Determining the Optimal Decision to Store or Contract Sale Food-Grade Corn, Field Corn, and Soybeans

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Abstract

A whole farm economic analysis was performed to maximize net returns utilizing variable maturity groups of corn and soybeans over different soil types. Demand for drying and storage equipment throughout harvest was generated based on profit-maximizing combinations of grain types, their respective maturity groups, and yield potential over different topsoil depths. Two marketing strategies were considered: cash and futures contract sales. It was found that drying and storage equipment became a limiting factor in the proposed system, but at different times during harvest. This bottleneck prevented additional grain from capturing value in the futures market and increasing net returns.

Keywords: farm management, maturity group, harvest logistics, specialty grains

Introduction

Properly selecting maturity groups based upon planting date and soil characteristics can have a significant impact on yield. However, maturity groups also play a role in harvest logistics and the demand for drying and storage equipment. This demand for drying and storage also drives decisions of how crops are marketed. Economically, optimal decision-making throughout this system manifests itself in maximum net returns. Furthermore, depressed grain prices have put pressure on farmers to improve their management and marketing strategies. One way to improve profitability is through the production of a specialty grain such as white food-grade corn. While processors will pay a premium for specialty grains, it is usually the case that they have strict quality standards that ultimately determine the price. Hence, producers must take considerable care in the harvest, dry down, and storage of specialty grains. This usually necessitates priority for the specialty grain to be harvested, dried, and stored ahead of other less valuable grain types. Ultimately, this can implicate decision making for other production from planting to marketing. Additionally, the capacity of drying and storage equipment dictates how producers take advantage of the futures market, strong basis, and opportunities for specialty grain production. Analysis can be performed on these capacities to determine if the equipment being used is under or oversized compared to production and what effect that has on returns.

Objectives

The purpose of this paper is to model a system typical of rainfed grain farms in western Kentucky. An enterprise mix of white corn, corn, and soybeans is considered for a 2600 acre farm in addition to two marketing strategies, cash and contract sales. Optimal decision-making as it pertains to variable rate maturity group selection over different topsoil depths and the effect it ultimately has on marketing strategy and drying and storage equipment is demonstrated.

Specifically, the proposed model maximizes net returns based on the optimal combination of planting date, maturity group selection, and marketing strategy. Constraints affecting this combination of variables include land, labor, yield, dryer and storage capacities, contract sale of white corn, and soil variation. Likewise, the demand for drying and storage of grain for futures contract sales will be analyzed for bottlenecks or slacks. The analysis is performed on dryer capacity as it increases or decreases to observe what effect a variation in capacity relative to fixed storage has on net returns.

Materials and Methods

Linear programming is used optimize the specified whole farm plan. Microsoft Excel and Solver add-in are used to organize the tableau and compute maximized net returns using the simplex method. The mathematical representation of the model can be found in the Appendix. Five planting date options are considered for all three crops. For white corn and corn, planting can take place March 25, April 8, April 22, May 6, or May 22. For soybeans, planting dates are April 22, May 6, May 20, June 3, and June 17. It should be noted that these dates represent a two-week window in which planting of a particular crop and its related maturity group(s) takes place. It is assumed the operation has the necessary technology to complete variable rate maturity group planting over varying topsoil depths. Three maturity groups for corn and soybeans are included so that yields are maximized according to planting date and soil type. For corn, maturity group 1 is represented by 2600-2650 growing degree days (GDD) till maturity, maturity group 2 2650-2700 GDD, and maturity group 3 2700-2750 GDD. However, white corn plantings are fixed and only utilize maturity group 2 (2650-2700 GDD) because of data limitations. Soybean maturity groups for selection consist of MG2, MG3, and MG4. Soil variability is modeled based up topsoil depth. Two topsoil depths, deep and shallow, constitute

80% and 20% of the tillable acres, respectively. These proportions are representative of soil characteristics in Henderson County, KY (NRCS, 2008). Soil variability based upon constituents such as sand, silt, and clay was not modeled due to computational constraints of Solver software and is recognized as a limitation.

