The Influence of Auto-Steer on Machinery Selection and Land Acquisition

Abstract

With the growing advancements in technology increasingly available to farmers, there is a need to recognize this influence when making farm management decisions. This study investigated the influence of auto-steer navigation on machinery selection and land investment decisions by developing a multifaceted machinery management model.

The results indicated that the addition of auto-steer allows for the purchase of smaller machinery while increasing net returns and lowering machinery costs. In addition, results indicated that auto-steer can also be purchased in lieu of larger machinery to support land expansion. Therefore, auto-steer should be considered when making farm management decisions.

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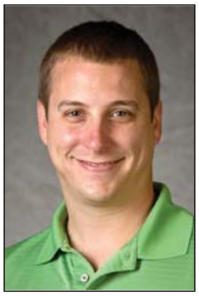
Introduction

Choosing machinery and land investments are two of the most difficult decisions faced by farm managers. Since both machinery and land are typically the most valuable assets to the farm, the ability of the farm manager to properly select equipment and plan for land expansion is imperative for financial success of the business. When selecting machinery, land area is an important factor in determining the optimal size of machinery for the farm. Conversely, when considering land expansion, current machinery capability must be considered to determine if it can support operating on additional land. Thus, machinery selection and land investment are interrelated and must be assessed together.



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Another factor to consider in land and machinery management decisions is the number of field days necessary to complete each operation. Factors that influence the number of field days required to adequately perform the agricultural tasks in a timely manner include the field capacity of the machines, land area, and hours worked per day. Kay, Edwards, and Duffy (2004) discussed ways to reduce the size of the machinery, hence machinery operating and ownership costs, and still accomplish all agricultural tasks on time. They mention, for example, reducing the number of field operations performed and diversifying the crop mix. These methods directly impact the number of field days which influence the optimal machinery size for the farm.

Advanced technologies can also have an impact on the number of field days required to complete an operation and by extension, the size of machinery and/or manageable land area. One of these technologies is GPS-based automated steering (auto-steer) for agricultural machinery. Several studies have reported the impact of auto-steer on field capacity and hours worked per day. Specifically, auto-steer can increase the field capacity of a machine by reducing the overlap between passes across the field. Additionally, auto-steer can impact the number of field days required to complete a task by extending a farmer's workday by allowing them to work effectively into the night (Shockley et al., 2011; Griffin, et al., 2008; Griffin et al., 2005; Hunt, 2001). Since auto-steer can affect the factors involved in machinery selection, it must be considered as a viable alternative to purchasing larger equipment. The objectives of this study, through a scenario framework, are to:

1.) Demonstrate the influence of auto-steer on a beginning farmer's optimal machinery selection decision;
2.) Demonstrate that auto-steer can influence machinery replacement decisions when implement failure occurs;
3.) Demonstrate that as land area increases, auto-steer can influence an established farmer's machinery investment decision; and
4.) Determine the maximum land expansion that is feasible when auto-steer is added to current equipment already at maximum field capacity.

Analytical Procedure

To accomplish the project objectives, a production environment and a machinery management model were established. The production environment consisted of a grain farm rotating corn and soybeans under no-till practices. The agricultural tasks requiring machinery included: burn down herbicide treatment; planting; pre-emergence application of herbicide (corn only); post-emergence application of herbicide; fertilizer application (nitrogen on corn only); and insecticide treatment (soybeans only). The best management practices guiding these tasks were extracted from University of Kentucky Cooperative Extension Service recommendations. The machinery required to perform the above tasks included a tractor, sprayer, planter, and fertilizer applicator. The size options for each of these machines considered in this project are reported in Table 1. The relevant performance data for the machines including field capacity, operating costs, and ownership costs were collected from the Mississippi State Budget Generator (Laughlin & Spurlock, 2007). Harvest requirements and data were included in the model but were not considered as an essential component of this study since the influence of auto-steer on machinery selection was only considered for the tractor and implements attached.

