The value of suitable working time for crop production machinery activities

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Abstract

The value of suitable field time is an important element in making several machinery management decisions and is examined within this study. A whole farm planning optimization model is used to determine marginal value product (change in mean net returns) and marginal willingness to pay for suitable field time for a Kentucky corn and soybean producer. The typical risk and return tradeoff is found wherein reduced fluctuation in net returns is possible at a cost of reduced mean net returns. While earlier planting dates for both corn and soybean production are initially relied upon for the risk neutral producer, greater diversity of crop production practices is used as a means of reducing yield risk. When suitable field time is constrained it can have values as high as US$266.09 per hour during harvest for the risk neutral farmer. Given the variability of change in farm returns resulting from additional suitable field time dependent on weather, a risk averse producer is only willing to pay a discounted amount from the mean change in farm net returns. The risk averse farmer's willingness to pay for additional suitable field time nonetheless can remain substantial ranging from about US$100-US$200 per hour during constrained harvest time.

Keywords: Farm machinery management, whole farm planning

Introduction

Farm management involves a host of interrelated components that have to be considered. Issues related to successful machinery management are not least among these. Indeed, of paramount importance to the success of most farm operations is good machinery management. What is the appropriate machinery complement? Should I own or custom hire? What if weather prohibits me from performing farm machinery operations in a timely manner? When should I replace my machines? What if my machinery operator performs poorly or fails to show up on time? What size of equipment should I acquire given the tradeoff for the need for timeliness versus the cost of larger machinery? This and a host of other questions must be addressed. The ability to timely perform machinery operations in as cost effective way as possible is crucial. The interrelationships of land management and machinery management become obvious in the timely performance of the required farm machinery activities. Human resource management also becomes interrelated in that machines typically require an adequately skilled operator. Additionally, a farmer's attitude towards risk influences various machinery management decisions as well.

Machinery management is further complicated by issues of suitable field working time. While the direct analysis of each of the above machinery management questions is beyond the scope of this paper, a difficult element underlying most machinery management decisions regards the value of time spent on farm machinery operations. Sometimes the calculations regarding costs of operations are not as difficult as more subtle element such as the marginal value of an additional or reduced hour of suitable field time. Addressing this issue is the primary focus of this paper. Specifically, a case example of a hypothetical Kentucky crop producer is used in developing estimates of the marginal value of suitable field time. In the achievement of this purpose, three objectives will be pursued:

1. A whole farm planning model is developed and solved with a discussion included on the farm net return results and the optimal crop production practices.
2. Economic and agronomic results are compared and contrasted for three different attitudes towards crop yield risk: risk neutral, low risk aversion and high risk aversion.

3. The lost average (mean) farm net returns due to reduction of suitable field time by period (week) is determined as well as the corresponding willingness to pay by the farmer for this lost suitable field time.

Methods

A hypothetical commercial sized corn and soybean producer in Kentucky, USA is considered. The farm has 1052 ha (2600 ac) of cropland with four soil types representative of Henderson County, Kentucky. Based on examination of soil survey data, an assumption of 80% of soil was assumed to have deep topsoil and the rest was considered shallow. Furthermore, 75% was assumed to be a silt loam with 25% a silt clay soil. These soil types guided use of default soil parameters used in DSSAT version 4 (Decision Support System for Agrotechnology Transfer), a crop growth simulation model (Hoogenboom et al., 2004). Thirty years of historical weather data was simulated to reflect a broad spectrum of weather conditions.

Several crop production practice considerations were modeled to reflect the complexity and breadth of agronomic decisions a farm manager needs to make. Possible corn planting dates ranged from March 25th to May 20th on a weekly basis. Three seed varieties were used reflecting different lengths of maturity: 2625, 2675 and 2725 growing degree days (GDD) mean requirements to reach maturity. When ready to harvest a two week window was allowed. Treatments also included various nitrogen fertilizer and plant population levels which are not reported in detail herein. Possible soybean planting dates ranged from April 22nd to June 17th on a weekly basis. Maturity group 2, 3 and 4 soybean varieties were included. Treatments also included various plant population levels which are not reported in detail herein. For further information see Shockley 2010.

