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A combine harvester econometric simulation model was developed with the goal of matching the combine forward speed to the maximum harvested net income per acre. The model considers the machinery management costs of owning a combine and platform header for harvesting wheat. A statistical Design of Experiment (DOE) was used to evaluate the model using tri-level variables; the medium values constituted the model base case. Of the 27 input variables, the optimum speed was significantly influenced by the crop area, G/MOG ratio, grain unit price, field yield, field efficiency, grain moisture content, probability of a working day in the post-optimum period, estimated harvesting day length, and the timeliness importance factor. The developed optimum speed prediction equation estimated the full model well (R2 = 0.94). Five inputs significantly influenced both the optimum speed and the harvested net income: G/MOG, grain price, field yield, estimated harvesting day length, and the timeliness factor. It is expected that the developed econometric model will be useful for determining the real-time economic performance of a combine harvester.

**Keywords**

Economics, Combine harvesters, Econometric modeling, Machinery management, Yield monitor

**Disciplines**

Agricultural and Resource Economics | Agricultural Economics | Agriculture | Bioresource and Agricultural Engineering | Other Economics

**Comments**

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**Abstract.** *A combine harvester econometric simulation model was developed with the goal of matching the combine forward speed to the maximum harvested net income per acre. The model considers the machinery management costs of owning a combine and platform header for harvesting wheat. A statistical Design of Experiment (DOE) was used to evaluate the model using tri-level variables; the medium values constituted the model base case. Of the 27 input variables, the optimum speed was significantly influenced by the crop area, G/MOG ratio, grain unit price, field yield, field efficiency, grain moisture content, probability of a working day in the post-optimum period, estimated harvesting day length, and the timeliness importance factor. The developed optimum speed prediction equation estimated the full model well ($R^2$ = 0.94). Five inputs significantly influenced both the optimum speed and the harvested net income: G/MOG, grain price, field yield, estimated harvesting day length, and the timeliness factor. It is expected that the developed econometric model will be useful for determining the real-time economic performance of a combine harvester.*

***Keywords.*** *Combine harvesters, Econometric modeling, Machinery management, Yield monitor.*

Precision farming has allowed producers to focus their field management decisions on specific field sections. Detailed field data, like soil properties, cropping history, and yield, can be used to verify past decisions and assist future decisions. Yield maps have demonstrated that grain yield varies spatially. For this reason, it is advantageous to adjust combine settings while harvesting in order to maintain optimum settings and reap the maximum possible harvest with minimal grain loss and damage. A prime criterion for judging optimum settings should be profit maximization. Precision farming technologies can assist in the determination of the combine harvester's economic performance while harvesting.

The purpose of adjusting combine settings is to improve the machine's performance and efficiency, one aim being to maximize the quantity and quality of grain in the combine grain bin. The principle variable that governs a combine's processor grain loss is the material-other-than-grain (MOG) feed rate. Processor grain loss rises exponentially with increasing MOG feed rate. On the other hand, low MOG feed rates have been shown to cause higher grain damage than high material feed rates (Mowitz, 2000). Slow forward speeds are associated with low MOG feed rates, though for high yielding fields, slow forward speeds can be associated with higher MOG feed rates and thus lower grain damage. For a given yield, the MOG feed rate is proportional to forward speed.

In a localized area of a field the yield can be assumed nearly constant. At this field location, the potential harvested gross income is equal to the total field-grain volume multiplied by the grain price (fig. 1). In order to maximize the quantity of grain harvested, the combine should be operated at the optimum MOG feed rate such that grain loss and grain damage are minimized. Harvesting at the combination of combine forward speed, header height, and header width that achieves the optimum MOG feed rate is expected to minimize the quantity of grain lost and damaged, and maximize the quantity of grain recovered in the combine grain bin. The combination of machine settings, forward speed, and MOG feed rate that maximizes the quantity of grain recovered was labeled by Quick as the combine "sweet spot" (Mowitz, 2002).

The forward speed or MOG feed rate that minimizes grain loss and damage may maximize the quantity of grain harvested, but these alone may not maximize the profitability of the harvest. Thus, it is hypothesized that the trade-off between the quantity of grain recovered and the combined costs of machinery, labor, timeliness, and grain loss will result in an economically optimized harvesting forward speed, which may or may not correspond to the combine material throughput that minimizes grain loss or to the minimum cost of harvesting (fig. 1).

