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ECONOMIC IMPACT OF ON-BOARD MODULE-BUILDING COTTON HARVESTERS ON REPLACEMENT SCHEDULE AND HARVEST COSTS

By

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ECONOMIC IMPACT OF ON-BOARD MODULE-BUILDING COTTON HARVESTERS ON REPLACEMENT SCHEDULE AND HARVEST COSTS

By

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The purpose of this study is to further understand the economic impact of the new on-board module-building cotton harvesters that both John Deere and Case IH have introduced to the market. This study will examine two different areas, the optimal asset replacement schedule and a machine's performance rate's effect on harvest costs due to rainfall loss. Using data collected from Willcut (2008), USDA crop progress reports, and a USDA weather station, models will be used to study the areas in question. The findings are that, the age of the associated assets begin replaced with the conventional harvester and the number of acres harvested a year have a clear impact on the replacement schedule. The second findings are that when weather conditions deteriorate later in the harvest season, the full benefits of a higher performance rate are seen when the new harvester is pushed to its full potential.

Key words: cotton, harvest, harvester, picker, production, asset, system, replacement, costs, performance rate, precipitation, loss

DEDICATION

This thesis is dedicated to my lovely wife Summer.

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CHAPTER I

INTRODUCTION

The cotton industry has seen technological advances throughout its history, and is once again in the infancy stage of a new industry-changing technology; the on-board module-building cotton harvester. Case IH and John Deere have both introduced harvesters that pick as well as build modules, eliminating the need to dump cotton into a boll buggy and then have a separate machine (module builder) form the module. The boll buggy and module builder machines are powered by associated tractors; these tractors would also be removed from harvesting costs. Labor saved with the new machines can be two or more workers as well as the operators for the eliminated machines.

Both harvesters create modules on board the picker, but that is where the similarities stop. According to the John Deere website, its harvester, the 7760, uses plastic wrap to "bale" the cotton into 7.5-foot diameter round modules, approximately one-quarter the weight (4,750 lbs) of conventional modules (20,000 lbs). This smaller module is unloaded onto a cradle on the back of the machine that carries it to the turn row while the harvester continues to pick. With the ability to carry a module while one is picking the Deere machine can almost always unload at the field-end without stopping. A tractor fitted with a round module mover attachment moves each module, and places four of them together. This group of modules can be picked up by conventional module trucks and transported to the gin. They can sit in the gin yard protected from the elements with the plastic wrapping. A special piece of equipment "unwraps" the modules directly on the feeder belt to the gin.

The Case IH website touts a machine, the Module Express™ 625, which creates conventional looking modules on the harvester that are up to 50% smaller (9,000 lbs) than conventional modules. These smaller modules stay in the harvester basket and are unloaded on the edge of the field where they are tarped similarly to conventional modules. The Case IH machine has to stop to unload and cannot continue picking once the module chamber is full. Thus sometimes the operator has to turn in the middle of the field, deadhead or not pick a full module in order to unload at the edge of the field. The process of transporting, storing, and ginning is the same as with the conventional system except that two modules can be transported on the module truck.

The new Case IH and John Deere machines can cost up to an additional $200,000 more than a conventional harvester but eliminate additional machines and labor and have exhibited better field efficiencies due to reduced unloading time. Willcutt et al. (2009), used time-in-motion data to test the engineering of the three systems with respect to performance rate and fuel use to find field efficiencies. Using Willcutt's research, this thesis will investigate the economic costs and benefits associated with adoption of this new technology. It will also incorporate important timing considerations into the analysis: How will the reduction of additional equipment affect the optimal conversion timing for farmers. In other words, if the new technology has a lower cost per acre, how does this affect the decision of when to actually purchase the new technology given that the old technology consists of four more assets of varying ages?

This thesis will also explore harvest costs when harvest days are stochastic. More, if the higher performance rate of the new technology will have a significant impact on the reduction of costs from cotton loss due to precipitation throughout the harvest season. Because the new John Deere machine has a higher performance rate and can harvest the same number of acres as the conventional in a shorter period of time, will this shortened harvest significantly reduce losses of cotton from precipitation? These losses include the quality and quantity loss of cotton. These losses will be explored as costs for harvesters with lower performance rates.

With this technology being new, there is not readily available objective information about the machines. Uncertainty and risk in the cotton industry will weigh on important decisions for farmers. An analysis is needed for any economic opportunity costs savings realized by farmers by switching to the new technology. This thesis will approach this problem from a two essay perspective. Essay one will examine a cotton harvesting system's optimal replacement time with development of a system replacement model. Essay two will look at cost savings of a higher performance rate with respect to late season harvesting losses due to rain.

CHAPTER II

OPTIMAL REPLACEMENT OF CONVENTIONAL COTTON HARVESTERS AND ADDITIONAL MACHINERY WITH ON-BOARD MODULE-BUILDING HARVESTERS

How do farmers determine the optimal replacement time for an old system of cotton harvesting equipment when a new, technologically advanced system becomes available? Approaching this as an individual financing problem, the appropriate adoption rate can be derived using an asset replacement model. This approach relies on the identification of different features of the each system's assets: price, salvage value, and age.

The agriculture literature has provided theoretical asset replacement decision models, using net present value techniques, for various assets. Perrin (1972) uses a single asset model to determine the optimal year of replacement. However, there has not been substantial work in the agricultural field on a replacement model where multiple assets (working together in a system) have been replaced with fewer assets (performing the same function), as is the case with the new cotton harvesters.

The cotton industry alone has had a precedence established in asset replacement when harvesting machines were introduced, then again when module builders were introduced. Peterson and Kislev (1981) gave a span of over 23 years as the cotton industry's response to mechanically harvested cotton, from only 6 percent mechanically harvested in 1949 to 100 percent in 1972. There is no expectation that all farmers will convert immediately to the new system. So depending on the age of the equipment, what is a reasonable timetable for conversion?

Using data from Willcutt et al. (2009), Case IH and John Deere, a budget was developed for a study conducted by Cotton Incorporated, Barnes et al. (2009). This budget examined the per-acre costs of the new cotton harvesting systems versus a conventional harvesting system. A model will be used, using the budget and its data, to determine a farm-level asset replacement schedule. This model will find optimal replacement schedules for conventional harvesting systems for varying ages of the different assets within the system. A replacement decision can be found that will most benefit a farmer with assets of certain ages: i.e., replace now or wait for equipment to wear out. Used in an extension capacity, economists can use a modified asset replacement model to provide farmers with the information to make decisions on replacing old technology with new technology and maybe capture any short-term profits available.

Objective

The general objective is to find the optimal year for a farmer to replace a conventional cotton harvesting system, which has a harvester, boll buggy, module builder and tractors when each machine is a different age, with a new on-board module building system. When each system is compared, determining the optimal year for a farm's conversion should be achieved. It is assumed and later shown that the new on-board module systems have a lower present value of perpetual operating costs. Thus, a conversion from the old system should occur at some point.

To achieve this, an optimal replacement model will be developed for each asset in the system. Then the three assets along with tractors in the conventional system will be combined into a model to compare with the on-board module building system. This will give an approximation of what year, from the present, is optimal for replacement of the conventional system.

Conceptual Framework

With the new technology of on-board module-building harvesters there is a trade-off problem. While there are higher initial costs of the new harvesters, there are also higher performance rates and a reduction in machinery and labor from eliminating a module builder and boll buggy. An agricultural machine has an optimal year in which to replace it. Theoretical work for asset replacement by Perrin (1972) gives models that can be used for agricultural machinery. His model includes such values as repair and maintenance costs, economics asset depreciation, and interest rate.

Assets are often used together to complete a single task. For a system such as cotton harvesting, the values in an asset replacement model can be different for each asset involved (i.e., each asset has its own life span and optimal replacement schedule). With the introduction of the new harvesters, the number of assets used in the harvesting system is reduced. There is a need to combine each asset in the old system into a system model to determine a year in which purchasing the new system is more cost effective than keeping the old one.

First, literature helps identify important variables in the asset replacement problem. Perrin's model has been duplicated and expanded in the literature. Chisholm (1974) developed a model which includes the interest on the sale of the asset at replacement time to determine optimal replacement age of an asset. Batterham and Fraser (1995) use Chisholm's model but argue to include income tax in asset replacement. Kay and Rister (1976) argue that Perrin assumed all expenses in his model and this included tax expenses. The assumption that sufficient information and results can be concluded without added tax expenses is not realistic in the current nature of increased tax incentives for agricultural machinery. Therefore current income tax incentives are needed to more accurately reflect farmer's decisions.

Perrin adapted his model to measure optimal replacement when replacing an asset with a technologically improved asset. Perrin's model provides a first-order maximizing condition as:

$$R_n + M'_n = \rho[M_n + C(0, s, \infty)] \tag{2-1}$$

Where n is the age of the asset that is tested for replacement, R is residual earnings (revenue minus costs), M' is marginal asset value or change in asset value [$R(c) + M'(c)$ is marginal revenue of keeping the conventional system], M is salvage value, ρ equals ln(1+r) which is annual growth rate at discount rate r (because this is a continuous time model), C is the present value of residual earnings from the new technology from age zero to it's optimal age of replacement (s) assuming perpetual replacements. This model states that the present asset should be kept until the year in which its marginal revenue equals the revenue from the capitalized value of the series of replacement machinery plus interest on the sale of the asset. This model is for maximizing profit when an asset generates positive returns. However, the same basic model can be used to minimize cost when the asset generates negative cash flow. The condition will be for costs, the optimal replacement year being the year in which the minimum costs for the present asset equals marginal opportunity costs (because costs are negative returns).

Kisapanidis, Mygdokos, and Gemtos (2005) have done work on optimal self replacement time for cotton harvesters in Greece. Their work uses four different models relevant to this thesis and shows what different factors are included in asset replacement decisions. The first equation states that the optimal year for asset replacement is the year in which accumulated depreciation is equal to the accumulated annual repair and maintenance cost.

$$D = R \,\&\, M \tag{2-2}$$

In this model *D* is accumulated annual depreciation and *R&M* is accumulated annual repair and maintenance costs. In the paper, they found the 14th year is the optimal replacement year for a cotton harvester using this method. The second method for optimal replacement is when accumulated depreciation, accumulated repairs and maintenance costs per machine hour or acre harvested is at a minimum.

$$\frac{D + R \,\&\, M}{H \,/\, Acres} = Minimum \tag{2-3}$$

In this model *H* is accumulated machine hours and *Acres* is accumulated acres harvested. For this model, again, the 14th year was found to be optimal. The third method gave the optimal year for replacement as the year in which the initial value of the asset and its accumulated repair and maintenance per machine hour or acre harvested is at a minimum.

$$\frac{IV + R\,\&\,M}{H\,/\,Acres} = Minimum \tag{2-4}$$

In this model IV is the initial value of the asset. The 17th year was found to be optimal for this model. The fourth method they use states that the optimal year of replacement is the year where the accumulated average total cost per machine hour is at a minimum.

$$ATC = \frac{TC}{H} = Minimum \tag{2-5}$$

In this model ATC is accumulated average total cost and TC is accumulated total cost. The 15th year was found to be optimal with this method. For the purposes of this paper costs will be constant each year except for R&M and depreciation.

The work done with the Greek cotton harvesters shows that with various optimal replacement methods tested, the optimal year is much higher than observed in practice. The work showed several different ways to test single asset replacement and they can be compared to each other (although this paper will only test one). Also, there is the question of what impact, if any, the addition of the extra assets (the system) makes to the replacement schedule of a large asset.

The hypothesis for this problem is that by adding the asset values of the boll buggy and module builder with the conventional harvester, the optimal age of replacement of the conventional system could be different than replacing just the conventional harvester in isolation. The theory is that by including the additional assets, the replacement schedule of the conventional harvester will be different. If the supporting assets are newer, the replacement of the old system will be delayed. If the supporting assets are older (relative to the harvester) then replacement of the old system will be sooner.

Methods

Each asset being studied in the harvesting systems must first be tested to find optimal self-replacement schedules. These assets will be tested with a method derived from Perrin, examining the present value of cash flows. The present value of cash flows is denoted by V_a for a discrete case and is calculated by:

$$V_a = \underbrace{\frac{1}{1-(1+i)^{-a}}}_{\#1}\overbrace{\left[\sum_{n=1}^{a}\frac{R_n}{\underbrace{(1+i)^n}_{\#2}} + \frac{M_a}{\underbrace{(1+i)^a}_{\#3}} - \underbrace{M_0}_{\#4}\right]}^{\textit{Costs}} \tag{2-6}$$

Where i is the interest rate, R_n is the costs in year n for the conventional system (repair and maintenance (R&M), labor, fuel, module protection and tax consideration), M_a is the asset value at the end of year a, M_0 is the asset's purchase price and a is the asset's age in the year of replacement. The equation should be solved for each year that could be considered. Other than the salvage value for the asset, each input is a cost; this will result in V_a being negative, signaling negative cash flows.

Table 2.1 shows an example of calculated cash flows. It should be noted that V_a reaches a maximum at age seven in the example. This is because yearly costs decrease because of higher depreciation early in the asset's life even though repair and maintenance costs are increasing each year. Because of the increasing marginal rate of R&M and the decreasing marginal rate of depreciation, eventually R&M increases to the point where total costs start an increasing trend. Therefore the total costs will reach a minimum. If this asset was being replaced with an identical asset, the end of year seven would be the optimal replacement year. The year of maximum present value of future cost streams for each asset will be the year in which that asset should be replaced.

Table 2.1 Finding Present Value of Perpetual Costs

Age	Value	Repairs	Rep. Disc	#1	#2	#3	#4	Costs	V_a
0	3000								
1	2307	-100	-91	11.00	-91	2097	3000	-994	-10930
2	1773	-200	-165	5.76	-256	1465	3000	-1791	-10319
3	1362	-320	-240	4.02	-497	1023	3000	-2473	-9946
4	1047	-420	-287	3.15	-783	715	3000	-3068	-9680
5	804	-520	-323	2.64	-1106	499	3000	-3607	-9516
6	618	-640	-361	2.30	-1468	349	3000	-4119	-9457
7	474	-720	-369	2.05	-1837	243	3000	-4594	-9436
8	366	-820	-383	1.87	-2220	171	3000	-5049	-9464

$3000 Hypothetical Asset with Hypothetical Repairs and Discount Rate of 0.1

Appendix A compiles the tables for each asset at the 1800 acreage level. Each table shows the present value of perpetual cash flows for each year in the asset's life. The year the value is at a maximum is the optimal year for replacement. Purchase price, R&M, depreciation of value, labor, fuel, module protection and tax consideration costs are all included in equation 2.6 for the present value of perpetual costs of each asset in the replacement decision. Each one of these values are calculated or derived from different techniques. The R&M costs are derived from the American Society of Agricultural and Biological Engineer's Standards, ASAE D497.6.

$$CRM = RF1 * P * \left[\frac{H}{1000}\right]^{RF2} \tag{2-7}$$

In this equation *CRM* is accumulated R&M costs, *RF1 and RF2* are repair factors given in ASAE Standards D497.6 Table 3 (2009) in Appendix Table B.1, *P* is list price in current dollars, and *H* is accumulated machine hours. This equation is based on number of machine hours and therefore will allow the model to be tested for different acreage levels. The ASAE standards provide repair factor numbers for the harvesters and the tractors involved. Repair factors for the boll buggy and module builder are not given, so the repair factors for the closest resembling piece of equipment available is used to give a good estimation of repair and maintenance costs for those machines. A forage wagon is the closest resembling machine in the ASAE standards. A boll buggy and a module builder are pulled behind a tractor, have storage capacity and moving parts. The repair factors given for a forage wagon should give a good estimation of expected R&M cost for the boll buggy and module builder.

