

## **Whole Farm Profitability Impact from Implementing and Harvesting On-farm Trials with Precision Agriculture Technologies**

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### **Introduction**

For a combination of reasons, farmers are motivated to conduct their own on-farm trials; however, on-farm trials are not costless. Farmers often cite reasons for not conducting on-farm trials including: 1) interference with other farming operations, 2) potential yield reduction by inferior inputs or non-optimal rates (too high or too low rates), 3) increased direct costs from over application of inputs and 4) increased probability of bad decision making from implementing experiment results on large acreage in the following year. This study addresses the first point that implementing and harvesting on-farm trials interferes with other farming operations by quantifying the yield penalties from delayed field operations on a representative U.S. Cornbelt farm.

The commercialization of the combine and cotton picker yield monitors reduced the time commitment of harvesting on-farm trials, motivating some farmers to re-examine field-scale on-farm planned comparisons. In addition to increased numbers of farmers conducting on-farm trials, some farms are implementing more trials on their farms (Griffin et al. 2008). Similar to yield monitors reducing data collection time requirements during harvest, time requirements during other times have decreased for on-farm trial implementation and data collection with precision agriculture technology such as automated controllers and automated guidance with global positioning systems (GPS), potentially reducing adverse timeliness of other farm operations.

Recent advancements in spatial statistical analysis have allowed farmers who are conducting field-scale on-farm trials to base their farm management decisions on statistically valid inference. Although it is known that benefits and costs of on-farm trials exist, neither is known with certainty. In addition, estimating the benefits of on-farm trials is more difficult than estimating the costs. This research estimates the cost of conducting on-farm trials from a whole-farm profitability standpoint using mathematical programming for a representative U.S. Corn Belt farm and suggests some possible benefits from previous empirical results.

To quantify potential whole-farm impacts of conducting on-farm trials, a linear programming (LP) model was formulated using PCLP Version 5 (Dobbins et al. 2001). PCLP has been used in an Extension context since 1968, e.g. in conjunction with the Purdue Top Farmer Crop Workshop, and was chosen to conduct this research because more than 7,000 farmers have relied upon, trusted, and inputted their own information over 25,000 times, validating the model (Candler et al. 1970; Doster 2002; McCarl et al. 1977). In addition, PCLP has been used by several research projects to address machinery (Danok et al. 1980; Griffin et

al. 2005), cropping systems and rotations (Cain 2006; Foltz et al 1991; Mellor 2005; Robertson 2006), labor availability (Nistor & Lowenberg-DeBoer 2006), financial and risk management (Brink & McCarl 1978, 1979; McCarl et al. 1977), harvest and on-farm drying systems (Davis & Patrick, 2002), and climate change ramifications (Doering 1977; Habeck 2002).

## **Background**

Some farmers have been reluctant to devote efforts necessary to properly conduct on-farm trials because of interference with other farming operations during both the implementation and data collection phases. Implementation of on-farm trials may occur before, during or after planting. For instance, tillage comparisons may occur prior to planting, cultivar trials implemented during planting, and foliar fungicide treatment comparisons implemented after planting. Even though precision agriculture technology, e.g. GPS automated controllers and yield monitors, has reduced field operation interference, it has not been eliminated. Yield monitor calibration requires time regardless if on-farm trials are being conducted and is recommended during harvest rather than post-calibration or post-processing data. If weigh scales are available in the field, it is anticipated that calibration takes two hours although a portion of this time crop is being harvested.

With most yield monitor brands, corn harvest is associated with two calibrations, one for wet corn and one for dry corn; additional calibrations are suggested when harvesting different corn hybrids (Doerge et al. 2006). Therefore, a cultivar trial may require multiple calibrations, i.e. one calibration for each treatment, whereas other types of on-farm trials that have a single cultivar, e.g. tillage, rates, seed treatment, a single calibration for each experiment may be all that is necessary.

## **Methods**

A linear programming (LP) model was used to determine optimal solutions to maximize contribution margins. LP is a mathematical tool for optimizing an objective function (Dantzig 1949) such as maximizing contribution margins with respect to a set of whole-farm constraints on land, labor, and capital under a given weather regime (Doster et al. 2008). Contribution margins are total crop sales revenue minus total direct costs, and can be considered returns to resources or fixed costs such as land, labor, and machinery. The base for comparison was a representative sized U.S. Corn Belt farm with a single equipment set (e.g. one corn planter, one soybean planer and one harvester). The base was modified in a series of LP runs.