## Literature Review

Combine economic models were developed by Schueller (1983) and Huisman (1983). Schueller's (1983) profit maximizing model calculated the profitability of grain flow rate control based upon yield, speed, and moisture content. The grain price, drying cost, and combine purchase price had significant effects upon profitability. The variables affecting

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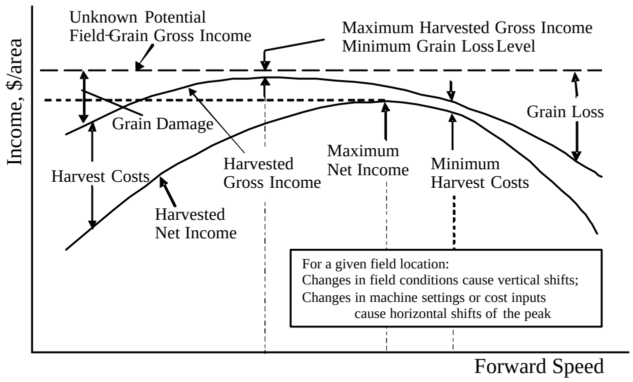


**Figure 1. Conceptual model of combine harvesting profit maximization for constant yield.**

the optimum grain flow rate included the available hours for harvesting, crop yield, in-field grain dry down rate, and the moisture content of the grain in the field.

Huisman (1983) optimized a combine harvester's operation by controlling forward speed and threshing cylinder speed with a cost minimization model. Machine costs, lost grain costs, and timeliness costs were included. The cost savings of automatic control were small compared to well-planned manually controlled adjustments and the regular inspection of losses. The cost savings were expected to be larger compared to poorly-planned manual operation. The optimum speed was significantly affected by the timeliness costs.

General machinery management models have been presented by Hunt (1967) and Kjelgaard and Wu (1983). Timeliness costs have been shown to be an influential input into the machinery selection process (Siemens et al., 1990; Whitson et al., 1981; Edwards and Boehlje, 1980).

Controlling a combine's functions is essential to maximizing a its performance. MOG feed rate and forward speed controllers have been developed (Schueller, 1983; Kruse et al., 1982; Kotyk et al., 1989; Huisman, 1983; Dronningborg Industries, 2003).

With an increasing number of combines being sold with factory installed precision farming sensors; a new source of machinery management information is available. Previously, combine efficiency and usage was collected using time-motion studies. Recently, research has been completed that demonstrates the use of precision farming data to extract machinery management information and field efficiencies (Taylor et al., 2002; Grisso et al., 2002).

Quick's patent disclosure (Quick, 2004) showed the derivation of the combine "sweet spot" and emphasized the importance of using machine harvested yield (MHY) instead of only processor grain loss (as in ASAE standard test procedures). MHY can be readily converted into harvested income. The disclosure leads to the idea of showing combine economic performance directly in the combine cab and eventually to automatic control of machine functions to optimize profitability.

Sound machinery management is critical to profitability and the introduction of precision farming technology is opening new avenues for understanding the optimization of machinery and production systems. A combine-specific econometric model will allow the owner-operator to receive the highest economic return for his harvesting equipment investment. The technology is being developed to measure a combine's economic performance in real-time.

### Objectives

The ultimate goal of the project was to predict combine economic performance in real time. The objectives of this research were to:

- develop algorithms that calculate the harvested net income for a given set of machine, economic, and crop parameters,
- determine the combine forward speed and MOG feed rate that result in the calculated maximum profit for a given set of machine, economic, and crop parameters.

