Estimating Cotton Harvest Cost per Acre When Harvest Days are Stochastic

Authors
Matthew Farrell
Mississippi State University
Maf56@msstate.edu

Gregory Ibendahl
Mississippi State University
Ibendahl@agecon.msstate.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31-February 3, 2009

Estimating Cotton Harvest Cost per Acre When Harvest Days are Stochastic

Abstract
The cotton harvesting industry is in the beginnings of its next technological advance, cotton harvesters that form cotton modules inside the machine then deposit them off the rows. These new machines eliminate the need for extra labor and equipment, but are more expensive than conventional pickers. Increased field efficiency is also a benefit of the on-board module builders. The problem facing producers is determining the optimal number of acres to plan for harvest when trying to decide which harvester to purchase. This paper examines two objectives. First, determine the cost per acre of both conventional and on-board module harvester systems for different acreage levels assuming harvest hours per year are fixed. Second, make the harvest hours per season stochastic to determine the cost per acre under different farm sizes for each type of cotton picker. The results show that the maximum benefits of the new machines are realized with larger farms when a larger number of acres need to be harvested in the harvest period. Results should help farmers plan both their cotton acre estimates as well as their purchase decisions for new cotton pickers.

Estimating Cotton Harvest Cost per Acre When Harvest Days are Stochastic

Cotton harvesting is continuing to evolve. From mechanized harvesters replacing hand picking to the introduction of the module builder, technology has continued to try and reduce farm cost of cotton harvesting. Currently both John Deere and Case-IH are in the process of introducing new machines that build partial modules right on board the harvester. By building modules on the machine, the new systems eliminate the need to build modules using a separate boll buggy, module builder, and associated tractors and labor. Because the new harvesters eliminate the need to stop and dump cotton into a boll buggy, the field efficiencies of the new machines is greatly increased. In other words, both the new Deere and Case-IH harvesters can harvest more acres per hour than conventional cotton pickers. Throughout the paper, harvester and picker will be use interchangeably.

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 pick. A tractor with accompanying attachment then moves four 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.

While there are many benefits to the new on-board module building harvesters, these benefits come at a cost. The new harvesters may cost up to $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. The increased field efficiency is important because it allows farmers to harvest more acres in a season than would be possible with a conventional picker. This increase in acres helps to lower the cost per acre to operate the picker.

Problem Statement

When considering a cotton harvester purchase, farmers must analyze their farm size and field efficiencies along with the stochastic harvest hours. Because harvest hours are stochastic, the number of acres harvested in each season will also be stochastic. Given that the cotton pickers have different field efficiencies, their ability to harvest a given number of acres each year will also vary.

The problem facing producers is determining the optimal number of acres to plan to harvest when trying to decide which cotton harvester to purchase. Each harvester's field efficiency and associated cost are beneficial for different farm sizes. Investment in such large farming equipment involves risk; therefore, the farmer needs to be able to make the correct decision when purchasing a harvester and preparing the number of acres that are optimal for lowest cost harvesting to reduce those risks.

The risk of planning for acres to be harvested is the stochastic nature of yearly harvesting days. As the number of harvested acres increases, the harvest cost per acre

decreases. However, trying to plan for more harvested acres increases the likelihood that not all the cotton will get picked or that some will have quality discounts. Similarly, planning to harvest fewer acres means that the likelihood of harvesting all the acres without incident increases but with a higher cost per acre as the machine is likely underutilized. Farmers want to fully utilize their machines but still get all their cotton harvested.

Objectives

This paper has two objectives. First, determine the cost per acre of both a conventional and on-board module harvester for different acreage levels assuming harvest hours per year are fixed. Second, make the harvest hours per season stochastic to determine the cost per acre under different farm sizes for each type of cotton picker.

The first objective should help show where a conventional picker and an on-board module picker are best suited. A cotton picker is a lumpy asset because partial pickers cannot be added to a farm. Thus, based on a fixed number of harvest hours, there will be a maximum number of acres that a picker can harvest during the season. This maximum acreage is also where the average cost per acre is lowest. Because the new pickers have greater field efficiencies, they can harvest more acres in a season than can the conventional pickers. The new pickers could be constrained to harvest the same number of acres as the conventional pickers, but then their cost per acre would be higher than if they used all the available harvest hours. Similarly, with a fixed number of harvest hours, it is impossible for a conventional picker to harvest as many acres as the newer pickers.

The second objective, where harvest hours are stochastic instead of fixed, should show the farm size each picker is best suited for. With harvest hours stochastic, each

system runs the risk of not completing harvest for a given farm size. The new harvesters, with their greater field efficiencies, can reliably pick more acres but often with a higher cost. In this second objective, once the stochastic harvest hour is reached in a given simulation, cotton may be still left to harvest. We assume it is harvested but at a higher cost per acre.

