# Calculating Cost Savings Per Acre When Harvest Days are Stochastic

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Abstract

New cotton harvesters have been introduced that have higher performance rate as well as eliminate extra labor and accompanying equipment. The new machines build partial modules on board the harvester. Higher field efficiency (performance rate) lets a farmers harvest his cotton in a shorter period. Precipitation causes cotton losses in both quality and quantity of the cotton. This paper seeks to measure cost per acre when harvest days are stochastic by using historic precipitation data. Cost per acre will include the cost of losses from a loss function from precipitation. Cost per acre will be adjusted for conventional versus new technology by quantify the losses that contribute to extra costs of extended harvesting.

## Introduction

Agriculture is continuing to evolve. New agriculture equipment capable of higher capacity, higher performance or better efficiencies are being introduced into the market yearly. New cotton harvesters have been introduced that have higher performance rate as well as eliminate extra labor and accompanying equipment. John Deere and Case-IH have introduced new machines that build partial modules right on board the harvester. Because they eliminate the need to dump cotton in a boll buggy, the field efficiencies of the new machines are greatly increased. Therefore they eliminate machinery and labor along with harvest more acres per hour than conventional cotton harvesters and need less days in a season to harvest the same acreage.

Both machines create modules on board the picker, but that is where the similarities stop. The John Deere harvester uses plastic wrap to "bale" the cotton into seven and a half foot diameter modules, approximately one quarter of the size of a conventional module. This module can then be unloaded from the machine onto a cradle that carries it to the turn row while it continues to harvest. A tractor with accompanying attachment then moves four round modules together which can then be transported in conventional module trucks. At the gin a special piece of equipment is used to "unwrap" the modules directly on the feeder belt.

The Case-IH machine creates conventional looking modules on their machine that are one half sized. These are unloaded off the rows and tarped similar to conventional modules. Module trucks can transport two of these modules to the gin where they are fed onto the feeder belt as usual.

The new harvesters may cost $200,000 more than a similar sized conventional picker. This increase in cost is offset by the reduction in equipment and labor along with the increased field efficiency (performance rate). The increased field efficiency is important because it allows farmers to harvest acres in a shorter time period, saving any losses because of late season harvests. This is due to loss in quality and quantity of cotton because of precipitation. These are losses in revenue, which are treated as costs, because costs are considered negative returns. But with harvestable days each season being stochastic, the amount of loss each year is varied. What risk of loss is eliminated with the higher performance rate of these new machines?

**Problem Statement**

The new harvesters that build the modules on the machine save time by eliminating dumping time. There is also data from Wilcut (2009) that suggests that performance rate (acres/hr) is increased not only by elimination of dump 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 onboard 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. They could also decide to stretch the cost over more acres but run a risk of not harvesting the total acres in the harvest time. 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 inputs included in the budget are listed in Table 1. The cost per acre for each machine changes as the number of acres varies. Table 2 shows an example of how varied harvest hours can affect each machines cost per acre. This paper seeks to understand the benefits of a shortened harvest.

In Mississippi (region used for data) the harvest time for cotton is typically between early to mid September and early November. Agriculture Engineer Herb Wilcut estimates that a conventional harvester will average around 220 machine hours each harvest season (this was also the hours for measure in the budget). Because of rain the harvest window needed for these 220 hours varies. The more rain, the more days will be needed to complete the 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. Benefits in cost savings are realized with a machine with higher performance rate when cotton is harvested as soon as possible after the boll opens and not left in the field. The problem is that because of the precipitation harvest days are unknown; therefore farmers can not be sure how it will take to harvest a set number of acres. There are a specific number of days that a machine with a certain performance rate needs to harvest a set number of acres. Precipitation decreases the harvest days each week 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 of keeping the old system over the technologically advanced one with respect to longer harvests?

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. 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 in 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.

If $(\tilde{H} \times R) < A_P$ use:

$$C_{TH} = \frac{C^* \times (\tilde{H} \times R) + [2(C^*) \times (A_P - (\tilde{H} \times R))]}{A_p} \quad \text{(Eq 1)}$$

If $(\tilde{H} \times R) \geq A_P$ use: $C^*$.

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, $\tilde{H}$ is the season's harvest hours, this is the value that is simulated. $R$ is the performance rate of the simulated machine and $A_p$ is the acres planted for the season for one machine.

It 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, a cost function for cotton loss will be added to the cost per acre of each harvester. We should be able to see a clearer picture if the higher costs of the new machines are worth eliminating some of the risk of increased costs of late season harvesting.