The benefits and costs of operating a tractor with auto-steer were gathered from data presented by Shockley et al (2011). Specifically, a Real Time Kinematic (RTK) GPS receiver coupled with an integral valve auto-steer system was used for this investigation. The total investment for the RTK auto-steer system was $35,000 with an estimated annualized cost of $4,900 using straight-line depreciation plus the opportunity cost of the capital invested. The benefits of auto-steer included a reduction of overlap to 0.5 foot, a five to twenty increase in speed depending on field operation, and the ability to drive faster during headland turns since entry rows are easier to navigate, and an increase in the operators work day from 13 hours to 15 hours. The ability of the operator to work longer hours is attributed to reduced fatigue and the ability to work into the night. The reduction in overlap and increase in speed directly impacted the field capacity of the machinery as well as variable costs and are dependent on the skill of the operator. For more details about overlap scenario and speed increase assumptions see Shockley et al. Input, labor, and fuel costs were all reduced due to the adoption of auto-steer and the increase in field capacity. Table 2 details the field capacities and input reductions of the different machines with and without auto-steer.

Production and crop performance data were obtained using the Decision Support System for Agrotechnology Transfer (Hoogenboom et al., 2004) biophysical simulation model. Corn and soybean yields were estimated for four soil types (deep and shallow silt loam and deep and shallow silt clay). The yields based on soil type were distributed according to representative soil surveys of the production area studied. In addition, a 50-50 split between acres planted in corn and soybeans was assumed to represent a two-year crop rotation typical for a Kentucky grain producer. The production practices utilized herein to estimate yields included five planting dates and varieties from three maturity groups. Planting occurred weekly from March 25 to April 22 for corn, and weekly from April 22 to May 20 for soybeans. Additionally, the varieties of soybeans were selected from maturity groups two, three, and four, and corn varieties consisted of those requiring 2,600, 2,650, and 2,700 growing degree days. This set of yield data was specifically chosen since both planting date and maturity group will directly reflect the timeliness cost associated with yield loss due to untimely planting. More detail on the estimated yields can be found in Shockley et al.

A machinery management model was formulated using mixed integer programming. This economic model incorporated three different optimization methods to maximize expected net returns by determining the optimal machinery size of the tractor and implements, the acres performed by each implement, and the optimal crop planning decisions (optimal maturing varieties and planting dates for corn and soybeans). Each method provided various constraints that contributed to the development of the model.

Machinery selection methodology provided the foundation for this model. The constraints required for this portion of the model included an expected net returns balance, net returns balance by year, a sales balance, and a machinery purchase requirement which ensured a machine was purchased before it can be used. Resource allocation was utilized to capture the competition for scarce resources that is often present in agricultural production. The constraints required for this portion included a land constraint with a crop rotation component, soil type proportionality constraint, and suitable field days available for machinery operations. Suitable field days available were the same for all soil types in this study. In addition, sequencing was utilized to establish the appropriate timing of agricultural tasks (e.g., a pre-plant burn down application of herbicide must occur before planting begins). The incorporation of all three methods provided a unique and multifaceted model that had the ability to select both optimal machinery and crop planning parameters. The model also had the ability to reflect machinery with and without auto-steer, specifically auto-steer on the tractor. For the purposes of this study, only the optimal machinery decisions are discussed.

Results

The following results are presented in a scenario framework due to the specialization of a machinery selection problem. Each scenario reflects a particular situation faced by a farm manager where equipment and/or land investment decisions are required. Each scenario corresponds to a particular objective of this study.

Scenario 1

A beginning farmer acquires 3,000 acres and needs to invest in new machinery. If the farmer does not consider the influence of auto-steer, a sub-optimal machinery set might be chosen. For a 3,000-acre farm, the model results indicated that a beginning farmer should purchase a 200-hp tractor, 60-foot sprayer, 12-row planter, and 12-row fertilizer applicator. This leads to an expected net return of $1,012,075 with machinery operating costs (labor, fuel, repair, and maintenance) of $34,553 ($11.52/acre) and machinery ownership costs of $69,298 ($23.10/acre).