Four basic assumptions of on-farm trials guided this study. On-farm trials: 1) were implemented at planting times with the highest potential corn production, 2) were harvested in the time period with highest

potential corn production, 3) were implemented and harvested on a good field day and 4) diverted 100% of resources away from other farming operations while being implemented and/or harvested. This diversion of resources, e.g. labor and machinery, was effectively modeled by reducing the number of days suitable for fieldwork and may be more relevant to farmers new to conducting planned on-farm trials rather than farmers experienced with the process.

Although yield monitors have reduced the time required to harvest on-farm trials, delays relative to production practices result due to yield monitor calibration, weighing loads, or other practice. Proper calibration of a yield monitor has been estimated to take at least 2 hours if a weigh scale is available in the field.

Although it is expected that Eastern Cornbelt farms utilizing yield monitor information would calibrate three times a year, i.e. once for soybean and once each for wet and dry corn, additional calibrations may be important if the farm is conducting on-farm trials. Table 1 presents the days required for calibration under differing scenarios. There are several realistic examples where the farmer would calibrate four or more times per season. If planned comparisons include hybrids, then an additional calibration may occur for each treatment. When the yield monitor was calibrated four times, taking 2 hours per calibration, then the number of good field days for harvest would be reduced by 0.9 days, thus influencing harvest timeliness.

**Table 1: Good field days required to calibrate yield monitor**

Number calibration sessions	Hours required for each yield monitor calibration						
	0	1	2	3	4	5	6
1	0.0	0.1	0.2	0.4	0.5	0.6	0.7
2	0.0	0.2	0.5	0.7	0.9	1.2	1.4
3	0.0	0.4	0.7	1.1	1.4	1.8	2.1
4	0.0	0.5	0.9	1.4	1.9	2.4	2.8
5	0.0	0.6	1.2	1.8	2.4	2.9	3.5
6	0.0	0.7	1.4	2.1	2.8	3.5	4.2
7	0.0	0.8	1.6	2.5	3.3	4.1	4.9
8	0.0	0.9	1.9	2.8	3.8	4.7	5.6
9	0.0	1.1	2.1	3.2	4.2	5.3	6.4
10	0.0	1.2	2.4	3.5	4.7	5.9	7.1

Assumes harvest can occur 8.5 hours per good field day

## Hypothetical Model Farm Scenario

A base farm that was considered timely with respect to spring planting and fall harvesting was chosen for this study. Tillage operations on the 1,214 ha conventional tillage farm included a 12.8 m field cultivator covering 11.1 ha hr<sup>-1</sup> after harvest of both corn or soybean and a 5.5 m chisel plow following corn harvest covering 4.4 acres hr<sup>-1</sup>. Corn was planted to 0.76 m rows with a 24-row planter at 8.6 m hr<sup>-1</sup> and soybeans planted to 0.38 m rows with a 31-row split-row planter at 8.5 ha hr<sup>-1</sup>. It was expected that planting takes 11.8 field days in the 75<sup>th</sup> to 85<sup>th</sup> percentile worst year. Corn was harvested with a 12-row header at 3.6 ha per hour and soybean is harvested with a 9.1 m platform at 4.98 acres hr<sup>-1</sup>. Corn and soybean can be harvested 10 and 7 hours per day, respectively. Total harvest time takes 28.4 field days. Both corn and soybean acreage received midseason herbicide applications with a 27 m self-propelled sprayer.

LP models are typically used for long term planning horizons and not for a single year, therefore prices and yields representative across several years were chosen. Long-run corn and soybean planning prices were \$98.43 Mg<sup>-1</sup> and \$229.65 Mg<sup>-1</sup>, respectively. Corn and soybean base yields were expected to be 1.73 Mg ha<sup>-1</sup> and 0.53 Mg ha<sup>-1</sup>, respectively, when planted and harvested in the optimal time periods. Per acre variable costs were \$452 and \$262 for corn and soybean, respectively.

The base yields for corn and soybean were the best yields in a typical year when planted and harvested in the respective time periods with highest production potential. In other words, yields are not expected to be higher than the base yields in a typical year; however, lower yields are expected when planting and/or harvesting operations were conducted time periods before or after the time periods with the highest production potential. For instance, the week of April 26 to May 2 has the highest corn yield potential with the next week of May 3 to 9 considered having the next best corn yield potential (Table 2). The time period September 27 to October 10 has the highest corn yield potential when planting occurs in the April 26 to May 2 time period (Table 2). It was assumed that if the farm manager implements an on-farm trial with anticipation of gathering data useful for farm management decision making, then the experiment would be implemented and harvested during the time periods with highest yield potential for the respective crop. The optimal time period for soybean planting was a week later than corn, May 10 to 16, while the harvest time period for highest soybean yield potential was the same as corn (Table 3).

