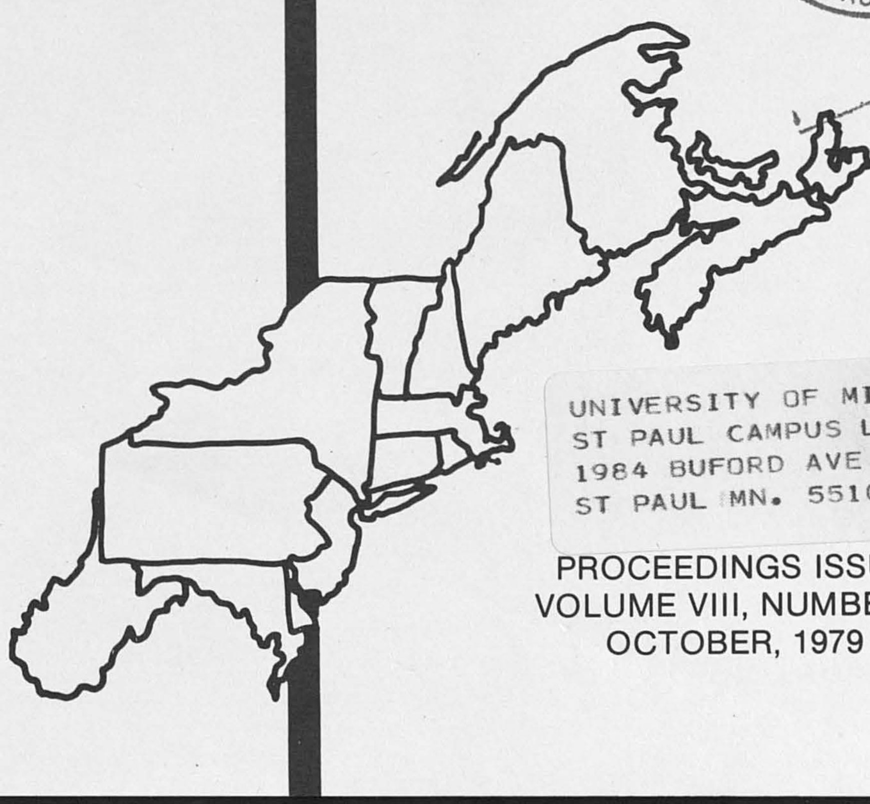
JOURNAL OF THE

Northeastern Agricultural Economics Council



PROCEEDINGS ISSUE
VOLUME VIII, NUMBER 2
OCTOBER, 1979

EVALUATION OF SELECTED CROPPING SYSTEMS ON PENNSYLVANIA DAIRY FARMS

W. F. Lazarus, L. D. Hoffman, and E. J. Partenheimer

Farmers in the Northeast have traditionally rotated crops in a particular field. This system has several advantages. Rotation of crops reduces the buildup of weeds, insects, and diseases specific to one crop. Legumes such as alfalfa fix nitrogen for use by the following grain crops. Including close growing crops in the rotation reduces soil loss. Growing several crops distributes labor requirements and reduces risk.

Some of the crops included in these rotations were usually less porfitable than others. Several developments since the mid-fifties have reduced the advantages of rotations and allowed farmers to concentrate on the production of the more profitable crops. More knowledge of plant nutrition and cheap commercial fertilizer reduced the value of legumes in the rotation. Pesticides were developed to control weeds and insects, and resistance to disease was bred into plants. Large machinery allowed more acreage to be covered in less time, and reduced tillage made erosion less of a problem. As a result corn acreage increased and small grain acreage declined in the better land areas of the Northeast. Many farmers went to continuous corn on at least part of their land.

Developments in the past few years have raised questions about growing continuous corn as compared to rotations including lower valued crops. Reduced yields have been observed with continuous corn. Increased energy prices have made the nitrogen fixed by legumes more valuable. Environmental concerns have raised questions about the huge increase in the application of pesticides and commercial nitrogen. In some states laws have been passed requiring the adoption of improved erosion control practices.

