ($6.49/acre)
Combine Repair and Maintenance (Per Combine Only) ($/acre)	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
Moving to Field Edge ($/acre)	$4.10	$4.10	$4.10	$4.10	$4.10	$4.10
Moisture Benchmark (40% moisture @ delivery)	20%	20%	20%	20%	20%	20%
Machinery Total (per acre)	**$ 17.64**	**$ 17.64**	**$ 18.72**	**$ 18.72**	**$ 19.72**	**$ 19.72**
Total Costs (per acre)	**$ 30.98**	**$ 28.77**	**$ 32.06**	**$ 29.85**	**$ 33.06**	**$ 30.85**
Wagon Rental (Fixed Cost)	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**	**$ 28,000**
Corn Yield	185	154	185	154	185	154
Cob Yield (tons per acre)	1.03	0.86	1.03	0.86	1.03	0.86
Corn + Cob Acres	1493	1493	1287	1287	1217	1217
Cob Production (tons)	1,538	1,284	1325.61	1107	1254	1046.62
Total Cob Variable Cost ($/ton)	$ 30.08	$ 33.45	$ 31.13	$ 34.71	$ 32.10	$ 35.87
Total Cob Fixed Cost ($/ton)	$ 18.21	$ 21.81	$ 21.12	$ 25.30	$ 22.34	$ 26.75
Cost of Collecting Cobs ($/ton)	*$ 48*	*$ 55*	*$ 52*	*$ 60*	*$ 54*	*$ 63*

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