### Table 2: Corn yield potential by plant and harvest time period

## Harvest Periods

Planting Periods	Harvest Periods				
	September 20 to 26	September 27 to October 10	October 11 to 31	November 1 to 14	November 15 to December 5
Yield Adjustment (%)					
Apr 22-25	90	96	94	90	85
Apr 26-May 2	0	100	98	94	89
May 3-9	0	95	98	94	89
May 10-16	0	92	94	90	85
May 17-23	0	0	84	84	79
May 24-30	0	0	74	74	69
May 31-June 6	0	0	0	0	56

**Table 3: Soybean yield potential by plant and harvest time period**

Planting Periods	Harvest Periods				
	September 20 to 26	September 27 to October 10	October 11 to 31	November 1 to 14	November 15 to December 5
Yield Adjustment (%)					
Apr 26-May	92	98	96	93.5	89
May 3-9	92.1	98.1	96.1	93.6	89.1
May 10-16	0	100	98.1	96.1	91.1
May 17-23	0	99.9	98	96	91
May 24-30	0	0	94	92.5	89
May 31-June 6	0	0	90	88.5	85
June 7-13	0	0	85	83.5	80

Other LP model parameters were assigned based upon prior information of farmer behavior. There were two full time laborers and four hired hourly laborers available for \$10 hr<sup>-1</sup> who could work 5, 6 or 6.5 days wk<sup>-1</sup> depending on the time period. In general, tractors and implements could be used 12 hours day<sup>-1</sup>. Acreage was constrained such that corn and soybean were grown in a 50:50 rotation.

## Analysis

To simulate the effect of conducting an on-farm trial, the days suitable for fieldwork were modified. Days suitable are the days that fieldwork can be conducted in the field, i.e. it is not raining, the soil is not too wet, and the crop is able to be harvested. The basic assumption number four that resources were diverted away from other field operations during implementation and harvesting of the on-farm trial reduced the number of days suitable for fieldwork. Each LP run changed information relative to time required to implement and/or harvest an on-farm trial by modifying the days suitable for fieldwork.

Three scenarios representing different time requirements to implement on-farm trials were used: 1) no additional time, 2) one-half day, and 3) one full day. Therefore, the days suitable for fieldwork were adjusted for the planting (April 26 to May 2) time period by removing 0, 0.5, and 1.0 from the current 2.4 suitable field days, respectively. The 2.4 suitable field days for April 26 to May 2 time period were determined to be the days suitable for fieldwork in the 75<sup>th</sup> to 85<sup>th</sup> percentile worst year.

The planting days suitable for fieldwork were held constant at 2.4 and 3.5, respectively, while the harvest time period was modified by removing 0, 0.5, 1.0, 1.5, and 2.0 days from the current 8.2 suitable field days for September 27 to October 10 for the 55<sup>th</sup> to 65<sup>th</sup> worst years. In an additional scenario, days suitable for fieldwork during the planting period and harvesting period were changed together. For both time periods, 0, 0.5, and 1.0 days were omitted from the current days suitable for fieldwork.

## Results

LP results indicated a reduction in whole-farm returns compared to the base situation of no on-farm trials. This reduction occurs because of increased yield penalties from diverting planting and harvesting operations away from corn and soybean production. In the scenario where the planting operation was delayed because resources were being diverted to implementing the on-farm trial for one-half day, a \$2,684 reduction in contribution margin resulted (Table 5). When resources were diverted away from the planting operation for one full day, the contribution margin decreased by \$5,448.

**Table 4: Whole farm costs of implementing or harvesting on-farm trials**

Days suitable	Contribution margin \$ farm <sup>-1</sup>	Cost of on-farm trial* \$ farm <sup>-1</sup>
Implement on-farm trial during planting period April 26 - May 2		

0.0	2.4	598,656	0
0.5	1.9	595,972	2,684
1.0	1.4	593,208	5,448

Harvest on-farm experiment during October 11 – 31

0.0	12.2	598,656	0
0.5	11.7	597,797	859
1.0	11.2	596,838	1,818
1.5	10.7	595,842	2,814
2.0	10.2	594,794	3,862