The depreciation for the assets in a given year will come from a remaining value equation from American Society of Agricultural Engineer's standards, ASAE D497.6. The equation is calculated with coefficients estimated based on used farm equipment sales at auction from 1984 to 1993.

$$RV = 100[C_1 - C_2(n^{0.5}) - C_3(H^{0.5})]^2 \tag{2-8}$$

In equation 2.8, *RV* is remaining value as a percent of list price, C_i is a remaining value coefficient given in of the ASAE Standards D497.6 Table 4 (2009) in Appendix Table B.2, *H* is annual machine hours and *n* is the age of the machine. Additionally, costs and depreciation schedules will be discounted with a general interest rate. The USDA's Farm Service Agency website has provided a list of interest rates for farm lending effective June 1, 2010. With these rates and private lending rates (First South Farm Credit), an average of 5% was decided on as the appropriate rate to use to discount costs over time. The marginal income tax rate of 28% was decided on as a good indicator of a typical farm income tax bracket. This 28% is not the average tax liabilities of the farm but only the marginal tax bracket that the last dollar of taxable income falls into.

Tax incentives are a major part of farm financing. IRS Publication 225 gives deductions for a 5 year Modified Accelerated Cost Recovery System (MACRS) 150% Declining Balance Method (Half-Year Convention) with percentage rates of 15, 25.5, 17.85, 16.66, 16.66 and 8.33 in Table 7-2. These rates are used for all the assets in the model as the "tax cost." These rates act as a tax shield for farmers that lower their out of pocket expenses.

For MACRS, the half-year convention is applied. This explains six years of percentage rates for a five year system. Only half of the first year's depreciation for an asset is applied in the first year. The asset is treated like it was placed in service on July 1st of the first year. This half-year is followed by 4 years of full depreciation followed by another half-year. This fulfills the five year depreciation recovery.

Other costs that will go into the model for the assets are hand labor, operator labor, fuel and module creation costs. The labor and fuel costs are from Willcutt and Barnes (2008) and the module protection costs (tarps or wraps needed for the module along with cotton lost in the filed due to the module type) are from budgeting with Barnes et al. (2009). Table 2.2 lists the assets and their associated costs.

For the conventional system, each asset involved will be combined together into one system (or testable asset). The different aspects of the self-replacement model, cost, depreciation, and replacement value will be combined to form the system. When replacement with the new technology is tested, the outcome will show that replacement should be done in fewer years than self replacement if the new technology is a cost-effective option and that the ages of the assets will influence replacement age.

Table 2.2 Machine Costs of Cotton Harvesting Operation

		Harvesters					
Cost	Measure	Conv	Deere	Case IH	Boll Buggy	M Builder	Tractors
Labor							
Operator	$/Hour	10.25	10.25	10.25	10.25	7.31	10.25
Labor Hand	$/Hour			7.31		7.31	
Fuel	Gal/Mach Hr*	10.53	17.69	12.97			18.00
Module	$/Acre	3.38	15.00	4.47			

*Gallons per Machine Hour

Perrin's model for replacement with a technologically improved asset will be modified for a discrete case and to accommodate the use of costs as negative revenue.

$$\overbrace{\sum_{i,j} R_{ij(a+1)} + \sum_{i}[M_{i(a+1)} - M_{i(a)}]}^{LHS} = \overbrace{r[\sum_{i} M_{i(a)} + C(0,s,\infty)]}^{RHS} \qquad (2\text{-}9)$$

In this equation *R* is the value of cost *j*, where *j* is a cost input, R&M, fuel, labor, tarp, tax for asset *i*; *i* is an asset used in cotton harvesting with *a* being the number of years of use for the asset. Years of use allows for the system to be tested at the end of a harvest season when decisions are being made for the next harvest season. *M* is the value of asset *i* in the year tested and C is the present value of residual earnings from the new technology from age zero to it's optimal age of replacement (s) assuming perpetual replacements.

LHS equals the left hand side of the equation and is the cost of keeping the system one more year. *RHS* equals right hand side of the equation and is the cost of replacing the conventional system with either the John Deere or Case IH systems. The LHS of the equation, cost of the conventional system in year a+1 along with its depreciation costs for that year, are compared with the RHS of the equation. The RHS is the adjusted sum of each asset's salvage value in the conventional system and the present value of cash flows for the new technology system with perpetual replacement (this cash flow is V_a for the new harvester and associated tractor for their appropriate year of replacement in the self replacement model). When data for each asset are inputted and the equation sides compared, a decision can be made about replacement. If the LHS > RHS, then the conventional system's costs are more and should be replaced in the year tested. If LHS < RHS, then keep the conventional system one more year and test again with each asset having one more year of use.

The equation can be calculated for every possibility of combinations of ages of the assets. For example a four year old harvester can be paired with a boll buggy, module builder and tractors that are all around their ages of replacement or that are all brand new. The differences in the values of the associated machines because of their ages will affect the decision of system replacement.

Also, different intensities will be tested; will the assets be asked to harvest 1400, 1800 or 2200 acres? These will show variability in the replacement schedule as the system is asked to perform more. The resulting numbers from the equation will allow for testing of specific inputs from the assets and the resulting answer of replacement or not. In other words, a farmer with varying ages of assets can look for his individual case and determine if replacement is more beneficial immediately or in the future. Different combinations of harvester ages and assets ages that will be beneficial for replacement will be found. When all the combinations are tested, an age for the conventional harvester will be found where no matter what the ages of the assets are; replacement with the new system is beneficial. At the very minimum, replacement should always occur on or before all the assets, including the harvester, in the old system reach their max lives in a self replacement decision

Results

The present value equation was used to find the optimal replacement schedule and resulting value of perpetual costs for each machine used in cotton harvesting. The decision for the year of optimal replacement was the year where the present value of costs was a minimum, this is the “MIN” technique. The farmer will need to replace that asset at the end of its optimal year and then continue this replacement cycle perpetually. The value is the perpetual cost of replacement. The costs for each asset were added together to “form” a system and have a perpetual cost of using a certain system.

When the harvesters’ optimum replacement years were calculated and observed, they seemed to differ greatly from what was being observed on farms as far as replacement timing (personal conversations with some farmers provide such extreme measures as to replacement every year or two because of warranty issues). For example, the new John Deere harvester at 1400 acres showed an optimal year of replacement at year 18. This long life is not observed outside of these calculations. To correct the replacement age to better reflect real world occurrences, a “5% rule” was adopted. The present value of costs decreased greatly in the first couple years of use but seemed to “flatten-out” before reaching the optimum replacement age at the minimum. There was very little benefit added to keeping the machine over the last part of its replacement cycle but possibly more to lose if keeping a more unreliable, older machine. Although R&M costs reflect the cost of repairing a broken machine, there is no measure for the loss of time spent in the machine shop being repaired. The risk of an older, less reliable machine may influence a farmer to purchase a new machine earlier.

The 5% rule was put into place to reflect the risk of an older machine verses the lack of benefit from keeping it. It moved the optimum replacement age of the harvester to the year were the present value was within 5% of the optimal value. The John Deere machine now was to be replaced at every 9 years. So nine years of additional use would have only grossed 5% more benefit while giving the farmer the costs and risks of reliability of an older machine. Figure 2.1 illustrates the “flattening-out” of the curve with little benefit after year 9 and max at year 18. Table 2.3 gives the year of optimal replacement for each harvester at each acreage level under the optimal and 5% measure technique

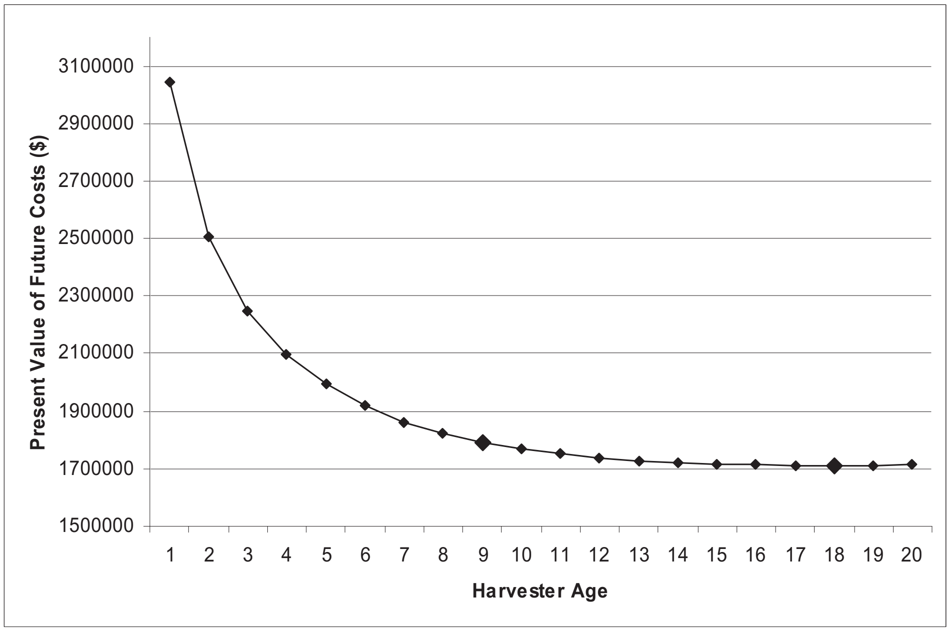

Figure 2.1 Perpetual Cost of The New John Deere Harvester at 1400 Acres

Table 2.3 Optimal Replacement Year for Harvesters with MIN and 5% Techniques

	1400		1800		2200	
	MIN	5%	MIN	5%	MIN	5%
Conventional	14	8	10	6	7	5
John Deere	18	9	12	7	9	5
Case IH	14	8	10	6	7	5

The present values and optimal ages of replacement for the machine were calculated for 1400, 1800 and 2200 acres and are in Tables 2.4, 2.5 and 2.6, respectively. It should be noted that only a fraction of the tractors' total use goes towards harvesting; therefore only a fraction of the tractors' costs are shown. The tables also show what the systems' costs would be when the harvester is measured consistently with the other machines or when the 5% rule is used.

Table 2.4 Present Value of Costs ($) of Perpetual Replacement, 1400 Acres

1400 Acres **Machine**	**Year**	**Present Value** **5%**	**Year**	**Present Value** **MIN**
Conventional	8	1,195,854	14	1,146,672
Boll Buggy	14	56,377	14	56,377
Module Builder	14	135,497	14	135,497
Tractor 1	11	304,792	11	304,792
Tractor 1	11	304,792	11	304,792
	System	**1,997,312**	**System**	**1,948,130**
John Deere	9	1,791,144	18	1,711,139
Tractor 2	11	95,719	11	95,719
	System	**1,886,863**	**System**	**1,806,858**
Case IH	8	1,516,871	14	1,455,560
	System	**1,516,871**	**System**	**1,455,560**

Table 2.5 Present Value of Costs ($) of Perpetual Replacement, 1800 Acres

1800 Acres **Machine**	**Year**	**Present Value** **5%**	**Year**	**Present Value** **MIN**
Conventional	6	1,461,203	10	1,413,284
Boll Buggy	9	68,390	9	68,390
Module Builder	9	168,944	9	168,944
Tractor 1	10	390,568	10	390,568
Tractor 1	10	390,568	10	390,568
	System	**2,479,672**	**System**	**2,431,753**
John Deere	7	2,192,799	12	2,124,786
Tractor 2	10	122,539	10	122,539
	System	**2,315,338**	**System**	**2,247,325**
Case IH	6	1,855,116	10	1,795,379
	System	**1,855,116**	**System**	**1,795,379**

Table 2.6 Present Value of Costs ($) of Perpetual Replacement, 2200 Acres

2200 Acres **Machine**	**Year**	**Present Value** **5%**	**Year**	**Present Value** **MIN**
Conventional	5	1,711,760	7	1,674,150
Boll Buggy	7	79,827	7	79,827
Module Builder	7	201,649	7	201,649
Tractor 1	9	475,941	9	475,941
Tractor 1	9	475,941	9	475,941
	System	**2,945,119**	**System**	**2,907,509**
John Deere	5	2,628,435	9	2,528,863
Tractor 2	9	149,197	9	149,197
	System	**2,777,632**	**System**	**2,678,060**
Case IH	5	2,174,921	7	2,128,036
	System	**2,174,921**	**System**	**2,128,036**

Results clearly show that the larger acreage (and thus use) results in a faster replacement cycle for all machines. Again, the “MIN” harvesters’ replacement cycles are longer but the present value makes it cheaper to operate over that time span perpetually. The system values for the John Deere harvesting system and the Case IH harvesting system are both less expensive to operate than the conventional system. This is the first step in setting up the system replacement with new technology. Because the new systems are cheaper to operate over time, farmers will ultimately switch at some point, but when is that point?

To stay consistent with the costs of the other assets, the harvesters’ present value of cost and associated replacement age will be measured using the “MIN” rule for the new technology replacement. Equation 2.9 is used to find the time when it is economically feasible for a farmer to switch from the conventional system to a new systems. Because of the long life cycle of the machines there are many scenarios that can be tested. For example, the 1400 acreage for the conventional harvester, boll buggy, module builder, and two tractors have optimum replacement years of 8, 14, 14, and 11 respectively. If every different combination of ages for assets were tested it would give 189,728 different scenarios (8x14x14x11=189,728).

To decrease the number of scenarios, all the machines except the harvester were given only general ages. The harvester, being the asset likely to have the highest cost impact, is tested for every year. Table 2.7, 2.8 and 2.9 show the different scenarios at the 1400, 1800 and 2200 acreage level respectively. They show the cost of keeping the conventional harvester one more year at each age in its replacement cycle matched up with assets that are young, medium, older, and replacement age. The tables also show the opportunity values of switching to the new systems. The different scenarios show the replacement decision that is most beneficial, either replace, "Yes" or keep, "No."