## Model Development and Methods

The developed econometric model is the combination of a combine and an economic model. The econometric model is based upon a predetermined area of a single crop (wheat in this case) for a purchased combine scenario. The model only considers harvesting-related operations and costs that can be controlled or predicted from predetermined inputs and combine performance measurements. The model assumes that minimizing grain loss and maximizing harvested net income are a priority to the operator. The model assumes an average rate of harvest during the crop season, an average yield, and a constant grain to MOG (G/MOG) ratio in order to develop the model and determine which inputs significantly influence the optimum speed. During real-time operation, the optimum speed is expected to fluctuate as weather, crop, and combine parameters change. The increase in separator hours was used to determine the harvest duration. The econometric model is applicable to any machine if the required functional performance curves and other combine inputs are known. The model was developed using a combine performance curve and data, whereas, a real-time controller would use combine performance measurements (clean grain mass flow, grain loss estimates, speed, width, etc.). A John Deere 9750 Single Tine-Separation (STS) combine was modeled. The combine functional performance data for this project was provided by John Deere Harvester Works, East Moline, Illinois (Payne, 2002).

### Combine Model

The combine model describes the functional performance of the machine. Three crop material feed rates were modeled: MOG feed rate, lost grain feed rate, and clean grain feed rate. The general combine model was developed to determine the harvested gross income using yield monitor clean grain feed rate measurements. Using the John Deere data set (Payne, 2002), the clean grain feed rate was regressed as a quadratic function ($R^2 = 0.99$) of the product of field capacity and yield. The MOG feed rate was regressed using multiple linear regression ($R^2 = 0.99$) between the ratio of the clean grain feed rate to the G/MOG ratio, and the forward speed. The grain loss percentage was modeled as a quadratic function ($R^2 = 0.73$) of the MOG feed rate. A quadratic fit was selected over an exponential fit ($R^2 = 0.80$) because the quadratic function indicates increasing losses at low MOG feed rates. The volume of lost grain was determined by multiplying the grain loss percentage by the harvested grain volume. The harvested gross income was calculated as the product of the harvested grain volume and the grain unit price.

## ECONOMIC MODEL

The economic model examines four costs: machinery cost, labor cost, machine grain loss cost, and timeliness costs. The four costs are all considered as variable costs except for the fixed cost of combine housing, insurance, and taxes. The harvest total cost is the sum of these four costs.

### *Machinery Costs*

The machinery cost is the sum of the combine and header total costs. The combine operating costs were modeled using the ASAE machinery management practices and data (*ASAE Standards,* 2001a, b) and were considered a function of the engine hours. The operating costs included repair and maintenance, fuel, and lubrication costs.

The combine ownership cost equations describing the combine current remaining value and engine hours were regressed from 54 different online John Deere equipment dealer's listings for 9750 STS combines. The combine data was gathered 3 February 2003 using the online search engine, MachineFinder (www.machinefinder.com). The majority of the combines were located in the Central to Midwestern United States with a few machines from other regions. The John Deere 9750 STS combine was introduced in 1999, thus machine ages ranged from 0 to 3 years. A linear regression of engine hours as a function of separator hours indicated that engine hours were consistently 40% higher than the separator hours ($R^2 = 0.98$). This indicates that these combines had been operated similarly during the first 3 years. The remaining value of the combine was predicted from listings containing only the model year, separator hours, and engine hours. Engine hours were not statistically significant ($\alpha = 0.05$) to the remaining value regression (p-value = 0.131), but were included in the remaining value prediction equation ($R^2 = 0.70$) because both engine hour and separator hour data are available on modern combines. The combine current remaining value equation also correlated well (r = 0.96) with the ASAE remaining value equation (*ASAE Standards*, 2001b). The econometric model considers a constant area. Changes in forward speed directly affect the duration of harvest. The remaining value equation is a function of both age and hours, thus changes in forward speed will affect the combine current remaining value.

The cost of depreciation was calculated as the combine purchase price minus the current remaining value. The purchase price was considered a fraction of the combine list price. The capital recovery factor was used to determine the amount of money required to recover the cost of depreciation and was a function of the real interest rate and the expected years of ownership (*ASAE Standards,* 2001a). The capital recovery cost was the sum of the cost of depreciation and interest on the remaining value of the machine. The combine ownership cost was the sum of the capital recovery cost and a constant housing, insurance, and tax cost, which is a percentage of purchase price (*ASAE Standards,* 2001a). Finally, the sum of the ownership and operating costs determines the combine total cost.

