

2001


## Profitability of Crop Rotations in Iowa in a Stress Environment

Derrick N. Exner  
*Iowa State University*

R. M. Cruse  
*Iowa State University, rmc@iastate.edu*

Copyright © Copyright 2001 by the Iowa Academy of Science, Inc.

Follow this and additional works at: <https://scholarworks.uni.edu/jias>

 Part of the [Anthropology Commons](#), [Life Sciences Commons](#), [Physical Sciences and Mathematics Commons](#), and the [Science and Mathematics Education Commons](#)

---

### Recommended Citation

Exner, Derrick N. and Cruse, R. M. (2001) "Profitability of Crop Rotations in Iowa in a Stress Environment," *Journal of the Iowa Academy of Science: JIAS*, 108(3), 84-89.

Available at: <https://scholarworks.uni.edu/jias/vol108/iss3/5>

This Research is brought to you for free and open access by UNI ScholarWorks. It has been accepted for inclusion in Journal of the Iowa Academy of Science: JIAS by an authorized editor of UNI ScholarWorks. For more information, please contact [scholarworks@uni.edu](mailto:scholarworks@uni.edu).

## Profitability of Crop Rotations in Iowa in a Stress Environment

DERRICK N. EXNER and R. M. CRUSE

Department of Agronomy, Iowa State University, Ames, IA 50011

Small grains crops have traditionally been included in Midwestern cropping systems, but their use is restricted by uncertain yields, poor prices, and lack of on-farm uses in operations without livestock. We compared the corn (*Zea mays* L.)—soybean (*Glycine max* (L.) Merr.) crop rotation to actual or simulated three-yr rotations at two sites in Iowa between 1986 and 1989. Water was generally more limiting than was nitrogen, which produced minimal response in the corn to which it was applied. April–November precipitation at Nashua, Iowa ranged from 59 to 111% of average, while at Des Moines, Iowa it was 77% of normal in 1988 and 102% in 1989.

Each rotation was subjected to economic analysis using Iowa State University figures for costs of operations and inputs. Commodity prices were set assuming nonparticipation in the government programs of the time. The rotations that depended on hay cuttings to recoup seeding costs never achieved that goal. Oat (*Avena sativa* L.) and wheat (*Triticum aestivum* L.) harvests did largely recover the cropping expenses of the systems that included them. Thus, in certain environments no sacrifice in short-term profitability is required in trade-off for the long-term conservation and economic benefits of diversified rotations.

INDEX DESCRIPTORS: small grains, cropping systems, crop rotation, stress, profitability, *Avena sativa* L., *Triticum aestivum* L., oat, wheat

Iowa farmers are only too aware of the frustrations of growing small grains. There are years in which producers disk the crop rather than harvest what remains after disease and weather have taken their toll. Midwestern producers also seem unable to achieve the test weights that food processors require, so local millers generally import their stocks of small grains from elsewhere. On the other hand, oat (*Avena sativa* L.) and wheat (*Triticum aestivum* L.) are less vulnerable to drought than corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) and even seem to benefit from some dry weather. Climate change models suggest a warmer, more variable climate for Iowa, leading to periods of greater evapotranspiration and possibly accompanied by reduced precipitation (Kattenberg et al. 1995). A shift in weather patterns could change the relative desirability of small grains and row crops. Small grains are also the traditional establishment host for alfalfa (*Medicago sativa* L.) and clover crops (*Trifolium* sp.), and this enterprise diversity constitutes another potential means of risk management. We desired to evaluate the net profitability of several alternative crop rotations to judge the liabilities and benefits of diversification beyond corn and soybean.

The predominant crop rotation in much of the Midwest is the two-yr sequence of corn and soybean. Cogent agronomic and economic reasons contribute to this situation; however, the rotation is not ideal from the standpoint of soil erosion. Inclusion of a third crop in the rotation could benefit both soil conservation and diversity on the farm. Small grains present possible options for this third crop, but their use is increasingly rare in the United States. Oat area, for example, has declined in Iowa from a harvested area of nearly 2.6 million ha in 1921 to an estimated 81,000 ha in 1999 (National Agricultural Statistics Service 2000) (Fig. 1). Historically, small grains were among the first crops raised by the settlers on Iowa's prairie sods (Hopkins 1946). They were grown to satisfy the feed requirements of non-ruminant draft animals, which could not efficiently utilize the low-grade feeds that sustained oxen, and their use was further stimulated by railroad transportation, which made pos-

sible cash grain markets (Thompson 1946). By the 1930s, however, tractors were displacing horses, reducing the on-farm demand for oat. Today wheat has migrated to the Great Plains, and oat crops frequently fall victim to diseases in Iowa's humid summers.

