Do Producer Risk Attitudes Effect the Sizing of On-farm Harvest, Drying and Storage Systems? *

by

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ABSTRACT

An on-farm harvest, drying and storage system simulation model is used to determine how producers' risk attitudes effect combine and dryer capacity. Stochastic dominance determines the risk efficient combine and dryer set for a 2000 acre farm in central Indiana. Capacities decrease as risk aversion increases.

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How do Producer Risk Attitudes Effect the Sizing of the On-farm Harvest, Drying and Storage System?

One problem facing farm managers is sizing the harvest, on-farm drying and storage (HDS) system. Producers have the challenge of sizing the HDS system to meet current and expected future production. Because of yield and moisture variability, producers may choose a system with a larger capacity than a least cost system recommended by agricultural engineers and agricultural economists. However, the total operating capacity of the larger system may not be completely used every year. For instance, the entire capacity will not be used during a year with a low crop yield or during a fall when the grain can dry naturally in the field. On the other hand, another capacity related risk is the operation becoming too large for the combine or drying system, thus creating a bottleneck.

A trade-off exists between capacity and cost. The full capacity of the system may not be used every year, but producers are paying for this extra capacity. On the other hand, the returns to a high capacity drying-storage system may be large in years of unfavorable harvest weather. Producers need to know if a larger system will pay for itself. A related question is how risk aversion of a producer affects the desired capacity of the HDS system.

Previous economic research involving on-farm drying and storage systems has largely concerned the profitability of alternative types of systems and determining the least cost system for given levels of production. Crop yields and moisture levels may vary during a harvest season as well as between years over the planning horizon. The effects of this variability of production and moisture as well as differences in risk attitudes have not been included in previous studies.

The objective of this paper is to analyze the tradeoff between the costs and returns associated with alternative levels of combine and dryer capacity and how this is affected by producers' risk attitudes. A simulation model is used to analyze the costs and returns of the harvest, drying and storage system on a yearly basis. Weather data for 33 years are used to provide a distribution of returns to operator labor and management. Stochastic dominance is used to determine which capacity producers with different levels of risk aversion would prefer. Risk neutral producers would prefer the system generating the lowest annual costs while a risk averse individual may be willing to take on the additional cost associated with a larger dryer or combine in order to avoid a bad outcome.

Review of Related Literature

Previous studies (Holmes, Klemme and Lindholm; Kiker and Lieblich; and Gempesaw and Gunasekaran) have focused on analyzing the profitability of investing in on-farm drying and storage systems. Weather data were used to simulate drying conditions and energy costs of different drying technologies. The results indicate that large-scale grain producers can profit from investing in on-farm drying and that high temperature systems have a higher probability of being a profitable investment. However, these studies have not considered how yield and moisture variability throughout the harvest season and over the planning horizon affects the investment. Previous studies have also not considered the effect of producers' risk attitudes on sizing the HDS system.

Two harvest simulation models, the Purdue Harvest Simulator and CORNSIM, were used to guide the development of the simulation model used in this study. Castain, et al. developed the Purdue Harvest Simulator to simulate corn production, harvesting, handling, drying, storage, and marketing on the farm level. CORNSIM simulates planting, plant growth, grain development, and field drying on a daily basis (Van Ee). Both models use weather data to simulate maturity date, field drying conditions, and yield loss during the harvest season.

Figure 1 provides a summary of the simulation process and the analytical methods used in this study. The number and pattern of suitable field days are estimated from a soil moisture budget using daily weather data on a year by year basis (Jones and Kiniry). The number of suitable field days derived from the soil moisture budget model can not exceed the reported number of field days for the same period as reported by Indiana Agricultural Statistics.

The model simulates corn pre-plant and planting activities given an endowment of suitable field days, machinery, and labor resources. Soybean pre-plant, planting, and harvest activities are simulated because soybean production may compete with corn production for harvest resources. Each year in the 1961 to 1995 period is considered separately.