An online search for John Deere 930 platform headers [9.1 m (30 ft)] returned 32 headers located in the Midwestern United States. The header current remaining value was regressed as an exponential function of its age ($R^2 = 0.37$). The depreciation cost was calculated as the difference between the header purchase price and the current remaining value for the current year. The ownership depreciation cost was the difference between the start-of-season depreciation cost and the end-of-season depreciation cost (age +1). The total header cost was calculated as the sum of a constant repair and maintenance cost and the ownership depreciation cost.

### *Machine Grain Loss Cost*

The data provided by John Deere Harvester Works (Payne, 2002) and others (Schueller, 1983; Huisman, 1983) shows that the grain loss percentage increases as the MOG feed rate increases. Increasing MOG feed rates are generally associated with increasing forward speeds, but it can also be attributed to changes in field conditions. The model assumes that minimizing grain loss and maximizing harvested net income are a priority to the operator. The machine grain loss cost was calculated as the grain unit price multiplied by the volume of lost grain. Increasing the grain unit price will increase the value of the grain loss quantity.

### *Labor Cost*

The labor cost was considered separately from the combine operating costs in order to investigate the significance of the labor cost in relation to the total harvest cost. The number of hours worked was equal to the difference between the current engine hours and the start-of-season engine hours. The labor hourly rate was multiplied by a labor factor to account for labor costs that occur when the combine was not harvesting. Two employees are considered in the base case scenario.

### *Timeliness Cost*

Timely harvesting is critical to maximizing profits. It is assumed that the operator will want to harvest as much crop as possible during the optimum period and will start harvest earlier if the total area cannot be finished during the optimum period. The optimum period was defined as the number of days that the crop moisture content was equal to the desired moisture content (13.5%) and that the grain quality remained at a Grade 1 level according to USDA grading standards for wheat. The timeliness model was designed to balance the pre-optimum and post-optimum period harvest costs about the optimum period. Grain harvested during the pre-optimum period was assumed to dry linearly to the desired moisture content from either the maximum allowed moisture content, or a moisture content between the maximum and desired moisture contents. A constant drying cost was applied to the volume of grain harvested during the pre-optimum period.

Two costs are applied during the post-optimum period: loss of grain quantity and quality, and loss of water weight. The loss of grain quantity and quality model was adapted from Bowers (1992). Bowers' equation includes a "timeliness importance" factor that represents the percent of remaining area lost per day following the optimum period. The remaining area lost accounts for yield loss due to shattering and reduced test weight.

The second post-optimum period harvest cost was the loss of grain water weight. Wheat grain is marketed by weight, thus, any reduction in that weight will result in a loss of potential profit. A linear post-optimum field-drying rate was assumed and begins on the first day following the optimum period. The average of the desired and final moisture contents gives the average points of water lost, which is multiplied by the yield and grain price to determine the dry grain cost for the post-optimum period area. Finally, the timeliness cost was calculated as the sum of the drying cost, post-optimum harvest cost, and the dry grain cost.

### *Harvested Net Income*

The harvested net income is equal to the harvested gross income minus the harvest total cost. For a unique set of inputs, the model calculates the harvested net income for each 0.2-kph (0.125-mph) speed increment over the input speed range [0.4 to 19 kph (0.25 to 12 mph)], finds the maximum harvested net income, and appends an output array with the corresponding optimum forward speed and values of selected costs and parameters. This process was iterated for each test in the statistical design of experiment.

### Model Analysis Procedure

A design of experiment (DOE) was created using JMP (JMP, 2002) statistical software to determine the significance of the model inputs (Appendix A). First, a fractional factorial (FF) screening design was used to determine the main effects of each input and eliminate insignificant variables. After determining which variables were significant, a central composites design (CCD) was used to test the eight or fewer significant variables and determine a model prediction equation. The CCD selects one of the three input variable levels (low, medium, or high) for each variable to make an input combination trial. The CCD is visualized as a cube where each vertex represents a high or low value for a single input while all other inputs are at a medium value. The recorded outputs from the CCD were analyzed in JMP to determine the influence of the variable responses, two factor interactions, and squares. The p-value for each variable was compared to $\alpha = 0.05$ and the insignificant variables, interactions, or squares were removed from the model prediction equation. Finally, the model prediction equation was tested against the full model using randomly selected input combinations. The prediction results were then analyzed in JMP to determine the correlation between the predicted and full model responses.