Purpose of the Study

The purpose of this study was to make an economic evaluation of selected cropping systems adapted to farms on the better cropland in the parts of Pennsylvania and surrounding states with growing seasons adequate for alfalfa and corn for grain. The cropping systems were compared in terms of returns to the farm operator's labor and management, referred to in this study as "returns." Returns to labor and management are computed by subtracting operating costs; ownership costs of real estate, livestock and equipment; and general farm overhead from gross receipts.

William F. Lazarus, former research assistant at The Pennsylvania State University, is a research assistant at the University of Illinois. Lynn D. Hoffman and Earl J. Partenheimer are respectively Assistant Professor of Agronomy and Professor of Agricultural Economics at The Pennsylvania State University. Journal Paper No. 5696 in the Pennsylvania Agricultural Experiment Station.

The specific objectives were:

1. To compare yields and input costs for five cropping systems using both conventional tillage and no-till methods of corn production.

2. To compare the cost of owning and operating machinery required for each cropping system and tillage method.

3. To compare the returns to the farm operator's labor and management for each cropping system and tillage method in dairy farm situations.

Linear programming models were developed for several resource situations and alternative cropping systems were compared by maximizing returns for each system. Two dairy farm sizes, 125 and 500 acres, were analyzed and no-till corn production was compared with conventional methods.

Cropping Systems Studied

Five cropping systems representing the rotations used on dairy farms in the better soil areas of Pennsylvania were selected for study. The description of each system below is followed by the letters that will be used to denote that system in the remainder of the study.

a. Continuous corn (CCC).

b. A two-year rotation of one year of corn and one year of soybeans (CS).

c. A three-year rotation of one year of corn and two years of alfalfa. Alfalfa is direct seeded. Two cuttings are harvested in the seeding year and three cuttings the following year (CAA).

d. A five-year rotation of two years of corn and three years of alfalfa. Alfalfa is direct seeded. Two cuttings are harvested in the seeding year and three cuttings are harvested in each of the following two years CCAAA).

e. A five-year rotation of one year of corn, one year of oats, one year of wheat underseeded to alfalfa and two years of alfalfa. One cutting of alfalfa is harvested in the seeding year after the wheat is harvested and the straw is removed. Three cuttings are made in each of the following two years (COWAA).

Yields for these cropping systems were obtained from a continuing experiment begun in 1969 by Dr. A. H. Hunter of the Department of Agronomy of The Pennsylvania State University. The study was designed to measure effects of cropping systems on yields over a number of years.

The plots, located at the Rock Springs Agronomy Research Farm in Central Pennsylvania, were replicated four times and were set up in such a way that each crop of each cropping system was grown each year. The soil was a highly fertile Class I Hagerstown silt loam with no erosion hazard. Lime and fertilizer were applied according to soil tests taken each year. Cultural practices recommended by Extension agronomists were followed as colsely as possible. The average yield for each crop and cropping system for the eight-year period 1970 to 1977, and the overall averages, are given in Table 1.

Corn and alfalfa yield differences among cropping systems were analyzed each year using analysis of variance techniques. In general, differences in hay yields were small. Differences in corn yields were significant at the five percent level in six of the eight years.

The average corn yield for all eight years was 140.9 bushels per acre. The corn yields in rotation with alfalfa were similar, with two bushels difference between the high and low eigh-year averages. The average of all corn yields in rotation with alfalfa was 145.3 bushels, 14.1 bushels higher than the continuous corn yield of 131.1 bushels. There was little difference between the first and second year corn in the CCAAA rotation. The first year corn yielded more in five years and the second year corn yielded more in three years.