Model when harvest hours fixed

According to USDA harvesting progress reports, the average harvest days per year for cotton is 63.6 days. This is associated with a September to November harvest period. Contributing Agriculture Engineer, Herb Willcut, used collected data to estimated average total harvest hours for those 63.6 harvestable days at around 220 hours per season picking. Therefore 220 harvest hours will be fixed for each machine to determine an average comparable cost per acre. .

Each harvester's performance rate (acres/hr) is calculated by time spent on-row actually picking as a percentage of total operating hours. These rates were affected by number of stops to dump cotton or bails, time spent turning from row to row, the speed of the machine, and any down time for repairs. Therefore, each machine's maximum acres were different per the average 220 hours. These performance rates and max acres are presented in Table 1.

The conventional and new machines have factors that affect both but were varied depending on machine ability. Each machine system also had specific factors and machinery cost associated with the different machines. These costs are provided in Table 2. The three systems had three general areas of cost: picking to module creation, module transportation, and ginning.

Simulation model when harvest hours are stochastic

Harvest days in a given year are stochastic. 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; in this model, these acres were harvested it a higher cost. 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. The cost per acre for each machine changes as the number of acres varies. Table 4 shows an example of how varied harvest hours can affect each machines cost per acre.

When acres planted exceed acres harvested in the harvesting time period being simulated, the remaining acres will not be left in the field, but harvested with possibly a quality or quantity loss. It is assumed that higher harvesting costs are associated with the additional acres. For this reason, in the stochastic model a multiplier is used to explain the higher cost per acre for acres not harvested in the harvestable time period. 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:

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

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.

Using 220 hours in 63.6 days of harvesting as a base, the yearly harvestable days for each year from 2000 to 2008 as shown in Table 3, were compiled into a PDF as shown in Figure 1. This PDF is smoothed using a Gaussian filter using Simetar software. 500 simulations of season's harvest hours were performed for different farm sizes for each harvester. The distribution of simulated harvest hours follows the skewed distribution in Figure 1. If the harvester can harvest given planted acres in the simulated harvestable hours, then the cost per acre for those acres is recorded. If there are remaining acres to be harvested then the multiplier increases harvesting costs for those extra acres. This cost is added with the acres harvested in the simulated harvestable hours to give a total cost; which is then divided by total acres planted to receive the cost per acre.

Results

Table 4 shows the results of a cost per acre comparison of the three systems at average harvest hours. Each machine was given the same harvest hours to operate and the comparisons are show for each hour set. As expected the machines showed a decrease in cost per acre as harvest hours increased. The assumption was made that the harvesters could pick as many hours as needed to finish with no restraint of a seasonable time frame. Because of the better performance rate, the new module building harvesters experience better benefits as acres increase.

Simulating the harvest hours produced data that was compiled into a fan graph for each harvester in Figure 2, Figure 3 and Figure 4; conventional, John Deere, and Case-IH respectively. The figures show the costing percentile ranges (5th, 25th, 75th, 95th) at the different size farms for each harvester. An average cost per acre line is also included. A farmer will be interested in a machine's harvestable acres where the lowest average cost per acre is realized. Table 4 lists each harvesters acreage ability where lowest per acre average costs are realized. The table also provides a range for cost per acre. This range provides farmers a 90 percent expectancy of per acre costs given stochastic harvest hours. In other words, a farmer can expect that his cost per acre, given stochastic harvest hours, to fall between the upper limit and lower limit with 90 percent certainty.

Discussion

John Deere and Case-IH have each introduced new on board module building cotton harvesters that have higher initial costs than the conventional harvester. The reduction of some equipment and labor provides the new systems with cost benefits. The increased field efficiency is beneficial as well because fixed costs can be spread over more acres than would be possible with a conventional picker. The results show that the increase in acres helps to lower the operating costs per acre for the harvesters. The conventional harvesting system will be less expensive to operate up to the maximum acres level it can handle. Acreage above this level lowers the cost per acre of the new machines until their maximum limit. If harvesting hours are fixed and the cotton acreage is above the maximum level for conventional machines, producers are best suited with the new harvesters.

The larger farm sizes will benefit the greatest from the new harvesters by planting the acreage, per machine, that is lowest cost per acre. For example, a farm that is 10,000 acres would need five John Deere machines (2000 optimal acres) or over five Case-IH machines (1700 optimal acres). They would either harvest additional acres with an increase in cost per acre with five machines or have six and harvest the total less than optimally. If that farm planted 10,200; then six Case-IH machines would run optimally or five John Deere machines would harvest acres at higher per acre costs. Results should help farmers plan both their cotton acreage estimates as well as their purchase decisions for new cotton pickers.