For small grains to reclaim a place in Midwest agriculture, situations must first be identified in which these crops do make a positive contribution to the overall profitability of a system. The objective of our research was to determine if modern varieties and production practices justify alternative crop complements on the typical contemporary farm—one that may not have livestock. Information pertinent to this question was generated by an experiment in the practice of strip intercropping conducted from 1986 to 1989 and involving two sites in Iowa. Treatments in these trials reflected various crop rotation options based on three different strategies: 1) the corn-soybean row crop rotation that is typical of much of the Midwest; 2) corn preceded by a sole-seeding of alfalfa and followed by soybean; and 3) corn followed by soybean and preceded by a year of a green manure forage legume that was seeded with a nurse crop of small grains, specifically oat or winter wheat. Information applicable to the crop sequences was abstracted from this experiment.

### LITERATURE REVIEW

For millennia, diversity has been the norm not the exception in cropping systems. Likewise in the United States, production of the same sole-seeded crop repeatedly on the same land only became practicable with the advent of inexpensive synthetic fertilizers, although not without recognition of the soil erosion potential (Jamison et al. 1968) and economic risks (Battese et al. 1972). While rotation has occasionally been defined to include continuous corn or the rotation of hybrids or varieties within the same crop, crop rotation is generally considered to mean growing two or more distinct crops in succession on the same land. A common crop rotation in much of the U.S. Midwest is the two-yr, corn-soybean rotation. Corn-soybean,

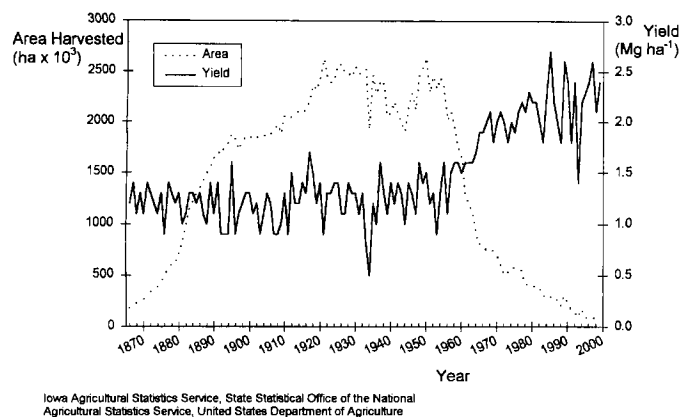


Fig. 1. Historical oat area harvested and average yield in Iowa, 1866 to 1999.

like any rotation, is necessarily judged according to the system to which it is compared.

Much of the research on crop rotation has focused on cropping systems that include a mix of row crops and sod crops or closely seeded crops, spring- as well as fall-seeded crops, deep- and shallow-rooted crops, and annual and perennial crops. These rotations encompass the diversity that can reduce weed pressure (Bullock 1992, Liebman and Dyck 1993, Karlen et al. 1994), nitrate leaching potential (Olsen et al. 1970), soil erosion (Jamison et al. 1968, Hussain et al. 1988, Reganold 1988), and local soil problems (Halvorson and Black 1974). Crop rotations that produce large amounts of above- or below-ground carbon have been shown to improve soil physical characteristics (e.g., aggregation and bulk density), largely through increasing soil organic matter (van Bavel et al. 1950, Hussain et al. 1988, Karlen et al. 1992).

Crop rotation likely persists as a practice as much for its near-term financial benefits as for long-term, soil-building attributes. Additional crop inputs are needed to compensate for the fertility and pest-control advantages that rotations can provide. As continuous row cropping increased in the latter half of the 20th century, there was controversy whether external inputs could completely substitute for those benefits. Studies determined the answer to be "yes" (Battese et al. 1972, Bolton et al. 1976, Baldock and Musgrave 1980), but other research (Barber 1972, Dick and Van Doren, Jr. 1985, Chase and Duffy 1991, Karlen et al. 1991, Bullock 1992, Copeland et al. 1993, Karlen et al. 1994) suggests that there often is a "rotation effect" benefit above and beyond the nutrient, pest, soil moisture, and other discrete benefits of crop rotation.

