Comparing Continuous Corn and Corn-Soybean Cropping Systems

Stan Daberkow, James Payne, and James Schepers[1]

Introduction

Recent projections by USDA indicate that several million acres of corn above historical levels will be needed over the next several years to meet increased industrial demand for corn by-products, especially ethanol (Collins 2007). A large share of the increased corn acreage will likely come at the expense of soybean acres (which are often planted in rotation with corn) leading to an increase in continuous corn cropping systems. However, monoculture corn production is often associated with adverse yield, cost, and environmental risks compared to more diverse cropping systems. For example, Neilsen et al. (2006) cite studies where continuous corn suffered average yield losses of 9%, nitrogen use increased 30-50 pounds per acre, and additional insect and weed management was required compared to corn-soybean rotations. Increased nitrogen and pesticide use may also lead to additional environmental risks (National Research Council 2007).

Despite these adverse yield, cost, and environmental risks, continuous corn is grown on a substantial share of U.S. acreage. The most recent national data indicate that about one-fourth of all corn acreage was planted to corn for at least two consecutive years (ERS 2006). Given that continuous corn is fairly widespread and persistent over time, these producers have apparently adopted practices that allow them to profitably grow corn without rotating with other crops. Neilsen et al. (2006) suggest a number of production practices which continuous corn producers should adopt to mitigate the risks associated with continuous corn production. They suggest that switching from a corn-soybean rotation to continuous corn will likely require changes in residue, nutrient, pest, seed, and equipment management. However, an empirical question is: to what extent do current production practices, costs, and yields differ between corn-soybean and continuous corn fields? Contrasting these two cropping systems would give some indication about the changes that could be expected in terms of corn production, input use and costs, and environmental risks as continuous corn acreage increases over the next several years.

Objectives

Using data from a 2005 national survey of fields growing corn for grain, we tested for differences between the two major cropping systems used to produce corn, focusing on differences in residue, nutrient, pest, and seed management; expected and actual yields; seed, pesticide, and fertilizer costs; and planting and harvesting machine capacity. Where the sample size was

[1] Stan Daberkow is Agricultural Economist, Resource and Rural Economics Division, Economic Research Service, U.S. Dept. of Agriculture; James Payne is formerly with the Resource and Rural Economics Division, Economic Research Service, U.S. Dept. of Agriculture; and James Schepers is Soil Scientist, Agricultural Research Service, U.S. Dept. of Agriculture. The views expressed here are those of the authors, and may not be attributed to the Economic Research Service, the Agricultural Research Service, or the U.S. Department of Agriculture. Daberkow is corresponding author: daberkow@ers.usda.gov.

sufficient, we also tested for regional differences in selected cropping practices, yields, and input costs. The two cropping systems were compared by statistically testing for differences in: 1) the share of planted acres on which a specific practice, input or technology was used or 2) mean values of selected input rates, yields or costs. A by-product of the comparative analysis provides an estimate of the adoption level of recommended practices by corn producers which may be instructive for grower education and Extension activities as well as for managers of environmental and conservation cost-sharing programs, such as the Conservation Security Program and Environmental Quality Incentives Program.

Background

Neilsen et al. (2006) presented a comprehensive overview of the variety of risks that continuous corn producers face relative to corn-soybean producers. They suggest that continuous corn yields are adversely affected (relative to corn-soybeans) because of the increased challenges associated with insect, disease, weed, residue, equipment, and nutrient management. However, they also suggest production practices which may help mitigate the adverse yield risks typically linked to continuous corn cropping systems. For example, continuous corn generates large amounts of residue, which can reduce soil erosion, but can leave cooler and wetter soils after planting, encourage diseases and insects, and decrease the efficacy of soil applied herbicides (see also, Randall et al. 1996). Additional tillage passes and/or avoiding no-till or minimum tillage systems may reduce yield reducing risks from increased residue.