Table 1

Crop Yields Per Acre,
1970 to 1977 Average from Long Term Rotation Experiment

	Unit	CCC	CS	CAA	CCAAA	COWAA	Average, Overall
Corn	bu.	131.2	137.2	146.4	144.4	145.2	140.9
Soybeans	bu.		30.0				
Oats	bu.					67.3	67.3
Wheat	bu.					47.8	47.8
Alfalfa hay, seeding year	ton			2.35	2.23	.75	1.81
Alfalfa hay, established	ton			4.79	4.98	4.64	4.79

Corn in rotation with soybeans yielded 137.5 bushels per acre, six bushels higher than continuous corn. Continuous corn yields were lower than yields in the other cropping systems in six of the eight years and tied with yields in the CS rotation in a seventh year. The difference between the continuous corn yields in individual years and the average yield of the corn grown in rotation with alfalfa for the same years ranged from 3.2 bushels to 30.6 bushels.

Studies done in several states confirm that corp rotation increases corn yields. Schrader, et. al. in Iowa reported increases in corn yields when rotated with legumes. First-year corn after alfalfa received 120 pounds of nitrogen from the preceding legume crop, while 80 pounds were contributed to the following corn crop. He hypotesized that the yield increases were due to nitrogen contributed by the legume. Other authors conclude that other effects besides nitrogen are probably involved. Adams, et. al. reported that in the Southern Peidmont Region of Georgia both perennial legumes and grass sods increased corn yields regardless of the level of fertilization. Research in Ohio showed yield increases with meadow rotations over continuous corn when either conventional or no-till methods were used Van Doren, et. al. and Triplett, et. al.

Crop Budgets

Budgets were developed for each crop. Seed, fertilizer, lime and pesticide application costs were based on rates actually used in the yield trial or recommended in the 1978 Agronomy Guide. The individual cash costs for crops are given in Table 2.

The crop budgets for corn silage were the same as for corn grain except for changes in fertilizer quantities and machine operating costs. The phosphorus was increased 25 pounds and the potassium was increased 80 pounds per acre to allow for removal of nutrients in the stalks. This increased the fertilizer cost by $13.02 per acre for a total of $76.52. Corn grain combining costs and labor requirements were eliminated and replaced by a custom silo filling charge of $35.70 per acre or $1.36 per ton.

Machinery Costs

Initial machinery complements were computed for each cropping system and farm size using an optimizing algorithm developed by Kizer and Partenheimer. This algorithm defines a least cost machinery system taking into consideration interest on investment, and timeliness of operations. These results were then checked with Extension specialists to find where the specific assumptions of this study might call for changes in the initial machinery systems selected. Where questions still existed, resource situations were programmed with alternate machine sizes and resulting labor coefficients, and the most profitable combination was selected. Machinery ownership costs ranged from $28.40 to $82.14 per acre, Table 3.

Table 2. Annual Cash Operating Costs Per Acre and Selling Prices for Crops

Item	Corn Grain, Continuous Conventional	Corn Grain, Continuous No-till	Soybeans	Direct-Seeded Alfalfa Seeding Yr.	Established Alfalfa	Oats	Wheat Seeded to Alfalfa
Seed	$ 12.06	$ 12.06	$ 13.50	$ 42.08	$ ----	$ 7.12	$ 52.08
Fertilizer	63.50[a]	63.50[a]	18.00	49.50	35.00	32.50	57.50
Lime	6.75	6.75	3.37	3.37	3.37	3.37	3.37
Herbicide	11.92	22.42	9.32	8.68	----	.34	----
Insecticide	4.69	4.98	----	2.31	2.31	----	2.31
Machine Operation	17.4	12.90	13.12	19.00	13.18	14.28	20.57
Twine	----	----	----	4.00	10.40	2.00	4.00
Crop Drying	36.74[b]	36.74[b]	----	----	----	----	----
Total Cash Operating Cost	152.80	159.35	57.31	128.94	64.26	59.61	139.83

[a]Nitrogen was reduced by 15 pounds ($3.00) for corn following soybeans and by 50 pounds ($10.00) for first year corn following alfalfa.

[b]Because of increased yields, drying costs were $38.39 for corn in the rotation with soybeans, and $40.86 for corn in rotations with alfalfa.