When the preceding crop in a rotation is nitrogen fixing, rotation effect and nitrogen contribution to the succeeding crop are confounded. Nitrogen contribution aside, studies have attempted to determine the mechanism for the rotation effect. Barber (1972) concluded that the value of an incorporated hay stand extended to corn crops multiple years later. Meese et al. (1991), rotating continuous cropping into corn-soybean rotation plots, observed corn and soybean yield decreases continued beyond the second year of monocropping. Crookston et al. (1991) found the rotation effect to be measurable beyond one year for soybean following corn but not for corn following soybean; in the latter case second-year corn yields were depressed relative to third- and later-year corn.

Mechanisms of the rotation effect are suggested by studies that find interactions between the magnitude of the rotation benefit and crop conditions, especially relating to soil moisture. Papers have documented increased benefits to crop rotation when crops were stressed

by too little moisture (Roder et al. 1989) or either too little or too much moisture (Barber 1972), although a negative correlation between drought stress and rotation benefit was suggested by Bolton et al. (1976). Soybean in rotations longer than two years exhibited greater water use efficiency than soybean following corn, an effect that was more pronounced in years with greater water stress (Copeland et al. 1993).

If the corn-soybean sequence qualifies for many of the yield benefits of crop rotation, it does so despite equivocal evidence as to its effects on soil parameters. It has been asserted that continuous corn returns more residue to the soil than the corn-soybean rotation (Karlen et al. 1991) and slows the decline in soil organic matter (Bullock 1992, Karlen et al. 1992). In contrast, Hussain et al. (1988) found soil in both the corn and soybean phases of a corn-soybean rotation to have generally greater soil aggregation and resistance to detachment at higher rainfall intensity, compared with soil in continuous corn. Laflen and Moldenhauer (1979) identified a soybean "soil effect," independent of residue ground cover, characterized by greater late spring soil loss from corn following soybean than from either continuous corn or soybean following corn.

Van Bavel et al. (1950) reported that over time cropping sequences sought different equilibria for yields, soil loss from water erosion, and soil aggregation (independent of changes due to soil loss). Changes in crop rotation resulted in movement to new equilibria, but all parameters degraded subsequent to the original rotation out of continuous alfalfa and bluegrass. Generally, the diminution of soil organic matter and soil physical parameters and the increase in soil erosion and external production inputs has been intrinsic to the transition from extended rotations to short rotations and continuous cropping (Bullock 1992). If cropping systems are the problem, they may also be part of the solution; crop rotation is one means of restoring a diversity that approaches the natural ecosystems (Karlen et al. 1992) that serve as a baseline in our understanding of soil quality and sustainability.

## METHODS

The corn-soybean rotation was compared with several simulated or actual three-yr rotations at two sites in Iowa between 1986 and 1989. The Northeast Research Center is near Nashua, Iowa, while Living History Farms lies on the outskirts of Des Moines, in central Iowa. The rotations were established in side-by-side 4.57 m strips to also gain information on the practice of strip intercropping. Data are reported from the inner four rows of 6-row crop strips and the centers of the small grains and forage strips, an analysis similar to that of Lesoing and Francis (1990). Excluding strip edges from analysis may not entirely eliminate border effects, but the relative performance of rotational treatments was likely not affected by the strip configuration.

### Nashua Site

The Nashua site was established in 1986 on land that had grown corn the previous year. The three-yr rotations were simulated with a two-yr alternation of corn and the third crop, leaving out the year of soybean. For economic analysis, the yields of soybean in the corn-soybean treatment were used in the simulated alternative rotations. Notwithstanding this limitation, the duration of the experiment was not sufficient to have fully captured crop rotation effects from a third year of soybean. The alternative rotations evaluated were named according to their "third year."

"AH2"—"annual" alfalfa established with herbicide and cut twice (hay sold).