The simulation model assumes that all pre-plant operations are completed before planting begins. PCLP, a farm linear-programming model, is used to determine the appropriate machinery and labor resources needed for timely completion of cropping operations under average conditions. Timeliness of operations is captured by the year-to year variation in the number of suitable field days, with an untimely operation having a lower recoverable yield. Planting begins once pre-plant operations are completed, it is a suitable field day, it is a period suitable for planting corn or soybeans, and labor resources are available.

A potential corn yield is assumed and is adjusted by yield loss penalties as harvest is delayed and as the grain dries in the field. In this study, a potential yield of 140 bushels/acre is assumed. The potential yield is adjusted for the deviation from the trend yield to capture weather effects during the growing season. The corn physiological maturity date is estimated by accumulating growing degree units. Daily relative humidity, temperature, and equilibrium moisture data are used to simulate the daily amount of field drying.

Soybean harvest begins on the average harvest date for each spring planting period (Christmas). Corn harvest occurs on suitable field days once soybean harvest is completed with yield penalties accruing if corn harvest is delayed. The progress of corn harvest depends upon the yield, level of grain moisture, number of suitable field days, and the endowment of machinery and labor resources. The flow of grain through the on-farm corn drying and storage system is simulated on a daily basis.

Weather data are used to determine the drying time and LP gas used by the high temperature dryer. The model accounts for the capacity of the grain dryer, wet holding bins, and storage bins. The model calculates the bushels dried each day and adds the dried bushels to the storage bins. If the model runs out of storage capacity, the additional bushels are dried to 15% moisture and stored off-farm. Harvested bushels that are not dried by the end of the day are added to the wet holding bin. If the model runs out of wet holding storage space, any additional grain harvested will be dried and stored off-farm. The model accounts for the amount of bushels dried and stored on-farm, dried on-farm and stored off-farm, and dried and stored off-farm because each method will have different drying and storage costs. The grain dryer will run every day there is grain in the wet holding bins.

The return to labor and management will be calculated for each simulation and used in determining the risk efficient harvest, drying and storage system. The economic cost of land, economic depreciation in equipment, opportunity cost of machinery and equipment, as well as annual production costs and the costs of the harvesting, drying, and storage system are subtracted from total revenue.