Table 3

Seasonal Labor Requirements and Machinery Ownership Costs Per Acre by Cropping System, Tillage Method, and Farm Size, Corn Harvested as Grain

Cropping System	Machinery Ownership Cost[a]	Labor Requirements[b]			
		Spring	Summer	Fall	Total
		(hours)	(hours)	(hours)	(hours)
125 Acres - conventional tillage					
CCC	$69.46	1.242	0.203	1.268	2.713
CS	75.05	1.239	0.203	1.014	2.456
CAA	77.44	1.320	3.280	0.426	2.456
CCAAA	75.53	1.132	3.909	0.506	5.547
COWAA	80.23	1.280	3.560	0.489	5.329
125 Acres - no-till corn planting					
CCC	$54.18	0.537		1.268	1.805
CS	69.46	1.289		1.014	2.453
CAA	78.68	1.010	3.105	0.426	4.641
CCAAA	76.99	0.781	3.618	0.506	4.905
COWAA	82.14	0.900	3.419	0.489	4.808
500 Acres - conventional tillage					
CCC	$38.44	0.883	0.150	0.846	1.879
CS	37.93	0.883	0.150	0.740	1.773
CAA	31.73	0.738	2.661	0.426	3.825
CCAAA	29.70	0.559	2.673	0.507	3.739
COWAA	28.40	0.616	2.525	0.419	3.560

[a]Details of the development of machinery ownership costs can be found in Lazarus

[b]The labor periods are as follows: Spring - March 15 to May 31
Summer - June 1 to August 15
Fall - August 16 to November 30

Some machines, such as a combine equipped with a corn head, were available in minimum widths (six feet or two rows for the combine) which were large in relation to the acres of use on the 125 acre farm. As a result machine ownership costs increased with the number of crops produced and the COWAA had the highest costs per acre. On the 500 acre farms all machines were more fully utilized. Ownership costs decreased 44 percent or more for all rotations, and reductions were generally greatest for rotations including alfalfa and small grains. Machinery sizes and numbers were increased in the CCC and CS cropping systems because all operations have to be performed in two short periods. The inclusion of two large tractors and two combines, along with other machines, increased per acre costs above those of the other cropping systems.

When all corn planting was done using no-till techniques, tillage equipment was eliminated in the CCC cropping system and equipment sizes were reduced in the rotations. Corn planter purchase price and ownership costs were increased slightly. Elimination of the tillage equipment decreased ownership costs sharply with the CCC system. The reduction in machine sizes decreased costs to a lesser extent with the rotations, and was offset by the increased planter costs on the 125 acre farm.

Dairy Budgets

Budgets were constructed for dairy cows and replacement heifers. Data on feed requirements, feed nutrient composition, storage and feeding losses, storage costs, operating costs, housing costs, labor requirements, and manure nutrient value were obtained from unpublished data assembled for Northeast Regional Research Project NE-111. A production level of 14,300 pounds of milk per year was used. Dairy housing costs, labor requirements and manure handling costs were based on a stanchion barn facility for the 50 cow herd. For the larger herd sizes, a freestall setup with a milking parlor was used in computing costs. Dairy budgets are shown in Lazarus.

Analysis of Rotations

Rotations were analyzed by including them one at a time, in linear programming models of dairy farms. Returns to the operator's labor and management were compared in the analysis. Returns to the operator's labor and management are a residual after all other costs, including general farm overhead and hired labor costs, are subtracted from gross returns.

Four dairy farm resource situations were studied. The first was a 125 acre farm with herd size limited to a maximum of 50 cows and using conventional tillage methods for corn. Hay, grain, and bedding purchases and sales were allowed at prices shown in Table 4. A minimun level of hay feeding was required for both heifers and replacements. In a second situation with a 125 acre farm and conventional tillage, cow numbers were limited only by feed production. No hay or grain purchase were allowed except for hay needed to meet the minimum requirements for heifers when the CS or CCC rotations were grown. The third conventional tillage resource situation used was a 500 acre farm with cows limited to a maximum of 150. The fourth situation was the same as the first except that no-till production methods were used for corn.