"AH4"—"annual" alfalfa established with herbicide and cut as many as four times, weather permitting (hay sold).

Table 1. Crop varieties, seeding rates, and crop protection materials used in the rotation studies conducted at Nashua and Des Moines.

	Hybrid/variety	Seeding Rate	Materials
Nashua			
Corn	Pioneer 3732	69,200 ha <sup>-1</sup>	alachlor <sup>a</sup> , cyanazine <sup>b</sup>
Soybean	1986-87 Elgin 1988-89 Corsoy 79	444,800 ha <sup>-1</sup>	1986-88 trifluralin <sup>c</sup> 1989 chloramben <sup>d</sup>
Alfalfa	1986 CUF 101 1987 MOAPA 69 1988, 1989 Nitro	22.4 kg ha <sup>-1</sup> sole-seeded 15.7 kg ha <sup>-1</sup> with oat	EPTC <sup>e</sup>
Des Moines			
Corn	Pioneer 3379	55,600 ha <sup>-1</sup>	Metolachlor <sup>f</sup>
Soybean	Asgrow 1937	61.6 kg ha <sup>-1</sup>	Metolachlor <sup>f</sup>
Alfalfa	1988, 1989 Nitro	22.4 kg ha <sup>-1</sup>	EPTC <sup>e</sup>
Wheat	Cody, hard red winter	151 kg ha <sup>-1</sup>	carboxin and thiram seed trt.

<sup>a</sup>Lasso

<sup>b</sup>Bladex

<sup>c</sup>Treflan

<sup>d</sup>Amiben

<sup>e</sup>Eptam

<sup>f</sup>Dual

"AO0"—"annual" alfalfa established with a nurse crop of oat. The oat grain and straw were harvested and the alfalfa was left for green manure.

"CO0"—sweetclover (*Melilotus officinalis* (L.) Lam.) established with a nurse crop of oat. The oat grain and straw were harvested, and the sweetclover was left for green manure.

"SB"—corn-soybean, two-yr crop rotation.

#### Des Moines Site

The Des Moines site was established in 1987. Two replications had been in perennial warm season grass previously and two replications in row crops. Because of field variability from preceding use, data are not reported for 1987. All years of the crop rotations were grown in the field. The rotational treatments were "AH4," "CO0," "SB," and:

"WC0"—winter wheat, seeded after soybean harvest with a later frost seeding of red clover (*Trifolium pratense* L.). The wheat grain and straw were harvested and the clover was left for green manure.

Corn and soybean varieties planted, seeding rates, and weed control materials used are shown in Table 1.

The "annual" alfalfa was nondormant alfalfa, whose active growth continues into the fall, thus extending both the harvest and nitrogen fixation. Four levels of nitrogen fertilizer were stripped across the rotational corn plots to better estimate the economics of nitrogen use in each rotation (Fig. 2). At planting all crops received potassium and phosphorus fertilizer calculated to meet or exceed crop removal.

To determine optimum fertilization, the "linear response and plateau" (LRP) model was fit to nitrogen response treatment-by-treatment in years showing a significant nitrogen effect. LRP generated the lowest nitrogen rate at which maximum yield would be obtained, and this rate and yield were used in calculation of crop rotation profitability. Each rotation was subjected to an economic analysis using Iowa State University figures for average fixed and variable

costs of operations and input prices (Duffy et al. 1985-1993). Commodity prices were set assuming nonparticipation in government programs. Land was charged at \$210 per ha (\$85 per acre) and labor at \$6.00 per hour.

#### RESULTS AND DISCUSSION

The years 1987 through 1989 were dry at these two Iowa sites (Table 2). At New Hampton, about 22 km from Nashua, 1988 was the 6th driest year recorded in the 20th century, and 1989 was the 11th driest year (data not shown). Water was generally more limiting than was nitrogen. The rotations that utilized forage legumes to fix nitrogen for the subsequent corn crop also depleted the soil of water prior to corn. Similarly, the drought affected the establishment and growth of first-yr alfalfa and clover.