Marketing strategies include spot cash sales and futures contract sales. Futures contract sales imply that a predetermined amount of either corn or soybeans is delivered in a specific month under terms established by buyer and seller where price is determined by the exchange where trading is conducted. In this instance, the exchange in which price data is derived is the Chicago Mercantile Exchange (CME). Within the model, production allocated to cash sales is assumed to be harvested and transported directly to a commercial elevator with no on-farm drying or storage required. Essentially, this means the crop in question has reached maturity and a moisture content of 15% where spoilage is not an issue. For contract sales, the assumption is made that on-farm drying and storage is utilized so that grain can be delivered at a later date. White corn production is based upon a 40000 bu contract to reflect real world transactions. This is representative of food processors establishing mills in high production areas and executing contract-based transactions to meet their demand for specialty grains. To observe interactions within the harvest window, weeks 35-47 are included in the model to complete the harvest of all three crops. White corn harvest can take place within week 35-40 and the entirety of the 40000 bu is harvested within one week. This one-week timeframe is imposed because of two reasons. First, the production level of white corn is predetermined, and the labor requirements for its harvest do not exceed weekly constraints. Second, grain quality is the main determinant of price ultimately received. It is hypothesized that producers want to harvest white corn and have it dried and stored with care before a significant impact on other crops occurs due to delayed harvest.

Corn harvest can take place over weeks 35-42 and requires two weeks to complete. Before the model is run and results returned, it is expected that a significant portion of acreage will be devoted to the grain and thus necessitates the two-week window. Soybean harvest is considered for weeks 38-47 and also requires two weeks to complete. Naturally, drying and storage operations parallel harvest and occur over weeks 35-47. Within the model, all three grains are assumed to be stored until week 47 as long as there is space. Typically, specialty grains will be stored until delivery is requested from the processor. This could be in a week or could be eight months later. Julian week 47 falls in the middle of November, and while forward contract soybean production is priced for this month, corn and white corn are not. This is due to a constraint limitation in Solver and is recognized as a restriction on the model since the interaction of storage over a longer period, and net returns cannot be observed. Finally, a rotation limit is imposed to reflect sound agronomic practices. 50% of the acreage is devoted to white corn or corn production and the other half to soybeans.

Futures contract prices for corn are average CME December futures, priced in April over five years from 2011-2016. Soybean futures contract prices are average November futures, priced in June over the same five-year period. The rationale behind selecting April and June for corn and soybean contract pricing is that these months are historically most advantageous for producers to add value to their production in the futures market. Furthermore, contract prices reflect drying and storage costs since those operations are imposed on contracted grain within the model. These costs are derived from Iowa State University Extension and Outreach "Monthly Cost of Storing Grain" decision aid (Edwards, 2015) and total \$0.08 and \$0.10 per bushel for corn and soybeans, respectively. An additional \$0.02 per week is subtracted from each bushel price as the weeks progress, i.e. every seven days a bushel sits in storage, it depreciates \$0.02 to reflect storage cost. Cash prices are average daily spot prices from 12 western Kentucky elevators within weeks 35-47 for corn and soybeans from 2011-2016. Since cash sale grain is transported directly from the field to a commercial elevator, $0.22/bu is deducted to reflect hauling cost. This was determined using the University of Tennessee Grain Hauling Cost Calculator (Smith, 2013) and assumes a 35 mile distance from field to the elevator. Lastly, white corn price is estimated by placing a $0.67/bu premium on the futures price of corn and includes the same drying and storage costs. This was estimated using an extensive dataset of prices paid for GMO white corn at an elevator in Henderson County, KY and is the daily average basis premium above futures price from 2011-2015. Variable costs per acre for corn and soybeans are derived from the University of Kentucky Western Kentucky Corn and Soybean Budgets 2016 (Halich, 2016). These values are $382.95 and $234.87 for corn and soybeans, respectively, and include all variable costs (seed, fertilizer, labor, etc.) with the exception of a cash rental rate of $175.00 /acre. For white corn, variable costs per acre are determined by holding all values on the UK corn budget constant, but increasing seed cost from $95.00 to $120.00 for total variable costs less cash rent of $407.95/acre. White corn seed cost was identified through consultation with a sales representative from Crop Production Services in Franklin, KY. This methodology for estimating white corn variable costs implies that it is a GMO and sprayed with glyphosate to control weeds as specified on the UK corn budget.

