CORN-SOYBEAN ROTATION: ITS IMPACT ON ACREAGE DECISIONS

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Introduction

The benefits from rotating crops are a key consideration in planting decisions. Rotations control crop-specific pests and diseases by altering the host environment. Thus, they increase yields and reduce expenditures on pesticides. Incorporating legumes, such as soybeans and alfalfa, into a rotation also reduces the amount of nitrogen fertilizer that needs to be applied on the subsequent crop. This benefit is particularly valuable for corn which requires large amounts of nitrogen to obtain high yields. These benefits limit the willingness of farmers to alter their crop rotations until prices change enough to compensate for the loss of the rotation benefits.

Objective of this study is to provide an initial assessment of the limit that the benefits of rotation place on cropping decisions. The study focuses on the corn-soybean rotation, which is widely believed to be the most common in the U.S. Benefits of the corn-soybean rotation are quantified based on a review of the agronomic and extension literature, a Delphi questionnaire distributed to a state extension agronomist in the ten largest corn producing states, and a review of the crop budgets developed by the extension service in these 10 states. A simple analysis is then conducted to estimate the limit that the benefits of the corn-soybean rotation place on the response of farmers to changes in corn and soybean prices.

Delphi Questionnaire

The Delphi process involves the use of a standardized instrument to elicit the opinions of experts on a subject. A Delphi process is considered useful when the information is used to examine the benefits and costs of a potential decision and when a list of experts can be identified (Turoff, 1971). Furthermore, the benefits and costs of crop rotation change over time as new varieties are released, as crop production techniques change, and as pests adapt. Thus, a Delphi process can help identify the current picture of the benefits and costs of the corn-soybean rotation.

The list of experts was identified as state agronomy specialists in the top ten corn producing states in the U.S: Iowa, Illinois, Nebraska, Minnesota, Indiana, South Dakota, Ohio, Missouri, Kansas, and Wisconsin. Responses were received from nine states, but only six provided useable numerical responses. Table 1 contains the Olympic averages calculated from the numerical responses to the two questions used in this analysis. An Olympic average removes the high and low values from the calculation, thus reducing the influence of the extreme or outlier responses. This consideration merits attention because of the small number of questionnaires distributed. The responses to the entire survey are reported in the appendix table at the end of this report.

The respondents indicated that planting corn after corn instead of planting corn after soybeans had three major impacts on corn production attributes. Corn yield declined by 10%, the use of nitrogen fertilizer increased by 21%, and the use of pesticides for insect control increased by 13%. Four major impacts on soybean production characteristics were identified when planting soybeans after soybeans instead of planting soybeans after corn. Soybean yields declined by 8%, the use of pesticides for insect control increased by 10%, the use of disease management strategies increased by 10%, and the amount of soil erosion declined by 12%.

Unsurprisingly, these expert estimates are consistent with the literature. The yield impacts from the Delphi questionnaire are similar to those reported, for example, by Gregoire (2004) and Lauer, Porter, and Oplinger (1997). Because soybeans add 15-60 pounds of nitrogen to the soil (Buchholz, *et. al*, 1999), optimal corn yields require less nitrogen fertilizer when corn is grown in rotation with soybeans rather than continuously (Vitosh and Jacobs, 1996). Last, the *Illinois Agronomy Handbook*, for example, also lists these benefits to the corn-soybean rotation over monoculture: (1) more weed control options, (2) fewer insect and pest problems, and (3) potential benefits of residue on soybean output and tillage practices.

Table 1. Impact of Changing Corn-Soybean Rotation on Selected Production Attributes, Ten Largest U.S. Corn Producing States, 2004.

Production Attribute	Impact of planting corn after corn instead of corn after beans	Impact of planting beans after beans instead of beans after corn
Yield	-10%	-8%
Nitrogen Fertilizer	21%	0%
Phosphorus and Potassium Fertilizer	0%	0%
Pesticides for Weed Control	1%	0%
Pesticides for Insect Control	13%	10%
Disease Management	3%	10%
Erosion	-1%	12%

Source: survey of state agronomy specialists in the 10 largest U.S. corn production states, Fall 2004.