Using the generalized age technique to reduce the number of calculations allowed for the results (i.e., from the different scenarios of Equation 2.9) to be graphed. Figure 2.2 plots the costs of keeping the conventional system (LHS) each year of a harvester's life for the different assets age groups at the 1400 acreage level. Figure 2.3 plots the opportunity values of switching to the John Deere new technology (JD RHS) for a farmer at the different asset groups and the 1400 acreage level. For Figure 2.2 and 2.3, as the assets increase in age, the cost curve is shifted upward.

Table 2.7 Replacement of Conventional Systems with New Systems, 1400 Acres

Associated Asset's Age	Cost of Conv System Next Year	Opportunity Value of		Replace With JD ?	Replace With Case ?	Harvestor Age
		JD System	Case IH System			
Young						
	82,547	73,965	56,400	Yes	Yes	1
	77,251	76,733	59,168	Yes	Yes	2
	75,790	78,685	61,121	No	Yes	3
	75,748	80,358	62,793	No	Yes	4
	76,397	81,890	64,325	No	Yes	5
	77,433	82,897	65,332	No	Yes	6
	78,706	83,404	65,839	No	Yes	7
	80,133	83,850	66,286	No	Yes	8
	81,662	84,248	66,683	No	Yes	9
	83,263	84,605	67,040	No	Yes	10
	84,913	84,927	67,362	No	Yes	11
	86,599	85,219	67,654	Yes	Yes	**12**
	88,310	85,484	67,919	Yes	Yes	13
	90,038	85,726	68,161	Yes	Yes	14
Medium						
	83,566	74,799	57,234	Yes	Yes	1
	78,270	77,566	60,002	Yes	Yes	2
	76,809	79,519	61,954	No	Yes	3
	76,767	81,192	63,627	No	Yes	4
	77,415	82,724	65,159	No	Yes	5
	78,452	83,731	66,166	No	Yes	6
	79,725	84,238	66,673	No	Yes	7
	81,152	84,684	67,119	No	Yes	8
	82,681	85,082	67,517	No	Yes	9
	84,282	85,439	67,874	No	Yes	10
	85,932	85,761	68,196	Yes	Yes	**11**
	87,618	86,053	68,488	Yes	Yes	12
	89,329	86,318	68,753	Yes	Yes	13
	91,057	86,560	68,995	Yes	Yes	14
Older						
	85,488	75,207	57,642	Yes	Yes	1
	80,192	77,974	60,409	Yes	Yes	2
	78,731	79,927	62,362	No	Yes	3
	78,688	81,600	64,035	No	Yes	4
	79,337	83,132	65,567	No	Yes	5
	80,373	84,139	66,574	No	Yes	6
	81,646	84,646	67,081	No	Yes	7
	83,073	85,092	67,527	No	Yes	8
	84,603	85,490	67,925	No	Yes	9
	86,203	85,847	68,282	Yes	Yes	**10**
	87,854	86,169	68,604	Yes	Yes	11
	89,539	86,461	68,896	Yes	Yes	12
	91,250	86,726	69,161	Yes	Yes	13
	92,978	86,967	69,403	Yes	Yes	14
Replacement Age						
	87,541	75,459	57,895	Yes	Yes	1
	82,245	78,227	60,662	Yes	Yes	2
	80,784	80,180	62,615	Yes	Yes	3
	80,741	81,852	64,287	No	Yes	4
	81,390	83,385	65,820	No	Yes	5
	82,426	84,392	66,827	No	Yes	6
	83,699	84,898	67,333	No	Yes	7
	85,126	85,345	67,780	No	Yes	8
	86,656	85,743	68,178	Yes	Yes	**9**
	88,256	86,100	68,535	Yes	Yes	10
	89,907	86,422	68,857	Yes	Yes	11
	91,592	86,713	69,148	Yes	Yes	12
	93,303	86,978	69,414	Yes	Yes	13
	95,031	87,220	69,655	Yes	Yes	14

All Numbers in $, Bold Number Max Age to Keep

Table 2.8 Replacement of Conventional Systems with New Systems, 1800 Acres

Associated Asset's Age	Cost of Conv System Next Year	Opportunity Value of		Replace With JD ?	Replace With Case ?	Harvestor Age
		JD System	Case IH System			
Young						
	98,622	95,427	72,830	Yes	Yes	1
	95,279	98,167	75,570	No	Yes	2
	95,562	100,098	77,501	No	Yes	3
	97,143	101,753	79,156	No	Yes	4
	99,334	103,269	80,672	No	Yes	5
	101,850	104,262	81,665	No	Yes	6
	104,554	104,755	82,158	No	Yes	7
	107,371	105,190	82,592	Yes	Yes	**8**
	110,256	105,576	82,979	Yes	Yes	9
	113,182	105,922	83,325	Yes	Yes	10
Medium						
	99,699	96,405	73,808	Yes	Yes	1
	96,356	99,145	76,548	No	Yes	2
	96,638	101,076	78,479	No	Yes	3
	98,220	102,731	80,133	No	Yes	4
	100,410	104,247	81,650	No	Yes	5
	102,927	105,240	82,643	No	Yes	6
	105,631	105,733	83,136	No	Yes	7
	108,447	106,168	83,570	Yes	Yes	**8**
	111,332	106,554	83,957	Yes	Yes	9
	114,259	106,900	84,302	Yes	Yes	10
Older						
	101,324	97,105	74,508	Yes	Yes	1
	97,981	99,845	77,248	No	Yes	2
	98,264	101,776	79,179	No	Yes	3
	99,846	103,431	80,833	No	Yes	4
	102,036	104,947	82,350	No	Yes	5
	104,552	105,940	83,343	No	Yes	6
	107,256	106,433	83,836	Yes	Yes	**7**
	110,073	106,868	84,270	Yes	Yes	8
	112,958	107,254	84,657	Yes	Yes	9
	115,884	107,600	85,002	Yes	Yes	10
Replacement Age						
	104,602	97,484	74,886	Yes	Yes	1
	101,259	100,223	77,626	Yes	Yes	2
	101,542	102,155	79,558	No	Yes	3
	103,123	103,809	81,212	No	Yes	4
	105,314	105,326	82,728	No	Yes	5
	107,830	106,319	83,721	Yes	Yes	**6**
	110,534	106,812	84,215	Yes	Yes	7
	113,351	107,246	84,649	Yes	Yes	8
	116,236	107,632	85,035	Yes	Yes	9
	119,162	107,978	85,381	Yes	Yes	10

All Numbers in $, Bold Number Max Age to Keep

Table 2.9 Replacement of Conventional Systems with New Systems, 2200 Acres

Associated Asset's Age	Cost of Conv System Next Year	Opportunity JD System	Value of Case IH System	Replace With JD ?	Replace With Case ?	Harvestor Age
Young						
	115,694	116,980	89,478	No	Yes	1
	114,647	119,694	92,193	No	Yes	2
	116,994	121,607	94,106	No	Yes	3
	120,505	123,245	95,744	No	Yes	4
	124,530	124,747	97,246	No	Yes	5
	128,808	125,727	98,226	Yes	Yes	**6**
	133,218	126,209	98,708	Yes	Yes	7
Medium						
	118,086	118,324	90,823	No	Yes	1
	117,040	121,039	93,537	No	Yes	2
	119,387	122,951	95,450	No	Yes	3
	122,897	124,589	97,088	No	Yes	4
	126,922	126,091	98,590	Yes	Yes	**5**
	131,201	127,072	99,570	Yes	Yes	6
	135,610	127,553	100,052	Yes	Yes	7
Older						
	120,532	118,883	91,382	Yes	Yes	1
	119,485	121,598	94,097	No	Yes	2
	121,832	123,510	96,009	No	Yes	3
	125,342	125,149	97,647	Yes	Yes	**4**
	129,367	126,651	99,149	Yes	Yes	5
	133,646	127,631	100,129	Yes	Yes	6
	138,055	128,112	100,611	Yes	Yes	7
Replacement Age						
	122,542	119,070	91,569	Yes	Yes	1
	121,495	121,785	94,284	No	Yes	2
	123,842	123,697	96,196	Yes	Yes	**3**
	127,352	125,336	97,834	Yes	Yes	4
	131,377	126,838	99,336	Yes	Yes	5
	135,656	127,818	100,317	Yes	Yes	6
	140,065	128,299	100,798	Yes	Yes	7

All Numbers in $, Bold Number Max Age to Keep

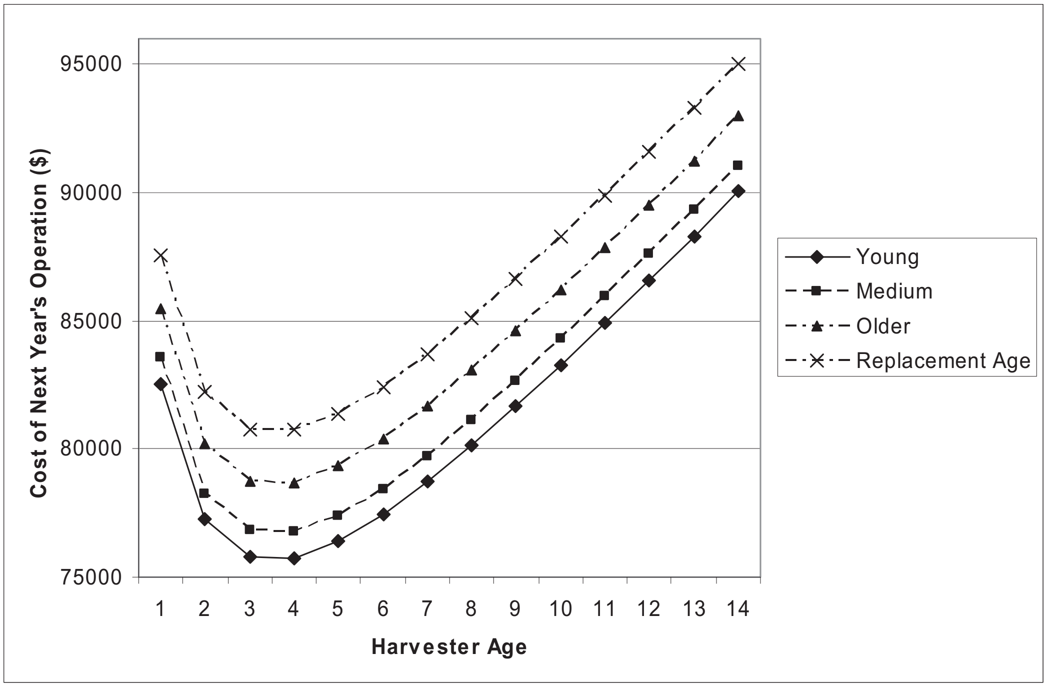

Figure 2.2 Total Conventional System's Next Year's Costs, 1400 Acres

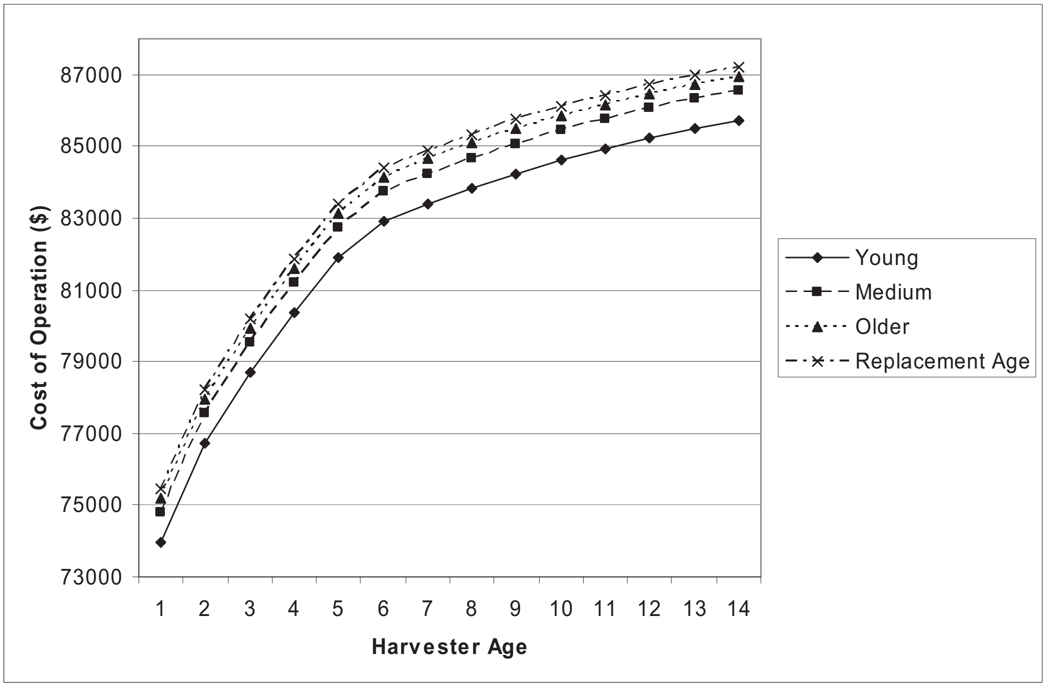

Figure 2.3 Opportunity Values of John Deere System, 1400 Acres

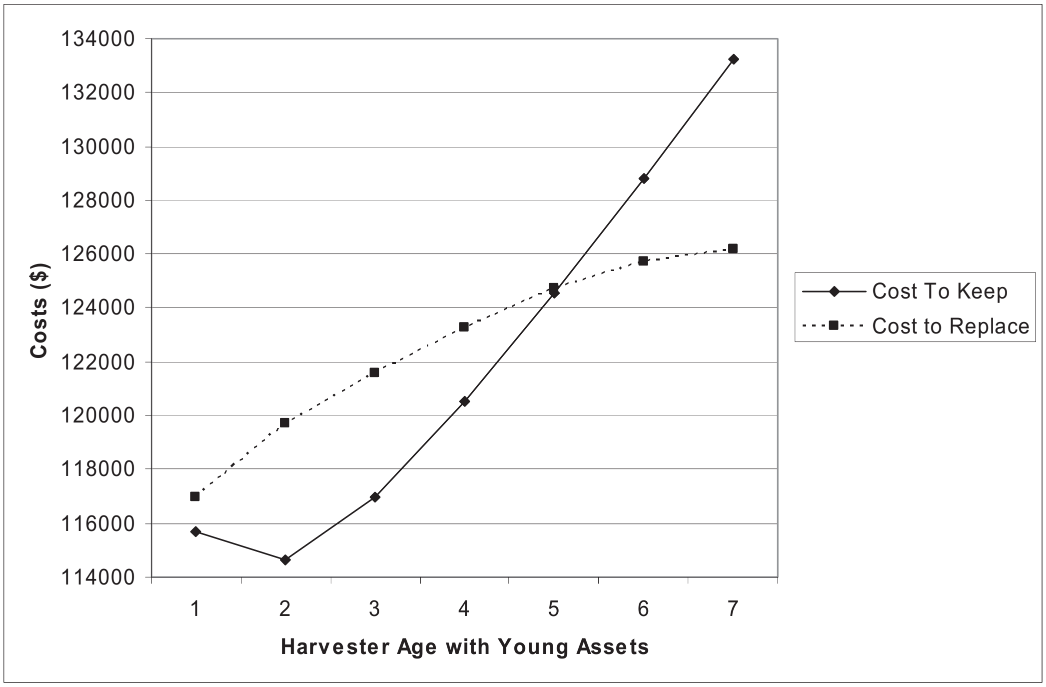

Figure 2.4 Conventional System's Replacement Decision with John Deere System When Associated Assets are Young, 2200 Acres

Figure 2.4 takes an individual case of a harvester with young associated assets at 2200 acres and plots the cost of keeping the system verses the cost of replacing with the John Deere System. A conventional harvester more than five years old with younger assets would benefit more by switching to the new technology because the cost of keeping the conventional system is more than switching to the new technology. The intersection point is somewhere in year five. Because of the varying nature of the inputs, an individual farmer will need to look at the inputs of the farm in question. Small variances such as labor wages, fuel prices, interest rate changes, tax changes or different machine costs could push the intersection point year from five up to six or back to four.