Yield data on maturity group and planting date for corn and soybeans is taken from a 2011 study by Shockley, Dillon, and Stombaugh in which a hypothetical farm in Henderson County, KY was modeled with simulated data. A summary of the production practices used in the simulation can be found in Tables 1 and 2. Per acre labor requirements and average days suitable for fieldwork in the harvest window is also taken from the Shockley, et al. study. Both white corn and corn require 0.219 hrs/acre of labor during harvest and soybeans require 0.119 hrs/acre. Weekly labor constraints are calculated by multiplying average days suitable for fieldwork by a 12-hour workday. The 2600 acre farm size corresponds with the upper one-third of all farms in management returns represented by net farm income in the Ohio Valley region of Kentucky where Henderson County is located (Pierce, 2008). White corn yields are estimated to have 87% of the yield potential of corn. This is determined by taking the ratio of white corn average yield to average corn yield for maturity group 2 from the Kentucky Hybrid Corn Performance Test (Kenimer, Kurd, & Lee, 2015) from 2013-2015 in Caldwell County, KY. Drying and storage equipment specifications are derived from a large farm in Logan County, KY and are scaled to the 2,600 acre farm size used in the model. Weekly drying capacity during harvest totals 18402 bu, which assumes a seven-day workweek and14-hour workday for the operator. Likewise, storage capacity totals 112926 bu. To analyze the effect that decreasing or increasing drying capacity has on net returns, the 18402 bu base model specification is replaced with a capacity ranging from 9000 to 39000 bu in 1000 bu increments. Running the model with varying capacities delivers different maximized net returns that allow the marginal value product (MVP) of storage capacity to be calculated.

Table 1. Summary of Corn Production Practices [a]

Planting Date	March 25, April 8, April 22, May 6, May 20
Maturity group (GDD)	2600-2650, 2650-2700, 2700-2750
Plant population (plants/acre)	32000
Row spacing	30”
Plant depth	0.5”
Nitrogen rate (actual lbs/acre)	175

Table 2. Summary of Soybean Production Practices [a]

Planting Date	April 22, May 6, May 20, June 3, June 17
Maturity group	MG2, MG3, MG4
Plant population (plants/acre)	111000
Row spacing	15”
Plant depth	1.25”