**Objectives**

This essay's general objective is to determine cost per acre for each harvester with different farm sizes and when harvest days are stochastic. This cost per acre will include tangible costs (fuel, labor, and machinery) as well as incurred costs of quality and quantity loss of cotton from the additional harvest days needed when using conventional machines compare to the new machines. To accomplish this, historic precipitation data for 60+ years along with USDA field working days (harvestable days) data will be used to develop appropriate probability distribution functions for simulation. This will provide a more accurate distribution for harvest days and precipitation amount to use in the simulations for different farm sizes. The simulated precipitation will be used in a quality and quantity loss function for cotton and then be added in the cost per acre function.

## Conceptual Framework

What a farmer is concerned with is the 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) demonstrated with a cost multiplier that acres harvested later in the season increases average cost 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 rain) had much more of an effect on the conventional machines.  But how much more of an effect; the loss function for cotton will be added to quantify the losses.

Harvest days are not constant because precipitation affects the harvest days 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. So therefore the longer the cotton sits in the field after defoliation, the less revenue a farmer can receive. So the time cotton is sitting in the field can be incurring costs to farmers.

Along with quantity, precipitation also deteriorates the quality of the cotton of an open boll. The rain 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 the reduction in quality. This decreases revenue from the cotton and therefore acts as a cost. If these machines can harvest the cotton sooner with the higher performance rate 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 is needed to find a scale of amount of precipitation to harvestable days. This paper seeks to determine if a higher performance rate of an on board module building cotton harvester will significantly decreases losses per acre of late season harvesting when those costs are quantified. This will be shown as cost per acre for different size farms.

**Methods**

The harvest days each week in a season are taken from USDA crop progress reports for Mississippi. This source was limited, only providing 8 years of data, seen in Table 3. This data was sufficient to create a pdf, but the accuracy was questionable because of the limited years.

To expand the data points and produce a more reliable pdf, the field working days each week in that 8 year period will be linked to its corresponding 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 Stone County, 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 we assume are 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.

Three farm sizes of 1400 acres, 1800 acres, and 2200 acres will be tested. The different harvesters, according to their performance rates, will need a minimum number of days to complete harvest. These numbers are given in Table 4.

Willcut et al. (2009) estimated the performance rate of the new machines verses the conventional with GPS time in motion analysis. He also estimated the average cotton harvesting season at 220 harvesting hours. This number was used in a ratio with the average for our historical harvestable days a season, 63, to convert hours needed for a farm size into the corresponding days needed. The 63 days comes from the average accumulated field working days from 0% cotton harvested until 100% harvested in crop progress reports.

The difference between the days needed by the conventional and Case-IH from the John Deere machine will be the days where precipitation contributes to additional cotton losses. The precipitation I the extra time period is put into the loss function and the resulting dollar amount is added to the additional acres and averaged into the total average cost per acre for the corresponding machine, farm size and rainfall amount.

The loss function that will be implemented in the cost per acre function is estimated by Martin, Barnett and Coble (2001). It is as follows:

$$\text{Loss per acre (\$)} = -5.02 + 15.0757z - .3166z^2 \qquad \text{(Eq 2)}$$

$$\qquad (2.07) \qquad (.60) \qquad (.04)$$

$$R\ Sq = .997$$

where z is total precipitation between defoliation and harvest and loss per acre is measured in dollars. The function was derived from test plots at the Delta Research and Extension Center in Stoneville, Mississippi with the assumptions of 650 lb per acre expected yield and $.60 cotton price. This continuous loss function was used as a tool for crop insurance and therefore can be a good estimator of financial loss.

We assume cotton loss, due to precipitation, is the same for each machine while the machines are harvesting at the same time in the season. The loss that is relevant to comparison is the extra days needed by the conventional machine for each farm size. The cost is per acre, therefore it will be added for each additional acre that is left to be picked by the conventional machine once the new machine has completed harvest. Then the average cost per acre will be calculated for the entire farm.

## Discussion and Outcomes

The need for a better distribution of harvestable days in a season will be achieved with the new precipitation data. This will give a more accurate pdf to draw samples from and convert to harvestable days. From this we will be able to estimate how different precipitation levels can affect cotton loss with the loss function. Figure 1 shows what continuous precipitation amounts cause what cost per acre.

This paper will determine what farm sizes have the lowest costs with the new on board module building cotton harvesters when harvest days are stochastic and late season harvesting incurs greater costs. Farmers with fixed acreage can determine which machines can give them the greatest cost reductions or what acreage a farmers should plant with each machine to realize the greatest cost savings.