Required machinery operations are based on University of Kentucky Cooperative Extension Service recommendations and common practice for the region and reflect a no-till operation. Four weeks before planting corn or soybeans, a burn down treatment with herbicide occurs. Then planting of corn and soybeans occurs for the given weeks analyzed. A pre-emergence herbicide application on corn occurs two weeks after planting. A post-emergence herbicide application on both corn and soybeans occurs four weeks after planting. Nitrogen application on corn occurs five weeks after planting. Insecticide application on soybeans occurs 15 weeks after planting. Harvest was determined by the average (across 30 years) maturity date in DSSAT for each planting date and maturity group combination. Physical harvest of the crop occurred three weeks after the maturity date determined for corn and four weeks after the maturity date determined for soybeans. Then, the farmer was allowed two weeks of harvest time to complete the harvest. Furthermore, stalk shredding of corn also occurs during the harvest weeks.

These farm machinery activities are performed using a typical machinery complement reflective of a commercial sized operation in the region. A 250 horse power 4WD (four wheel drive) tractor and a 200 horse power combine (with an 8 row header for corn harvest and a 7.62 m flex header for soybean harvest) are owned. Farm implements include a 12.80 m anhydrous applicator, a split row no-till planter for 16 rows, a grain cart with a capacity of 12.7 tonnes and a 6.10 m stalk shredder. A 27.43 m boom self propelled sprayer is also owned. Machinery data standards (performance rates, machinery costs, etc.) are embodied in the Mississippi State Budget generator which is used for both its price data and ability to perform the calculations of such coefficients (Laughlin and Spurlock, 2007).

Farm machinery operations are limited by field conditions which dictate whether or not a given time is suitable or not for fieldwork. Following Shockley 2010 a suitable field day was defined as one that did not experience precipitation in excess of 0.38 cm per day. The monthly median level across all 30 years is used to depict suitable working field days which are further separated into weeks for the machinery constraints.

A whole farm economic optimization model is formulated using linear programming to represent this decision-making environment. Production activities reflecting crop mix and crop production practices are included. Likewise, requirements of performing all necessary farm machinery operations, purchasing adequate inputs and not exceeding available resources such as land are included as well. Especially noteworthy here is the inclusion of weekly constraints such that the suitable working field times available are not exceeded in the performance of required farm machinery activities. Marketing constraints embody the fact that commodity sales may not exceed the amount produced on the farm for any given year. Corn price is US$0.1677/kg ($4.26/bu) and soybean price is US$0.3586/kg ($9.76/bu) after hauling costs. Crop rotation constraints reflect a two year rotation between corn and soybean production activities. The farm manager is maximizing expected farm returns net of operating costs under the risk neutral case. Thus, farm net returns reflect a return to land, machinery ownership and management. Under the cases reflecting a farm manager who is risk averse, a standard mean-variance modeling procedure is used to discount mean net returns by a risk aversion penalty multiplied by the variance of net returns across years reflecting uncertainty in crop yields due to varying weather patterns across years. Two attitudes towards risk are examined: a low and a high aversion to yield risk. Based upon the underlying conditions and the farm manager's attitude towards risk, an optimal whole farm plan is determined regarding the crop production practices to be undertaken.

Results and Discussion

The base risk neutral case wherein a farm manager is unconcerned with fluctuation in net returns from varying yields displays an expected net return of US$1,064,615 (Table 1). This represents an average across the 30 years of weather analyzed and depicts a return above operating costs. Notably, these returns have not been reduced for land, machinery ownership and management expenses. The typical resulting risk and return tradeoff is displayed in the results. Specifically, as risk aversion increases there is the opportunity to reduce risk as measured by standard deviation of net returns but at a cost of lower mean net returns. Furthermore, the coefficient of variation (CV) and minimum observed net returns lowers as risk aversion increases. While the risk neutral farm experienced a 17.52% CV (meaning about two thirds of the time net returns are within plus or minus 17.52% of the mean of US$1,064,615) the highest risk averse solution results in a drop to a CV of 11.58% for a mean return of US$972,824.