Table 2.10 shows the age of the harvester when replacement is beneficial for each set of assets at each acreage level. A trend can be seen that shows the harvesting system should be replaced at an earlier age when asked to harvest more acres. Also, it shows that the age of the associated assets has an impact on the timing of the harvesting system.

Table 2.10 Harvester Age for Optimal Replacement with John Deere System with Varying Asset Ages and Acreage

	Acreage		
Assets	1400	1800	2200
Young	12	8	6
Meduim	11	8	5
Older	10	7	4
Replacement Age	9	6	3

The decision to replace a conventional system of any age with a Case IH harvester was found to be optimal. The Case IH machine was always cheaper than the conventional system. Some of the decisions suggested to replace a conventional harvester when the harvester was newer, it then said to keep the system for a number of years as the harvester ages, then suggested replacement again at an older age. This was actually where the objective function was being minimized, which would not be a good decision for a farmer. Therefore, these first years were ignored, as a trend could clearly be seen for the maximizing condition.

Conclusions

Chisholm (1974) and Kay and Rister (1976) both found that the resulting optimum replacement age of machines was often longer than what was being observed in the field. This was also an observation of this work. While it can be comprehendible that the boll buggy, module builder and even tractors be kept more than ten years, it is an unlikely case for harvesters that are bought new. This was the reason the 5% rule was adopted. There may be a reliability factor that farmers take into account when harvester purchasing decisions are made. This factor is hard to quantify. There is, however, the assumption that an older machine will have reliability issues that could cost farmers and that in the last few years there is relatively little gain in benefits as far as cost of keeping the harvester an extra year.

The tractor costs associated with the conventional system for the boll buggy and module builder are major contributing factors for the total present value of costs for the system. These costs are attributed to the overall harvesting cost and are significant but tractors would not be eliminated from the farm with the purchase of the new harvesters. The present value of costs of the different systems absolutely shows that eventual conversion to the new technology will benefit farmers. There are some cases, however, where keeping the conventional system years longer may benefit farmers in the short run. Another observation was that as the harvesting system is asked to harvest increasingly more acres in a season, the replacement decision moves in the direction of replacing with the new system earlier. This is because the old system's assets' costs are greatly increased with increased use.

On a small scale, farmers could use the model to decide in what year is most beneficial for them to replace equipment with newer technology. On a large scale, the optimum conversion age of the harvesting systems with assets having varying machine lives can provide an idea of an industry-wide conversion. The mechanized harvester, when initially introduced, took 23 years to be the standard for the industry. That conversion was a replacement of labor with machinery. This conversion will be replacing a system of machinery designed for a production purpose with a system of less machinery performing the same task. It will be interesting to compare the conversion to machine operations with the conversion to fewer machines when the new harvesters are completely phased in.

This work could also benefit new studies into agricultural asset replacement when assets perform together. As previously stated, agriculture literature does not provide much in multiple asset replacement. As technological advances increase, this thesis can provide a basis for others to continue the research into production systems replacement when new ways for producing the same commodity arise.

There are many important extensions to the research that will not be researched in this thesis but are worth mentioning. An industry adoption rate could be developed from a replacement model if the size of farm is included in the replacement decision. Also, developing a product demand function could be done using the aspects of real farm data. The expansion of this research can be an objective look at this new technology's impact and worth to the cotton industry and manufacturing of cotton harvesting equipment.

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CHAPTER III

CALCULATING COST SAVINGS PER ACRE OF ON-BOARD MODULE-BUILDING COTTON HARVESTERS WHEN WEEKLY HARVESTABLE DAYS ARE STOCHASTIC

The new harvesters that build the modules on the machine save time by reducing unloading time. John Deere touts a “non-stop” harvest while the Case IH machine has to adjust its module unloading according to field size and yield. Row length and yield affect the creation of completed modules for the Case IH machine. Thus, sometimes the operator has a choice between unloading smaller modules or turning and dead heading from the middle of the field when a module is complete, which decreases field efficiency. There is also data from Willcutt (2009) that suggests that performance rate (acres/hr) is increased not only by a reduction in unloading time but also because the new machines harvest cotton with the same picking efficiency at higher speeds. These two aspects increase the total number of acres that a new harvester is capable of handling in a season. This allows the new machine the ability to harvest a fixed number of acres sooner in a season. Thus, the new on-board harvesters can either harvest more acres in a given harvest window or can harvest a given number of acres quicker.

Farmers can make the decision to plant fewer acres to assure complete harvest in the harvest time, but run the risk of high per-acre costs. The costs are higher because the fixed costs are spread over fewer acres. They could also decide to stretch their fixed costs over more acres but run a risk of greater harvest costs as the season progresses or a risk of not getting all acres harvested. Each harvester, because of its performance rate, has a maximum number of acres that can be harvested in a given number of yearly harvest hours.

A budget was created to determine cost per acre for each machine. The budget was broken down into sections of factors affecting all systems, specific factors per system and machinery costs. The inputs included in each section of the budget are listed in Tables 3.1, 3.2 and 3.3. The cost per acre for each machine changes as the number of acres varies, as acreage harvested increases fixed costs are spread over more acres. The focus of this second essay will expand on the budgeted numbers when a stochastic element is introduced and seek to quantify extra costs associated with longer harvests due to lower performance rates and therefore any savings from a higher performance rate.

Table 3.1 Factors Affecting Both Systems in Budget for Costing of Machines per Acre

Factors Affecting Both Systems		
Input		Measure
Interest rate		%
Diesel fuel	-	$/gallon
Cotton yield (lbs of lint)	-	lb/acre
% Lint (turnout)	-	%
% Seed	-	%
Cotton price (lint)	-	$/lb
Cottonseed price	-	$/ton
Annual use of module truck	-	Loads/yr
Average hauling distance	-	truck
Gin use	-	Bales/yr
Cost to operate gin	-	$/hr

Table 3.2 Specific Factors in Budget for Costing of Machines per Acre

Specific Factors Input		Measure
Performance rate	-	Acres/hour
Acres to harvest	-	Acres/year
Module weight	-	pounds
Other labor - price	-	$/hr
Other labor - quantity	-	# of people
Cotton left in the field	-	lb per module
Tarp cost	-	$/tarp
Tarp - uses per year	-	uses/yr
Tarp - life of tarp	-	years
Ginning rate	-	Bales/hr
Extra ginning cost	-	$/hr
Quality discount	-	$/lb
Cotton lost at gin	-	lb of seed cotton per module
Module truck load size	-	Modules/truck
Avg per module truck load	-	hrs/load (roundtrip)
Plactic wrap	-	$/round module
Time to stage JD module	-	Minutes/module

Table 3.3 Machines in Budget

Machinery Involved
Harvester
Boll buggy
Module builder
Tractor for boll buggy
Tractor for module builder
JD bale mover attachment
Tractor for JD mover
Module truck
Special gin equipment

In Mississippi (region used for data) the harvest time for cotton is typically between early to mid September and early November. Agriculture Engineer Herb Willcutt estimates that a conventional harvester will average around 220 machine hours each harvest season (this was also the hours for measure in the constructed budget). Because of precipitation the harvest window needed for these 220 hours varies. The more precipitation, the more real days will be needed to complete harvest.

Once the cotton boll opens, weather elements decrease both quality and quantity of the cotton until it is harvested. Weather elements also keep the harvester out of the field during harvest season. The problem is that because of the uncertainty in precipitation, available weekly harvest days are unknown; therefore farmers can not be sure how long it will take to harvest a set number of acres. A specific number of days is needed for a machine with a certain performance rate to complete harvest of a set number of acres. As precipitation increases the harvest days each week decreases and extends the date of completed harvest. With this uncertainty of length of season comes uncertainty of costs. When harvest days are stochastic, there needs to be an accurate measure of what cost savings are realized by farmers with the new machines with higher performance rates. Ultimately, what are the additional costs, with respect to lower performance rates, of keeping the old system?

Objective

This essay's general objective is to determine extra cost associated with rainfall for each harvesting system with different farm sizes and when harvest days are stochastic. This cost will include costs of quality and quantity loss of cotton from the additional harvest days needed when using conventional machines compared to the new machines. To accomplish this, historical precipitation data for 60+ years along with USDA field working days (harvestable days) data will be used to develop appropriate probability distribution functions for use in a risk simulation model. This will provide a more accurate distribution for harvest days and precipitation amounts to use in the simulations for different farm sizes. The simulated precipitation will be used in quality and quantity loss functions for cotton and calculated according to performance rate and farm size.

Conceptual Framework

As with the first essay there is a tradeoff problem. There are the higher initial costs of the new machines but theoretically higher cost savings from a shorter harvest period because of less cotton loss. Farrell and Ibendahl (2009) looked at optimal acres to be planted for the different harvesters. The simulation used the stochastic nature of harvest days in a season. It treated the season as a time period where a certain number of acres had to be harvested. Equation 3.1 and 3.2 has the decisions for cost per acre calculations if harvest was completed in time or not. If the simulated harvest days allowed for the acres to be completed then the regular cost per acre was used. If the simulated harvest days in the time period did not allow for a complete harvest, then the extra acres were all tagged with a higher per acre cost due to extra labor needed and loss of quality and quantity of cotton. These acres with the higher costs were averaged into the total cost per acre for the farm. To represent the assumption of higher harvesting costs for this model a multiplier of two is used.

$$\text{If } (\widetilde{H} \times R) < A \text{ then } C_{TH} = \frac{C^* \times (\widetilde{H} \times R) + [2(C^*) \times (A - (\widetilde{H} \times R))]}{A} \tag{3-1}$$

$$\text{If } (\widetilde{H} \times R) \geq A \text{ then } C^* \tag{3-2}$$

Where C_{TH} is the total harvest costs per acre, C^* is the cost per acre for all acres harvested in the optimal harvest time period, $\widetilde{H}$ is the season's harvest hours. Harvest hours per season was the variable that was simulated in this work. R is the performance rate of the simulated machine and A is the acres planted for the season for one machine.

The model used cost as a determining factor for the decision of optimal acres. When harvest days are stochastic, each machine for each farm size (1400, 1800, and 2200 acres) had a corresponding acreage level in which cost per acre was lowest. The cost per acre (total cost divided by total acres harvested) averaged in the increased costs of any late season harvesting. These late season costs (a doubling of normal costs) were a rough glimpse at additional cost per acre after optimal harvest time. This provided that a machine capable of a shorter harvest period could decrease costs either by shorter harvest or by spreading the costs over more acres, but these costs were not accurately quantified. For more tangible numbers that economists and farmers both could use, cost functions for cotton loss will be added to the cost per acre of each harvester. There should be a clearer picture of the higher costs of the new machines being worth eliminating some of the risk of increased costs of late season harvesting.

Farrell and Ibendahl (2009) demonstrated with a cost multiplier that acres harvested later in the season increases average costs per acre. But when compared to each other, conventional machines had more “high cost” acres than the new technology, meaning longer harvest periods (due to precipitation) had much more of an effect on the conventional machines. One problem with this paper was the arbitrary cost multiplier of “2”. The loss functions for yield and price of cotton will be added to quantify the losses.

Precipitation has a large impact on the production of cotton, specifically late season production. The number of weekly harvest days are not constant because precipitation affects each day’s harvest chances each week in a season. Farmers risk higher costs from loss of cotton or additional labor when more precipitation decreases harvest days and pushes the harvest season further back. Precipitation not only keeps the harvester out of the field but decreases cotton yield as well as changes the quality of the cotton. When 70% of the cotton bolls are open, defoliant chemical is applied to the field, maturity of the cotton is stopped, and the remaining bolls open. This increases the chance of quantity loss by wind and rain. Therefore, the longer the cotton sits in the field after defoliation, the less revenue a farmer can receive; making cotton loss a cost to farmers.

Along with quantity, precipitation also deteriorates the quality of the cotton of an open boll. The precipitation can have an affect on cotton’s color grade. The degree of reflectance and yellowness are part of cotton’s color grade. Cotton Incorporated defines reflectance as the brightness or dullness of a sample of cotton and yellowness as the degree of color pigmentation. Cotton receives discounts in price for reduction of quality. This decreases revenue from the cotton and therefore acts as a cost. If these machines can harvest the cotton sooner because of higher performance rates it will save farmers these discount costs and they will receive higher prices.

These new machines decrease the risk for farmers of late season harvesting. In Mississippi, as the harvesting season progresses, precipitation increases. This means marginal losses increase later in the season. Temperature is also a factor. Late season freezes act as natural defoliants, so therefore harvesting cotton sooner can help with controlled defoliation.

Theoretically an increase in weekly precipitation causes harvestable days to decrease. But good data are needed to find a relationship between precipitation and harvestable days. This paper seeks to determine if a higher performance rate of an on-board module building cotton harvester will significantly decrease losses per acre of late season harvesting when those costs are quantified with accurate rainfall and therefore harvestable days data. This will be shown as loss per acre for different size farms. The hypothesis for this essay is that when harvest days are stochastic, cotton losses from rainfall is affected relatively more with machines that have lower performance rates.

Methods

The data for harvest days each week in a season are taken from Field Working Days (FWD) reported in USDA's crop progress reports for Mississippi. This source was limited, only providing 10 years of data, seen in Table 3. These data were sufficient to create a probability density function (pdf), but the accuracy was questionable because of the limited years.