Applying SB soybean yields to the evaluation of other treatments at Nashua during this period could have introduced bias in either direction. Soybean in rotation with deep-rooted sweetclover or alfalfa during a drought may have less soil moisture than the "benchmark" soybean in the corn-soybean rotation of the SB treatment. On the other hand, soybean in rotations of more than two years has exhibited greater water use efficiency (Copeland et al. 1993) and yield (Crookston et al. 1991) than soybean following a single year of corn in a corn-soybean rotation.

Corn yield response to nitrogen fertilizer was weak where April-November precipitation was low (Tables 2, 3, Fig. 2); even when N response was statistically significant, it was not great except for Nashua in 1986 (Fig. 2). Although no soil moisture measurements were made, crop appearance in the area suggested that the limiting factor was moisture. Table 4 provides yields of crops by site and year, averaged over treatment and nitrogen rate; small grain and forage yields were more stable over the course of the experiment than were yields of corn and soybean.

AH2 and AH4, the rotations that depended on hay cuttings to recoup seeding costs, never achieved that goal (Figs. 3 and 4). How-

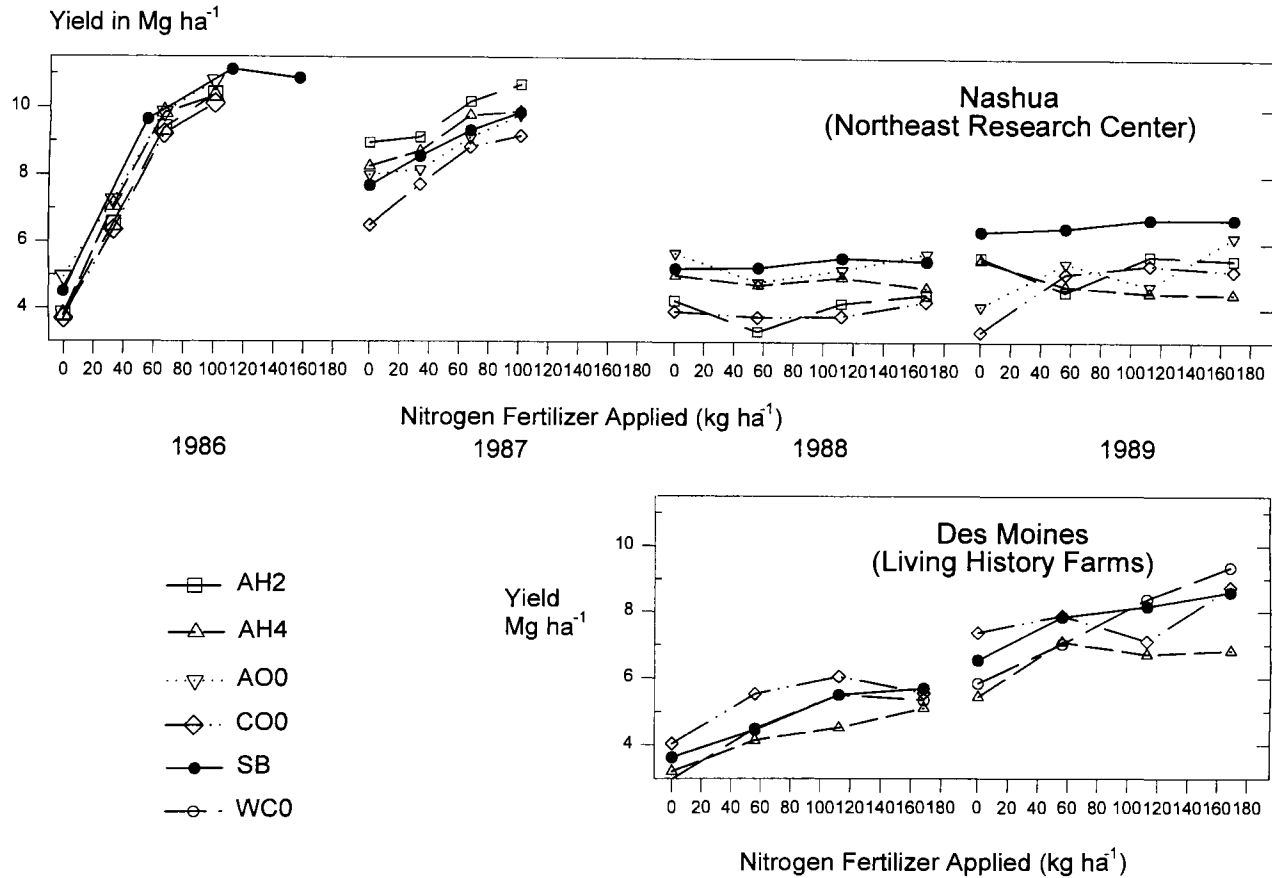


Fig. 2. Corn response to nitrogen fertilizer by treatment in simulated crop rotations at Nashua (1986–1989) and at Des Moines (1988–1989).