Nutrient management practices, such as setting reasonable yield goals, soil and tissue testing, and use of crop consultants, are recommended for all corn producers but especially for continuous corn acreage (University of Nebraska 2000). Compared to corn after legumes, additional nitrogen and phosphate and less potassium may be required for corn after corn, leading to a net increase in fertilizer costs. Insect pest management is typically problematic in continuous corn, especially for soil pests such as Western rootworm, and may require more intensive scouting, use of soil insecticides, or Bt seed. While fungicides are used infrequently for any corn cropping system, pre- and/or post-emerge weed treatment may differ between cropping systems because of residue levels, weather, cultivation, or use of herbicide tolerant seeds (Erickson et al.). Finally, Neilsen et al. (2006) discuss potential yield loss in continuous corn due to reduced stand establishment (e.g., residue, disease, and cold soil concerns) and lengthened harvesting season (i.e., stalks may remain in the field longer before harvest)[2]. Continuous corn may result in producers starting to plant later because of cooler and wetter soils. This could require larger equipment or long working days to mitigate these concerns if the desire is to complete planting on the same date as with a corn-soybean rotation.

[2] A reviewer took issue with the “lengthened harvest season” argument and offered the following persuasive counter example: For a given location, the time available for timely harvest of 100 acres of corn exceeds the time available for timely harvest of 50 acres of corn and 50 acres of soybeans. Corn harvest can be extended over many weeks without substantial loss of yield. On the other hand, to minimize yield loss and maintain quality, soybean harvest must be performed in a relatively (compared to corn) narrow window.

Data and Methods

Data for the analysis come from USDA´s 2005 Agricultural Resource Management Survey (ARMS) which is a multi-frame, probability based sample of corn producers[3]. The ARMS data used in this study are from a field-level survey of farms producing corn for grain in the 19 largest corn producing states[4]. Information was collected on input use (i.e., seed, fertilizer, and pesticides), production practices (i.e., tillage, pest, and nutrient management), sources of information on nutrient management, field operations, and machinery size (i.e., tillage, planting, cultivation, fertilizer and pesticide applications, and harvesting), and bio-tech and precision agriculture technologies used in the production of corn for grain. Respondents were also asked about costs per acre for three major inputs: seed, fertilizer, and pesticides. In addition, the sampled field's cropping history for the two previous years was recorded which allowed us to distinguish fields growing continuous corn (for at least three years) from those in a corn-soybean rotation[5]. Restricting the analysis to these two major cropping systems resulted in 1,044 usable observations (i.e., fields) of which 223 were in continuous corn and 821 were in a corn-soybean rotation.

Each corn field sampled in the ARMS represents a known number of fields with similar attributes. By appropriately weighting the data for each field, inferences about the entire planted area of the surveyed states is possible. Only fields which were planted for grain and in a continuous corn (CC) or corn-soybean (CS) cropping system were examined. These two production systems were estimated to account for about 50.2 million acres of corn planted for grain in the surveyed states in 2005 (Table 1)[6]. About 42 million acres were planted in a CS rotation and 8.2 million acres were in CC.

Paired t-tests were used to test for differences in means and proportions between the two cropping systems and, due to the complex design of the ARMS survey, standard errors were estimated using a jackknife replication approach (Dubman 2000). Comparison of means is often used to analyze results from experiments in which factors other than the item of interest or “treatment” (i.e., crop rotation in this case) are "controlled" by making them as similar as possible. In the case of ARMS, the fields were selected randomly irrespective of whether they were in a CC or CS crop rotation. When comparing means from "uncontrolled experiments," caution must be exercised in interpreting the results (Fernandez-Cornejo and McBride 2000). Conditions other than the "treatment" are not equal in surveys where farms or fields are selected randomly. Thus, differences between mean estimates for yields or other variables from the survey cannot necessarily be attributed to the use of crop rotation since the results are influenced by many other factors not controlled for, including irrigation, weather, soils, nutrient and pest management practices, other cropping practices, operator characteristics, pest pressures, and others.

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[3] ARMS documentation and questionnaires can be accessed at: http://www.ers.usda.gov/Data/ARMS/.
[4] The surveyed states were: CO, GA, IL, IN, IA, KS, KY, MI, MN, MO, NE, NY, NC, ND, OH, PA, SD, TX, and WI. These states accounted for nearly 90% of all the 81.8 million acres planted to corn for all purposes in 2005.
[5] Cropping history was available for four years for most but not all sampled fields. A preliminary analysis using this smaller sample size showed results similar to those reported here.
[6] Other rotations were used on another 21 million acres of corn planted for grain in the surveyed states in 2005.