Table 3.4 Weekly Field Working Days

Year	Start of Harvest											End of Harvest
2000	6.9	5.5	5.5	5.8	6.4	6	6.7	6.9	6.9	6	2.1	1.7	2
2001	3	2.7	5.7	5.7	6.7	6.7	4.2	5.2	6.1	6.8	6.9	6.9	5.5
2002	6.4	6.6	6.7	4.8	2.3	2.8	0.5	3.9	2.3	2	2	4	5
2003	5.1	4.9	5.9	6.2	5.4	7	4.4	5.6	5.6	6.3	6.5	6.3	
2004	5.5	6.6	4.7	6.5	6.8	5.4	4.2	3.8	4.9	3.1	4.9	3.7	2.5
2005	2.9	6.1	5.8	5	5.6	6.6	6.8	6.8	6.9	6.6	6.5	5.2	4.4
2006	6.2	6.6	5.6	4.8	6	6.8	6.5	1.9	2.1	4	4.1	3.1	6
2007	5.5	6	4.7	5.9	5.5	6.4	6.6	4.7	2	5.9	6.9	5.7	
2008	3.7	1.9	3.1	6.5	6.9	5.7	5.1	5.3	6.5	4.9	3.1	5.7	3.3
2009	5.6	4.7	1.4	0.6	3.3	1.4	1.1	2.8	1.8	5.9	6.1	5.9	5.8

According to USDA Crop Progress Reports in MS. Weeks span from the first week of Septemper to the last week of November

To expand the data points and produce a more reliable pdf, the field working days each week in the 10 year period will be linked to its corresponding weekly precipitation amount. When an estimate of precipitation to field working days is developed into a function, precipitation (which is recorded much further back) will provide an improved distribution from which to draw from and convert to field working days. Historical precipitation data from Stoneville, MS weather station for 60+ years will be used.

Cotton harvest season in the Delta region ranges from 12 to 15 weeks. These weeks from 2000-2009 have corresponding field working days (which is assumed to be days suitable for harvesting). For each one of these weeks, historic measures of precipitation can be found. Logically the more rain each week means the fewer days that are suitable for harvest. The precipitation for a week then will be simulated and from this amount, harvestable days each week can be calculated. These are summed together each week until the sum equals the total days needed for complete harvest for the corresponding farm size and performance rate of the machine.

The field working days are reported by a county agent each week in his weekly report. These are a rough estimate of days that the county agent deemed worthy for field work. A measurable relationship between precipitation and field working days is critical to completing the objectives of this paper. The weekly real field working days are available from NASS crop progress reports. Daily rainfall is also available for each week reported. The actual dates for each crop progress report are matched with the same days of precipitation. This way the weekly field working days have a precipitation level associated with them.

One day of a small rain event may keep the harvester out of the field for one day while one day of a large rain event may keep the harvester out of the field longer depending on soil saturation. Therefore the intensity and duration of rainfall needs to be accounted for when measuring field working days. To accomplish this, regression techniques are used with the number of field working days as the dependent variable. Appendix C shows the different models in which independent variables were tested.

The ten different restricted models in Appendix C were tested using hypothesis tests in Statistical Analysis Software (SAS) (code in Appendix D). They were each tested against the general model (C.1) with the null hypothesis being that eh restricted model provides a better fit of the data. In each case, standard F-test procedures were used to test the null hypothesis; rejection of the null providing evidence in favor of using the general model, and failure to reject the null providing evidence in favor of the restricted model. Estimates of the general and restricted models as well as the p-value for each F-test are presented in Appendix C.

For three of the restricted models (C.5, C.6 and C.11), the null hypothesis failed to be rejected at standard significance levels, which suggests that any of the three models could be used instead of the general model. Model C.5 was chosen from the three because it had a higher R square than the other two and because all the estimated coefficients were significant at a 5% level unlike the other two. For the annual thirteen week harvest season, model C.5 (equation 3.3) was broken down into three periods, first five weeks of the season, next four weeks of the season and the last four weeks of the season. Equation 3.4 provides the estimated coefficients.

$$FWD_t = \beta_0 + \beta_1 P_{1,t} D_t + \beta_2 P_{2,t} D_t + \beta_3 P_{3,t} D_t + \beta_4 P_{1,t} 2Wk_t \\ + \beta_5 P_{2,t} 2Wk_t + \beta_6 P_{3,t} 2Wk_t + \varepsilon_t \tag{3-3}$$

$$FWD_t = 6.598 - 0.422 P_{2,t} D_t - 0.546 P_{2,t} D_t - 0.570 P_{3,t} D_t - 0.249 P_{1,t} 2Wk_t \\ - 0.333 P_{2,t} 2Wk_t - 0.438 P_{3,t} 2Wk_t + \varepsilon_t \tag{3-4}$$

The equation provided different coefficients for rain event days and rainfall for a two week period for each of the three periods. In the equation *FWD* is field working days a week in the t^{th} observation, D_t is the number of rain events in the week of the t^{th} observation, $2Wk_t$ is the total precipitation amount for the t^{th} observation week and the previous week and ε_t is mean zero error term (to capture the combined effects not in the model). $P_{1,t}$ is a dummy variable equal to one if the t^{th} observation is in period one, $P_{2,t}$ is a dummy variable equal to one if the t^{th} observation is in period two, and $P_{3,t}$ is a dummy variable equal to one if the t^{th} observation is in period three. The model has an R square of 0.731 and St Error of 0.909. All the coefficients are significant at a 0.05% level.

Three harvester intensities of 1400 acres, 1800 acres, and 2200 acres will be tested. This is how many acres one machine will be pushed to complete in one season. The different harvesters, according to their performance rates, will need a minimum number of hours to complete each acre amount. These numbers are given in Table 3.5.

Table 3.5 Performance Rate and Resulting Hours Needed to Complete Harvest

Performance Rate	Conv and Case IH 6.5	John Deere 7.5
	Hours Needed	Hours Needed
1400 Acres	215.4	186.7
1800 Acres	276.9	240.0
2200 Acres	338.5	293.9

Performance Rate in Acres per Hour

The Model and Simulation

The simulation is performed with the Simulation and Econometrics to Analyze Risk (Simetar©). The first step is to take the data for each day during harvest season and create an empirical distribution. The empirical distribution is used because it is working with observed data. Rainfall data is full of a large number of zeros, days without rainfall events. An empirical distribution does not try to fit a "fixed" distribution to the data and allows for a random draw-like simulation. This allows the simulation to take many draws of exactly zero instead of many very small draws around zero such as 0.0005. The histograms (twenty bins) for the empirical distributions of each period are in Appendix E. When the simulated results were compared with the real data, the percentage of resulting zeros, or days without a rain event, reflected each other. A count if zero function was used for the real data and the simulated date to achieve this. Also in the model, to count rain events for the *FWD* equation, there contained an "if" function that counted the number of days with any amount of rain, rain events. The days with a rainfall event were given a one and days with no rainfall event were given a zero. The number of days that were given a zero (without a rain event) reflected the number of days in the real data that did not have rain events.

A different distribution will be used for every day during the harvest season. With a different distribution for each day, a draw can be made for every day to simulate a rainfall event for that day that will help reflect changes in the seasonal pattern of rainfall. The resulting daily rainfall events are sum together weekly to form D_t. The amount of each rainfall event is summed together as well; the weekly sum of rainfall along with the previous week is R_t. When these two values are put in the *FWD* equation for their respective period, the number of days that are suitable for harvest is found. *FWD* is the number of days that a harvester is able to get into the field to harvest. Different day lengths are tested (6, 7, and 8 hour days) for variation of harvest length as an element of risk. By multiplying the number of hours of harvest time each day by the FWD each week by the performance rate of the machine, the number of acres harvested by a given machine each week will be found. These numbers are summed together until the intensity size (1400, 1800, or 2200 acres) is reached and harvest is complete for a given season of harvest and rainfall. The machines with the lower performance rate will take more time to complete harvest.

Yield and Price Loss

Yield and grade loss (price discounts) are significant factors for cotton producers to have to deal with once defoliant has been applied. Williford et al.(1995) measured yield and grade effects from rainfall after defoliation using data collected from USDA Delta Research and Extension Center field test plots in Stoneville, Mississippi (the data was taken from the mid 1990’s so more recent data may be beneficial). From this data it was found that yield loss due to rainfall was estimated at 1.8% lbs/acre reduction for every inch of accumulated rain during the defoliation period. The grade loss was on a 100% index with the grade index falling 1.43% for every accumulated inch of rain. Therefore a price discount of that percentage will be given for every accumulated inch of rain during the defoliation period.

In the model, the defoliation period is the two weeks prior to the week being harvested. Because of this, the cotton harvested at the beginning of the week will be completely defoliated. For the yield and price loss, the simulated rainfall accumulated in the two weeks prior to harvest is the amount used for loss calculation. The resulting percentage loss and discount for yield and price are multiplied by the tested yield and price. For these purposed the price of cotton is $0.60/lb and yield is 900lbs/acre. For example one inch of accumulated rainfall during the harvest period would result in a new yield of 883.8lbs/acre and a price of $0.59/lb. Approximately $17.30 in lost revenue per acre for one inch of rain.

Loss per acre will be the same each week for each machine while the machines are simultaneously harvesting. Because of the difference in number of acres harvested each week by each machine, weekly losses will be different. This will give a more accurate estimation for all losses week to week during the season. The loss that will be most relevant for comparison is the extra days needed to complete harvest by the lower performance rate for each farm size. The average cost per acre is calculated from the average of the sums of each week in the harvest season with each corresponding additional loss.

Results

Equation 3.3 was used to find the number of field working days (FWD) each week in the harvest season based on an amount of simulated rainfall for each day in the week. Figure 3.1 shows the mean FWD simulated for each week in the harvest season. Figure 3.1's horizontal axis starts on Week 3 because there is two weeks of defoliation prior to the first week of harvest. There is a slight increase in days early in the season then a gradual decline as the season progresses. According to the National Weather Channel's website, www.weather.com, October is Mississippi's second driest month. They list September with an average precipitation of 3.48 inches, October 3.35 inches, and November 4.66 inches. This decrease in rain from September to October can explain the early season increase.

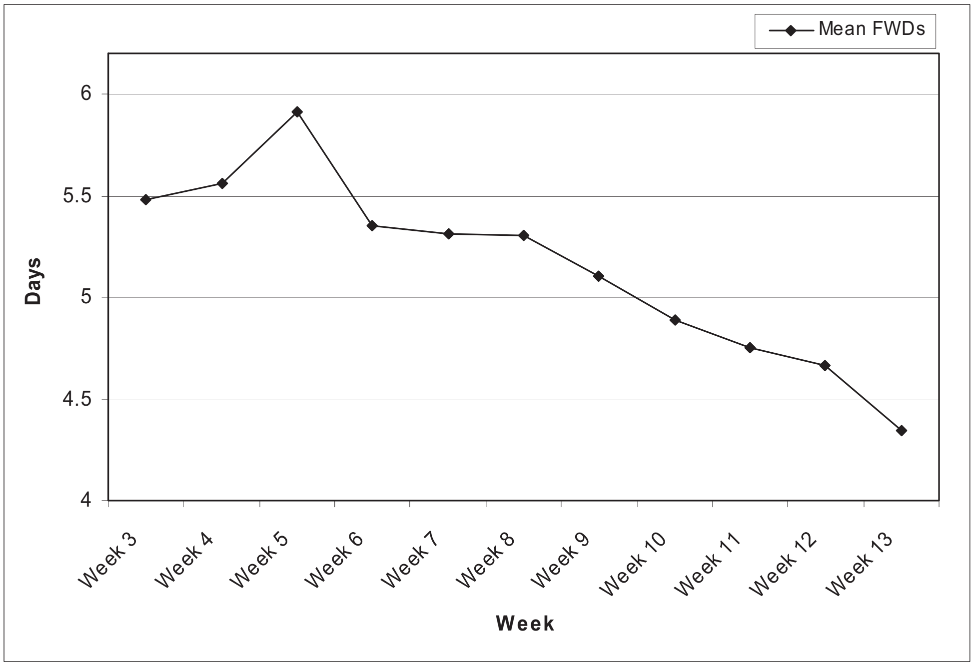

Figure 3.1 Mean Weekly Field Working Days During Harvest Season

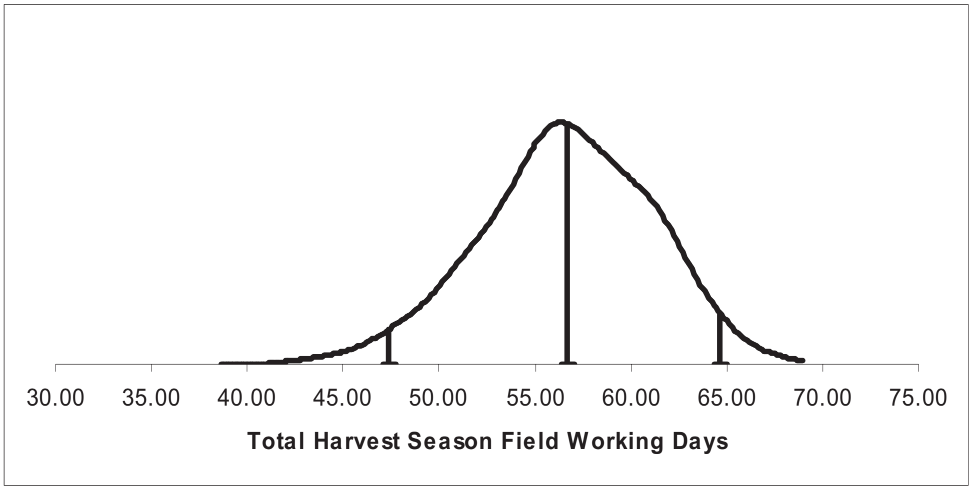

Figure 3.2 Mean Total Field Working Days During Harvest Season

The simulated FWD for each week were summed together to form a season total FWD. Figure 3.2 shows the distribution of seasons' total FWD. The average was 56.64 with a standard deviation of 4.46. There was a minimum and maximum of 38.60 and 68.96 respectively. A slight right-hand skew is seen that reflects the slightly more years with a higher number of field working days.

The inches of simulated rainfall were used for the quality loss and the quantity loss. These two percentage losses were taken away from the yield and price tested. They were added together to get the total dollar loss per acre for all acres harvested each week. Figure 3.3 shows the simulated mean weekly loss per acre from a combined quality and quantity loss. Again, there is a decline in the first part of the season. This is because of the decrease in precipitation in October. Once the mean weekly loss hits a minimum in Week 6, there is a steady increase for the rest of the season.