[a] No-till tillage practices

Results

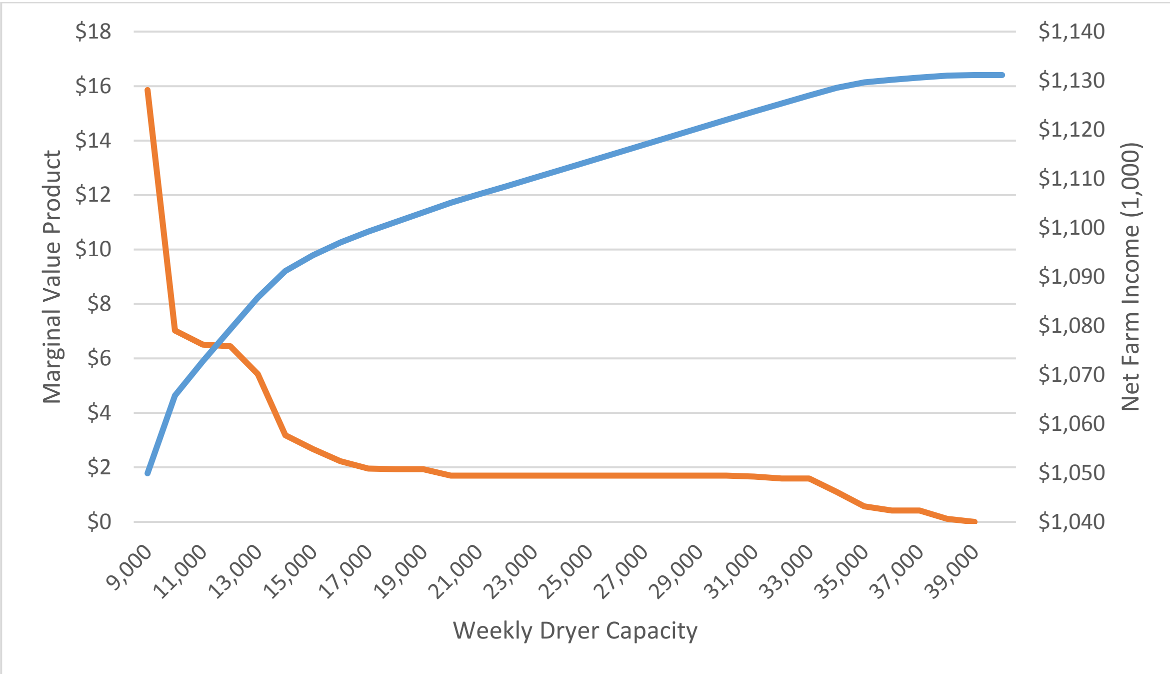
Once the data is organized and the model is run, maximized net returns total $1,101,980.48. Caution should be taken when interpreting these returns since no land rental or associated opportunity cost was included in its calculation. As such, this number represents returns to land, labor, and management. To arrive at this figure, 128 and 140 acres of maturity group 2 white corn need to be planted on March 25 and April 22, respectively. This acreage also satisfies the 40000 bu production requirement as per the hypothetical contract. Since corn planting can involve multiple maturity groups across different topsoil depths on a given planting date, results require a bit more analysis. With variable rate technology assumed, the model selects March 25 as an ideal planting date for 127 acres of maturity group 1 across shallow topsoil, 275 acres of maturity group 2 on deep topsoil, and 233 acres of maturity group 3 on deep topsoil. Additional corn planting takes place on April 22 and requires 82 and 214 acres of maturity groups 2 and 3 across deep topsoil, respectively. The model also incorporates 74 acres of maturity group 2 on shallow topsoil on the same planting date. Soybean maturity groups identified to maximize net returns include MG3 and MG4. April 22 is the first planting date selected with 624 acres of MG3 planted across deep topsoil and 156 acres of MG4 planted across shallow topsoil. Finally, a second planting date of May 20 is chosen to plant 416 acres of MG3 across deep topsoil and 104 acres of MG4 across shallow topsoil. The results of these planting decisions are not surprising considering they are the yield maximizing combinations of planting dates and maturity groups over different topsoil depth. Once again, it should be noted that planting dates are the start of a two-week window, not a single day in which all planting is expected to be completed. Moreover, acres planted of all grain types sum to 2600, meaning all the land was used under the rotation limit.

Marketing decisions are interpreted as the bushel amount harvested in a given week (week 35-47) that should be obligated to either cash or contract sale to maximize net returns. A total of 161479 bushels of corn are sold in the spot market over week 35-39. Soybean production sold in the cash market totals only 5493 bu during weeks 40 and 41. Since white corn production must equal 40000 bushels and be sold contractually, 18402 bushels of this contract are harvested in week 35, another 18402 in week 37, and 3196 in week 38. No corn is selected for contract sale. This is due to the model is giving preference to higher value white corn and soybean production for ultimate contract sale to maximize net returns under drying and storage constraints. Finally, futures contract soybean production totals 72926 bu harvested over weeks 40-45.