Extension service personnel for Iowa, Illinois, Indiana, Nebraska, and Wisconsin publish separate budgets for planting corn after corn and for planting corn after soybeans. A simple average of the numbers reported by these five states reveals that, compared to the corn-soybean rotation, (1) yields are 8% (11 bushels/acre) lower for corn-corn, (2) variable costs are 10% ($20/acre) higher for corn-corn, (3) total fertilizer costs are 7% ($4/acre) higher for corn-corn, and (4) total pesticide expenses are 38% ($11/acre) higher for corn-corn. Only Iowa's budget divides fertilizer expense into (1) nitrogen and (2) phosphorus and potash. Nitrogen is listed at $40/acre for corn-corn and $30/acre for corn-soybeans. Phosphorus and potash is listed at $14/acre for corn-corn and $15/acre for corn-soybeans. Although it is difficult to definitely compare results from the Delphi questionnaire with the state budgets because the categories differ, the two sets of data appear to be broadly consistent. The biggest difference occurs for pesticides, with the Delphi questionnaire revealing a smaller increase than the state budgets.

Only Indiana prepares separate budgets for planting soybeans after soybeans and for planting soybeans after corn. Compared to planting soybeans after corn, (1) yields are 10% (4.7 bushels/acre) lower while (2) variable costs are only 2% ($2/acre) lower when planting soybeans after soybeans. Historically, expenditures for insect control and disease management when producing soybeans have been considered minimal. However, concern over nematodes and plant diseases in soybeans have been increasing during recent years, especially in northern production regions. Bergland (1999) notes that root rot, white mold, and brown stems rot are common pathogens that build up if soybeans are planted continuously. Porter, *et al*. (2001) found that the highest levels of soybean cyst nematode eggs were found in rotations where soybeans had been planted for two years or longer. Given the recent emergence of these concerns and their greater prominence in northern production regions, it is not surprising that the Delphi results, compared to the Indiana state budgets, imply a higher cost when planting beans after soybeans than when planting soybeans after corn.

Analysis: Rotation Benefits and Acreage Response

To examine the impact that the benefits from the corn-soybean rotation have on acreage decisions, several assumptions are made. First, yield and variable cost for corn planted after soybeans and for soybeans planted after corn are assumed to equal the simple average yield and variable costs reported in the budgets for the top ten corn producing states. Second, the yields for corn planted after corn and for soybeans planted after soybeans are assumed to decline from the rotation yields by the average percent obtained from the Delphi questionnaire (see Table 1). Third, the variable cost for corn after corn is assumed to be 10% higher than for corn after soybeans while the variable cost for soybeans after soybeans is assumed to be the same as for soybeans after corn. This assumption is based on the state budgets for those states that published separate budgets for corn and soybeans planted in rotation and planted continuously. The state budgets are considered

more complete and internally consistent than the information generated by the Delphi questionnaire, which solicited information for only selected categories. Last, to initialize the analysis, the price of corn for the corn-soybean rotation is assumed to be $2.00/bushel, implying a return over variable cost of $93/acre.