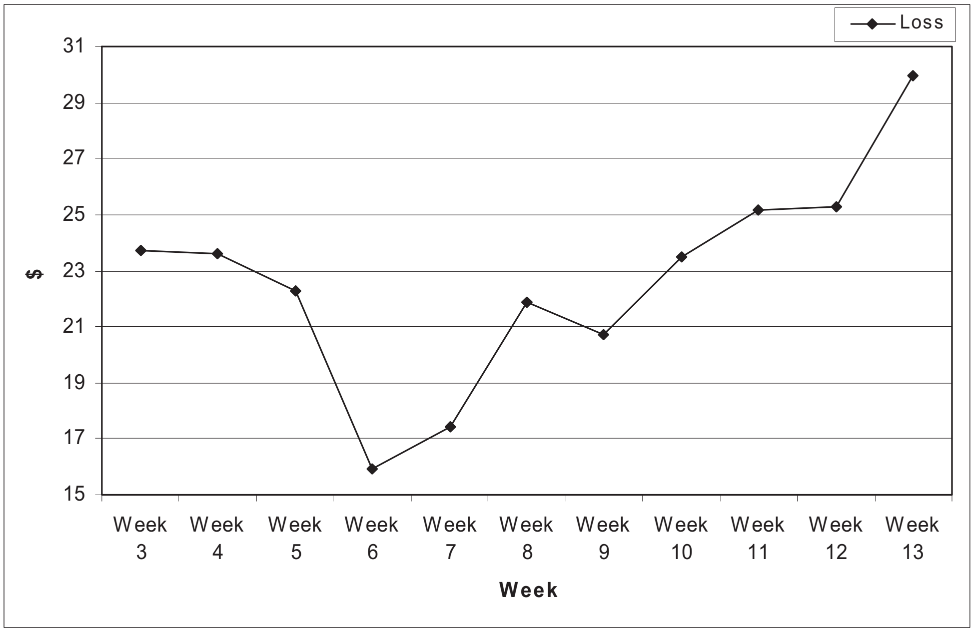

Figure 3.3 Mean Weekly Losses per Acre

Tables 3.6, 3.7 and 3.8 show the loss of revenue from precipitation for the six, seven and eight hour days respectively for the different performance rates at the different acreage levels. This revenue loss is from a reduction in the quality of the cotton and a decrease in yield. The loss is also broken down in per acre cost. There are two different ways to look at the results for each harvester's performance rate, how the hours harvested each day affects per acre loss and how the acreage level affects per acre costs.

Table 3.6 Revenue Loss of Quality and Quantity, 6 Hour Days

6 Hour Days	1400		1800		2200	
	John Deere	Conventional	John Deere	Conventional	John Deere	Conventional
Total	$ 26,902	$ 27,192	$ 35,031	$ 35,670	$ 44,376	$ 46,211
StDev	15,418	14,643	17,868	17,039	20,266	19,234
Per Acre	$ 19.22	$ 19.42	$ 19.46	$ 19.82	$ 20.17	$ 21.00
SD Per Acre	$ 11.01	$ 10.46	$ 9.93	$ 9.47	$ 9.21	$ 8.74

Table 3.7 Revenue Loss of Quality and Quantity, 7 Hour Days

7 Hour Days	1400		1800		2200	
	John Deere	Conventional	John Deere	Conventional	John Deere	Conventional
Total	$ 27,134	$ 26,891	$ 34,937	$ 35,022	$ 43,170	$ 44,171
StDev	16,752	15,556	19,271	18,069	21,506	20,401
Per Acre	$ 19.38	$ 19.21	$ 19.41	$ 19.46	$ 19.62	$ 20.08
SD Per Acre	$ 11.97	$ 11.11	$ 10.71	$ 10.04	$ 9.78	$ 9.27

Table 3.8 Revenue Loss of Quality and Quantity, 8 Hour Days

8 Hour Days	1400		1800		2200	
	John Deere	Conventional	John Deere	Conventional	John Deere	Conventional
Total	$ 27,615	$ 27,125	$ 34,527	$ 34,938	$ 42,749	$ 43,165
StDev	18,136	16,654	20,220	19,246	22,696	21,441
Per Acre	$ 19.73	$ 19.37	$ 19.18	$ 19.41	$ 19.43	$ 19.62
SD Per Acre	$ 12.95	$ 11.90	$ 11.23	$ 10.69	$ 10.32	$ 9.75

The harvesting hours a day level compares the same risk at different acreages. At the six hour day level, both harvesters' cost per acre increases as the acreage level increases. This is because more late season harvesting equals more days with rainfall. The conventional harvester and lower performance rate has a higher loss per acre than the John Deer harvester and higher performance rate for each acre level. As the acreage increases, the conventional's marginal increase of cost per acre is more than the Deere's marginal increase. The difference between the two increases from $0.20 to $0.36 to $0.83 per acre as the acreage increases. This shows that the lower performance rate is affected disproportionately more by late season harvesting than the higher performance rate. The simulation ran 1000 times and 261 simulations for the conventional harvester did not complete harvest. The John Deere did not complete twenty out of 1000.

The seven hour day level saw both harvesters' cost per acre increase as the acreage level increased, the same as the six hour level. The disproportionate increase in cost per acre was seen at this level as well. What is different is that at the 1400 acre level the conventional harvester actually had less loss per acre than the Deere harvester by $0.17. As the acreage increased the Deere once again had less loss per acre by $0.05 and $0.46 for 1800 and 2200 acres respectively. The conventional system did not complete harvest fifteen times while the John Deere did not complete harvest only once.

At the 8 hour day level while the conventional harvester's loss per acre increased as acreage increased, the John Deere harvester's cost per acre decreased from the 1400 level to the 1800 by $0.55. The cost then increased only $0.25 to the 2200 level. This still meant the 2200 acre level had less loss per acre than the 1400 acre level. As with the seven hour level, the eight hour level had the conventional with less loss at the 1400 level, $0.36 less. As with the seven hour level as well, the Deere had less loss at the 1800 and 2200 acre level, $0.23 and $0.19 respectively. It is interesting to note that there was a marginal gap difference of $0.59 of gain for the Deere between the Deere and the conventional from 1400 to 1800, but from the 1800 to 2200 there was a gain for the conventional of $0.04.

To look at the results from an acreage standpoint would allow the chance to see how the costs change when the acreage is held constant and the risk is changed. The 1400 acre level actually saw a decrease in cost per acre as the risk increased (fewer hours in a day) for the Deere harvester. The conventional harvester has a dip; it decreases from the eight to seven hour level and increases from the seven to six hour level. The 1400 acre level can take advantage of the better conditions early in the season, because a higher percentage of overall acres are harvested in the time when conditions are becoming better week to week. This therefore allowed for a longer harvest only into the middle of the season, giving more weeks of favorable conditions. Also at the 1400 acre level, the conventional harvester had a lower cost per acre than the John Deere for the seven and eight hour levels. At 1400 and longer hours a day, there was not enough risk to significantly hurt the conventional harvester and it could take advantage of the mid season dry period better than the John Deere.

The 1800 and 2200 acre levels saw the John Deere harvester's loss per acre was less for every hour level. They also saw an increase in losses per acre for both machines as hours a day decreased. As with the conventional harvester's dip in loss per acre from eight to seven to six at the 1400 acre level, the 1800 level saw the conventional harvester have a difference in loss per acre from the Deere of \$0.23 to \$0.05 to \$0.36 for eight, seven and six respectively. The 6 hour level is probably pushing the harvest later into the season after the drier period where the increase in rainfall can have more of an effect. This follows the trend of the conventional harvester being more affected by the late season costs of harvesting.

Conclusions

There were some areas of the work, other than the results, that stuck out as important. The data that was used was only for one central location in the Mississippi Delta and tests with other regions could help provide more insight into the affect performance rate has on cost per acre with cotton loss due to rainfall. The field working days equation was a linear model, while some tests were ran for nonlinear models, the linear models provided better results. One of the striking occurrences for the rainfall data was the mid harvest season dry period. This could be reason to push planting back a couple weeks and start harvest later, especially with the higher performance rate machines.

The trend in the rainfall data that was decreasing early in the season before it increased had a definite effect on the results. Because the higher performance rate was able to harvest more acres earlier in the season, it was penalized because of the higher per acre losses earlier. The lower performance rate could take advantage of the midseason dry period and harvest more acres during the lower per acre loss weeks when there were lower acres and higher hours a day to harvest. One of the most interesting findings was that the higher performance rate actually had a higher variance in every situation. This could be a result of the early season higher per acre losses.

The question of the increased weight of the new machines could be raised as to the ability of the new machines to get into the field as quickly after a rainfall as the conventional machines. Although unclear to what extent, the new machines weigh more than the conventional ones in the field. This is due to the engineering of the new machines as well as the ability of the new machines to carry more cotton. The cotton is also compacted making it denser. If future analysis finds that the machines are held out of the field longer after it rains due to its size, then the field working days equation must be adjusted to reflect this. This could also have an affect on performance rate with different amounts of ground moisture. Larger rainfall events will be assumed to affect this delay exponentially more as the event is more intense.

The results show that the best use of the higher performance rate is pushing it to its full potential. When asked to harvest more acres or have more risk with fewer hours a day to harvest, the higher performance rate machine showed its greatest advantages over the lower performance rate. A lower performance rate with similar climate conditions may be more advantageous to a smaller acreage farm. The higher performance rate harvester will benefit a farm that harvests a large acreage and wants to take full advantage of the higher performance rate. On large scale operations this could even mean purchasing fewer harvesters. Farmers with fixed acreage can determine which machines can give them the greatest cost reductions or what acreage should be planted with each machine to realize the greatest cost savings.

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CHAPTER IV

CONCLUSIONS

When John Deere and Case IH both introduced their harvesters into the market place, there was much buzz. The information coming from the companies about the machines where designed as marketing tools. Cotton Incorporated saw the need for independent research and assembled a team of experts to analyze the machines. From that initial study, the need was there for more research. Out of that, this thesis was born.

Additional research topics were discussed and ultimately two stuck out as interesting areas: the farmer’s replacement response to the machines and the benefits of improved performance rates. These two areas resulted from looking at the costs and benefits of the new machines. The machines were going to cost farmers more to purchase than the conventional machines, but there was a reduction of labor and additional machinery. Also there was the finding that the performance rate was improved. While the answers in this thesis from the study areas may seem obvious, the reasons why were interesting.

In the essay about the optimal replacement schedule of the machines, if a comparison of just the harvesters was made it would seem like replacement with a new harvester is never beneficial. Only when the associated asset values of the conventional system are eliminated as well, do the new machines look like a viable replacement option. Eliminating the tractors for the boll buggy and module builder from the harvesting operations were major contributors of cost reduction. These tractors will probably still be used on-farm, but the costs will not be associated with harvesting. The additional cost of loss from a lower performance rate was not included as a cost in the first essay. This loss may or may not have a significant effect on replacement timing, but future inclusion could be interesting. The decision for replacement could be highly affected by changes in costs, tax rates and interest rates. These factors could be tested with sensitivity analysis in the future for further research.

The interesting event in the harvesting season rain pattern is the decrease of rain form September to October. This pattern was observed in the Mississippi delta region and could be different for other cotton producing regions. This led to a machine with a higher performance rate that was harvesting more acres early in the season, incurring higher per acre costs from rain loss. Because of this, it could be proposed that delaying planting a few weeks and ultimately harvest a few weeks could benefit a higher performance rate. It would handle similar acreage levels but be able to take better advantage of the October dry period. On the other hand, by allotting more acres to be harvested per new machine, a farmer could spread costs over more acres. Even though a comparison of rain loss per acre versus more acres to lower costs was not done, it could be argued that the increase in revenue from the new machines increased acreage would offset any negatives.

Clearly the ultimate result of these studies indicates that the new machines must be pushed to their full potential to realize the maximum benefits. While waiting a few years to trade in the conventional system for the new system may be beneficial, the conversion would be before or at least the same time as the current replacement schedule for the conventional harvester would be. When the risk of labor and multiple machines' unreliability is eliminated from the operations, some uncertainties of costs are eliminated as well. While larger scale harvesting operations may see the maximum benefit from the new machines, small scale operations are not hurt. Because risk could hurt smaller operations disproportionately more than larger scale operations, the elimination of risk could benefit in the reverse manner.

This thesis does not endorse one brand of on-board module-building cotton harvester over another. This is usually a personal decision of the farmers that already have relationships with certain suppliers (paint color preference). Each machine has its benefits so replacement timing and performance rate differences should be compared to the conventional machine and not to each other.

APPENDIX A

FUTURE VALUE OF PERPETUAL REPLACEMENT TABLES

Table A.1 Present Value of Perpetual Costs for Conventional Harvester, 1800 Acres

Age	Value	#1	#2	#3	#4	V_a
0	364,642				364,642	
1	254,564	21.000	-4,642	257,210	364,642	-2,353,542
2	214,621	10.756	-4,685	195,262	364,642	-1,872,254
3	186,282	7.344	-15,803	152,595	364,642	-1,673,363
4	163,950	5.640	-31,180	118,106	364,642	-1,566,384
5	145,455	4.620	-49,231	88,721	364,642	-1,502,035
6	129,687	3.940	-75,867	69,678	364,642	-1,461,203
7	115,986	3.456	-110,125	59,349	364,642	-1,435,849
8	103,920	3.094	-145,379	50,643	364,642	-1,421,516
9	93,190	2.814	-181,390	43,251	364,642	-1,414,724
10	**83,580**	**2.590**	**-217,952**	**36,944**	**364,642**	**-1,413,284**
11	74,925	2.408	-254,886	31,541	364,642	-1,415,742
12	67,096	2.257	-292,036	26,900	364,642	-1,421,097

0.05 Interest Rate, #2 and #3 Include Tax Benefits

Table A.2 Present Value of Perpetual Costs for New John Deere Harvester, 1800 Acres

Age	Value	#1	#2	#3	#4	V_a
0	495,746					
1	353,651	21.000	-22,316	354,873	495,746	-3,426,957
2	298,733	10.756	-35,966	270,003	495,746	-2,814,961
3	259,733	7.344	-62,689	211,486	495,746	-2,548,051
4	228,972	5.640	-93,481	164,169	495,746	-2,397,426
5	203,478	4.620	-126,385	123,850	495,746	-2,301,805
6	181,724	3.940	-169,607	97,636	495,746	-2,237,000
7	162,804	3.456	-221,978	83,305	495,746	-2,192,799
8	146,129	3.094	-274,616	71,212	495,746	-2,163,473
9	131,287	2.814	-327,307	60,933	495,746	-2,144,455
10	117,980	2.590	-379,871	52,149	495,746	-2,132,854
11	105,984	2.408	-432,151	44,616	495,746	-2,126,744
12	**95,122**	**2.257**	**-484,017**	**38,137**	**495,746**	**-2,124,786**
13	85,255	2.129	-535,354	32,553	495,746	-2,126,020

0.05 Interest Rate, #2 and #3 Include Tax Benefits

Table A.3 Present Value of Perpetual Costs for New Case IH Harvester, 1800 Acres

Age	Value	#1	#2	#3	#4	V_a
0	454,572					
1	317,346	21.000	-7,384	320,645	454,572	-2,967,528
2	267,552	10.756	-8,959	243,419	454,572	-2,367,542
3	232,224	7.344	-24,267	190,229	454,572	-2,119,600
4	204,384	5.640	-44,817	147,234	454,572	-1,986,238
5	181,328	4.620	-68,633	110,602	454,572	-1,906,018
6	161,672	3.940	-103,091	86,862	454,572	-1,855,116
7	144,591	3.456	-146,989	73,986	454,572	-1,823,509
8	129,549	3.094	-192,073	63,132	454,572	-1,805,641
9	116,173	2.814	-238,046	53,918	454,572	-1,797,174
10	**104,193**	**2.590**	**-284,655**	**46,055**	**454,572**	**-1,795,379**
11	93,403	2.408	-331,679	39,320	454,572	-1,798,443
12	83,644	2.257	-378,924	33,535	454,572	-1,805,119