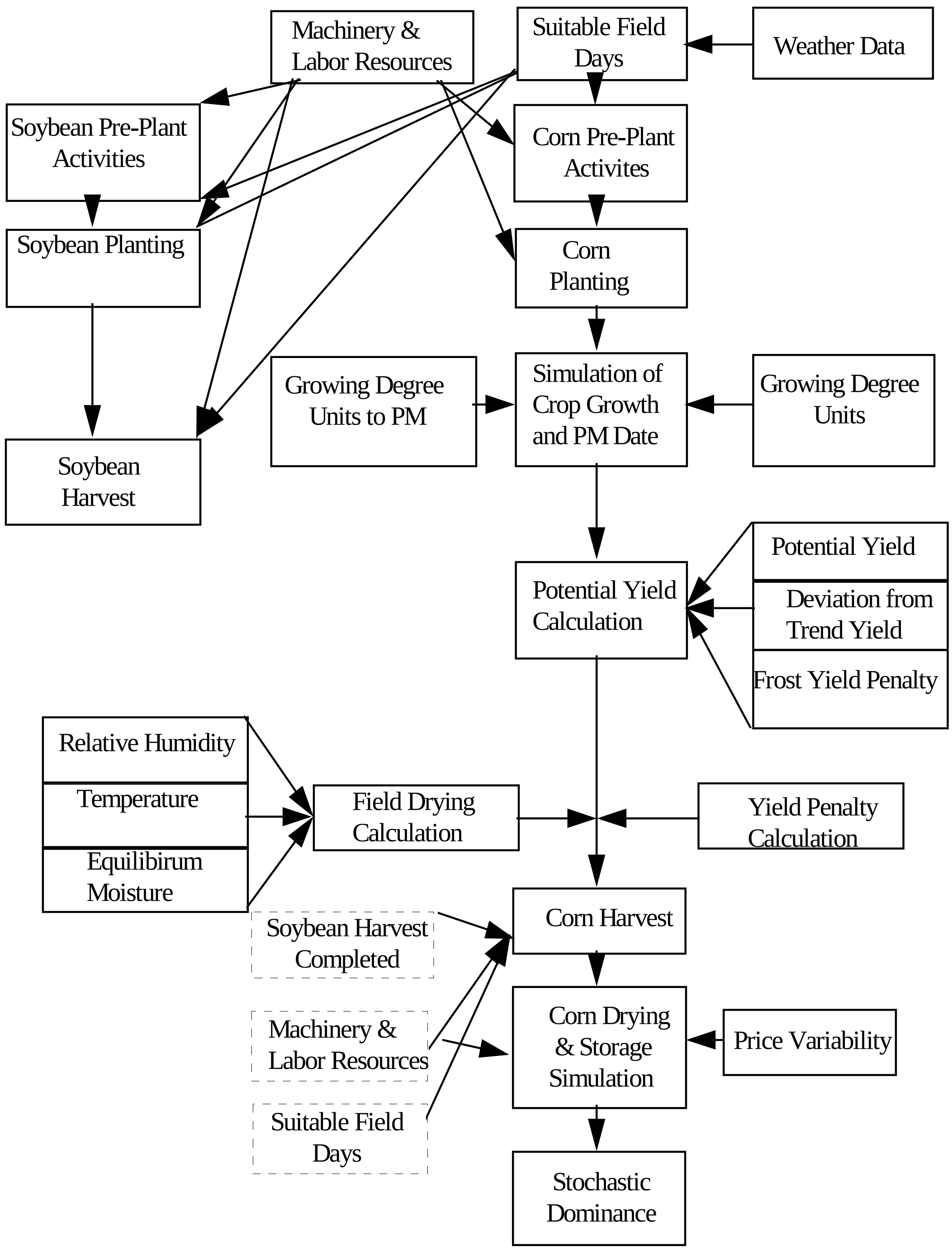

Figure 1. Overview of Simulation Model and Methods.

Data

The simulation model uses daily temperature precipitation, solar radiation and relative humidity data for Kokomo to model corn development and grain drying (Purdue Applied Meteorology Group). Weather data were used to indicate suitable field days with the historical number of suitable field days used to limit the number of field days in each spring period (Indiana Agricultural Statistics Service).

Crop information from Pioneer Hi-Bred International, Inc., Indiana Agricultural Statistics Service and Purdue University Extension Agronomists, Elsworth Christmas and Bob Nielsen, were used in describing the crop development, grain drying and harvest sections of the simulation model.

Industry sales representatives were contacted for capacity and list price information of the components of the on-farm harvest, drying and storage system. This study used price and capacity information for John Deere combines (Reynolds Farm Equipment), GSI grain dryers (Woodruf), Brock wet holding bins (Towne), GSI storage bins (Woodruf), and Sukup fans (Towne). The capacity and list price of each component information is used to estimate the list price as a function of bushel capacity.

Expert opinion was used for commercial drying and storage rate information and HDS system component design and sizing recommendations.

Methods

A base scenario for a 2000 acre farm located in central Indiana was simulated. A corn-soybean rotation was assumed. A minimum tillage system was simulated for corn and a no-till system simulated for soybeans. Sensitivity analysis was performed on the capacity of the combine, and dryer by increasing and decreasing the capacity of each individual component by 10%, 20%, 30, 40, and 50%.