Given these assumptions, the price of corn that generates a $93 return over variable costs for corn grown after corn is $2.37/bushel. The price of soybeans that generates a $93 return over variable costs for soybeans grown after corn is $4.62/bushel but for soybeans grown after soybeans is $5.02/bushel. These prices imply a soybean-corn price ratio of 2.31 for corn and soybeans planted in rotation (i.e., $4.62/$2.00). In contrast, the price ratio is 1.95 (i.e., $4.62/$2.37) using the corn and soybean prices that equalize the returns over variable cost for soybeans planted after corn and for corn planted after corn. This calculation implies that, for a farmer in this hypothetical situation, the soybean-corn price ratio has to be less than 1.95 before it is rational to consider altering the corn-soybean rotation by planting corn after corn. Analogously, the soybean-corn price ratio has to exceed 2.51 (i.e., $5.02/$2.00) before a farmer in this hypothetical situation would be interested in altering the corn-soybean rotation by planting soybeans after soybeans. Stated somewhat differently, the soybean-corn price ratio must increase by more than 9% (i.e., 2.51/2.31) for this farmer to rationally alter the corn-soybean rotation by planting soybeans after soybeans and the ratio has to fall by at least 16% (i.e., 1.95/2.31) for corn to be planted after corn instead of planting soybeans after corn.

Table 2. Corn and Soybean Prices and Price Ratios that Offset Benefits of Corn-Soybean Rotation, Ten Largest U.S. Corn Producing States, 2004.

	Crop Pattern			
Production Attribute	Corn after Beans	Corn after Corn	Beans after Corn	Beans after Beans
Yield (bushels/acre)	132.1	118.9	43.2	39.7
Variable cost ($/acre)	$171	$189	$107	$107
Price that gives $93/acre return over variable cost	$2.00	$2.37	$4.62	$5.02
Bean-Corn price ratio for competing crop pattern	2.31	1.95	2.31	2.51

NOTES: (1) See text for discussion of procedures used to generate table. (2) Competing decision and calculation of soybean-corn price ratio were: corn after beans vs. beans after corn ($4.62/$2.00); corn after corn vs. beans after corn ($4.62/$2.37); beans after corn vs. corn after beans ($4.62/$2.00); beans after beans vs. corn after beans ($5.02/$2.00). (3) Source: original calculations.

Implications of Analysis

Because of the higher yields and lower costs associated with rotating corn and soybeans, a range exists for the soybean-corn price ratio over which changes in the ratio will not provide incentives for farmers to shift out of their corn-soybean rotation to plant corn after corn or soybeans after soybeans. Based on information obtained from the literature as well as state budgets and a Delphi questionnaire of a state agronomist in the ten largest U.S. corn producing states, this analysis suggests that this range lies between soybean-corn price ratios of 1.95 and 2.51. Note that an asymmetry exists in how much the soybean-corn price ratio has to change in order to induce a farmer to break the corn-soybean rotation. The reason for the asymmetry is that the benefit of planting corn after soybeans is greater than the benefit of planting soybeans after corn.

As with all farm level decisions, a farmer should use his/her own yield and cost data. To illustrate the importance of the yield data, consider a situation where the corn-to-soybean yield ratio is 3.6 instead of 3.05 as in the illustration above. Thus, the yield of corn after soybeans is 155.5 bushels/acre instead of 132.1 bushels/acre. This change implies that the no change range on the soybean-corn price ratio for this producer is 2.43 to 3.11 instead of 1.95 to 2.51.

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APPENDIX A
Results of Corn-Soybean Cropping Pattern Questionnaire
Fall 2004

1. **What share of cropland in your state is currently cultivated using the following corn and/or soybean cropping patterns across years?**

Corn – Soybean Planting Pattern	Mean
50% Corn - 50% Soybeans	67%
Continuous Corn	13%
2 Years Corn -Then 1 Year Soybeans	8%
50% Soybeans - 50% Wheat	4%
Continuous Soybeans	4%
2 Years Soybeans -Then 1 Year Corn	2%

2. **In your opinion what important factors led farmers in your state to change rotations in recent years?**

Changes in government programs.
(1) Wheat acres to corn and soybeans due to wheat scab. (20 Alfalfa acres to soybeans and corn due to dairy farmers selling out. (3) Profitability of corn/soybeans versus other crops.
Rotation changes are based on soil moisture prior to planting. Also, insurance plays a big part in their decision to plant corn.
Prices, available planting window, delayed planting
Price, Price, Price
Low soybean yields, soybean aphids, bean leaf beetles
Commodity price, input cost, pest introductions
(1) Wheat has declined due to disease, low yields and price. (2) Another crop has replaced it. Low soybean yields and the expectation that this will recur. (3) High corn yields and the expectation that this will recur. – In general, more "upside potential" seen for corn than for other crops.