## Results and Discussion

The base case harvested net income per area was \$431.06/ha (\$174.45/acre) at the optimum forward speed of 7.9 kph (4.9 mph) (table 1). The base case harvested gross income, harvested net income, and harvest total costs per area over the input speed range are depicted in figure 2. The harvested gross income is approximately constant at slow speeds with a maximum at 2.8 kph (1.8 mph), which is the point of minimum grain loss. At speeds greater than 10 kph (6 mph), the harvest total cost rises due to the increase in machine grain loss. The harvested net income decreases at slow speeds due to high machinery, labor, and timeliness costs.

The DOE indicated that the optimum speed was significantly influenced by nine inputs: the crop area, G/MOG, grain price, field yield, field efficiency, grain moisture content, probability of a working day during the post-optimum period ($PWD_{post}$), expected harvesting day length, and

**Table 1. Base case results corresponding to the maximum harvested net income.**

| Output | Result |
|---|---|
| Optimum speed, kph (mph) | 7.9 (4.9) |
| MOG feed rate, t/h | 25.55 |
| Machine grain loss, % | 1.82 |
| Clean grain feed rate, t/h | 27.66 |
| Machinery cost, \$/ha (\$/acre) | 35.72 (14.45) |
| Machine grain loss cost, \$/ha (\$/acre) | 9.20 (3.72) |
| Labor cost, \$/ha (\$/acre) | 6.06 (2.45) |
| Timeliness cost, \$/ha (\$/acre) | 23.80 (9.63) |
| Harvest total cost, \$/ha (\$/acre) | 74.77 (30.26) |
| Harvested gross income, \$/ha (\$/acre) | 505.83 (204.71) |
| Harvested net income, \$/ha (\$/acre) | 431.06 (174.45) |

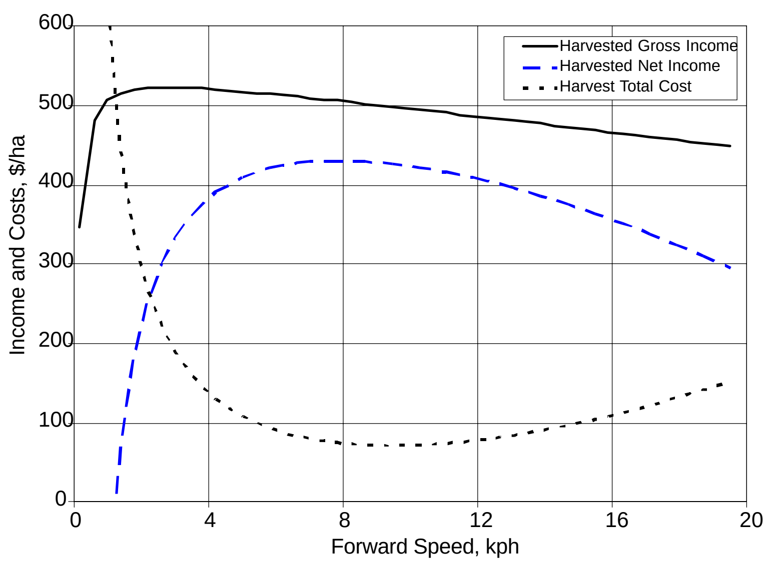


**Figure 2. Yield monitor-based econometric model for the base case.**

the timeliness factor. The CCD only allows eight factors; to accommodate the procedure, the grain moisture content was disregarded because it was ranked 9th according to the t-ratio, only slightly less significant than the $PWD_{post}$. The optimum speed prediction model correlated well with the full model (r = 0.972).

The maximum harvested net income was significantly influenced by six inputs: G/MOG, grain price, field yield, expected years of ownership, expected harvesting day length, and the timeliness factor. The combine list price, grain moisture content, and $PWD_{post}$ were moderately significant, but had p-values slightly greater than the level of significance ($\alpha$ = 0.05). The harvested net income prediction model correlated well with the full model (r = 0.981). Five inputs significantly influenced both the optimum speed and the harvested net income: G/MOG, grain price, field yield, expected harvesting day length, and the timeliness factor. The prediction models indicate that these variables influenced the results either alone or as an interaction with another variable.