Table 4

Buying and Selling Prices for Crops

Crop	Unit	Selling Price	Buying Price
Corn grain	bu.	$ 2.09	$ 2.49
Soybeans	bu.	5.18	----
Oats	bu.	1.32	1.72
Wheat	bu.	2.50	2.90
Alfalfa hay	ton	52.80	67.80
Straw	ton	32.50	47.50

Conventional-tillage 125 acre farm, 50 cows

The returns, crop sales, feed purchases, and labor use for the conventional tillage 125 acre farm with herd size limited to 50 cows are shown in Table 5. This situation was intended to be typical of those farms where herd size was limited by capital, labor supply, or facilities rather than feed availability. The full-time labor supply was two men, the operator and one full-time worker. A small amount (26 to 50 hours) of part-time labor was needed for the spring season for all cropping systems. Summer part-time labor was also needed for the cropping systems containing hay.

The CCAAA rotation gave the highest annual returns at $17,856. Annual returns with continuous corn and the COWAA rotation were about $1,300 less than the CCAAA rotation. The CS and CAA rotations yielded net returns about $2,700 below CCAAA. More detailed results including rations fed can be found in Lazarus.

Conventional-tillage 125 acre farm, cows limited by feed production

The returns, crop sales, feed purchases, and labor use for a dairy situation with the dairy herd size limited by feed production are presented in Table 6. This situation was intended to be typical of those farms where the operator desired to produce all hay and grain fed. No grain purchases were allowed, and the only hay purchases permitted were to meet the minimum required for replacements. The minimum daily hay requirement of four pounds per day for lactating dairy cows was eliminated with the realization that an increase in herd health problems could result. Full-time labor supplies of the farm operator and two hired workers were assumed for all rotations except the continuous corn cropping system. In the latter case a third worker was hired because of the large number of cows. Additional part-time labor was available for each system.

Continuous corn supported the largest herd size of 177 cows and gave the highest annual returns ($70,613). This was due mainly to the high energy production per acre with corn silage. With the exception of the CS rotation, returns were roughly proportional to corn acreage. The second most profitable cropping system was CCAAA with annual returns of $48,375. Herd size was 111 cows. The lowest returns were obtained with The COWAA rotation which had only 20 percent of the land in corn. The only crops sold were the soybeans, which were not used for livestock feed.

Table 5

Farm Organization and Returns to Operator's Labor and Management, Alternative Cropping Systems, 125 Acre Dairy Farm, Herd Size Limited to 50 Cows, Conventional Tillage

Item	Units	Cropping System				
		CCC	CA	CAA	CCAAA	COWAA
Returns - annual	dollar	16,592	15,101	15,095	17,856	16,437
Herd Size	head	50	50	50	50	50
Crops Sold						
Corn Grain	bushel	11,813	3,988	1,147	2,358	
Soybeans	bushel		1,875			
Wheat	bushel					128
Oats	bushel					1,682
Alfalfa Hay	ton			204	205	189
Feed Purchased						
Alfalfa Hay	ton	69	69			
Soyben Meal	cwt.	485	485	343	343	447
Straw	ton	63	63	63	63	20
Full-time Labor	men	2	2	2	2	2
Part-time Labor	hour	39	39	288	332	334

Table 6

Farm Organization and Returns to Operator's Labor and Management, Alternative Cropping Systems, 125 Acre Dairy Farm, Herd Size Limited by Feed Production, Conventional Tillage

Item	Units	Cropping System				
		CCC	CS	CAA	CCAAA	COWAA
Returns - annual	dollar	70,613	34,406	33,125	43,338	27,459
Herd Size	head	177	96	102	111	81
Crops Sold						
Soybeans	bushel		1,875			
Feed Purchased						
Alfalfa Hay	ton	14	8			
Soybean Meal	cwt.	3,153	1,758	1,503	1,361	813
Molasses	cwt.		233	260	269	
Straw	ton	224	122	129	141	59
Full-time Labor	men	4	3	3	3	3
Part-time Labor	hour	453		100		

Conventional-tillage 500 acre farm, 150 cows

The returns, crop sales, and labor use for a 500-acre dairy farm with conventional tillage are shown in Table 7. A three-man full-time labor supply was assumed for this situation and additional part-time labor was hired. Herd size was limited to 150 cows.