Dryer capacity reaches it maximum four out of the thirteen weeks of harvest (week 35, 37, 40, 41). Naturally, these weeks coincide with the majority of the harvest of white corn and soybeans. Referencing shadow prices, there are considerable gains to be made by expanding dryer capacity. During week 35, if the dryer capacity could dry one more bushel, it would increase net returns by $0.53. Similar situations occur in weeks 37, 40, and 41, with shadow prices of $0.12, $0.60, and $0.68, respectively. Of course, increasing the actual size of the dryer would not take place in the short-run, but increasing the temperature at which the dryer runs could expand weekly capacity. However, it is known that this could cause quality issues (shatter) and devalue the grain. Storage reaches its full capacity in week 45 at the conclusion of soybean harvest. Clearly, dryer capacity is affected by the weekly throughput of grain while storage is dependent on how quickly it accumulates. One constraint that was not emphasized at the beginning of this study, but presents an interesting shadow price is land. If one more acre of land were added to the system, net returns would increase by $294.11, which is higher than a typical $200.00 rental rate in western Kentucky.

When all other factors in the model are held constant and dryer capacity is allowed to vary, predictable yet interesting results are returned. As weekly dryer capacity increases in 1000 bu increments from 9000-39000 bu, net returns increase until capacity reaches 39000 bu and the MVP of dryer capacity is zero. This relationship can be seen in figure 1. Further analysis of this relationship reveals some intriguing points. First, at a capacity of 10000 bu/week, the MVP of dryer capacity equals $15.85 compared to $0.10 when it is set to 39000 bu/week. At the lower end, more grain is allocated to cash sales and value is lost when it cannot be dried, stored, and sold in the futures market. At the upper end of this range, not much can be gained because dryer capacity can easily accommodate large throughput. However, the greatest decline in the MVP of weekly dryer capacity occurs between 10000 and 11000 bu where it falls from $15.85 to $7.02, a 55% decrease. Second, once dryer capacity reaches 21000 bu/week, MVP does not decrease until capacity reaches 32000 bu/week. That is, MVP is constant at $1.69 from 21000-31000 bu/week. Within this range, a producer would be indifferent to increasing or decreasing the capacity of a dryer. Finally, the greatest incremental increase in dryer weekly leading to the largest increase in net farm income occurs as capacity is adjusted from 9000 to 10000 bu and totals $25,415.63. This increase in net returns is representative of soybeans undergoing drying, storage, and sale in the futures market where there was only capacity for white corn production before. By and large, an $81,245.14 increase in net returns occurs between 9000 and 39000 bu of dryer capacity.

Figure 1. Net farm income and MVP as weekly dryer capacity increases



Conclusions

Overall, producers with access to variable rate maturity group planting technology need to be aware of the implications their planting strategy has on net returns and the use of harvest equipment such as dryers and grain bins. Additionally, marginal analysis of drying or storage equipment can provide insight into opportunities to increase net returns. As it was shown in the model, if only one of these reaches its full capacity, it can have a significant impact on net returns. This demand for storage and drying equipment is driven by what maturity group was planted when. If a farmer grows a specialty grain such as white corn to increase profitability, the system can become even more constrained. An extension of this analysis would include the determination of optimal dryer and storage complements, in addition to an investment analysis on the proposed equipment set. Principally, the model constructed for this paper is an example of the ever-changing and more complex management decisions producers are faced with in the era of precision agriculture. With proper analytical tools, farmers can be better equipped to understand what effect certain technologies have on their production system as a whole. When this understanding is reached, more profitable decisions can be made.