Results

Traditionally, corn production in the United States is concentrated in three regions: the Northern Plains, Lake States, and Cornbelt (Table 1). The regional acreage distribution of the two cropping systems was much different, with the Cornbelt states accounting for most (61%) of the CS acres but only 38% of the CC acres. Also, a large share (20%) of continuous corn production was located outside the three major corn growing regions, compared to only about 4% of the CS acreage[7]. Similar proportions of the two cropping systems were found in the Northern Plains and Lake States.

Table 1. Comparison of location, physical characteristics, and selected technologies used on continuous corn (CC) and corn-soybean (CS) fields on farms producing corn for grain, 2005.

Item	CC	CS
Number of fields in survey	223	821
Planted acres in states surveyed (mil.)	8.2	42.0
	(percent of planted acres)	
Region 1/		
Northern Plains	24	20
Lake States	18	16
Corn Belt	38_B	61_A
Other States	20_B	4_A
Highly erodible land (HEL) designation	29	20
Wetland designation	4	4
Irrigated	30_B	8_A
Precision technologies		
Yield monitor	47	47
Guidance system	10	13
VRT (fertilizer, pesticides or seed) 2/	11	12

1/ Northern Plains=ND, SD, NE & KS; Lake States=MN, WI, & MI; Cornbelt=OH, IN, IL, IA, & MO; Other States=CO, GA, KY, NY, NC, PA, & TX.
2/ VRT=variable rate technology

A and B indicate significant column difference tests based on pairwise two-tailed [$Ho{:}B_1=B_2$] delete-a-group Jackknife *t*-statistics at a 90% confidence level or higher with 15 replicates and 28 degrees of freedom.

Source: 2005 USDA Agricultural Resource Management Survey.

The survey also included questions about several physical characteristics of the sampled fields and whether selected technologies were used in 2005 (Table 1). With the exception of irrigation, the choice of cropping system was not related to either a highly erodible land (HEL) or wetland designation of the field or to the adoption of precision technologies. A much larger share of CC acreage was irrigated which is related to the large amount of corn production in the lower rainfall areas of the Northern Plains. Regardless of cropping system, yield monitors have

[7] The largest continuous corn acreage outside of the three major corn regions was in TX and CO.

become fairly widespread but guidance systems and variable rate technology (VRT) adoption remains modest.

Actual and Expected Yields by Cropping System

Contrary to much of the research literature, neither expected yields nor actual yields reported by corn-for-grain producers in 2005 differed significantly between the CC and CS crop rotations (Table 2)[8]. Furthermore, the ratio of yield goals (or expected yields) to actual yields, an indication of yield loss due to weather, pests, or other unexpected factors, did not vary by cropping system. Apparently, at least in 2005, continuous corn producers did not suffer a significant yield penalty compared to corn-soybean producers[9]. Producers who have already switched to CC note that it is difficult to avoid a yield penalty with second-year corn unless they have taken into account differences imposed by the corn residue and differences in nutrient requirements or unless weather conditions are favorable. The likelihood of a third-year yield penalty is considerably reduced because the soil-plant system is well on its way to establishing a new equilibrium (Wieland 2007).

Residue Management by Cropping System

Residue management is clearly one of the major challenges associated with continuous corn production. Given the larger amounts of residue, no-till systems are more difficult to manage in CC production than in CS[10]. As expected, a larger share of the CS acreage uses a no-till system compared to CC (Table 3). Likewise, it is more difficult for CC to be conventionally tilled, unless a moldboard plow is used, than a CS system. In fact, the survey data indicate that a greater share of the CS acres was conventionally tilled while no CS acres were moldboard plowed[11]. As recommended by Neilsen et al. (2006), continuous corn producers reported significantly more tillage trips (and total field operations) than did the corn-soybean producers (Table 2). The survey indicates that, for both cropping systems, most acres are currently utilizing either reduced or conservation tillage systems which can generate energy and labor cost savings as well as address soil erosion concerns (Werblow 2005).