The PCLP linear program sized labor and machinery resources. The combine in the base scenario was sized to complete soybean harvest in 12 suitable field days and corn harvest in 15 suitable field days. Labor was constrained to working ten hours per day in the field. All pre-plant activities must be completed before planting can begin. Similarly, all soybeans must be harvested before corn harvest is initiated.

Daily weather data for 33 years were used to add variability in the number and sequence of suitable field days. Weather data also determined the date of corn physiological maturity and rate of field drying. The simulation model provides an estimate of the harvested yield for corn and soybeans for each of the 33 years. Given the harvested yield, @Risk (Palisade) is used to create a distribution of corn and soybean prices and resulting revenues for each year. A distribution of returns to labor and management is created using the price distributions generated by @Risk.

A stochastic dominance program developed by Cochran and Raskin and modified by Preckel is used to determine the risk efficient set. The risk efficient set is determined using First Degree Stochastic Dominance (FDSD), Second Degree Stochastic Dominance (SDSD) and Stochastic Dominance with Respect to a Function (SDRF). For SDRF, the coefficients of absolute risk aversion ranged from 0 to 10^{-6} for risk neutral, 10^{-6} to 10^{-5} for slightly risk averse, 10^{-5} to 10^{-4} for moderately risk averse, and 10^{-4} to 10^{-3} for extremely risk averse producers.

Preliminary results from the simulation model were reviewed by experts in grain drying (Maier) and farm management (Dobbins, Doster, and Patrick) and served as an informal validation of the model. Initial results were also presented to a group of large-scale grain farmers attending the 1997 Top Farmer Crop Workshop at Purdue University. Producers indicated that the model seemed to produce reasonable results.

Results

A combine that completes soybean and corn harvest in 33 suitable field days has the largest average return to labor and management (Table 1). However, there is not much difference in the mean returns for combines with capacity to complete harvest in 28 to 33 suitable field days. Although a larger capacity combine can complete harvest in fewer field days with less yield loss, the larger annual costs of ownership and operation reduce the average return to labor and management. A smaller combine has lower annual ownership and operating costs. However, the increased yield loss associated with the smaller combine reduces the annual returns to labor and management.

Table 1. Simulation Summary Statistics for the 2000 Acre Farm Combine Sensitivity Analysis.

Scenario	Field Days[1]	Average Return[2]	Yield (15% Moisture)	Yield Penalty[3]
+50%	21	$54,026	134.22	3.40
+40%	22	$59,341	133.82	3.56
+30%	23	$64,464	133.74	3.61
+20%	24	$68,194	133.5	3.74
+10%	27	$72,306	133.11	4.06
Base	28	$74,412	132.93	4.13
-10%	32	$74,410	131.57	5.02
-20%	33	$74,613	131.24	5.25
-30%	38	$69,755	130.23	5.98
-40%	42	$64,692	129.08	6.91
-50%	48	$48,028	126.69	8.75

[1] Average number of suitable field days needed to complete soybean and corn harvest.
[2] Average return to labor and management.
[3] Average simulated yield loss (%).

The dryer defined for the base scenario generates the largest average return (Table 2). The dryer defined for the base scenario has excess capacity for the optimal combine capacity. There is no need to increase capacity. Significant losses are associated with smaller dryer capacities even with the availability of off-farm drying.

The risk efficient set for the 2000 acre farm is listed in Table 3. Risk neutral producers prefer the 20% smaller combine because it has the largest average return. A more risk averse producer would prefer the 20% or 30% smaller combine because the lower tail of the cumulative distribution is further to the right.

Table 2. Summary Statistics for the 2000 Acre Farm Dryer Sensitivity Analysis

Scenario	Dryer Capacity (Bushels)[1]	Average Return[2]
-50%	292	$65,777
-40%	350	$70,011
-30%	409	$72,796
-20%	467	$73,005
-10%	526	$74,155
Base	584	$74,412
+10%	642	$74,273
+20%	701	$73,686
+30%	759	$73,218
+40%	818	$72,484
+50%	876	$71,759

[1] Capacity of the drying plenum (bushels per hour).
[2] Average Return to Labor and Management.