Table 2. April–November precipitation as percent of normal for 1986–1989 at Nashua and Des Moines.

Year	Site	
	Nashua	Des Moines
%		
1986	111	—
1987	79	—
1988	65	77
1989	59	102

Table 3. Levels of significance for corn yield response to crop rotation and nitrogen by year at Nashua and at Des Moines.

Site	Year	Rotation	Nitrogen	Rotation × Nitrogen
Nashua	1986	**	**	N.S.
Nashua	1987	*	**	N.S.
Nashua	1988	**	N.S.	N.S.
Nashua	1989	**	N.S.	**
Des Moines	1988	N.S.	*	N.S.
Des Moines	1989	*	**	**

\*Statistical significance at 95% confidence level  
 \*\*Statistical significance at 99% confidence level

ever, oat and wheat harvests (grain and straw) did largely pay for cropping expenses. Except in the establishment year at Nashua, in which moisture was adequate, the oat/alfalfa-corn-soybean rotation and the oat/sweetclover-corn-soybean rotation were as profitable as (or no more unprofitable than) the corn-soybean rotation. During the period of this experiment, corn producers were eligible for price support that would have particularly improved the profitability of the two-yr corn-soybean rotation, an advantage not reflected in these calculations. From another standpoint, net profit of sole-seeded alfalfa would have been helped by retaining the forage for harvest in the year after its establishment. Producers likely would have pursued

different profit-optimization strategies with these different complements of crops. On the basis of comparison used here, however, three-crop selections that included small grains fared better than either corn-soybean or the three-yr sequences that included sole-seeded alfalfa.

It is not remarkable that even in years of relatively more precipitation, net profit of most crop systems hovered near zero. Producers pursue various strategies to lower fixed and variable costs below the average figures that we used in calculating system profits. Moreover, government payments to Iowa producers during the four years of

Table 4. Crop yields by site and year, averaged over treatments and nitrogen rates.

Site/Crop	1986	1987	1988	1989
Mg ha <sup>-1</sup>				
Nashua				
Corn	11.14	9.85	4.70	5.47
Soybean	3.45	3.07	1.88	2.14
Oat grain	2.58	2.96	2.80	4.10
Oat straw	3.10	2.47	2.24	4.84
Alfalfa, 4 cut	3.33	6.17	4.52	6.69
Des Moines				
Corn			5.43	8.13
Soybean			0.73	2.14
Oat grain			1.74	3.46
Oat straw			1.73	4.23
Wheat grain			3.62	4.79
Wheat straw			2.00	3.97
Alfalfa, 4 cut			2.80	5.94

this experiment comprised on average 66% of net farm income (Economic Research Service 2000). The significance of the study lies in the relative differences among these experimental systems, not in their absolute values.

Notwithstanding the economic and policy exigencies that have made the corn-soybean rotation the prevailing cropping practice in Iowa, the data from these two trials suggest that more complex crop sequences may have immediate economic advantages—at least under certain environmental conditions—even before long-term economic, environmental and rotational benefits are considered. The small grains included in several of the simulated rotations of this study were adapted to the seasons of reduced rainfall that occurred during the experiment. Those treatments generated revenue at the same time they produced green manure for the benefit of succeeding crops in the rotation. This study was not designed to fully implement and continue three-yr rotations at both sites. Research cited suggests that had it been, the observed benefit of small grains in dry seasons might have been greater still.

