A comparison of agricultural systems at the Allee Research Center

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**Recommended Citation**

Shannon, Dennis; Honeyman, Mark S.; McMillin, Roger; Jolly, Robert W.; Osei, Edward; Duffy, Michael D.; and Grundman, Dean, "A comparison of agricultural systems at the Allee Research Center" (1994). *Leopold Center Completed Grant Reports*. 45.  
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Abstract
The petrochemical-dependent agriculture that developed in the export-oriented economy of the 1970's proved vulnerable to high energy costs and volatile export markets as well as detrimental to soil and water resources. This project was designed to compare a petrochemical-based, high-tillage, low-management cropping system (System I) with two alternative systems: a ridge-till, reduced fertilizer and pesticide, high-management system (System II) and a rotational, low-pesticide, low-fertilizer conventional tillage system (System III).

Keywords
Agricultural Economics, Agronomy, Corn-soybean cropping systems, Economic and environmental impacts

Disciplines
Agricultural and Resource Economics | Agricultural Economics | Agricultural Science | Agronomy and Crop Sciences | Economics | Environmental Indicators and Impact Assessment

Lead Investigators
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Background

The petrochemical-dependent agriculture that developed in the export-oriented economy of the 1970's proved vulnerable to high energy costs and volatile export markets as well as detrimental to soil and water resources. This project was designed to compare a petrochemical-based, high-tillage, low-management cropping system (System I) with two alternative systems: a ridge-till, reduced fertilizer and pesticide, high-management system (System II) and a rotational, low-pesticide, low-fertilizer conventional tillage system (System III).

The systems approach in agricultural research combines expertise from various disciplines to formulate systems, much as farmers synthesize a variety of facts to formulate their farming plans. However, the systems approach only documents the differences between systems; it usually does not pinpoint the variables responsible for the differences.

The objective of this project were
1. to demonstrate three distinct farming systems with each crop grown each year,
2. to compare the systems in an interdisciplinary, whole-system approach,
3. to demonstrate alternative farming systems that use energy, including fuel, fertilizer, and pesticides more efficiently,
4. to establish baseline data before beginning the systems and to document the changes that occur as a result of the cropping systems, and
5. to involve researchers and the general public via field days and advisory committees.

This project was established by the Iowa State University Agriculture and Home Economics Experiment Station in 1987 and continued for six years. Leopold Center funding included years two through five.

Approach and methods

This project, intended as a systems approach to both research and demonstration, evaluated three distinct cropping systems on a large scale. The long-term nature of the study allowed more meaningful comparison of the systems' characteristics, including costs, machinery, labor and fuel requirements, yields, and effects on soil nutrients and pests.

System I used conventional tillage, fertilization, and weed control methods. On continuous corn and corn-soybean rotations, seedbed preparation involved a chisel plow and disk; dry fertilizer and herbicides were broadcast. In System II, continuous corn and corn-soybean rotations were grown in ridge-till. Crop scouting, soil testing, and manure were used to reduce pesticides and commercial fertilizers; herbicides and starter fertilizers were banded. System III, a five-crop rotation, used manure, crop scouting, and soil testing. Pesticides were used only for rescue treatments.

Several changes were made in System III management for 1991 and subsequent years to correct production problems encountered in previous years. From 1988 to 1990, the crop sequence for the System III rotation was oats, hay, corn silage/rye, soybeans, corn. Because of weed control problems and yield reductions, the row-crop portion of System III was changed to ridge-tillage. This had worked well in System II and on demonstration plots at this location. The tillage change required modifying the crop sequence to oats, hay, corn, soybeans, corn silage. This allowed silage harvesting without damaging the ridges for the next year's row crop. The rye cover...
crop after silage was replaced with spring barley because the rye was difficult to control and reduced the following crop yield by reducing soil moisture. Finally, when rotary hoeing and cultivation were not sufficient to control weeds, post-emergence herbicide was used in System III soybeans to minimize hand weeding. Each system/rotation combination was replicated four times on 1.2-acre plots, and each crop was grown every year.

Manure management: Both Systems II and III used manure to offset use of purchased fertilizer. This decision assumed that these cropping systems were linked to a profitable livestock operation and that manure was always available in needed quantities. It also assumed that the manure was available to the cropping operation for the cost of hauling and spreading. The risks and returns associated with livestock production were not reflected in the crop budgets, but the value of manure was accounted for in the reduction in commercial fertilizer costs; thus, the net cost for manure was the hauling charge minus the value of nutrients in the manure.