Table 1. Summary farm net return results by risk aversion attitude

	Risk Neutral	Low Risk Averse	High Risk Averse
Mean Net Returns (US $)	1,064,615	1,052,901	972,824
Maximum Net Returns (US $)	1,417,453	1,398,218	1,224,121
Minimum Net Returns (US $)	688,761	702,152	733,239
Standard Deviation Net Returns (US $)	186,495	163,662	112,665
Coefficient of Variation (%)	17.52	15.54	11.58

The economically optimal corn production practices varies dependent upon risk attitude (Table 2). For risk neutrality, heavy emphasis is placed on the early March 25th planting at about 84% of corn planted with the remainder planted April 15th. As yield risk aversion increases, greater diversity in planting dates is used with shifts to later planting dates. April 15th corn planting is foregone with a preference for planting on April 22nd with the addition of April 1st initially and then April 8th as well. A combination of early and late harvest is used as needed. A dominance of 2725 GDD maturity corn at 72% of land planted gives way to greater diversity as risk aversion increases but with about half of corn planted in the earlier 2625 GDD variety. Greater diversity of corn production practices is used to reduce yield risk as well as relying upon more stable yielding production practices. Notably, corn yield drops from 10,261 kg/ha for the risk neutral solution to 9,352 kg/ha for the high risk averse solution, a decrease of about 9%.

Table 2. Optimal corn production practices (ha) and yields (kg/ha) by risk aversion attitude

Planting date, harvest time, maturity[1]	Risk Neutral	Low Risk Averse	High Risk Averse
March 25 Early harvest 2625 GDD (ha)			70
March 25 Late harvest 2625 GDD (ha)			127
March 25 Early harvest 2675 GDD (ha)	146	146	
March 25 Early harvest 2725 GDD (ha)	146	146	15
March 25 Late harvest 2725 GDD (ha)	148	81	71
April 1 Late harvest 2725 GDD (ha)		67	76
April 8 Early harvest 2625 GDD (ha)			74
April 8 Early harvest 2725 GDD (ha)			4
April 15 Late harvest 2725 GDD (ha)	86		
April 22 Early harvest 2725 GDD (ha)		4	
April 22 Late harvest 2675 GDD (ha)			88
April 22 Late harvest 2725 GDD (ha)		82	
Corn Yield (kg/ha)	10,261	10,025	9352

[1] Harvest time refers to early (first week of two) or late (second week of two) harvest and maturity refers to average growing degree days (GDD) required

The economically optimal soybean production practices varies dependent upon risk attitude just as corn did but to a lesser degree (Table 3). For risk neutrality, almost the entire soybean planting occurs April 22nd at the earliest opportunity with a mere 1% being planted the week following. Harvest is fairly evenly distributed and maturity group 4 soybeans are all that is planted. As yield risk aversion increases, greater diversity in planting dates is used with shifts to later planting dates. Early planted soybeans (April 22nd are eliminated in favor of April 29th and May 6th planted soybeans again with entirely maturity group 4 soybeans. However, the high risk averse solution results in a combination of four different weeks of planting from the earliest to the latest on June 17th. Furthermore, all three maturity groups of soybean are planted. Notably, harvest time can be partially managed through the use of varying maturity groups in the spreading out of harvest requirements. As for corn, greater diversity of soybean production practices is used to reduce yield risk as well as relying upon more stable yielding production practices. As partial evidence of this, soybean yield drops slightly (6.50%) from 4188 kg/ha for the risk neutral solution to 3915 kg/ha for the high risk averse solution.

Table 3. Optimal soybean production practices (ha) and yields (kg/ha) by risk aversion attitude

Planting date, harvest time, maturity[1]	Risk Neutral	Low Risk Averse	High Risk Averse
April 22 Early harvest MG 3 (ha)			19
April 22 Early harvest MG 4 (ha)	241		
April 22 Late harvest MG 4 (ha)	281		
April 29 Early harvest MG 2 (ha)			220
April 29 Early harvest MG 3 (ha)			118
April 29 Late harvest MG 4 (ha)	5	250	
May 6 Early harvest MG 4 (ha)		276	
May 13 Late harvest MG 4 (ha)			47
June 17 Early harvest MG 4 (ha)			123
Soybean Yield (kg/ha)	4188	4171	3915

[1] Harvest time refers to early (first week of two) or late (second week of two) harvest and maturity refers to standard maturity group 2, 3 or 4 soybeans

The question of the value of time suitable for performing field work can be determined in two different ways. One is to consider what the change in mean net returns would be from one additional hour of suitable field time. This therefore represents the marginal value product of suitable field time, or the value of the additional yield resulting from using this extra resource. Another way to think of value is to consider what the farmer is willing to pay for an additional hour of suitable field time. While this is the same as the change in mean net returns for a risk neutral producer, it is not the same for a risk averse farmer. Risk averse farmers won't be willing to pay the full additional average net returns earned on the extra suitable field time available. This is because there is undesirable variability on the amount of additional yield enjoyed from the additional time because of weather. Thus, the risk averse farmer discounts this value given the gamble being faced. Consequently, both the marginal value product and willingness to pay perspectives on the value of suitable field time are calculated and discussed.