#### LITERATURE CITED

- BALDOCK, J. O., and R. B. MUSGRAVE. 1980. Manure and mineral fertilizer effects in continuous and rotational crop sequences in central New York. *Agronomy Journal*. 72(3):511–518.
- BARBER, S. A. 1972. Relation of weather to the influence of hay crops on subsequent corn yields on a Chalmers silt loam. *Agronomy Journal*. 64(1):8–10.
- BATTESE, G. E., W. A. FULLER, and W. D. SHRADER. 1972. Analysis of crop rotation experiments, with application to the Iowa Carrington-Clyde rotation-fertility experiments. *Agriculture and Home Economics Experiment Station, Iowa State University Research Bulletin*. 574: 577–595.
- BOLTON, E. F., V. A. DIRKS, and J. W. AYLESWORTH. 1976. Some effects of alfalfa, fertilizer and lime on corn yield in rotations on clay soil during a range of seasonal moisture conditions. *Canadian Journal of Soil Science*. 56(1):21–25.
- BULLOCK, D. G. 1992. Crop rotation. *Critical Reviews in Plant Science*. 11(4):309–326.
- CHASE, C. A., and M. D. DUFFY. 1991. An economic analysis of the Nashua tillage study: 1978–1987. *Journal of Production Agriculture*. 4(1):91–98.
- COPELAND, P. J., R. R. ALMARAS, R. K. CROOKSTON, and W. W. NELSON. 1993. Corn-soybean rotation effects on soil water depletion. *Agronomy Journal*. 85(2):203–210.
- CROOKSTON, R. K., J. E. KURLE, P. J. COPELAND, J. H. FORD, and W. E. LUESCHEN. 1991. Rotational cropping sequence affects yield of corn and soybean. *Agronomy Journal*. 83(1):108–113.
- DICK, W. A., and D. M. VAN DOREN, Jr. 1985. Continuous tillage and rotation combinations effects on corn, soybean, and oat yields. *Agronomy Journal*. 77(3):459–465.
- DUFFY, M., W. EDWARDS, and D. JUDD. 1985–1993. Estimated costs of crop production in Iowa. *Iowa State University Cooperative Extension Service Bulletin*. FM-1712.
- ECONOMIC RESEARCH SERVICE, USDA. Information contact: Roger Strickland. 2000. United States and state farm income data. <http://www.ers.usda.gov/80/briefing/farmincome/finfdmu.htm>
- HALVORSON, A. D., and A. L. BLACK. 1974. Saline-seep development in dryland soils of northeastern Montana. *Journal of Soil and Water Conservation*. 29(2):77–81.
- HOPKINS, S.H. 1946. The pattern of farm management. Pages 336–353. *In A century of farming in Iowa, 1846–1946*. Iowa State College Press.
- HUSSAIN, S. K., L. N. MIELKE, and J. SKOPP. 1988. Detachment of soil as affected by fertility management and crop rotations. *Soil Science Society of America Journal*. 52:1463–1468.
- JAMISON, V. C., D. D. SMITH, and J. F. THORNTON. 1968. Soil and water research on a claypan soil. Technical Bulletin No. 1379. Agricultural Research Service, U.S. Department of Agriculture in cooperation with Missouri Agricultural Experimental Station. U.S. Government Printing Office, Washington, D.C. 111 p.

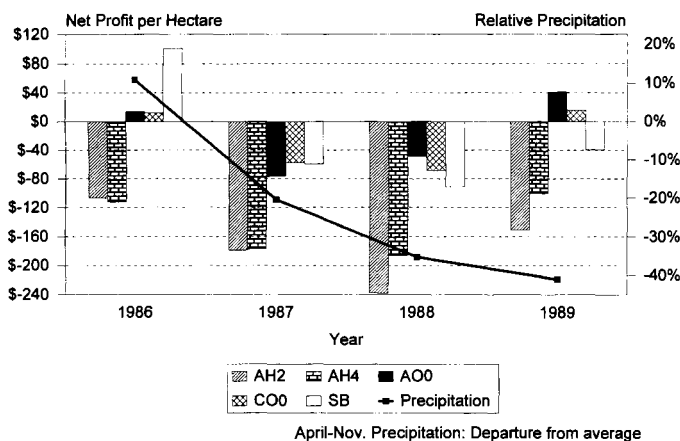


Fig. 3. Net profit in five simulated crop rotations at Nashua, 1986–1989.