Table 3. Risk Efficient Set for the Kokomo 2000 Acre Farm.

Component	FDSD	SDSD	Risk Neutral	Slightly Risk Averse	Moderately Risk Averse	Extremely Risk Averse
Combine	Base	-10%	-20%	-20%	-20%	-20%
	+10%	-20%				-30%
	-10%	-30%				
	-20%					
	-30%					
Dryer	Base	Base	Base	Base	Base	Base
	+10%	+20%			+20%	-10%
	+20%	-10%				-20%
	-10%	-20%				-30%
	-20%	-30%				-40%
	-30%	-40%				-50%
	-40%					
	-50%					

Conclusions

This paper studied the effect of producers' risk attitudes on sizing the on-farm harvest, drying and storage system. It was hypothesized that risk averse producers may want a larger capacity system to compensate for bad weather years. In contrast, risk neutral producers prefer the capacity system that generates the largest return to labor and management and may prefer a smaller capacity system.

It was found that a risk neutral producer would prefer a combine that completes harvest in 33 good field days. A more risk averse producer would prefer a smaller combine that would complete harvest in 35-38 days. The sizing guidelines developed by agricultural engineers and agricultural economists seem to be appropriate. They suggest that producers should size combines to complete harvest in 26-30 field days. Although this is a slightly larger system than suggested by study results, the differences in returns are small. Furthermore, the agricultural engineering guidelines may recognize that farmers tend to expand their operation and there is little cost associated with this additional capacity. Increasing combine capacity reduces average returns. However, average returns are higher for a 50% larger combine than the returns from a 50% smaller combine.

A risk neutral producer would prefer the dryer defined for the base scenario. A risk averse producer would prefer a smaller capacity dryer because of the lower annual cost. The dryer sizing recommendations also seem to be appropriate. Producers building excess capacity also have lower average returns. Like the results for the combine, a 50% larger dryer has larger average returns than returns from a 50% smaller dryer.

Risk averse producers preferred smaller combine and dryer capacities for each farm size. The years with the lowest returns to labor and management in the 33 year period were 1974, 1983 and 1988. These years had weather effects that sharply reduced the potential yield before harvest. A larger capacity combine or dryer would not be needed for a short crop. A larger system would increase annual costs and reduce average returns. The smaller capacities had lower annual costs moving the lower portion of the cumulative probability distribution further to the right. The position of the lower portion of the cumulative distribution is important in stochastic dominance with distributions further to the right being preferred as risk aversion increases.

This model has not considered any system dynamics. Future research can incorporate the effect of increasing farm size on combine and dryer capacity. Another limitation of this study is that the combine and dryer were both correctly sized for the base scenario. Producers are likely to trade combines more frequently than they increase their dryer capacity. The likely result is that the combine is too large for the current dryer capacity for many farms.

The model does not capture catastrophic loss events. The yield loss function was a smooth exponential function. However, it is likely that snow or wind can greatly increase the amount of stalk lodging and ear drop loss to greater levels than simulated in the model. Further research could also determine the sensitivity of results to alternative damage loss functions.

The study also simulated 1000 and 3000 acre farms for central Indiana. The results were similar for the 1000 acre and 3000 acre farms. The combine should be sized to complete corn and soybean harvest in 27-33 suitable field days. The dryer sizing recommendations developed by agricultural engineers were appropriate. The capacities defined for the base simulation had the largest average return to labor and management. When risk preferences were considered, producers that were risk averse preferred smaller capacity combines because of the lower annual operating and ownership costs.

The larger study also simulated 1000, 2000, and 3000 acre farms in northern and southern Indiana. The sizing relationships were the same for each location. However, when you compare the same sized farm across locations, larger capacity systems are preferred in northern Indiana than southern Indiana because of the fewer suitable field days in the fall in the north.

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