0.05 Interest Rate, #2 and #3 Include Tax Benefits

Table A.4 Present Value of Perpetual Costs for Boll Buggy, 1800 Acres

Age	Value	#1	#2	#3	#4	V_a
0	22,007					
1	15,234	21.000	450	15,435	22,007	-128,569
2	13,597	10.756	1,044	12,205	22,007	-94,203
3	12,404	7.344	915	9,932	22,007	-81,965
4	11,440	5.640	501	8,044	22,007	-75,933
5	10,624	4.620	-89	6,396	22,007	-72,529
6	9,912	3.940	-1,204	5,325	22,007	-70,476
7	9,279	3.456	-2,781	4,748	22,007	-69,268
8	8,708	3.094	-4,418	4,244	22,007	-68,639
9	**8,189**	**2.814**	**-6,099**	**3,801**	**22,007**	**-68,390**
10	7,712	2.590	-7,810	3,409	22,007	-68,399

0.05 Interest Rate, #2 and #3 Include Tax Benefits

Table A.5   Present Value of Perpetual Costs for Module Builder, 1800 Acres

Age	Value	#1	#2	#3	#4	V_a
0	28,308					
1	19,596	21.000	-3,276	19,854	28,308	-246,353
2	17,490	10.756	-6,185	15,700	28,308	-202,146
3	15,955	7.344	-9,848	12,775	28,308	-186,405
4	14,716	5.640	-13,712	10,346	28,308	-178,646
5	13,666	4.620	-17,643	8,227	28,308	-174,267
6	12,750	3.940	-22,098	6,850	28,308	-171,627
7	11,935	3.456	-27,004	6,107	28,308	-170,073
8	11,202	3.094	-31,850	5,459	28,308	-169,264
9	**10,534**	**2.814**	**-36,622**	**4,889**	**28,308**	**-168,944**
10	9,921	2.590	-41,308	4,385	28,308	-168,955

0.05 Interest Rate, #2 and #3 Include Tax Benefits

APPENDIX B

AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS STANDARDS

Table B.1 Repair and Maintenance Repair Factors from ASAE Standards EP497.6(2009)

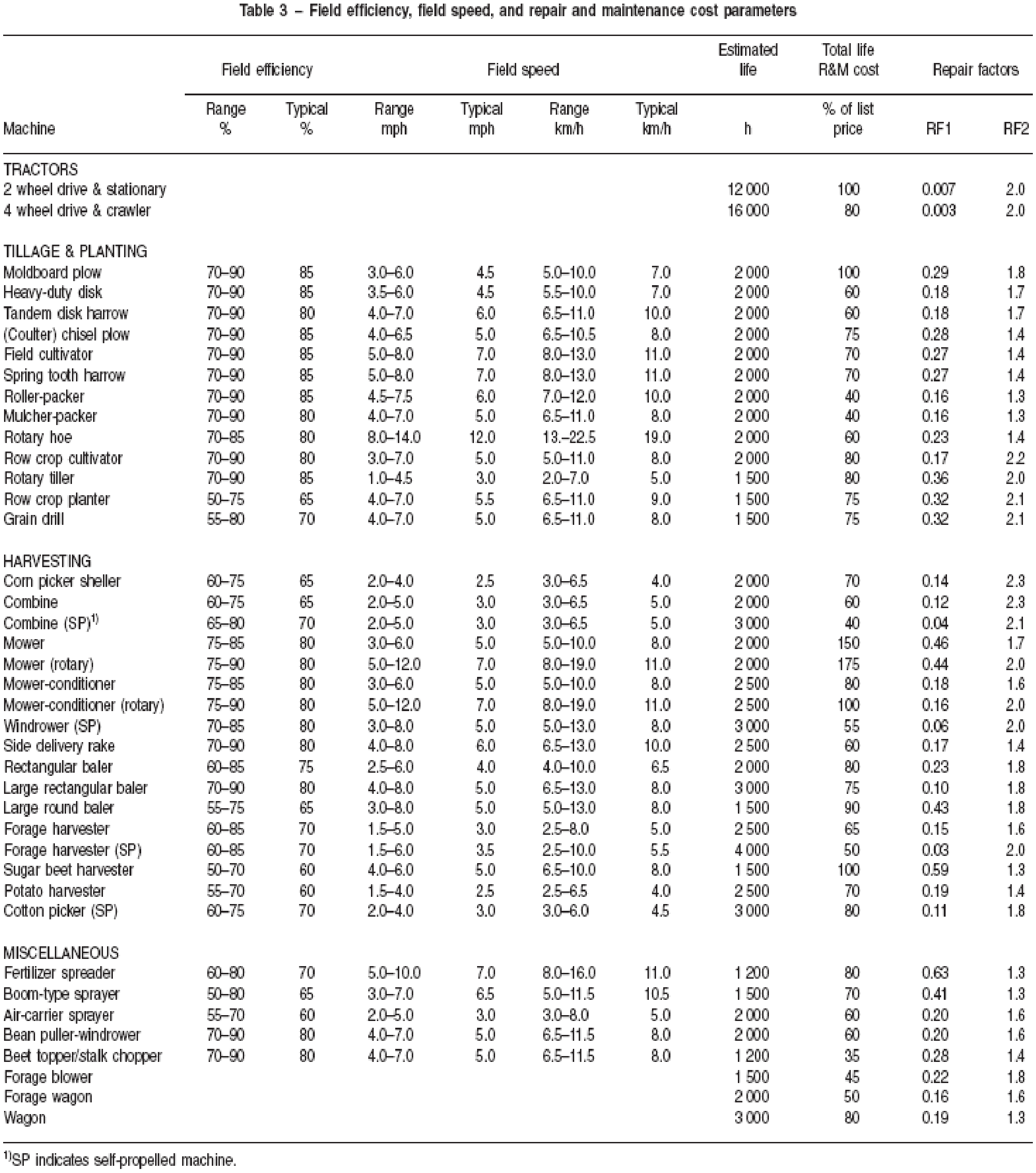

Table 3 – Field efficiency, field speed, and repair and maintenance cost parameters

	Field efficiency		Field speed				Estimated life	Total life R&M cost	Repair factors	
Machine	Range %	Typical %	Range mph	Typical mph	Range km/h	Typical km/h	h	% of list price	RF1	RF2
TRACTORS										
2 wheel drive & stationary							12 000	100	0.007	2.0
4 wheel drive & crawler							16 000	80	0.003	2.0
TILLAGE & PLANTING										
Moldboard plow	70–90	85	3.0–6.0	4.5	5.0–10.0	7.0	2 000	100	0.29	1.8
Heavy-duty disk	70–90	85	3.5–6.0	4.5	5.5–10.0	7.0	2 000	60	0.18	1.7
Tandem disk harrow	70–90	80	4.0–7.0	6.0	6.5–11.0	10.0	2 000	60	0.18	1.7
(Coulter) chisel plow	70–90	85	4.0–6.5	5.0	6.5–10.5	8.0	2 000	75	0.28	1.4
Field cultivator	70–90	85	5.0–8.0	7.0	8.0–13.0	11.0	2 000	70	0.27	1.4
Spring tooth harrow	70–90	85	5.0–8.0	7.0	8.0–13.0	11.0	2 000	70	0.27	1.4
Roller-packer	70–90	85	4.5–7.5	6.0	7.0–12.0	10.0	2 000	40	0.16	1.3
Mulcher-packer	70–90	80	4.0–7.0	5.0	6.5–11.0	8.0	2 000	40	0.16	1.3
Rotary hoe	70–85	80	8.0–14.0	12.0	13.–22.5	19.0	2 000	60	0.23	1.4
Row crop cultivator	70–90	80	3.0–7.0	5.0	5.0–11.0	8.0	2 000	80	0.17	2.2
Rotary tiller	70–90	85	1.0–4.5	3.0	2.0–7.0	5.0	1 500	80	0.36	2.0
Row crop planter	50–75	65	4.0–7.0	5.5	6.5–11.0	9.0	1 500	75	0.32	2.1
Grain drill	55–80	70	4.0–7.0	5.0	6.5–11.0	8.0	1 500	75	0.32	2.1
HARVESTING										
Corn picker sheller	60–75	65	2.0–4.0	2.5	3.0–6.5	4.0	2 000	70	0.14	2.3
Combine	60–75	65	2.0–5.0	3.0	3.0–6.5	5.0	2 000	60	0.12	2.3
Combine (SP)[1]	65–80	70	2.0–5.0	3.0	3.0–6.5	5.0	3 000	40	0.04	2.1
Mower	75–85	80	3.0–6.0	5.0	5.0–10.0	8.0	2 000	150	0.46	1.7
Mower (rotary)	75–90	80	5.0–12.0	7.0	8.0–19.0	11.0	2 000	175	0.44	2.0
Mower-conditioner	75–85	80	3.0–6.0	5.0	5.0–10.0	8.0	2 500	80	0.18	1.6
Mower-conditioner (rotary)	75–90	80	5.0–12.0	7.0	8.0–19.0	11.0	2 500	100	0.16	2.0
Windrower (SP)	70–85	80	3.0–8.0	5.0	5.0–13.0	8.0	3 000	55	0.06	2.0
Side delivery rake	70–90	80	4.0–8.0	6.0	6.5–13.0	10.0	2 500	60	0.17	1.4
Rectangular baler	60–85	75	2.5–6.0	4.0	4.0–10.0	6.5	2 000	80	0.23	1.8
Large rectangular baler	70–90	80	4.0–8.0	5.0	6.5–13.0	8.0	3 000	75	0.10	1.8
Large round baler	55–75	65	3.0–8.0	5.0	5.0–13.0	8.0	1 500	90	0.43	1.8
Forage harvester	60–85	70	1.5–5.0	3.0	2.5–8.0	5.0	2 500	65	0.15	1.6
Forage harvester (SP)	60–85	70	1.5–6.0	3.5	2.5–10.0	5.5	4 000	50	0.03	2.0
Sugar beet harvester	50–70	60	4.0–6.0	5.0	6.5–10.0	8.0	1 500	100	0.59	1.3
Potato harvester	55–70	60	1.5–4.0	2.5	2.5–6.5	4.0	2 500	70	0.19	1.4
Cotton picker (SP)	60–75	70	2.0–4.0	3.0	3.0–6.0	4.5	3 000	80	0.11	1.8
MISCELLANEOUS										
Fertilizer spreader	60–80	70	5.0–10.0	7.0	8.0–16.0	11.0	1 200	80	0.63	1.3
Boom-type sprayer	50–80	65	3.0–7.0	6.5	5.0–11.5	10.5	1 500	70	0.41	1.3
Air-carrier sprayer	55–70	60	2.0–5.0	3.0	3.0–8.0	5.0	2 000	60	0.20	1.6
Bean puller-windrower	70–90	80	4.0–7.0	5.0	6.5–11.5	8.0	2 000	60	0.20	1.6
Beet topper/stalk chopper	70–90	80	4.0–7.0	5.0	6.5–11.5	8.0	1 200	35	0.28	1.4
Forage blower							1 500	45	0.22	1.8
Forage wagon							2 000	50	0.16	1.6
Wagon							3 000	80	0.19	1.3

[1] SP indicates self-propelled machine.

Table B.2 Remaining Value Coefficients from ASAE Standards EP497.6(2009)

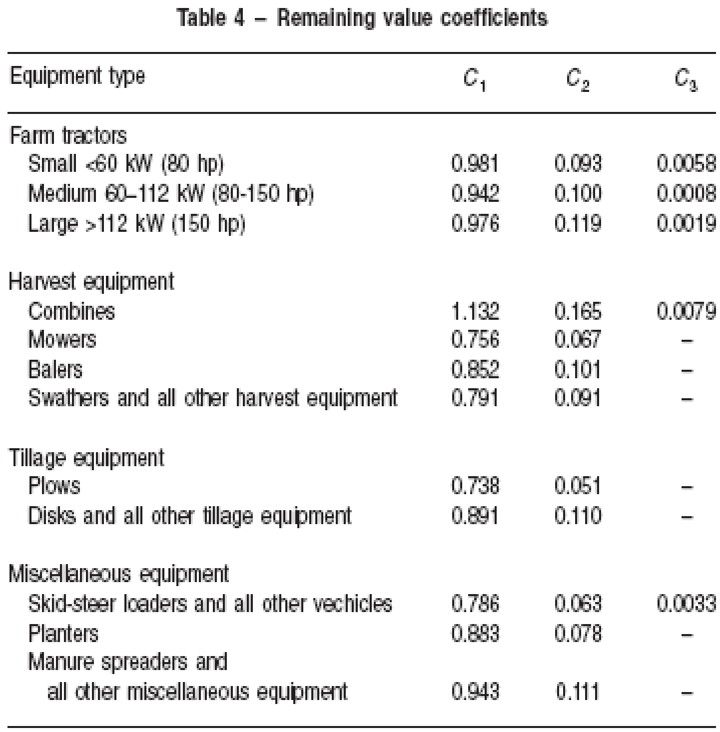

Table 4 – Remaining value coefficients

Equipment type	C_1	C_2	C_3
Farm tractors			
Small <60 kW (80 hp)	0.981	0.093	0.0058
Medium 60–112 kW (80-150 hp)	0.942	0.100	0.0008
Large >112 kW (150 hp)	0.976	0.119	0.0019
Harvest equipment			
Combines	1.132	0.165	0.0079
Mowers	0.756	0.067	–
Balers	0.852	0.101	–
Swathers and all other harvest equipment	0.791	0.091	–
Tillage equipment			
Plows	0.738	0.051	–
Disks and all other tillage equipment	0.891	0.110	–
Miscellaneous equipment			
Skid-steer loaders and all other vechicles	0.786	0.063	0.0033
Planters	0.883	0.078	–
Manure spreaders and all other miscellaneous equipment	0.943	0.111	–

APPENDIX C

FIELD WORKING DAYS REGRESSION TESTS

FWD_t = Number of field working days a week in the t^{th} observation, reported by NASS Crop Progress Reports