Nutrient Management by Cropping System

Because of the implications for crop yields, profitability, and the environment, nutrient use and management are critical aspects of corn production in general. While some research (e.g., Neilsen et al. 2006) suggests that nutrient management should differ by cropping system, the 2005 survey found only modest differences (Tables 2 and 4). Nitrogen application rates, soil testing, and most application timing indictors were not significantly different between CC and CS production. When the previous crop was soybeans, a higher share of acres received all commercial nitrogen in the Fall whereas, when the previous crop was corn, a higher share was applied in the Spring before planting—which may be related to the higher residue associated with continuous corn. Phosphate and potassium use did vary by cropping system with higher

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[8] Both yield goal (yield the producer expected at planting) and actual yield (yield at harvest) were reported by the farmer. No independent actual yield measurement was available.

[9] A reviewer pointed out that our statistical test may have had insufficient power to detect yield differences and that the differences reported in Table 2 were in fact real (i.e., the CS yield of 149 bu/ac was higher than the CC yield of 143). Such an explanation is closer to conventional wisdom about differences in yields between cropping systems, but other considerations, as discussed in the conclusion, could also account for our statistical result.

[10] The tillage system data presented in this table are based on an estimate of residue left on the field after planting. The residue estimate is a function of the previous crop and the number and type of tillage operations used on the field prior to and including the planter.

[11] This result is not surprising given that very little residue remains after soybean harvest and moldboard plowing is much more costly than other tillage operations such as chiseling.

applications of both nutrients reported for CS production[12]. With the exception of the use of crop consultants for nitrogen recommendations, information often used for nutrient recommendations, such as soil and tissue testing, was no different between the two systems. Manure use was more probable on CC acres which likely reflects proximity to local livestock production rather than the choice of cropping system.

Table 2. Comparison of mean yields, input use and costs, equipment, and field operations on continuous corn (CC) and corn-soybean (CS) fields on farms producing corn for grain, 2005.

Item	Unit	CC	CS
Yield goal	Bu./acre	155	160
Actual yield	Bu./acre	143	149
Ratio: yield goal/actual yield	---	1.08	1.07
N application rate	Lb./acre	134	125
P_2O_5 application rate	Lb./acre	39_B	53_A
K_2O application rate	Lb./acre	45_B	68_A
Seeding rate	Seeds/acre	28,500	28,500
Days from State mean planting date 1/	Days	-1.5_B	-6.0_A
Days from Jan. 1 to plant date	Days	119_B	115_A
Equipment size:			
Planter	No. rows	7.96_B	10.14_A
Harvester	No. rows	5.67_B	6.63_A
Number of field operations:			
Total trips 2/	No.	6.31_B	5.83_A
Tillage trips (prior to and including planting)	No.	3.50_B	2.77_A
Input cost			
Seed	$/acre	41.13	39.14
Pesticides	$/acre	27.74	25.72
Fertilizer	$/acre	58.50	64.12

1/ Difference from the state average planting date which is defined as the first day of the most active planting period published in NASS, 1997.

2/ Includes tillage, planting, fertilizer and pesticide applications, cultivation, and harvesting.

See footnotes on Table 1.

Source: 2005 USDA Agricultural Resource Management Survey.

[12] Anecdotal evidence suggests that, given the immobility of P and K, some CS producers apply sufficient amounts of these nutrients on the soybean field to also fertilize the following crop of corn (i.e., apply sufficient amount of P and K on soybeans for both crop-years). While we ask respondents about the cropping history of our surveyed corn fields, we only ask for P and K application data for the current crop on that field. Consequently, we do not have data on the input use of the previous crop. Our questionnaire asks that farmers report the amount of P and K applied for the production of the current crop. Therefore, if a producer is applying nutrients this year for next year's crop he should only report the net amount intended for use by the current crop planted on the surveyed field.

Table 3. Comparison of residue management practices on continuous corn (CC) and corn-soybean (CS) rotated fields on farms producing corn for grain, 2005.