The G/MOG ratio was significant because it directly influenced the MOG feed rate and consequentially the machine grain loss feed rate. The optimum speed varied from 6.4 to 8.9 kph (4.0 to 5.5 mph) from the low to the high values of G/MOG. As the field yield increased, slower forward speeds became optimum. The forward speed decreased from 9.3 kph (5.8 mph) at the low yield level to 6.9 kph (4.3 mph) at the high yield level, a decrease of 2.4 kph (1.5 mph). Changes in the grain price had the most significant effect on the harvested net income. However, the optimum speed did not change appreciably from the low grain price to the medium grain price, and decreased only 0.4 kph (0.25 mph) when the grain price increased to the high value. The influence of the grain price on forward speed was most noticeable in two factor interactions, especially with field yield. From the low grain price and low field yield combination to the high grain price and high field yield combination, the forward speed decreased 2.8 kph (1.8 mph). The expected harvesting day length was defined as the number of hours available for harvesting each day (*ASAE Standards,* 2001a). Increasing the expected harvesting day length from the low to high values decreased the optimum forward speed by 3.2 kph (2.0 mph). This indicates that a greater number of available harvesting hours per day increases the area harvested during the optimum period, and consequently reduces pre-harvest and post-harvest timeliness costs. Increasing the timeliness factor from the low to high values caused a 2.4 kph (1.5 mph) increase in the optimum speed.

For the base case, the machinery cost was the largest cost, making up 48% of the harvest total cost (table 2) and 57% of the harvest total cost for the low timeliness factor. The combine ownership cost was the most influential machinery cost comprising 40% of the harvest total cost and 84% of the machinery cost. Combine ownership costs were considerably greater than the operating cost, lost grain cost, drying cost, or loss of water weight cost. Changing the combine list price from the low value to the high value varied the machinery cost from 43% to 53% of the harvest total cost, respectively, but this increase did not change the optimum speed. High ownership costs indicate that more area must be harvested in order to reduce the per area machinery cost. For 1620 ha (4000 acres), the machinery cost was reduced to 34% of the harvest total cost (fig. 3).

Increasing the area from 810 to 1620 ha (2000 to 4000 acre) increased the timeliness cost from 16% to 43% of the harvest total cost for the medium timeliness level (fig. 3). Due to the higher timeliness costs for 1620 ha (4000 acre) compared to 810 ha (2000 acre), the optimum forward speed

**Table 2. Itemized harvest costs corresponding to the maximum harvested net income for the base case.**

| Harvest Cost | Sub-Cost Item | Total Cost, \$/ha (\$/acre) | Percent of Total Cost |
|---|---|---|---|
| Machinery cost | Ownership | 30.14 (12.20) | 40.3 |
| | Operating | 4.78 (1.93) | 6.4 |
| | Header | 0.80 (0.33) | 1.1 |
| | **Sub-Total** | **35.72 (14.45)** | **47.8** |
| Machine grain loss cost | (1.82% loss) | **9.20 (3.72)** | **12.3** |
| Labor cost | | **6.06 (2.45)** | **8.1** |
| Timeliness cost | Drying | 1.17 (0.47) | 1.6 |
| | Dry grain | 3.55 (1.43) | 4.7 |
| | Post-optimum harvest | 19.09 (7.73) | 25.5 |
| | **Sub-Total** | **23.80 (9.63)** | **31.8** |
| **Total Cost** | | **74.77 (30.26)** | **100.0** |