## References

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Table 1. Factors in Budget for Costing of Machines Per Acre

| Factors Affecting Both Systems | | Specific Factors | | Machinery Costs | |
|---|---|---|---|---|---|
| Interest rate | % | Performance rate | Acres/ hour | Picker | $/acre |
| Diesel fuel | $/gallon | Acres to harvest | Acres/ year | Boll buggy | $/acre |
| Cotton yield (lbs of lint) | lb/acre | Acres to harvest - calculated | Acres/ year | Module builder | $/acre |
| % Lint (turnout) | % | Module weight | pounds | Tractor for boll buggy | $/acre |
| % Seed | % | Other labor - price | $/hr | Tractor for module builder | $/acre |
| Cotton price (lint) | $/lb | Other labor - quantity | # of people | Round bale mover attach | $/acre |
| Cottonseed price | $/ton | Cotton left in the field | lb per module | Tractor for round mover | $/acre |
| Tractor hours/tractor | Hrs/year | Ginning rate | Bales/ hr | Module truck | $/acre |
| Annual use of module truck | Loads/yr | Extra ginning cost | $/hr | | |
| Average hauling distance | miles (roundtrip) - Module truck | Quality discount | $/lb | | |
| Gin use | Bales/yr | Cotton lost at gin | lb of seed cotton per module | | |
| Cost to operate gin | $/hr | Module truck load size | Module s/truck | | |
| | | Ave time per module truck load | hrs/load (roundtrip) - Module truck | | |
| | | Tarp cost | $/tarp | | |
| | | Tarp - uses per year | uses/yr | | |
| | | Tarp - life of tarp | years | | |
| | | Plactic wrap | $/roun d module | | |
| | | Time to stage round module | Minute s/module | | |

Table 2. Varied Harvest Hours on Per Acre Cost

| Harvester | Average | Harvest hours | | | | |
|---|---|---|---|---|---|---|
| | | 180 | 200 | 220 | 240 | 260 |
| Conventional | $ 94.35 | 106.5623 | 99.84354 | 94.34636 | 89.76538 | 85.88916 |
| New Deere | $ 96.41 | 109.6057 | 102.3505 | 96.41454 | 91.46787 | 87.28223 |
| New Case IH | $ 88.45 | 103.3114 | 95.13518 | 88.44554 | 82.87085 | 78.1538 |

Table 3. Yearly Harvestable Days and Hours

| _Year | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|
| Harvest Days | 66.4 | 72.1 | 49.3 | 69.2 | 62.6 | 70.8 | 57.7 | 65.8 | 58.4 |
| Harvest Hours | 230 | 249 | 171 | 239 | 217 | 245 | 200 | 228 | 202 |

Data is based on a ratio of 63.59days/220hrs

Table 4. Performance Rate and Resulting Hours and Days Needed

| | Conv and Case IH | | John Deere | |
|---|---|---|---|---|
| Performance Rate Acres/Hour | 6.8 | | 7.8 | |
| | Hours Needed | Days Needed | Hours Needed | Days Needed |
| 1400 acres | 205.9 | 59.0 | 179.5 | 51.4 |
| 1800 acres | 264.7 | 75.8 | 230.8 | 66.1 |
| 2200 acres | 323.5 | 92.6 | 282.1 | 80.8 |

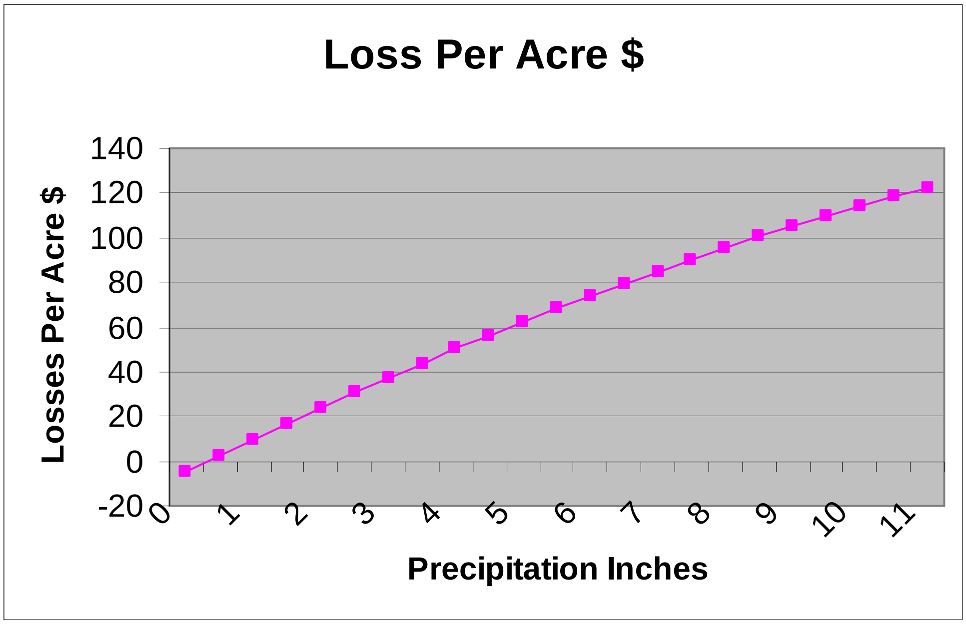

Figure 1 Precipitation's Affect on Loss Per Acre