Item	CC	CS
	(percent of planted acres)	
Tillage system		
Conventional till (< 15% residue after planting)	15_B	25_A
Moldboard plow	6_B	0_A
Reduced till (15-30% residue after planting)	35	31
Conservation till (> 30% residue after planting)	49	43
No till	15_B	28_A

See footnotes on Table 1.

Source: 2005 USDA Agricultural Resource Management Survey.

Table 4. Comparison of nutrient management practices on continuous corn (CC) and corn-soybean (CS) fields on farms producing corn for grain, 2005.

Item	CC	CS
	(percent of planted acres)	
Nutrient use		
Treated with commercial nitrogen	95	96
Nitrogen application rate > 200 lb./acre	12	8
N inhibitor	2_B	12_A
Manure use	12_B	7_A
Treated with commercial phosphate	85	85
Treated with commercial potassium	58_B	74_A
Nitrogen application timing		
All applied before planting--fall	3_B	18_A
All applied before planting-spring	42	32
All applied after planting	16_B	8_A
Applied in fall and before planting-spring	9	17
Applied before planting-spring and after planting	12	11
Applied before planting-fall and after planting	6	6
Applied in fall and before and after planting	na	2
Soil/tissue testing		
N soil test	32	26
N app. rate 10% > recommended rate	9	5
N app. rate 10% < recommended rate	10	11
P soil test	35	34
Tissue test	2	6
Source of information about nitrogen application rates		
Crop consultant	31_B	18_A
Fertilizer dealer	32	38
Extension service	5	6
Yield goal 20% > actual yield	29	21

N=nitrogen; P=phosphorus; >= greater than; <=less than;
na= insufficient observations
See footnotes on Table 1.
Source: 2005 USDA Agricultural Resource Management Survey.

Regardless of the cropping system, the use of most nutrient management practices is limited and remained similar between the two cropping systems. For example, nitrogen soil testing was used on less than 35% of all acres[13]. Fertilizer dealers were listed as a primary source of information about nitrogen application rates on 32-38% of the corn acres, while only 5-6% of the acres relied on the Extension Service. Also, the share of acres receiving over 200 lbs. per acre of nitrogen (a rate about 33% above the average) was statistically the same (8-12%) for both cropping systems. Yield goal can be another critical aspect of nitrogen management because Extension services often make application rate recommendations based on a farmer's yield goal (e.g., University of Nebraska 2000). Yield is becoming less important when making fertilizer N recommendations in some corn producing areas, especially where weather uncertainties cause unpredictable N losses. Many producers still relate yield goal to crop N requirement and prefer to adjust fertilizer N rates based on anticipated losses and credits.

To the extent that yield goals influence nitrogen application rates, an unrealistic yield goal in excess of actual yields can lead to more nitrogen being applied than is used by the crop[14]. Setting realistic yield goals seems to be problematic (i.e., yield goal greater than 20% above actual yield) for producers on 21-29% of all acres, depending on the cropping system (Table 4). Production records from a 500,000 acre-area in South Central Nebraska between 1988 and 1992 showed corn producers set overly optimistic yield goals by an average of 10% (16 bu/acre) and N applications exceeded fertilizer N recommendations by 26% (28 lb N/acre) (Schepers et al. 1997). Between 1988 and 2005, yield goals exceed production by 19 bu/acre and N application rates exceeded recommendations by 26 lb. N/acre. In 2005, yield goals for irrigated corn in this management area averaged 6.5 bu/acre above the average production level (183 bu/acre) and the average fertilizer N application rate was 46 lb. N/acre (37%) above what was recommended (Moravek 2007).

Pest Management by Cropping System

Weed and insect management in a continuous corn cropping system is typically considered more challenging because of increased residues which may lead to loss of efficacy of soil applied pesticides, an increase in certain weed species, and greater populations of insects, especially corn rootworm and European corn borer (Neilsen et al. 2006). In 2005, there was little difference between the two cropping systems in terms of herbicide or fungicide use, herbicide timing, or in the share of acreage planted to herbicide-tolerant seed varieties[15] (Table 5). However, insect management did vary by cropping system with CC producers more likely to use insecticides and CS producers utilizing Bt seed varieties. Also, weed control through cultivation was more prevalent in continuous corn production[16]. As Neilsen et al. (2006) note, pest scouting is recommended for all cropping systems but is more critical for monoculture systems. CC producers did report using paid scouting on a larger share of acreage than the CS producers. Despite the large share of acreage treated with pesticides, particularly herbicides, only about half of the acreage of either crop rotation was systematically scouted.