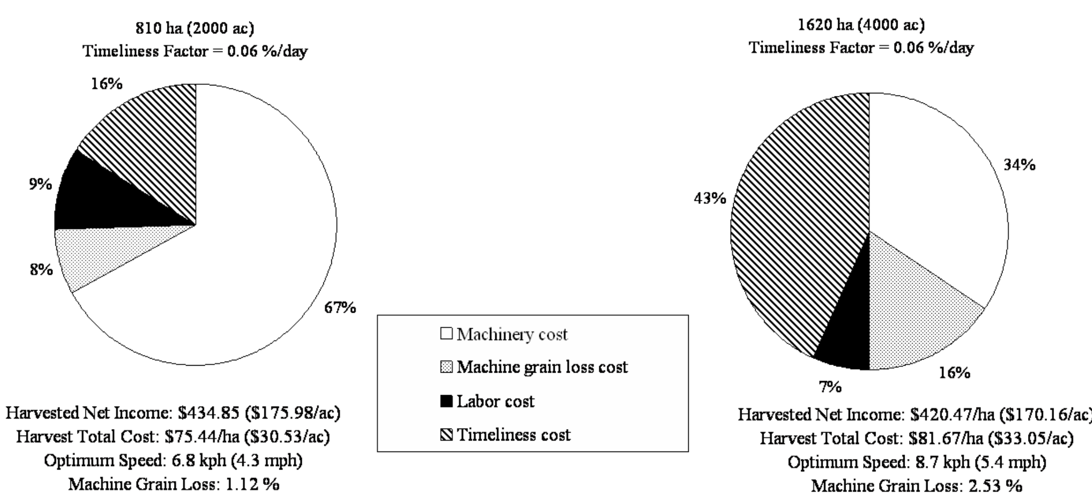


**Figure 3. Affect of increasing the harvest area on the harvest costs.**

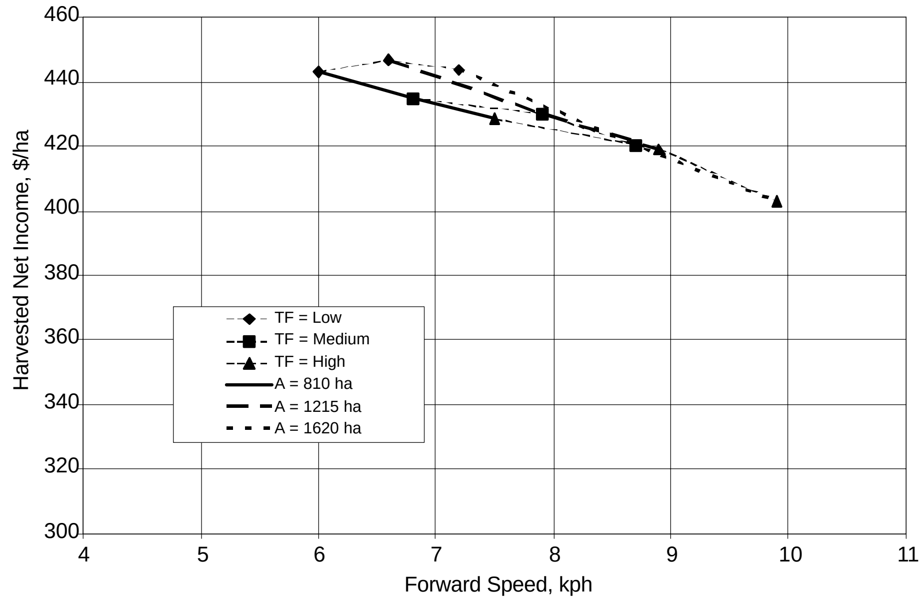


**Figure 4. Effect of the interaction of the area (A) and timeliness factor (TF) on the maximum harvested net income and optimum forward speed.**

increased from 6.8 to 8.7 kph (4.3 to 5.4 mph), respectively. This increase in the optimum forward speed doubled the machine grain loss cost from 8% to 16% of the harvest total cost (fig. 3). However, the maximum harvested net income per area was higher for 810 ha (2000 acre) than for either 1215 or 1620 ha (3000 or 4000 acre) at the medium and high timeliness levels (fig. 4). Harvesting more area did not equate to higher harvested net incomes per area, due to the increase in timeliness costs.

When the timeliness factor is at the low value, harvesting 1620 ha (4000 acre) returns a net income per area comparable to harvesting 810 and 1215 ha (2000 and 3000 acre), but the optimum forward speeds only differ by 1.2 kph (0.7 mph) from the high to low area values (fig. 4). When the timeliness factor increases for a given area, the area becomes too much for the combine to harvest in a timely fashion and requires faster optimum forwards speeds and consequentially reduced harvested net incomes per area.