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APPENDIX: MATHEMATICAL SPECIFICATION OF THE ECONOMIC DECISION-MAKING MODEL

The economic decision-making model described in the text is depicted mathematically as follows:

Maximize:

$$
\begin{aligned}
(1)\quad NR = & -\sum_{CPD}\sum_{TSD} VCW * WHITE_{CPD,TSD} - \sum_{CPD}\sum_{CMG}\sum_{TSD} VCC * CORN_{CPD,CMG,TSD} \\
& -\sum_{SPD}\sum_{SMG}\sum_{TSD} VCS * SOY_{SPD,SMG,TSD} + \sum_{WK} PWCONT_{WK} * WCONT_{WK} \\
& +\sum_{WK} PCCONT_{WK} * CCONT_{WK} + \sum_{WK} PCCASH_{WK} * CCASH_{WK} \\
& +\sum_{WK} PSCONT_{WK} * SCONT_{WK} + \sum_{WK} PSCASH_{WK} * SCASH_{WK}
\end{aligned}
$$

Subject to:

$$(2)\ \sum_{CPD} WHITE_{CPD,TSD} + \sum_{CPD}\sum_{CMG} CORN_{CPD,CMG,TSD} + \sum_{SPD}\sum_{SMG} SOY_{SPD,SMG,TSD} \le ACRES_{TSD} \quad \forall WK$$

$$
\begin{aligned}
(3)\quad & \sum_{CPD}\sum_{TSD} LABREQW_{WK,CPD} * WHITE_{CPD,TSD} + \sum_{CPD}\sum_{CMG}\sum_{TSD} LABREQC_{WK,CPD,CMG} * CORN_{CPD,CMG,TSD} \\
& + \sum_{SPD}\sum_{SMG}\sum_{TSD} LABREQS_{WK,SPD,SMG} * SOY_{SPD,SMG,TSD} \le HRSSFW_{WK} \quad \forall WK
\end{aligned}
$$

$$(4)\ -\sum_{CPD}\sum_{TSD} YLD_{WK,CPD,TSD} * WHITE_{CPD,TSD} + WCONT_{WK} \le 0 \quad \forall WK$$

$$(5)\ -\sum_{CPD}\sum_{CMG}\sum_{TSD} YLD_{WK,CPD,CMG,TSD} * CORN_{CPD,CMG,TSD} + CCASH_{WK} + CCONT_{WK} \le 0 \quad \forall WK$$

$$(6)\ -\sum_{SPD}\sum_{SMG}\sum_{TSD} YLD_{WK,SPD,SMG,TSD} * SOY_{SPD,SMG,TSD} + SCASH_{WK} + SCONT_{WK} \le 0 \quad \forall WK$$

$$(7)\ WCONT_{WK} + CCONT_{WK} + SCONT_{WK} \le DRYCAP \quad \forall WK$$

$$
\begin{aligned}
(8)\quad & STORREQ_{WK} * WCONT_{WK} + STORREQ_{WK} * CCONT_{WK} \\
& + STORREQ_{WK} * SCONT_{WK} \le STORCAP \quad \forall WK
\end{aligned}
$$

$$(9)\ \sum_{WK} WCONT_{WK} = 40000$$

$$(10)\ \sum_{CPD}\sum_{TSD} WHITE_{CPD,TSD} + \sum_{CPD}\sum_{CMG}\sum_{TSD} CORN_{CPD,CMG,TSD} \le 1300$$

(11) $\sum_{SPD}\sum_{SMG}\sum_{TSD} SOY_{SPD,SMG,TSD} \leq 1300$

(12) $PERCENT_{"DEEP"} * WHITE_{CPD,TSD="SHAL"} + PERCENT_{"SHAL"} * WHITE_{CPD,TSD="DEEP"} = 0 \quad \forall CPD$

(13) $\sum_{CMG} PERCENT_{"DEEP"} * CORN_{CPD,\, CMG,\, TSD="SHAL"} \left(-\sum_{CMG} PERCENT_{"SHAL"} CORN_{CPD,\, CMG,\, TSD="DEEP"} \right)$
$= 0 \;\; \forall CPD$