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[13] Surprisingly, of the 26% of the CS acres that are soil-tested about 1/5 received at least 10% more nitrogen than the recommended rate (Table 4). Also, about 2/5 of the soil-tested acres report applying less than the recommended rate.

[14] The data indicate that producers tend to be somewhat optimistic with respect to their yield goal (i.e., yield goals exceeded actual yields by 7-8%) regardless of cropping system (Table 2). It should be pointed out that national yields in 2005 were not influenced by extreme weather events—based on USDA's 2001 baseline (WAOB/USDA 2001) the expected or trend yield for 2005 was 146 bu/acre while actual yields were 148.

[15] Neilsen et al. (2006) suggest that the both the herbicide product mix and rates may have to be adjusted when switching to a CC cropping system.

[16] Most producers using CC cropping on furrow-irrigated fields also use cultivation to build the ridges.

Table 5. Comparison of pest management practices on continuous corn (CC) and corn-soybean (CS) fields on farms producing corn for grain, 2005.

Item	CC	CS
	(percent of planted acres)	
Pest management		
Applied herbicide	94	96
Applied before weed emergence	57	66
Applied after weed emergence	72	64
Applied insecticide	38 $_B$	23 $_A$
Applied fungicide	*	*
Cultivated to control weeds	35 $_B$	11 $_A$
Systematic scouting for insects or weeds	48	50
Paid scouting service	24$_B$	13$_A$
Seed technologies		
Herbicide-tolerant 1/	36	25
Bt 1/	26 $_B$	39 $_A$

1/ Includes stacked varieties.
*= <1%
See footnotes on Table 1.
Source: 2005 USDA Agricultural Resource Management Survey.

Seeding and Equipment Management by Cropping System

Neilsen et al. (2006) suggest that residue levels and related soil temperature should have an impact on seeding rates and dates (Table 2). Relative to CS producers, CC producers did plant several days later based on our measure of both national and state adjusted planting dates[17]. However, the seeding rate did not differ between the two cropping systems.

One of the benefits of a corn-soybean rotation is the possibility of spreading out the planting seasons and possibly utilizing smaller equipment. CC producers reported using significantly smaller planters and harvesters than the CS farmers. However, machine capacity may not be so much a function of cropping system as size of farm, climate considerations, or other enterprises on the farm. Based on data from the entire farm (not presented here) we tested for differences in both the type of farm and acres planted to corn and soybeans on the farm. Total soybean plus corn acreage on farms with continuous corn averaged 436 acres compared to 709 acres for farms with a corn-soybean rotation (a statistically significant difference). Furthermore, only 68% of the farms with a continuous corn system were classified as a crop (rather than livestock) farm, compared to 87% of farms with a corn-soybean system[18].

Selected Regional Comparisons

While national means and proportions were used to analyze differences between the two major cropping systems, regional comparisons can be useful in highlighting practices that seem to be

[17] Days between Jan. 1 and the plant date is a national measure of planting date and does not account for the very early planting dates in, for example, Texas. Days between the State typical plant date and sampled field plant date, adjusts for the different planting dates between the northern and southern states.
[18] Farm type was based on the largest share of sales for either crop or livestock commodities.

concentrated in a particular part of the country due to climate, soils, or other factors[19]. For example, moldboard plowing is prevalent on CC in the Lake States; no-till systems on CS areas of the Northern Plains; nitrogen soil tests, paid scouting, insecticide use, and irrigation on CC in the Northern Plains; and manure use through-out the Lake States (Table 6). Some clear differences between CC and CS were apparent for certain regions for seeding rates and tillage trips—seeding rates were significantly higher for CC in the Northern Plains while there were more tillage trips for CC in the Northern Plains and Lake States[20]. No consistent regional patterns emerged for two key variables of interest to this study: yield indicators and nitrogen application rates[21]. Nitrogen application rates tended to be higher in the Cornbelt States (for both rotations) compared to most (but not all) other regions and systems.