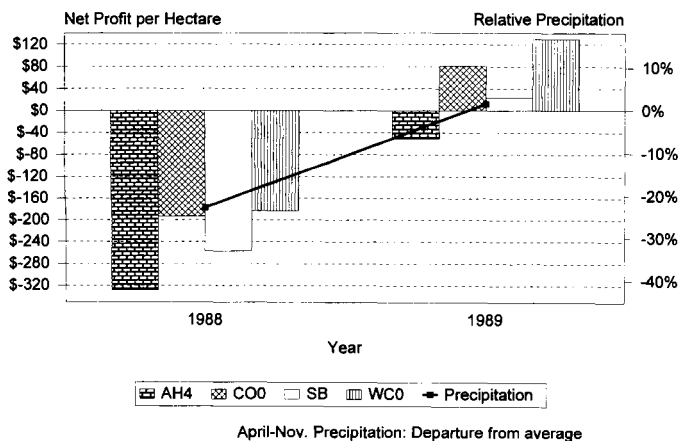


Fig. 4. Net profit in four crop rotations at Des Moines, 1988–1989.

- KARLEN, D. L., E. C. BERRY, T. S. COLVIN, and R. S. KANWAR. 1991. Twelve-year tillage and crop rotation effects on yields and soil chemical properties in northeast Iowa. *Communications in Soil Science and Plant Analysis*. 22(19&20):1985-2002.
- KARLEN, D. L., N. S. EASH, and P. W. UNGER. 1992. Soil and crop management effects on soil quality indicators. *American Journal of Alternative Agriculture*. 7(1&2):48-55.
- KARLEN, D. L., G. E. VARVEL, D. G. BULLOCK, and R. M. CRUSE. 1994. Crop rotations for the 21st century. *Advances in Agronomy*. 53: 1-45.
- KATTENBERG, A., F. GIORGI, H. GRASSL, G. A. MEEHL, J. F. B. MITCHELL, R. J. STOUFFER, T. TOKIOKA, A. J. WEAVER, and T. M. L. WIGLEY. 1995. Climate models—projections of future climate. Pages 285-357. *In* J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.) *Climate change 1995, the science of climate change*. Cambridge University Press, Cambridge.
- LAFLEN, J. M., and W. C. MOLDENHAUER. 1979. Soil and water losses from corn-soybean rotations. *Soil Science Society of America Journal*. 43(6):1213-1215.
- LESOING, G., and C. FRANCIS. 1990. Strip cropping corn and soybeans under dryland and irrigated conditions in eastern Nebraska. *University of Nebraska Crop Production News*, Lincoln, NE. Vol. 10, no. 10.
- LIEBMAN, M., and E. DYCK. 1993. Crop rotation and intercropping strategies for weed management. *Ecological Applications* 3(1):92-122.
- MEESE, B. G., P. R. CARTER, E. S. OPLINGER, and J. W. PENDLETON. 1991. Corn/soybean rotation effect as influenced by tillage, nitrogen, and hybrid/cultivar. *Journal of Production Agriculture*. 4(1):74-80.
- NATIONAL AGRICULTURAL STATISTICS SERVICE, USDA. 2000. Iowa agricultural statistics: Historic stocks (1886-1997). <http://www.nass.usda.gov/ia/>
- OLSEN, R. J., R. F. HENSLER, O. J. ATTOE, S. A. WITZEL, and L. A. PETERSON. 1970. Fertilizer nitrogen and crop rotation in relation to movement of nitrate nitrogen through soil profiles. *Soil Science Society of America Proceedings*. 34(3):448-452.
- REGANOLD, J. P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. *American Journal of Alternative Agriculture*. 3(4):144-155.
- RODER, W., S. C. MASON, M. D. CLEGG, and K. R. KNIEP. 1989. Yield-soil water relationships in sorghum-soybean cropping systems with different fertilizer regimes. *Agronomy Journal*. 81(3):470-475.
- THOMPSON, S.H. 1946. The marketing phase of Iowa farm living. Pages 228-240. *In* *A century of farming in Iowa, 1846-1946*. Iowa State College Press.
- VAN BAVEL, C. H. M., and F. W. SCHALLER. 1950. Soil aggregation, organic matter, and yields in a long-time experiment as affected by crop management. *Soil Science Society of America Proceedings*. 15:399-404.