(14) $\sum_{SMG} PERCENT_{"DEEP"} * SOY_{SPD,SMG,TSD="SHAL"} \left(-\sum_{SMG} PERCENT_{"SHAL"} * SOY_{SPD,SMG,TSD="DEEP"} \right)$
$= 0 \quad \forall SPD$

Activities include:

NR = Whole farm net returns

$WHITE_{CPD,TSD}$ = Production of white corn under corn planting date CPD on topsoil depth TSD in acres

$CORN_{CPD,CMG,TSD}$ = Production of corn under corn planting date CPD of corn maturity group CMG on topsoil depth TSD in acres

$SOY_{SPD,SMG,TSD}$ = Production of soybeans under soybean planting date SPD of soybean maturity group SMG on topsoil depth TSD in acres

$WCONT_{WK}$ = Bushels of white corn harvested in week WK sold in contract market

$CCONT_{WK}$ = Bushels of corn harvested in week WK sold in contract market

$SCONT_{WK}$ = Bushels of soybeans harvested in week WK sold in contract market

$CCASH_{WK}$ = Bushels of corn harvested in week WK sold in cash market

$SCASH_{WK}$ = Bushels of soybeans harvested in week WK sold in cash market

Constraints include:

(1) Objective function

(2) Land resource limitation by topsoil depth

(3) Labor resource limitation

(4) White corn marketing limit by week

(5) Corn marketing limit by week

(6) Soybean marketing limit by week

(7) Dryer capacity in bushels per week

(8) Storage capacity in bushels

(9) White corn contract requirement in bushels

(10) Corn rotation limitation

(11) Soybean rotation limitation

(12) Ratio of topsoil type planted to white corn

(13) Ratio of topsoil type planted to corn

(14) Ratio of topsoil type planted to soybeans

Coefficients include:

VCW = White corn variable cost in dollars per acre

VCC = Corn variable cost in dollars per acre

VCS = Soybean variable cost in dollars per acre

$PWCONT_{WK}$ = Price of white corn sold in contract market in dollars per bushel in week WK

$PCCONT_{WK}$ = Price of corn sold in contract market in dollars per bushel in week WK

$PSCONT_{WK}$ = Price of soybeans sold in contract market in dollars per bushel in week WK

$PCCASH_{WK}$ = Price of corn sold in cash market in dollars per bushel in week WK

$PSCASH_{WK}$ = Price of soybeans sold in cash market in dollars per bushel in week WK

$LABREQW_{WK,CPD}$ = Labor requirement for harvest of white corn under corn planting date CPD in week WK

$LABREQC_{WK,CPD,CMG}$ = Labor requirement for harvest of corn under corn planting date CPD of corn maturity group CMG in week WK

$LABREQS_{WK,SPD,SMG}$ = Labor requirement for harvest of soybeans under soybean planting date SPD of maturity group SMG in week WK

$YLD_{WK,CPD,TSD}$ = Expected yield under corn planting date CPD on topsoil depth TSD in week WK in bushels

$YLD_{WK,CPD,CMG,TSD}$ = Expected yield under corn planting date CPD of corn maturity group CMG on topsoil depth TSD in week WK in bushels

$YLD_{WK,SPD,SMG,TSD}$ = Expected yield under soybean planting date SPD of soybean maturity group SMG on topsoil depth TSD in week WK in bushels

$DRYCAP$ = Grain drying capacity in bushels per week

$STORREQ_{WK}$ = Storage requirement for contract sales in week WK

$PERCENT_{"DEEP"}$ = Proportion of acreage available with deep topsoil

$PERCENT_{"SHAL"}$ = Proportion of acreage available with shallow topsoil

Indices include:

CPD = Corn planting date

TSD = Topsoil depth ("*DEEP*" or "*SHAL*")

CMG = Corn maturity group

SPD = Soybean planting date

SMG = Soybean maturity group

WK = Week