However if the beginning farmer recognizes that auto-steer impacts the field capacity of agricultural machines and hours worked per day when making his/her machinery selection, the model results indicated that the farmer should invest in a smaller tractor equipped with auto-steer. Specifically, if the farmer considers auto-steer as a viable option for his/her farm and factors in all relevant costs and benefits, the optimal machinery set is a 150-hp tractor, 60-foot sprayer, 8-row planter, and a 10-row fertilizer applicator. This leads to an expected net return of $1,035,506, a 2.3 percent increase over the optimal machinery set without auto-steer. In addition, both machinery operating and ownership costs (including the annualized cost of auto-steer which is reflected in total ownership cost) decreased to $31,818 ($10.61/acre) and $68,701 ($22.90/acre), respectively. This demonstrates that a beginning farmer should consider advanced technologies (e.g., auto-steer) when investing in new machinery. If not, the farmer could pass up a great opportunity to increase expected net returns and decrease machinery costs by supplementing auto-steer for larger equipment.

Scenario 2

A farmer currently manages 2,000 acres with an optimal machinery set of a 150-hp tractor (without auto-steer), 60-foot sprayer, 8-row planter, and 12-row fertilizer applicator. The expected net return for the farm is $675,523 with machinery operating and ownership costs of $23,432 ($11.72/acre) and $63,988 ($31.99/acre), respectively. One day the fertilizer applicator breaks down and the farmer needs to invest in a new applicator. The farmer could purchase the same size fertilizer applicator as before, which would be optimal if auto-steer was not considered.

However, if auto-steer was considered, the model results indicated that the farmer should actually purchase auto-steer and invest in a 6-row fertilizer applicator instead of the larger 12-row applicator previously owned. With the current equipment set, the benefits of auto-steer would be reaped across all implements and allow for a smaller fertilizer applicator to be purchased. With the purchase of auto-steer and a smaller fertilizer applicator, the expected net returns would increase to $690,918. On the other hand, machinery operating expenses would increase to $23,495 ($11.75/acre) due to the smaller applicator. In addition, machinery ownership costs would also increase to $68,711 ($34.36/acre) due to the purchase of auto-steer. Even though machinery operating and ownership costs increased, the input cost savings was greater than the increased machinery cost due to auto-steer which resulted in an increase of 2.3 percent in expected net returns. Therefore, a farmer should consider auto-steer when making machinery replacement decisions and realize that benefits of auto-steer may be reaped on all implements, not just the one being replaced.

Scenario 3

An established farmer is currently managing 3,000 acres with the following optimal machinery set: 200-hp tractor, 60-foot sprayer, 12-row planter, and 12-row fertilizer applicator. The opportunity arises to purchase the neighboring farm which is 550 acres. The farmer has the ability and is willing to invest in larger machinery to support the additional 550 acres. If the farmer does not consider advanced technologies such as auto-steer, the model results indicated that the farmer is required to invest in a larger tractor and planter to manage the additional acres. Specifically, the farmer should have a 300-hp tractor, instead of a 200-hp tractor, and a 16-row planter, instead of a 12-row planter. With the additional acres and larger machinery, the farm's expected net return is $1,167,832 with machinery operating and ownership costs of $51,442 ($14.49/acre) and $83,363 ($23.48/acre), respectively.

However, if the farmer adds auto-steer, the farmer can manage all 3,550 acres with the original equipment set and not be required to purchase the larger tractor and planter. The model results indicated that if auto-steer was added to the original machinery set, the expected net return would be $1,217,014, which is 4.2 percent greater than if the farmer invested in larger equipment. Moreover, the machinery operating costs ($36,251 or $10.21/acre) would be less than larger equipment and the farmers current total ownership cost of $69,298 would only increase by $4,900, the annual cost of auto-steer, but the cost per acre would decrease to $20.90/acre from $23.09/acre due to the additional 550 acres. This scenario demonstrates that an established farmer with a current equipment set can invest in auto-steer instead of purchasing larger equipment to support the expansion of the farm.