\*Change in contribution margin resulting from less timely field operations

Like planting operations, yield penalties were associated with harvest operation delays. Although one motivation for farmers to conduct on-farm trials with precision agriculture technology is that yield monitors have reduced the time requirements at harvest, some delay of harvest may still be necessary to carry out proper on-farm testing. In scenarios where the yield monitor may need to be continually calibrated for differing hybrids, moisture, or even if weigh wagons or spot checks were used instead of yield monitors, harvest operations may be delayed. When harvest operations were delayed by 0.5 and 1.0 days during the September 27 to October 10 time period, contribution margins decreased by \$859 and \$1,818, respectively, considerably less than if the planting operation were delayed by the same time. However, the harvest time period is longer (14 days instead of the 7 days for the planting period) and additional harvest delays may exist so additional reduction in days suitable for harvest operations were considered. When harvest was delayed by 1.5 and 2.0 days, contribution margins fell by \$2,814 and \$3,862, respectively, relative to no delays. In other words, diverting harvest operation resources two days to ensure proper collection of on-farm trial data may reduce crop revenue by nearly \$3,900.

The previous discussion of harvest operation yield penalties assumed no delayed planting. Although planting time delays without harvest time delays may be possible with yield monitors, the converse is not likely if on-farm trials were implemented at planting. A sensitivity of both planter and harvest time delays are presented in Table 6. When days suitable for fieldwork during both the planting and harvesting time periods were both reduced by 0.5 days, a reduction in contribution margin of \$3,543 resulted. When days suitable for planting were decreased by one full day while the harvesting period days suitable was reduced by 0.5 days a

\$6,307 reduction in contribution margin was calculated. When one full day was removed from both planting and harvesting time periods, a \$7,266 reduction in contribution margin was calculated.

**Table 5: Costs from planting and harvesting on-farm trials**

Reduction in days suitable April 27 - May 2	Reduction in days suitable October 11-31		
	0	0.5	1.0
0	\$0	\$859	\$1,818
0.5	\$2,684	\$3,543	\$4,501
1.0	\$5,448	\$6,307	\$7,266

## Summary and Conclusions

Conducting on-farm trials is not a costless venture. In this modest example, diverting one-half day of resources away from production to plant on-farm trials cost nearly \$2,700. Diverting one full day of planting time reduced crop revenue by nearly \$5,500. Implementation of on-farm trials during non-planting time periods resulted in no yield penalties under the scenarios presented in this study, even though yield penalties were possible for the earliest midseason time period tested.

Losses increase further if there are additional delays at harvest. While yield monitors may reduce the time required to collect on-farm trial data, delayed harvest operations lead to reduced yield potential and crop quality. However, when harvest operations were delayed, whole farm profitability decreased by over \$800 when harvest resources were diverted for 0.5 days and nearly \$3,900 when diverted for 2.0 days.

In scenarios where both the planting and harvesting time periods are affected by on-farm trials, even greater costs occur. If both operations require all farm resources to be diverted away from production for one full day, yield reductions associated with implementing and harvesting the on-farm trial cost over \$7,000. These costs do not include inputs, application costs, other direct costs, human capital, analysts, or other fees associated with on-farm testing. These costs are merely the reduction in whole-farm profitability due to yield penalties associated with field operations being diverted away from other farming operations.

Many studies and Extension publications stress the importance of yield monitor calibration. In cases where the yield monitor was calibrated annually by crop species, daily, per hybrid or variety, or other interval, some delay of harvest occurs. Whether yield monitor calibration intervals are a function of on-farm trials or exist otherwise impacts the partial budgeting for on-farm trials. If an on-farm trial is to be harvested with a yield monitor, it is likely that the farm manager would properly calibrate the yield monitor to increase the probability of collecting data usable for farm management decision making. Without a formal use of yield monitor data, calibration would still be important but may have lesser value to the farm manager. Unlike some farm operations such as transportation of equipment, yield monitor calibration is assumed to always occur during a good field day because grain suitable for harvest is necessary.

Farmers considering on-farm trials for the first time may want to consider implementing trials during time periods other than planting such as pre-plant tillage treatments or midseason applications to reduce costs and downside risk. Cultivar trials may require additional calibrations and results have time limited usefulness due to the short time period that cultivars remain on the market. In addition, turn-around time on proper analysis for cultivars trials may not be sufficient to obtain early discounts, especially for corn hybrids. Overall, the costs of individual on-farm trails are highly dependent upon the efficiency and ability of the individual farmer to manage the additional planning required.

### **Limitations of Model**

The B-21 LP model is a deterministic model that does not take into account any stochastic properties or risk. The input values are used as ‘exact’ values; therefore, the results are only as good as the information provided to the model. The B-21 LP model has ‘perfect foresight’ meaning that if all field operations are not able to be completed, then that acre will not even be planted.

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