Table 6. Regional comparison of selected production indicators on continuous corn (CC) and corn-soybean (CS) fields on farms producing corn for grain, 2005.

Item		**Northern Plains**		**Lake States**		**Cornbelt States**	
		CC	CS	CC	CS	CC	CS
Number of fields in survey		36	184	46	157	48	355
Planted acres in states surveyed (mil.)		2.0	8.4	1.5	6.5	3.1	25.6
		Percent of planted acres					
Moldboard plow		0_{CD}	1_{C}	11_{ABDF}	1_{AC}	8	0_{C}
No till system		20_{B}	49_{ACDEF}	8_{BF}	6_{BF}	13_{B}	24_{BCD}
Irrigated		80_{BCDEF}	33_{ACDEF}	10_{ABEF}	3_{ABE}	0_{ABCDF}	1_{ABCDE}
Manure use		6_{CD}	5_{CD}	19_{ABF}	15_{ABF}	12	6_{CD}
All nitrogen applied in Fall		2_{BDF}	10_{ACDF}	0_{BDF}	27_{ABCE}	6_{DF}	19_{ABCE}
Nitrogen soil test		69_{BCDEF}	49_{ACDEF}	14_{ABD}	35_{ABCEF}	10_{ABD}	15_{ABD}
Applied insecticide		33_{BD}	12_{ACEF}	29_{B}	14_{AEF}	48_{BD}	29_{BD}
Paid scouting service		57_{BDEF}	22_{ADE}	na	8_{AB}	3_{ABF}	12_{AE}
	Units	Units per acre					
Yield goal	Bu.	159	149_{F}	151_{F}	155_{F}	161	166_{BCD}
Actual yield	Bu.	143_{D}	143_{D}	160	164_{ABEF}	142_{D}	149_{D}
Nitrogen application rate	Lbs.	127	125_{CEF}	91_{BEF}	125_{E}	154_{BCD}	139_{BC}
Seeding rate	Seeds	27900_{BDE}	25500_{ACDEF}	28600_{B}	30200_{ABF}	29800_{AB}	29000_{BD}
Tillage trips (through planting)	Number	3.0_{BC}	2.3_{ACDEF}	3.8_{ABDF}	3.2_{BCF}	3.3_{B}	2.8_{BCD}
Input costs							
Seed	$	42.12_{B}	37.27_{AD}	36.57	41.00_{B}	46.59	39.28
Pesticides	$	na	22.37_{CF}	28.37_{BD}	21.33_{CF}	28.27	27.41_{BD}
Fertilizer	$	59.55	50.22_{DEF}	44.73_{EF}	57.09_{BF}	66.37_{BC}	69.85_{BCD}

na=insufficient observations
Letters A, B, C, D, E, and F indicate significant column difference tests based on pairwise two-tailed [$Ho{:}B_1=B_2$] delete-a-group Jackknife *t*-statistics at a 90% confidence level or higher with 15 replicates and 28 degrees of freedom. A=column 1, B=column 2, etc.
Source: 2005 USDA Agricultural Resource Management Survey.

[19] Of course, the statistical tests become less robust due to the smaller sample size as found in Table 6.
[20] Some of the extra trips in the Northern Plains could be attributed to cultivation required for furrow irrigation. Also, producers with irrigation have a higher yield potential which may explain the higher seeding rates.
[21] Actual yields in the Lake States that exceeded yield goals is apparently due to the exceedingly favorable temperature and rainfall in that region in 2005.

Input Cost Comparisons
For individual producers, differences in input costs between CC and CS are a critical economic consideration in the choice of cropping system (Table 2). At the national level, 2005 per acre costs for seed, pesticides and fertilizer were not significantly different between the two cropping systems. Even at the regional level, there was only limited evidence that CC production was more costly (i.e., seed costs in the Northern Plains and pesticide costs in the Lake States). While fertilizer costs tended to be higher in the Cornbelt (for both systems) than in other regions, they were not significantly different from, for example, continuous corn in the Northern Plains[22]. Despite concerns in the literature about higher production costs for continuous corn compared to corn-soybean rotations, the 2005 survey data did not reveal consistent cost differences using our particular statistical test.