The marginal value products (or change in mean net returns) for the relevant weeks are displayed in Table 4. Notably, if a given weekly machinery operation constraint has more than adequate suitable field time available, additional suitable field time does not increase yield. Likewise, the farmer is not willing to pay anything for suitable field time during those weeks where suitable field time is not constrained. When time is constrained, however, varying marginal values are realized. Planting time during week 17 for the risk neutral scenario results in a value of US$21.08 per hour. Harvest time experiences even higher marginal values with US$217.86, 266.09 and 266.09 for weeks 35, 36 and 37 respectively. These results provide numerical evidence to support what the authors and many farmers have anecdotally noted previously; there is a high value at some times for the performance of machinery operations at critical periods such as harvest. Under risk aversion, the marginal values associated with planting, albeit shifted to week 18, steadily increases and the marginal value of harvest time when constrained remains quite high but at an often slightly reduced level. Notably, these marginal value products increase for planting time but generally decrease for harvest time as risk aversion increases. This is the result of the different combinations of crop production practices used across attitudes towards risk.

While the discounts under risk aversion to the willingness to pay for additional suitable field time are less than the mean change in farm returns, harvest time remains quite valuable. At the lowest (other than zero for unconstrained weeks) level, there is a willingness of a highly risk averse farmer to pay US$101.28 for an additional hour of suitable field time. However, willingness to pay for planting time is reduced to a value of only US$8.52 for the highly risk averse farmer during week 17. Notably, these values represent a marginal willingness to pay and should not be extended excessively. For example, a farmer with low risk aversion may be willing to pay US$197.19 for one more additional suitable field hour in week 36 but not ten times that for ten additional hours.

Table 4. Marginal value and willingness to pay for suitable field working time by week and risk aversion attitude

	Risk Neutral	Low Risk Averse	High Risk Averse
Marginal Value – Week 17 (US$/hr)	21.08	0	0
Marginal Value – Week 18 (US$/hr)	0	85.11	117.73
Marginal Value – Week 35 (US$/hr)	217.86	208.77	231.89
Marginal Value – Week 36 (US$/hr)	266.09	259.88	231.89
Marginal Value – Week 37 (US$/hr)	266.09	259.88	231.89
Willingness to Pay – Week 17 (US$/hr)	21.08	0	0
Willingness to Pay – Week 18 (US$/hr)	0	32.47	8.52
Willingness to Pay – Week 35 (US$/hr)	217.86	158.14	101.28
Willingness to Pay – Week 36 (US$/hr)	266.09	197.19	101.28
Willingness to Pay – Week 37 (US$/hr)	266.09	197.19	101.28

Summary and Conclusions

The value of suitable field time is an important element in making several machinery management decisions. A whole farm planning optimization model was used to determine marginal value product (change in mean net returns) and marginal willingness to pay for suitable field time for a Kentucky corn and soybean producer. Optimal solutions results for farm net returns summary statistics and optimal crop production practices were determined. The typical risk and return tradeoff is found wherein reduced fluctuation in net returns is possible at a cost of reduced mean net returns. Earlier planting dates of both corn and soybean were most profitable but greater planting date diversity and a shift to later planting dates were used to manage risk with increasing risk aversion. A greater diversity of other crop production practices was used to reduce yield risk. Furthermore, yield risk also is lowered by relying upon more stable yielding production practices but with slightly deceasing average farm crop yields as risk aversion increased. When suitable field time is constrained it can have values as high as US$266.09 per hour during harvest for the risk neutral farmer. Given the variability of change in farm returns resulting from additional suitable field time dependent on weather, a risk averse producer is only willing to pay a discounted amount from the mean change in farm net returns. The risk averse farmer's willingness to pay for additional suitable field time nonetheless can remain substantial ranging from about US$100-US$200 per hour during constrained harvest time.

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