The range of cost per acre for each machine at its optimal acreage will give farmers an idea to assist in decision making regarding risk for the harvesting season. While crop and cotton prices will ultimately drive cotton acreage, the estimates from this paper should give some guidance about whether their cotton equipment is adequate for their farm. When it comes to the decision between the John Deere machines or Case-IH machines the question for farmers is usually "What's your favorite color?"

Table 1. Performance rate and maximum acres based on 220 harvest hours

Harvester	Performance Rate	Maximum Acres
Conventional	6.6	1452
New Deere	8.5	1870
New Case IH	7	1540

Data for performance rate taken from on the row time in motion analysis

Table 2. Factors affecting 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	Modules/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		
		Plastic wrap	$/round module		
		Time to stage round module	Minutes/module		

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. 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 5. Lowet cost per acre and 90th percentile range .

Harvester	Acreage	Avg. Cost	90% of per acre costs will fall between.
Conventional	1600	$98	$89-$116/acre
John Deere	2000	$100	$92-$117/acre
Case-IH	1700	$90	$82-$107/acre .

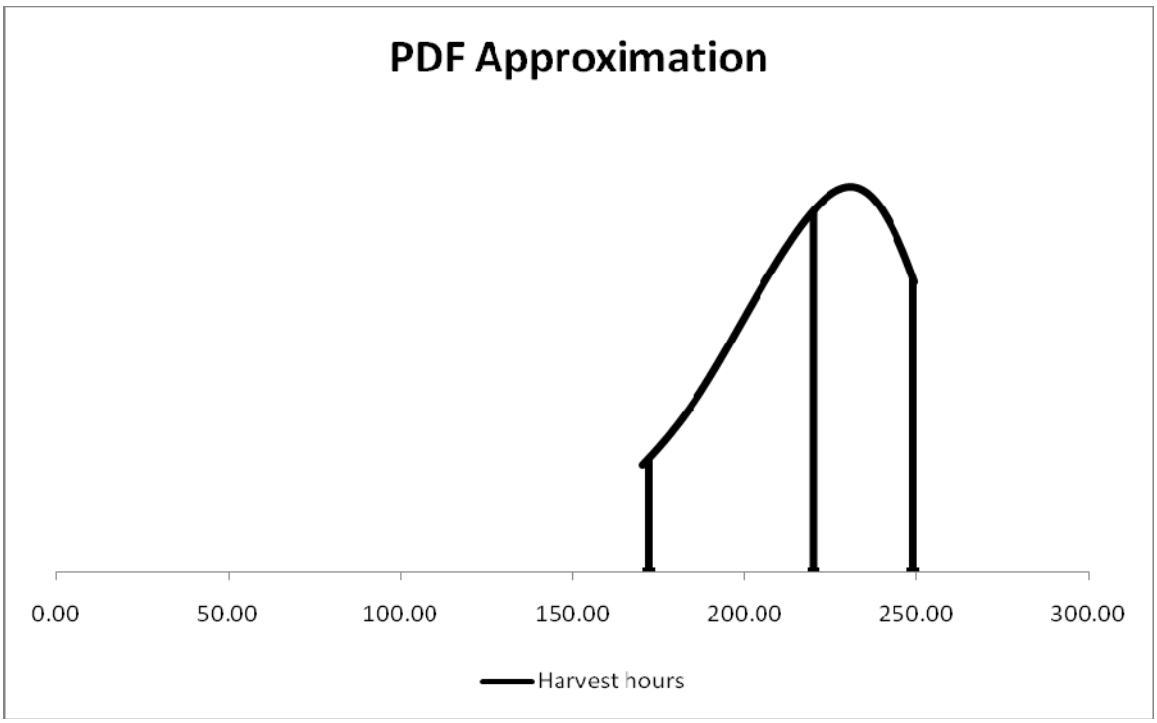

Figure 1. PDF of harvest hours from year 2000-2008

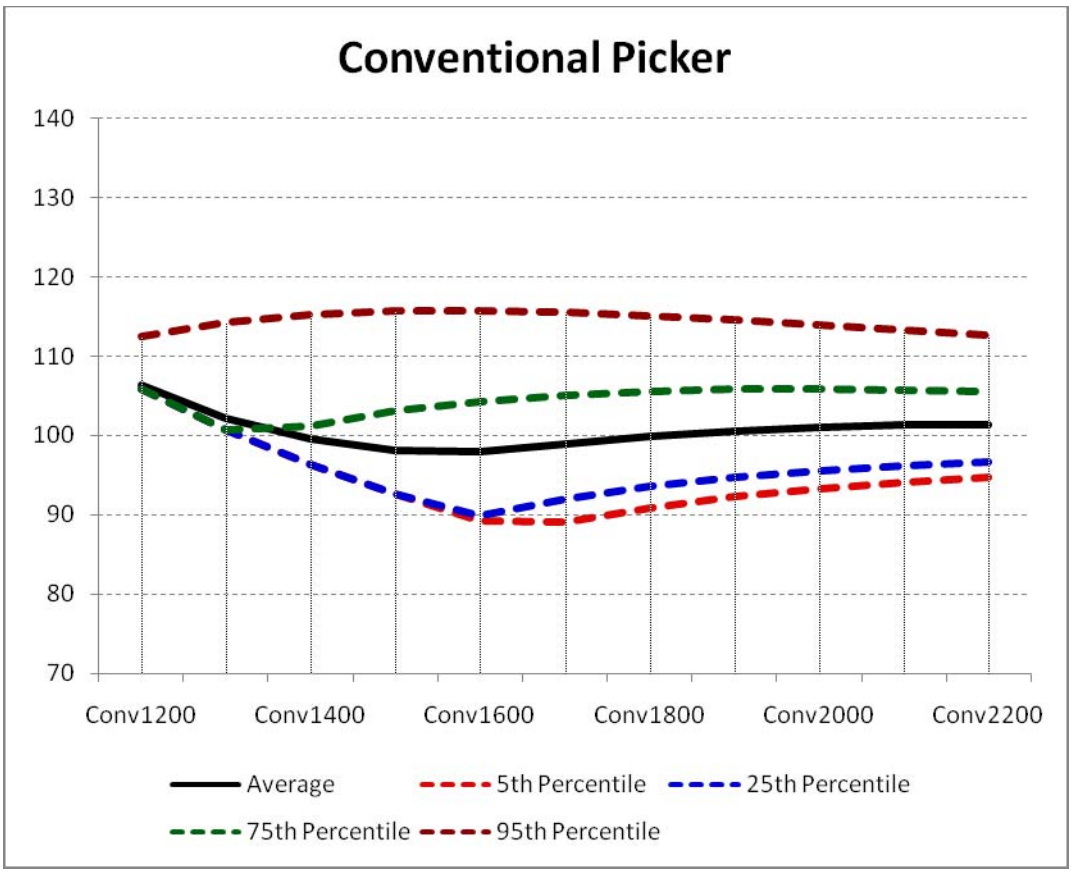

Figure 2. Fan graph of conventional harvester cost per acre given # of acres planted