Operating at the minimum machine grain loss level was not profitable due to high machinery and timeliness costs at the slower forward speed. Including or not including the machine grain loss cost significantly affected the optimum speed and the allowed grain loss level: 7.9 kph (4.9 mph) at 1.8% loss versus 9.9 kph (6.1 mph) at 3.8% loss, respectively. In regions where post-optimum period grain quality losses are not a concern, the loss of water weight contributes a significant portion of the timeliness cost of harvesting. The dry grain cost was 35% of the timeliness cost at the low timeliness factor and 15% at the base case. For the area increase from 810 to 1620 ha (2000 to 4000 acre), the dry grain cost increased from 2.2% to 6.6% [$1.63/ha to $5.44/ha ($0.66/acre to $2.20/acre)] of the harvest total cost. Thus, for 1620 ha (4000 acre), $8800 was lost because a portion of the yield was harvested below the desired moisture content (13.5%) in the field.

## CONCLUSION

A combine harvester econometric model was developed to determine the maximum harvested net income and the optimum forward speed for a given harvesting scenario. For the base case, the machinery cost was 48% of the harvest total cost and the combine ownership cost was the greatest machinery cost, comprising 40% of the harvest total cost. Reducing the machinery cost by increasing the harvest area did not equate to higher harvested net incomes per area due to an increase in timeliness costs. Also, operating at the minimum machine grain loss percentage was not profitable due to high machinery and timeliness costs at the slower forward speed. The optimum forward speed was significantly influenced ($\alpha = 0.05$) by the area, G/MOG, grain price, field yield, field efficiency, grain moisture content, probability of a working-day during the post-optimum period, harvesting day length, and the timeliness factor. Five inputs significantly influenced both the optimum speed and the harvested net income: G/MOG, grain price, field yield, harvesting day length, and the timeliness factor. It is expected that the developed econometric model will be useful for determining the real-time economic performance of a combine harvester.


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## APPENDIX

**Appendix A. Model input space (medium values are at the base case).**

| Variable | Low | **Med** | High |
|---|---|---|---|
| Area, ha (acre) | 810 (2000) | **1215 (3000)** | 1620 (4000) |
| G/MOG, t/h:t/h | 0.75 | **1.13** | 1.50 |
| Grain price, $/t ($/bu) | 55.11 (1.50) | **91.85 (2.50)** | 128.60 (3.50) |
| Yield, t/ha (bu/acre) | 4.4 (65) | **5.7 (85)** | 7.1 (105) |
| Interest rate, % | 0.06 | **0.08** | 0.1 |
| Inflation rate, % | 0.01 | **0.03** | 0.05 |
| Fuel price, $/L ($/gal) | 0.13 (0.50) | **0.26 (1.00)** | 0.40 (1.50) |
| Lube factor, decimal | 0.05 | **0.15** | 0.25 |
| Labor wage, $/h | 5.00 | **10.00** | 15.00 |
| Labor factor, decimal | 1 | **1.1** | 1.2 |
| Number of employees, decimal | 1 | **2** | 3 |
| Combine list price, $ | 180000 | **200000** | 220000 |
| Expected years of ownership, years | 1 | **3** | 5 |
| Initial separator hours, hours | 750 | **900** | 1050 |
| Fuel consumption rate, L/h (gal/h) | 38 (10) | **49 (13)** | 61 (16) |
| Header width, m (ft) | 7.6 (25) | **9.1 (30)** | 10.7 (35) |
| Header list price, $ | 16500 | **18500** | 20500 |
| Header repair and maintenance cost, $ | 50 | **250** | 450 |
| Field efficiency, decimal | 0.5 | **0.7** | 0.9 |
| Moisture content, % | 14.5 | **16.5** | 18.5 |
| Drying cost, $/t/point ($/bu/point) | 0.18 (0.005) | **0.55 (0.015)** | 0.92 (0.025) |
| Pre-optimum period probability of a working day, decimal | 0.5 | **0.7** | 0.9 |
| Optimum period probability of a working day, decimal | 0.5 | **0.7** | 0.9 |
| Post-optimum period probability of a working day, decimal | 0.5 | **0.7** | 0.9 |
| Optimum period length, days | 2 | **6** | 10 |
| Expected harvesting day length, hours/day | 5 | **10** | 15 |
| Timeliness importance factor, % area lost/day | 0.2 | **0.6** | 1.0 |