Solid manure was applied to System II and III plots from the beef feeding trials at the Allee Research Farm. Application rates of eight to 13 tons per acre were the lowest rates that could be applied uniformly over an entire plot by using commercially available spreaders. Manure consistency and moisture content caused variability in application rates. The range of nutrients, moisture, and acidity (pH) of the manure were 0.48-3.6% for nitrogen (N), 0.17-0.63% for phosphorus (P), 0.33-3.0% for potassium (K), 61-82% for moisture, and 5.6-9.2% for pH. (Typical yearly manure applications supplied 190 lb N, 97 lb P, and 124 lb K per acre.) N content was the most variable due to precipitation and the amount of grain in the feed ration. Soil P and K values increased during the study in Systems II and III.

Findings

Table 1 shows average crop yields for all years. Yields for corn, soybeans, and oats were adjusted to standard moisture contents of 15.5%, 13.0%, and 14.0%, respectively. Corn silage yields were adjusted to 65% standard moisture content; hay and straw yields are as harvested. In addition to a six-year average, Table 1 shows a five-year average, omitting 1991 data because of extreme differences in planting dates due to weather that spring—the 1991 oat crop failed.

In all years except 1992, continuous corn yielded less than corn following soybeans. The difference was about 13 bushels in System I and three bushels in System II (five-year average). Average rotated corn yields, similar for all three systems, ranged from 120 to 125 bushels/acre. Soybean yields were similar overall, between Systems I and II, and in the last four years in System III. During the first two years, System III soybean yields were much lower because of extreme weed pressure and moisture stress. Oat yields were quite variable, and hay yields were fairly consistent.

Investigators also gathered data on velvetleaf and foxtail populations for each rotation. Each system was designed with its own weed control strategy (chemical, mechanical, crop rotation). The entire area had heavy weed pressure in 1987, the set-up year. Generally, weed populations decreased over time; however, there were some weather-related exceptions, particularly in Systems II and III, which relied on timely mechanical cultivation. In System

Table 1. Annual average crop yields (bushels/acre). Asterisk(*) = tons/acre for hay, oat straw and silage.¹

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<tr>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Continuous corn</td>
<td>64</td>
<td>98</td>
<td>109</td>
<td>105</td>
<td>165</td>
<td>124</td>
<td>111</td>
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<tr>
<td>Corn following soybeans</td>
<td>77</td>
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<td>115</td>
<td>115</td>
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<td>Soybeans following corn</td>
<td>46</td>
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<td>36</td>
<td>38</td>
<td>49</td>
<td>47</td>
<td>44</td>
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<td><strong>System II</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Continuous corn</td>
<td>67</td>
<td>109</td>
<td>101</td>
<td>92</td>
<td>183</td>
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<td>113</td>
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<tr>
<td>Corn following soybeans</td>
<td>59</td>
<td>128</td>
<td>110</td>
<td>37</td>
<td>174</td>
<td>135</td>
<td>107</td>
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<td>Soybeans following corn</td>
<td>40</td>
<td>45</td>
<td>40</td>
<td>38</td>
<td>49</td>
<td>44</td>
<td>44</td>
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<tr>
<td><strong>System III</strong></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Oat grain</td>
<td>86</td>
<td>49</td>
<td>98</td>
<td>0</td>
<td>105</td>
<td>24</td>
<td>60</td>
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<td>Oat straw*</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Hay following oats*</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Corn</td>
<td>63</td>
<td>101</td>
<td>117</td>
<td>55</td>
<td>168</td>
<td>151</td>
<td>109</td>
</tr>
<tr>
<td>Soybeans</td>
<td>11</td>
<td>28</td>
<td>40</td>
<td>56</td>
<td>49</td>
<td>37</td>
<td>37</td>
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<tr>
<td>Corn silage*</td>
<td>6</td>
<td>14</td>
<td>11</td>
<td>10</td>
<td>23</td>
<td>13</td>
<td>13</td>
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</tbody>
</table>

¹ numbers rounded to nearest bushel (or ton)
Ill, weed control improved when ridge tillage was implemented in 1991. The foxtail population in corn decreased markedly. The change to ridge tillage reduced System III velvetleaf and foxtail populations to acceptable levels. Weed control was adequate during the last three years of the project.

Crop residue data were also collected. In each system, less residue (12–29% less ground cover) followed soybeans than corn. In all systems, crop residue was greater the last three years; this corresponds to higher crop yields for those years. System I residue was less than System II because of increased tillage. System III residue levels increased when ridge tillage was adopted and the number of full-pass tillage operations was reduced.

Soil samples were taken in fall of the set-up year and again at completion of the trial in 1993, and P, K, and pH were measured by rotation. Baseline soil P and K levels were high at the beginning of each trial. In 1987, lime was applied as needed to equalize soil pH in the plots. Levels of P changed little over the six years, except for a slight decrease in the System I corn-soybean rotation and a slight increase in System II continuous corn. All system rotations showed increased soil K levels, and System II continuous corn showed the greatest increase in soil K. The System II increases may have related to the use of manure as a N source with the accompanying P and K from manure. Soil acidity (pH) changed little; the greatest change noted was in System I continuous corn, which relied on the largest amount of anhydrous ammonia fertilizer. (Anhydrous has an acidifying effect.)