The returns with the COWAA and CCAAA rotations increased relatively more than the continuous corn, when compared to the smaller dairy farm. Returns with these two rotations were about $12,000 higher than with continuous corn. This was due to the fact that per acre machinery ownership costs dropped relatively less for continuous corn. Machinery ownership costs were high with the small farm size for COWAA and CCAAA rotations because the tractor, combine, and tillage tools, which were the smallest commercially available machines, were large relative to the acreage on which they were used. Ownership costs for these machines were spread over relatively few acres and per acre costs were high. Ownership costs for these machines were distributed over more acres with the large farm. For continuous corn, machinery on the small farm was efficiently utilized and ownership cost reductions in moving to the large farm size were less. The CS and the CAA rotations yielded returns similar to continuous corn.

Table 7

Farm Organizations and Returns to Operator Labor and Management, Alternative Cropping Systems, 500 Acre Dairy Farm, Herd Size Limited to 150 Cows, Conventional Tillage

Item	Unit	Cropping System				
		CCC	CS	CAA	CCAAA	COWAA
Returns - annual	dollar	94,947	92,260	95,822	107,550	106,631
Heard Size	head	150	150	150	150	150
Crops Sold						
Corn Grain	bushel	51,839	20,539	9,494	14,338	
Soybeans	bushel		7,500			
Wheat	bushel					4,780
Oats	bushel					6,730
Alfalfa Hay	ton			910	914	769
Feed Purchased						
Alfalfa Hay	ton	207	207			
Soybean Meal	cwt.	1,456	1,456	1,030	1,030	1,115
Straw	ton	190	190	190	190	15
Full-time Labor	men	3	3	3	3	3
Part-time Labor	hour	1,165	1,112	2,173	2,109	2,018

No-till corn, 125 acre farm, 50 cows

The returns, crop sales, feed purchases, and labor use for a 125 acre dairy farm with no-till corn planting are shown in Table 8. Herd size was limited to 50 cows. Continuous corn annual returns increased by about $1,800 over the returns using conventional tillage. This increase made continuous corn more profitable than the CCAAA rotations. Annual returns with the other cropping systems rose slightly. This rise reflected the hired spring labor reduction, as well as reduced machinery costs. Added returns from the dairy activity tended to overshadow differences among cropping systems, as it did with the conventional tillage situation. Machinery costs changed due to elimination or reduction in size of the tillage equipment and the increased cost of the corn planter. Spring labor requirements were reduced due to the elimination of tillage for the corn. The annual cash operating costs for corn were increased due to increased pesticide costs. Machinery costs were lowered with all cropping systems except the COWAA rotation. Here the increased cost of the no-till planter offset the savings from the tillage equipment size reduction.

Table 8

Farm Organizations and Returns to Operator Labor and Management, Alternative Cropping Systems, 125 Acre Dairy Farm, Herd Size Limited to 50 Cows, No-till Corn Planting

Item	Unit	Cropping System				
		CCC	CS	CAA	CCAAA	COWAA
Returns - annual	dollar	18,403	15,497	15,169	18,023	16,450
Herd Size	head	50	50	50	50	50
Crops Sold						
Corn Grain	bushel	11,813	3,988	1,147	2,358	
Soybeans	bushel		1,875			
Wheat	bushel					128
Oats	bushel					1,682
Alfalfa Hay	ton			204	205	189
Feed Purchased						
Alfalfa Hay	ton	69	69			
Soybean Meal	cwt.	485	485	343	343	447
Straw	ton	63	63	63	63	20
Full-time Labor	men	2	2	2	2	2
Part-time Labor	hour		45	230	316	382

Comparison of Systems

A summary of returns to operator labor and management is presented in Table 9. Continuous corn had by far the highest annual returns on the samll, conventional tillage dairy farm where herd size was limited by feed production. It also gave the highest returns on the 125 acre, 50 cow dairy farm with no-till corn planting. The CCAAA rotation gave the highest annual returns in the 125 acre, 50 cow farm with conventional tillage.