D_t = Days, days with a rain event in the t^{th} observation

R_t = Inches, weekly inches of rain for the t^{th} observation

R_{t-1} = Lag In, weekly inches of rain prior to the t^{th} observation

$2Wk_t$ = In/Lag, total inches for rain for two week period of R_t and R_{t-1}

$P_{1,t}$ = dummy variable equal to one if the t^{th} observation is in period 1

$P_{2,t}$ = dummy variable equal to one if the t^{th} observation is in period 2

$P_{3,t}$ = dummy variable equal to one if the t^{th} observation is in period 3

The General Model

$$\begin{aligned} FWD_t = \beta_0 + \beta_1 P_{1,t} D_t + \beta_2 P_{2,t} D_t + \beta_3 P_{3,t} D_t + \beta_4 P_{1,t} R_t + \beta_5 P_{2,t} R_t + \beta_6 P_{3,t} R_t \\ + \beta_7 P_{1,t} R_{t-1} + \beta_8 P_{2,t} R_{t-1} + \beta_9 P_{3,t} R_{t-1} + \beta_{10} P_{2,t} + \beta_{11} P_{3,t} + \varepsilon_t \end{aligned} \tag{C-1}$$

The Restricted Models

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 R_t + \varepsilon_t \tag{C-2}$$

F-test versus the General Model
P-value = <.0001

Table C.1 Whole Season

R Square	0.580	P-value	St Error
Intercept	6.307	1.220E-77	0.14418
Days	-0.185	1.233E-02	0.07284
Inches	-0.615	4.158E-14	0.07209

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 R_t + \beta_3 R_{t-1} + \varepsilon_t \tag{C-3}$$

F-test versus the General Model
P-value = 0.0061

Table C.2 Whole Season with Lag Week

R Square	0.698	P-value	St Error
Intercept	6.607	8.396E-85	1.302E-01
Days	-0.566	1.338E-15	6.182E-02
Inches	-0.195	2.154E-03	6.208E-02
Lag In	-0.354	1.918E-10	5.098E-02

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 2Wk_t + \varepsilon_t \tag{C-4}$$

F-test versus the General Model
P-value = 0.0026

Table C.3 Whole Season with Two Week Variable

R Square	0.688		
		P-value	St Error
Intercept	6.551	2.031E-85	0.1287248
Days	-0.515	2.490E-15	0.0570057
In/Lag	-0.290	5.030E-11	0.0403018

$$FWD_t = \beta_0 + \beta_1 P_{1,t} D_t + \beta_2 P_{2,t} D_t + \beta_3 P_{3,t} D_t + \beta_4 P_{1,t} R_t + \beta_5 P_{2,t} R_t + \beta_6 P_{3,t} R_t + \beta_7 P_{1,t} R_{t-1} + \beta_8 P_{2,t} R_{t-1} + \beta_9 P_{3,t} R_{t-1} + \varepsilon_t \tag{C-5}$$

F-test versus the General Model
P-value = 0.2780

Table C.4 Each Period Slope Shifter with Lag

R Square	0.742		
		P-value	St Error
Intercept	6.648	6.070E-84	1.259E-01
Days 1	-0.472	1.923E-08	7.825E-02
Days 2	-0.631	1.377E-06	1.240E-01
Days 3	-0.591	1.522E-08	9.728E-02
Inches 1	-0.144	0.06160	7.607E-02
Inches 2	-0.205	0.14560	1.400E-01
Inches 3	-0.404	0.00423	1.384E-01
Lag In 1	-0.325	1.798E-06	6.466E-02
Lag In 2	-0.380	6.772E-06	8.058E-02
Lag In 3	-0.480	0.00040	1.315E-01

$$\begin{aligned} FWD_t = \beta_0 + \beta_1 P_{1,t} D_t + \beta_2 P_{2,t} D_t + \beta_3 P_{3,t} D_t + \beta_4 P_{1,t}\, 2Wk_t \\ + \beta_5 P_{2,t}\, 2Wk_t + \beta_6 P_{3,t}\, 2Wk_t + \varepsilon_t \end{aligned} \tag{C-6}$$

F-test versus the General Model
P-value = 0.1939

Table C.5 Each Period Slope Shifter with Two Week Variable

R Square	0.731		
		P-value	St Error
Intercept	6.598	2.199E-86	0.122553
Days 1	-0.422	1.261E-07	0.075135
Days 2	-0.546	2.360E-07	0.099607
Days 3	-0.570	8.946E-09	0.092219
In/Lag 1	-0.249	5.557E-06	0.052281
In/Lag 2	-0.333	4.829E-06	0.069520
In/Lag 3	-0.438	6.993E-06	0.093221

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 R_t + \beta_3 R_{t-1} + \beta_4 P_{2,t} + \beta_5 P_{3,t} + \varepsilon_t \tag{C-7}$$

F-test versus the General Model
P-value = 0.0336

Table C.6 Intercept Shifter Dummys

R Square	0.717		
		P-value	St Error
Intercept	6.869	3.888E-74	1.644E-01
Days	-0.554	1.646E-15	6.056E-02
Inches	-0.215	0.000632	0.0611926
Lag In	-0.366	3.159E-11	5.012E-02
Period 2d	-0.252	0.204832	0.197335
Period 3d	-0.576	0.005172	0.202144

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 2Wk_t + \beta_3 P_{2,t} + \beta_4 P_{3,t} + \varepsilon_t \tag{C-8}$$

F-test versus the General Model
P-value = 0.0152

Table C.7 Intercept Shifter Dummys with Two Week Variable

R Square	0.708		
		P-value	St Error
Intercept	6.822	3.621E-74	0.1644525
Days	-0.505	2.551E-15	0.0557789
In/Lag	-0.306	4.787E-12	0.039937
Period 2d	-0.255	2.034E-01	0.1995632
Period 3d	-0.590	4.590E-03	0.2043008

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 R_t + \beta_3 R_{t-1} + \beta_4 P_{3,t} + \varepsilon_t \tag{C-9}$$

F-test versus the General Model
P-value = 0.0324

Table C.8 Intercept Shifter Only Third Period Dummy

R Square	0.713		
		P-value	St Error
Intercept	6.761	1.943E-81	0.1410533
Days	-0.553	1.844E-15	0.0607171
Inches	-0.216	0.000603	0.061339
Lag In	-0.368	2.610E-11	5.022E-02
Period 3d	-0.465	0.012311	0.183134

$$FWD_t = \beta_0 + \beta_1 D_t + \beta_2 2Wk_t + \beta_3 P_{3,t} + \varepsilon_t \tag{C-10}$$

F-test versus the General Model
P-value = 0.0148

Table C.9 Intercept Shifter Only Third Period Dummy with Two Week Variable

R Square	0.704		
		P-value	St Error
Intercept	6.712	9.448E-82	0.1403817
Days	-0.504	2.958E-15	0.0559178
In/Lag	-0.308	3.872E-12	0.040011
Period 3d	-0.478	1.096E-02	0.1850959

$$\begin{aligned} FWD_t = \beta_0 + \beta_1 P_{1,t} D_t + \beta_2 P_{2,t} D_t + \beta_3 P_{3,t} D_t + \beta_4 P_{1,t} 2Wk_t + \beta_5 P_{2,t} 2Wk_t \\ + \beta_6 P_{3,t} 2Wk_t + \beta_7 P_{2,t} + \beta_8 P_{3,t} + \varepsilon_t \end{aligned} \tag{C-11}$$

F-test versus the General Model
P-value = 0.1574

Table C.10 Slope Shifters for Each Period with Intercept Shifter Dummys

R Square	0.736		
		P-value	St Error
Intercept	6.454	8.977E-63	0.1912435
Days 1	-0.394	3.082E-06	0.0804038
Days 2	-0.593	1.025E-07	0.1046758
Days 3	-0.550	3.941E-07	0.1023117
In/Lag 1	-0.237	2.078E-05	0.0535029
In/Lag 2	-0.354	2.093E-06	0.0709507
In/Lag 3	-0.425	2.533E-05	0.0970626
Period 2d	0.404	0.1633378	0.2881117
Period 3d	0.051	0.8671581	0.3045475

APPENDIX D

SAS CODE FOR MODEL RESTRCTION TESTS

```
proc reg data=FWD;
Title "General Model";
model fwd = d1days d2days d3days d1rain d2rain d3rain d1rainm1 d2rainm1
d3rainm1 d2 d3;

test d1days=d2days=d3days, d1rain=d2rain=d3rain, d1rainm1=0,
d2rainm1=0, d3rainm1=0, d2=0, d3=0;

test d1days=d2days=d3days, d1rain=d2rain=d3rain,
d1rainm1=d2rainm1=d3rainm1, d2=0, d3=0;

test d1days=d2days=d3days,
d1rain=d1rainm1=d2rain=d2rainm1=d3rain=d3rainm1, d2=0, d3=0;

test d2=0, d3=0;

test d1rain=d1rainm1, d2rain=d2rainm1, d3rain=d3rainm1, d2=0, d3=0;

test d1days=d2days=d3days, d1rain=d2rain=d3rain,
d1rainm1=d2rainm1=d3rainm1;

test d1days=d2days=d3days,
d1rain=d1rainm1=d2rain=d2rainm1=d3rain=d3rainm1;

test d1days=d2days=d3days, d1rain=d2rain=d3rain,
d1rainm1=d2rainm1=d3rainm1, d2=0;

test d1days=d2days=d3days,
d1rain=d1rainm1=d2rain=d2rainm1=d3rain=d3rainm1, d2=0;

test d1rain=d1rainm1, d2rain=d2rainm1, d3rain=d3rainm1;
run;
quit;
```

APPENDIX E

HISTOGRAMS FOR EMPIRICAL DISTRIBUTIONS OF RAINFALL DATA

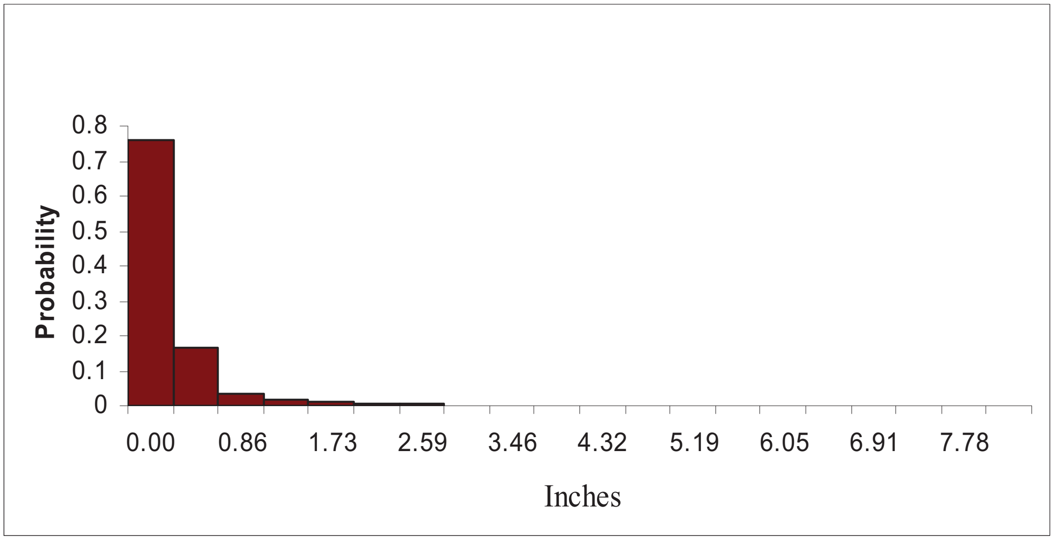

Figure E.1 Distribution of Rainfall Events, Period 1

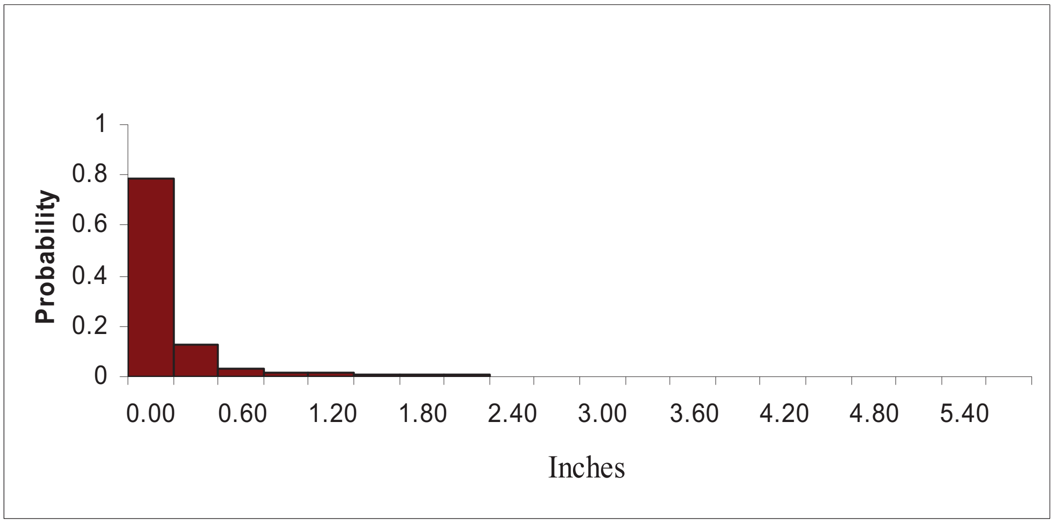

Figure E.2 Distribution of Rainfall Events, Period 2

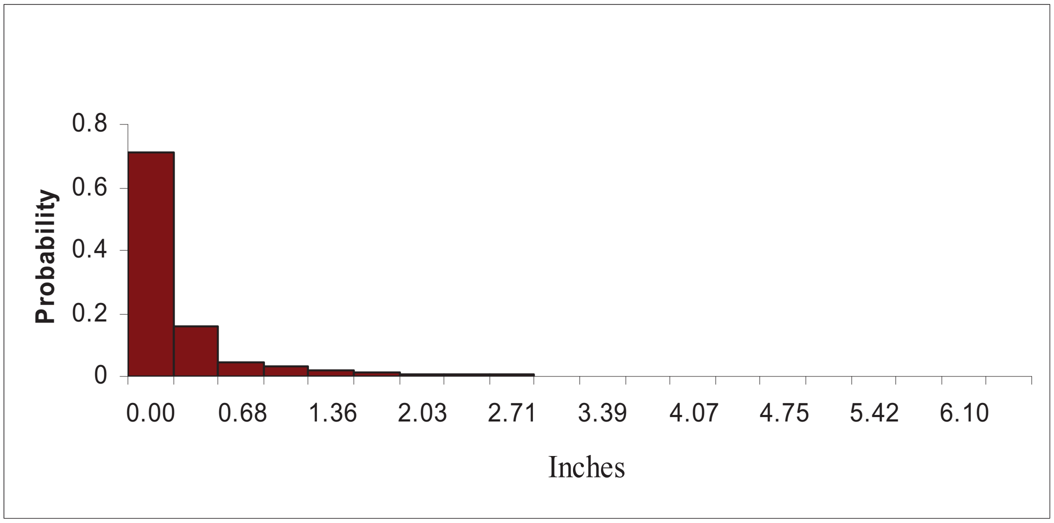

Figure E.3 Distribution of Rainfall Events, Period 3