Conclusion

Our objective in this analysis was to use field-level survey data to contrast the two major cropping systems used to produce corn in the United States: continuous corn and corn in rotation with soybeans. The comparisons focused on differences in nutrient, pest, seed, and residue management practices but also examined selected input costs, yields, and selected physical characteristics of the fields. Significant differences between the two cropping systems for many production practices implies that, as CS producers switch to continuous corn production, they may want to consider adopting practices commonly used by current continuous corn producers in order to maintain yields and profits. For example, no-till systems, early planting, and fall nitrogen fertilization are much more prevalent in corn-soybean systems than in continuous corn which has to deal with large crop residues after harvest. Other practices or technologies associated with a particular cropping system, such as irrigation, use of crop consultants, manure use, and adjustments in equipment size, are less common in corn-soybean production and would not likely change, at least in the short-run, with a switch to continuous corn since these characteristics are likely linked to such factors as region, availability of crop consultant services, livestock production and farm size. Some of the ambiguity about the impact of changing cropping systems may be related to the assumptions underlying the statistical technique employed in this analysis which does not control for the wide variety of factors associated with the decision to adopt a particular cropping system or practice.

One of the most interesting findings of this analysis is that there are many similarities between these two major cropping systems. The share of acres using the most common nitrogen and weed management practices was not significantly different across the two systems. At the national level, the proportion of corn acres exhibiting different levels of environmental sensitivity (i.e., HEL, wetlands) did not vary by cropping system, nor did the use of precision technologies, reduced and conservation tillage, input costs, or seeding rates.

Perhaps the most puzzling result from the survey was that our statistical tests comparing yield indicators (expected or actual) or nitrogen application rates did not reveal significant differences between cropping systems, which is contrary to much of the literature and Extension

[22] Regional differences in input use are well-documented. For example, K is not required in large quantities in Nebraska, but much more is needed in the Corn Belt. Also, the potential for N losses is greater in the Corn Belt where fall N application is permitted. In contrast, major parts of Nebraska have various types of N management regulations that are aimed at reducing N rates by avoiding N applications before critical leaching periods.

recommendations. One likely implication of our results is that there is extensive variability within the different production systems with respect to yields and nitrogen fertilizer use. Without additional analysis beyond comparisons of means between cropping systems, we cannot fully explain these results[23]. For example, analysis of yields typically requires a multivariate approach which includes such factors as weather, previous year's yield on that field, pest levels, residue levels, tillage systems, inherent soil productivity of each field, input quantities, etc. Likewise, nitrogen application rates would likely be influenced by factors beyond the previous crop such as manure use, yield goal, fertilizer cost, application timing, soil-tests, etc. Furthermore, these results were for only one year and the summary statistics are based on farmer responses not from experimental plots where many factors can be controlled. Another explanation is that continuous corn producers, over time, have learned to manage production risks associated with monoculture corn and avoided yield reductions, at least in 2005. For example, producers who have used the CC system for a number of years manage crop residues by cutting the stalks, cleaning residues from the area where the seed will be placed and timely planting. Also, farmers are likely well aware of productivity differences across fields and may utilize the more highly productive soils for CC.

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[23] A reviewer pointed out an alternative explanation of our statistically insignificant result involving the possible lack of sufficient power of our tests which resulted in a type II error. The implication of such an explanation can be illustrated using the summary data for the Cornbelt (Table 6) where actual yields, input use and input costs were, in general, not found to be significantly different between the two cropping systems. If the reported mean data for the two systems were really different then there would be a 7 bu/ac yield advantage for CS; a 15 lb/ac lower nitrogen application rate for CS; and a $7.31/ac lower seed cost for CS compared to CC. The net economic advantage for CS relative to CC of the additional nitrogen (15 lb/ac @ $0.45/lb), additional seed cost, and reduced yield (7 bu/ac @ $3/bu) is approximately $36/ac.

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