Figure 1 shows the returns to land and management for each crop rotation as dollars per acre. Fall crop prices from the Newell area were used to calculate the crop budgets; the prices varied somewhat from year to year. The crop budgets included crop input costs, labor, machinery expenses, grain drying, and interest charges, but did not include land rent or federal feedgrain program payments. Continuous corn had the lowest returns. System II continuous corn was more than twice as profitable as System I continuous corn. All rotations were generally more profitable near the end of the trial, reflecting higher yields, improved management, better weather conditions, and improved weed control. Corn-soybean rotations were most profitable, with System II having an $8/acre greater return than System I for the five-year average. The profitability of the System III rotation was less than the corn-soybean rotations but more than continuous corn for the five-year average. When average returns for the last two years of the study are compared, the System II corn-soybean rotation and the System III rotation are equally profitable ($184/acre); System I corn-soybean rotation returns are lower ($162/acre). System III rotation returns increased as the study progressed, except for 1991. The oat crop, while necessary to establish the hay legume seeding, was frequently the least profitable in the System III rotation.

System I rotations incurred higher variable costs than System II. In each case the continuous corn "rotations" were higher than the corn-soybean rotations. System III was the lowest-cost rotation in the project. Overall corn drying costs were the largest variable; they increased the total variable costs for 1992.

**Average growing season rainfall and temperature over the project period**

<table>
<thead>
<tr>
<th>Year</th>
<th>Rain</th>
<th>Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>23in.</td>
<td>64°F</td>
</tr>
<tr>
<td>1989</td>
<td>15in.</td>
<td>63°F</td>
</tr>
<tr>
<td>1990</td>
<td>35in.</td>
<td>62°F</td>
</tr>
<tr>
<td>1991</td>
<td>29in.</td>
<td>63°F</td>
</tr>
<tr>
<td>1992</td>
<td>26in.</td>
<td>58°F</td>
</tr>
<tr>
<td>1993</td>
<td>33in.</td>
<td>59°F</td>
</tr>
</tbody>
</table>

*Fig. 1. Return to land and management (dollars/acre)*
In terms of hours of labor used in each rotation, the amount of labor decreased as the study progressed because hand weeding was eliminated and project management improved. System I rotations were the least laborious; with ridge tillage, the System III labor usage resembled that of System II. Systems II and III required more labor than System I, partly because of manure application.

The System III rotation required the least energy and continuous corn in System I required the most—about seven times more than System III in 1993. Because N fertilizer, used for corn production, has a high energy value, the continuous corn rotations required the most energy. System I used about twice as much energy as System II for the same rotations.

Implications
Continuous corn performed poorly overall, requiring more energy, input costs, and labor. It consistently produced lower yields and generated lower returns to land and management than the corn-soybean rotations when compared within systems. The system changes from System I to System II were positive, particularly in economic performance—namely, lower input costs and higher returns. However, yields did not differ between System I and System II. System II, which embodies many recommendations of the Soil Conservation Service and ISU, serves to verify the profitability and compatibility of these recommendations.

A transition effect: The five-year System III crop rotation was the most lengthy and the most complex in terms of cropping and management. Because major changes were made in System III to improve performance; its rotation performed well only after the transition period. During this time, the change from the long-term, continuous corn production to the more complex five-year crop rotation may have caused changes in soil tilth, pests, microbes, and structure.

This project unintentionally served as a measure of a manager's ability to successfully implement three distinct cropping systems simultaneously—a scenario unlikely to occur on an actual farm. It proved more difficult than expected, in part because of extreme weather conditions during several years and rather difficult soils to manage. A comparison of management-intensive crop rotations such as this can magnify biases, strengths, and weaknesses in management. This accounts in part for the fact that the more complex System III performed well only after the four-year transition. Had the study continued, System III may have continued to improve or perform as well as System II. The simplicity of System II's corn-soybean rotation was clearly an advantage from a management standpoint. The primary soil type was Canisteo, a relatively high-clay till soil with poor surface and internal drainage. During episodes of heavy precipitation, field operations were difficult to complete in a timely manner. In a soil with better drainage characteristics, System III would have probably performed better with less transition time.

While this study could not evaluate every agricultural consideration (e.g., water quality, soil erosion, risk, socioeconomic aspects, aesthetics or distribution of farm labor), some inferences could be drawn. Overall, the study suggests that a complex cropping system can compete economically if high management is applied and adequate time for transition is allowed.

Education/outreach: Annual field days attracted approximately 70 persons on average. In addition, project staff conducted numerous visits and tours on request, and they used data from the comparisons in various presentations and conference papers. Annual progress reports explored risk factors, machinery budgets, pest considerations, and other aspects of the systems comparison.