Continuous corn yielded the highest returns in the feed limiting situation because corn gave the highest energy production. No energy feed purchases were allowed except for limited amounts of molasses. Thus, it supported a much larger herd size than the other systems. The higher returns to continuous corn in the no-till system were due mainly to lower machinery costs arising from the elimination of the tillage equipment.

Table 9

Summary of Annual Returns to Operator Labor and Management by Cropping System, Farm Size, and Tillage Method

	CCC	CS	CAA	CCAAA	COWAA
Conventional Tillage					
Small Farm					
50 Cow Maximum	16,592	15,101	15,095	17,856	16,437
Cow Limited by Feed Production	70,613	34,406	33,125	43,338	27,459
Large Farm					
150 Cow Maximum	94,947	92,260	95,822	107,550	106,631
No-till Corn Planting					
Small Farm					
50 Cow Maximum	18,403	15,497	15,169	18,023	16,450

The CCAAA rotation was very competitive from an annual returns standpoint in all situations except the feed limited dairy farms. The CAA rotation yielded the same amount of alfalfa but less corn than the CCAAA rotation and gave significantly lower annual returns than the latter in all situations. Even though the latter rotation has 6.7 percent less land in alfalfa it produces the same amount of hay because 13.3 percent less of the land is in first year alfalfa. Hay production in the establishment year of direct seeded alfalfa is only half that of later years.

Because equipment for small grain was needed, the COWAA rotation had the highest machinery ownership costs for the small farm size, and this caused returns to be below those from continuous corn and CCAAA. On the 500 acre farm, machinery costs for this rotation were more nearly in line with the other cropping systems. Thus returns were higher than those from continuous corn and close to those from CCAAA. The CS rotation gave annual returns which were lowest or second lowest in all situations.

Shifting to no-till from conventional tillage increased returns with cropping systems which had a large proportion of the land in corn. The increases were due to reductions in machinery ownership costs and labor costs per acre.

Summary and Conclusions

Continuous corn yields were ten percent below yields of corn grown in rotation with alfalfa on the highly productive soils used for the rotation experiments. In spite of lower yields, continuous corn was one of the two most profitable rotations on small farms. Contributing to profitability was its low machinery costs per acre. It yielded returns slightly below CCAAA on the 50 cow farm with conventional tillage, slightly above the same rotation with no-till corn production, and far above all other rotations when herd size was limited by feed production. The later situation was due to the very high energy production per acre obtained from corn and corn silage.

Continuous corn lost its competitive advantage on the large farm. Production of hay and straw became more attractive alternatives with more land per cow. With 500 acres, equipment for all rotations could be used efficiently and machinery costs per acre declined markedly. The decline was much less for continuous corn than for other systems for two reasons: (1) With all land in corn, machinery was efficiently utilized on the small farm; and (2) On the large farm the very short planting and harvesting season made large numbers and sizes of machines necessary.

The CCAAA rotation gave the highest or very nearly the highest returns in all cases except for the small dairy farm with cows limited by feed production. It would be an excellent rotation on highly productive land except where the cow to land ratio is very high. In the latter case the dairyman may be better off to put all of this land in corn and corn silage and purchase hay.

The COWAA rotation was competitive only on the large farm with a low cow to land ratio. On smaller, more intensive farms it is less profitable because of higher machinery costs and lower feed production per acre. Adding another year of alfalfa and another year of corn would have increased the competitive position of this rotation. The CS and CAA rotations were always less profitable than CCAAA. Only half the land in the CS rotation produces feed for the dairy herd. The CAA produces less corn and only the same amount of alfalfa as the CCAAA rotation.

No-till corn planting increases returns over conventional tillage where tillage equipment can be eliminated or reduced in size. Where tillage equipment sizes are determined by requirements of other crops, no-till planting has little effect on returns. There are also labor savings with no-till.

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