Scenario 4

A farmer is currently operating using a machinery set that includes a 200-hp tractor, 60-foot sprayer, 12-row planter, and 12-row fertilizer applicator. This farmer is currently managing 3,470 acres, the maximum land area given the capabilities of the current machinery set. This farmer would eventually like to expand the operation; however, the farmer recently purchased the current set of equipment and is reluctant to purchase larger machinery to support expansion. The farmer would like to know if there are any alternatives to support land expansion and if so, to what extent. One option the farmer could consider is the adoption of auto-steer. Since auto-steer reduces the number of field days required to perform agricultural tasks, the addition of auto-steer to his current equipment could support land expansion.

The model results indicated that the addition of auto-steer could support an increase in land area of up to three percent utilizing the current machinery set. Under this scenario, the farmer could acquire an additional 102 acres and not have to purchase larger equipment. However, the additional acres could be larger than the results indicated if supported by the field capacity of the harvester. In addition, results indicated that if auto-steer was adopted by the farmer and no land expansion occurred, net returns for the farm would increase by three percent due to the input savings that occur from reduced overlap. This demonstrates that a farmer who is reluctant to invest in new machinery can adopt auto-steer to support possible land expansion up to three percent even if the current machinery is operating at maximum capacity. If land expansion does not occur, the farmer still receives greater net returns than without auto-steer.

Summary and Conclusion

The four scenarios explored in this study revealed the importance of considering advanced technologies such as auto-steer when making machinery selection and land investment decisions. The first scenario demonstrated that a beginning farmer could select a set of smaller machines with the auto-steer option added than would be required without auto-steer. The second scenario demonstrated that auto-steer should be considered even when replacing a single implement. The addition of auto-steer was found to increase expected net returns and allow for a smaller implement to be purchased since the benefits of auto-steer would be realized on implements as well.

The third scenario demonstrated that an established farmer with a current set of equipment could adopt auto-steer rather than purchase a larger tractor and planter to support land expansion. Finally, the fourth scenario indicated that an established farmer with equipment operating at maximum capacity can adopt auto-steer and support a three percent increase in land area with the same machinery set. This study provides evidence that advanced technologies, which influence the number of field days required to perform agricultural tasks, should be considered when making land expansion or machinery purchase decisions.

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Table 1. Machinery size options available for optimization model decisions

Tractor: 150-hp, 200-hp, 300-hp
Sprayer (Broadcast): 27 ft., 40 ft., 50 ft., 60 ft.
No-Till Split-Row Planter[1]: 8-row, 12-row, 16-row
Liquid Fertilizer Applicator[2]: 6-row, 8-row, 10-row, 12-row

[1] The planter can operate on both 30 inch corn rows and 15 inch soybean rows. In addition, a 200-hp tractor or larger was required to operate the 12-row planter and a 300-hp tractor was required to operate the 16-row planter due to draft requirements.
[2] The liquid fertilizer applicator is operating on 30 inch corn rows.

Table 2. Field capacities and expected input reduction for each machine option with and without auto-steer

Sprayer width	Field Capacity w/o Auto-steer	Field Capacity with Auto-steer	Pre-planting Chemical Reduction	Post-planting Chemical Reduction
(ft.)	(Ac/hr)	(Ac/hr)	(%)	(%)
27	15.87	18.23	10.77	3.53
40	23.81	28.57	10.88	2.35
50	29.41	34.48	10.93	1.87
60	35.71	41.67	10.96	1.55

Fertilizer Applicator	Field Capacity	Field Capacity with Auto-steer	Fertilizer Reduction
	(Ac/hr)	(Ac/hr)	(%)
6-Row	7.63	9.00	6.55
8-Row	10.20	11.76	4.82
10-Row	12.66	14.49	3.82
12-Row	15.38	17.24	3.16

Planter	Field Capacity	Field Capacity with Auto-steer	Seed Reduction
	(Ac/hr)	(Ac/hr)	(%)
8-Row	10.20	11.23	4.84
12-Row	15.15	16.39	3.16
16-Row	20.41	21.74	2.35