3. **Assume a farmer historically has used a 50% corn – 50% soybean cropping pattern, but decides to increase corn acres next year. Given this situation, how does planting corn after corn instead of corn after soybeans impact the following characteristics of corn production?**

Corn Production Characteristic	Mean
Corn yield	-10%
Nitrogen fertilizer use	21%
Potassium & Phosphorus fertilizer use	0%
Pesticide use for weed control	1%
Pesticide use for insect control	13%
Disease management	3%
Erosion	-1%

4. Assume a farmer historically has used a 50% corn – 50% soybean cropping pattern, but decides to increase soybean acres next year. Given this situation, how does planting soybeans after soybeans instead of soybeans after corn impact the following characteristics of soybean production?

Soybean Production Characteristic	Mean
Soybean yield	-8%
Nitrogen fertilizer use	0%
Potassium & Phosphorus fertilizer use	0%
Pesticide use for weed control	0%
Pesticide use for insect control	10%
Disease management	10%
Erosion	12%

Written responses noted (1) that the impact on pesticide use for insect control depends on the degree of the problem with aphids and rust.

5. Compared to a 50% corn - 50% soybean cropping pattern, how does a 2 year corn – then 1 year soybean cropping pattern impact the following production characteristics?

Production Characteristic	Mean
Corn yield	-5%
Soybean yield	5%
Corn Nitrogen fertilizer use	39%
Potassium & Phosphorus fertilizer use	21%
Pesticide use for weed control in Corn	1%
Pesticide use for weed control in Beans	0%
Pesticide use for insect control in Corn	24%
Pesticide use for insect control in Beans	-10%
Disease management in Corn	2%
Disease management in Beans	-10%
Erosion	-8%

Written responses noted (1) that little has been published in this rotational issue and (2) that the impact on pesticide use for insect control depends on the degree of the problem with aphids and rust.

6. Compared to a 50% corn - 50% soybean cropping pattern, how does adding a fall-winter cover crop to the 50% corn - 50% soybean cropping pattern impact the following production characteristics?

Production Characteristic	Mean
Corn yield	0%
Soybean yield	1%
Corn Nitrogen fertilizer use	0%
Potassium & Phosphorus fertilizer use	0%
Pesticide use for weed control in Corn	0%
Pesticide use for weed control in Beans	0%
Pesticide use for insect control in Corn	1%
Pesticide use for insect control in Beans	0%
Disease management in Corn	0%
Disease management in Beans	0%
Erosion	-10%

Note: Written responses noted (1) that the impacts depended on the type of cover crop, (2) that little has been published on this rotational issue, and that the environment might prevent this rotation from being an option.

7) We have extensively surveyed the academic and extension literatures, but, given that we are not agronomists, we would appreciate your recommendations on key articles in the literature. We also would appreciate knowing about ongoing unpublished research in the area of crop rotations.

University of Wisconsin has 5 long-term rotation trials. Lauer, *et al.*: Lancaster since 1967, Corn / Soybean since 1982; Corn/Soybean since 1984, Corn/Soybean/tillage since 1998; Posner: WICST since 1991

Crop rotation is the most basic and oldest agronomic method known that is used to control pests. Roundup Ready technology has greatly reduced the complexity of using herbicides when changing crops with a given rotation.

Much of the published literature has a strong site specificity, so may not always represent (or predict) effects of changing crop rotations. Sorry to mark this all up, but I have trouble seeing how “simplified” opinions (especially “% change” guesses) can be of any real use. I strongly suggest that you discard this approach as likely to mislead, but can’t think of a better approach.

<u>Suggested Articles/Readings</u>

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