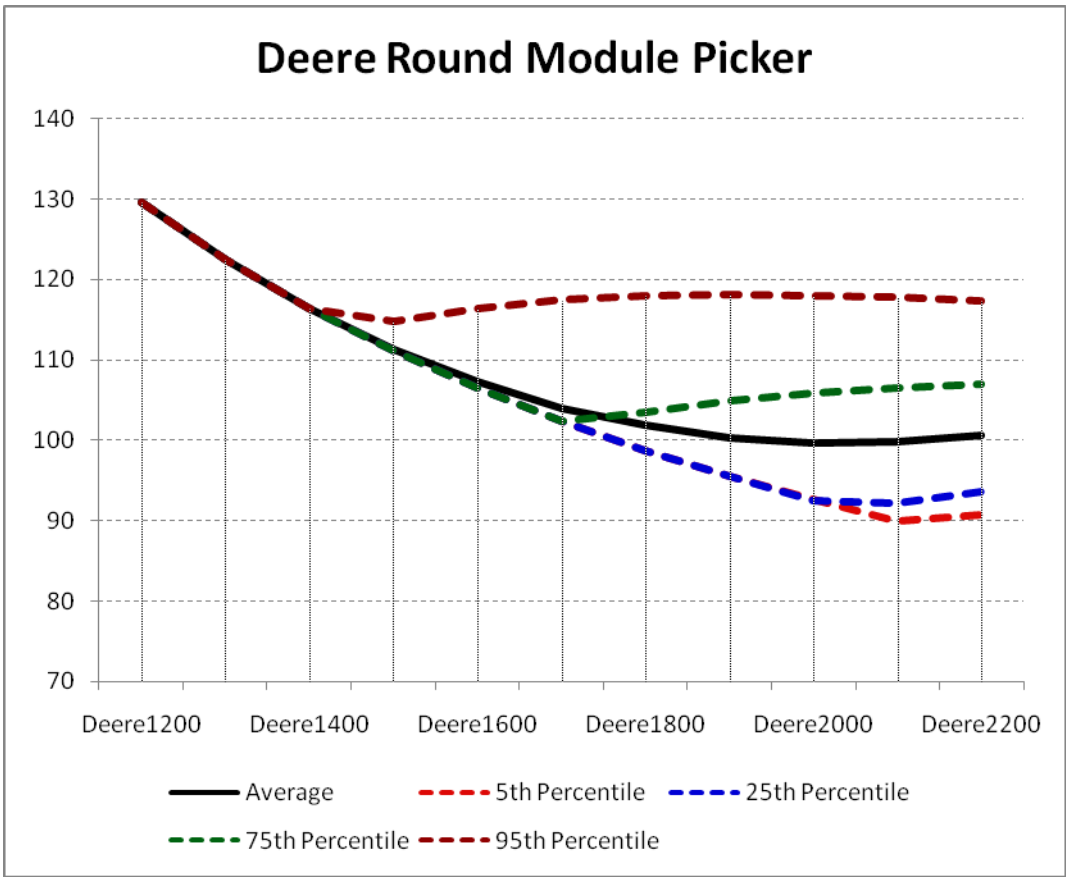

Figure 3. Fan graph of Deere module harvester cost per acre given # of acres planted

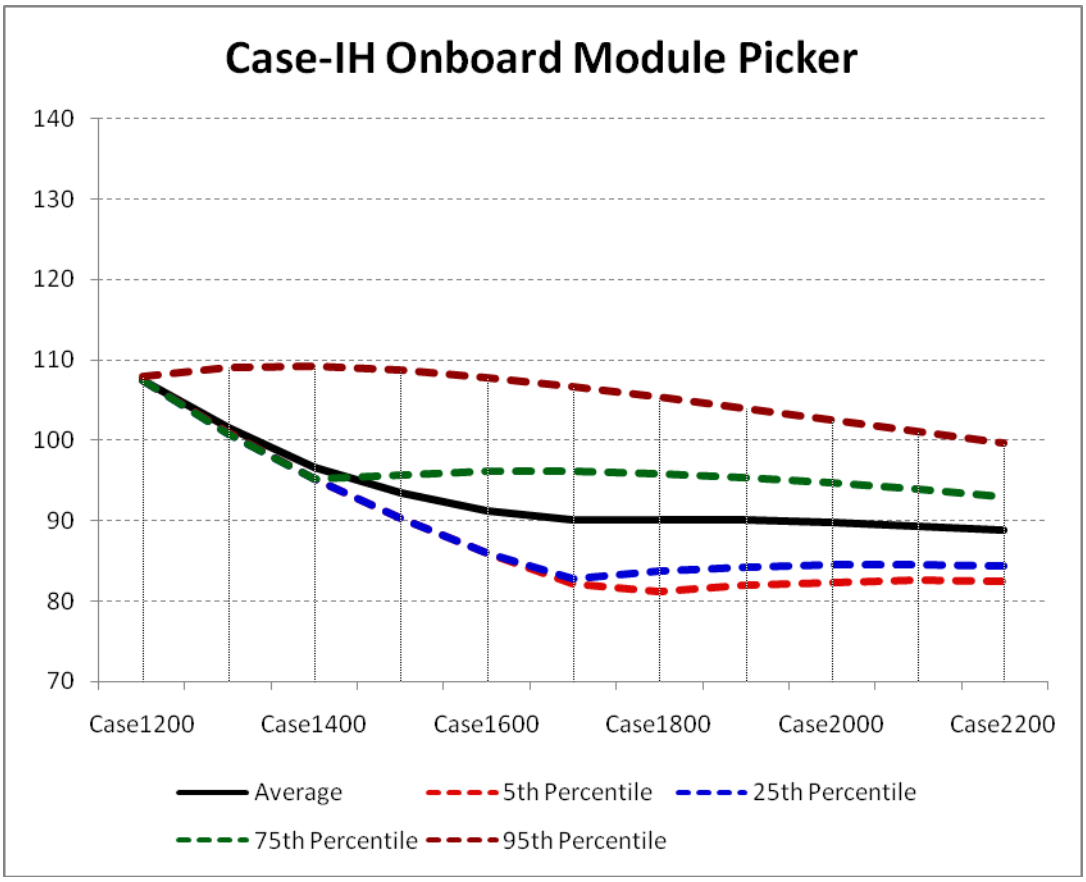

Figure 4. Fan graph of Case IH module harvester cost per acre given # of acres planted