Nutrient, Labor, Energy and Economic Evaluations of Two Farming Systems in Iowa

D. L. Karlen, M. D. Duffy, T. S. Colvin

How do conventional and alternative farming practices affect nutrient, labor, energy, and economic budgets on two central Iowa farms? This question was asked because the effects of alternative soil and crop management practices must be quantified to help identify agronomically productive, environmentally safe, economically feasible, and socially acceptable farming systems.

The National Research Council's (NRC) Alternative Agriculture report was written to show that alternative farming methods were feasible and could be profitable. One criticism of the report was that the case studies were not supported by quantitative data. To obtain a better understanding of the complex interactions occurring between farming systems and the environment, it will be necessary to develop farmer-researcher partnerships in addition to conducting more traditional component research.

This study was conducted on two adjacent 80-acre tracts in central Iowa that have been managed using conventional and alternative practices for several years. The alternative tract is part of the Richard and Sharon Thompson farm (Case Study no. 5 in the NRC report). Several component studies have provided quantitative information on profile N, water infiltration, aggregate stability, crop yield, and earthworm effects of the alternative farming practices; but nutrient, labor, energy, and economic assessments were needed to evaluate the economic feasibility and social acceptability (primarily labor requirements) of the practices. To make those assessments, a cooperative farmer-researcher partnership was implemented.

What are the differences in the nutrient, labor, energy, and economic budgets for a well-managed conventional and alternative farming system in central Iowa?

Nutrient budgets were developed for 1984 through 1993 by subtracting estimated crop removal from nutrient inputs supplied through commercial fertilizer or animal manure plus municipal sewage sludge. Estimated N-P-K application and removal by crops grown on the north and south fields under either management system differed by less than ±4% over the 10-yr. Our calculations show that more N was removed from the conventional fields than was applied through the fertilizer (Fig. 1). This was expected because the soybean crop was dependant upon residual nutrients from the fertilizer applied to the corn crop. Therefore, to achieve a simple N balance without depleting soil organic matter or other soil N sources, these data show that the soybean crop would have to obtain at least 53% of the N removed with the grain through dinitrogen fixation.

For the alternatively managed fields, the total N that had to be accounted for in the fields receiving animal manure plus sludge was estimated by adding a similar N fixation credit for soybean and hay to the already surplus amount of N (Fig. 1). This required accounting for 962 lb N/acre, 244 lb P/acre, and 844 lb K/acre applied (or fixed) in excess of crop removal between 1984 and 1993. Soil-test records document increases in Bray P1 extractable P and ammonium-acetate exchangeable K, while excess N could be accounted for by higher soil organic matter concentrations in the alternatively managed fields. This increase was good for soil structure, but since organic matter releases N slowly, it may

Full scientific article from which this summary was written begins on page 540 of this issue.
create a soil N reserve that is more difficult to manage for crop production than N supplied by inorganic fertilizers.

Field time for the conventional operation averaged 1.06 h/acre per year, while for the alternatively managed fields, it averaged 1.90 h/acre per year. Increased labor was required for the alternative system because (i) more time was required to spread the manure and sludge than to apply commercial fertilizer, (ii) more cultivations were required to avoid the use of herbicides, and (iii) multiple harvests were required to include hay in the 5-yr rotation. This difference may be a factor that will influence a farmer’s decision on adopting the alternative farming practices, especially if their operation involves large amounts of land or if they are committed to off-farm employment.

Energy and economic budgets were highly dependent on whether the nutrients in the manure plus municipal sewage sludge were considered as an input cost for the crop or as a disposal cost to be charged against the animal enterprise. When averaged for the two extremes, there was little difference between the farming systems in estimated energy use. Economic assessments for 1989 through 1993, without including government deficiency payments for corn, showed that the return to management averaged $28.97/acre for the conventional operation and $30/acre for the alternative farming system in central Iowa.

Economic comparisons at less than the whole farm level often assume that the management and labor requirement is essentially the same. For this study, however, the differences are important. The alternative system may have required more management because more crops were included, manure was used instead of commercial fertilizer, and more cultivations were used to avoid using herbicides. The $28.97 and $30/acre estimates for "return to management" were computed by subtracting estimates of all costs, including an arbitrary labor charge of $6/h. With these assumptions, the difference in average economic return per acre for the two farming systems was small. However, by assuming the management requirement for both systems is the same and placing an arbitrary charge of $10/acre as a management fee, the direct crop labor cost would be $25.37/acre for the conventional system compared with $31.40/acre for the alternative system. Dividing the hours of direct crop labor for each farming system shows a return that is 44% greater for the conventional system ($23.82/h vs $16.53/h).

The assumptions made with regard to computing the economic return for the two systems will undoubtedly reflect personal preferences. Overall, we conclude that both farming systems are sustainable based on the nutrient, labor, energy, and economic budgets. Furthermore, our results demonstrate the effectiveness of developing farmer-researcher partnerships to quantitatively evaluate the effects of alternative farming systems.

**10-yr Nutrient Balance**

(Without N Fixation)

Fig. 1. A 10-yr N, P, and K balance, without including N fixation, for two conventionally managed (Conv.-North and Conv.-South) and two alternatively managed (Alt.-North and Alt.-South) farming systems in central Iowa.

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Nutrient, Labor, Energy, and Economic Evaluations of Two Farming Systems in Iowa

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Farmer-researcher partnerships are needed to ensure soil and crop management practices are productive, environmentally safe, economically sound, and socially acceptable. We developed a farmer-researcher partnership to compare nutrient, labor, energy, and economic budgets for two "conventional" 40-acre fields where a 2-yr corn (Zea mays L.) and soybean [Glycine max (L.) Merr.] rotation is used with those for two adjacent fields where a 5-yr corn, soybean, corn, oat (Avena sativa L.), and hay rotation is used. Conventional fields received commercial fertilizer and herbicides. Alternative fields received no herbicides and a mixture of animal manure plus municipal sewage sludge as the primary nutrient source. A 10-yr nutrient budget suggests that N fixation would have to provide at least 53% of the N removed by soybean grain to prevent depletion of soil organic matter or other soil N sources from conventional fields. By assuming similar amounts of N fixation in the alternative fields, we show that 962 lb N/acre, 244 lb P/acre, and 844 lb K/acre were applied (or fixed) in excess of crop removal. Soil-test P, K, and organic matter changes reflect these applications. More fieldwork hours per acre per year were required to handle manure, avoid using herbicides, and harvest hay than to use conventional practices. Energy budgets were dependent on whether nutrients in the manure plus municipal sludge were considered as (i) an input cost for the crop, or (ii) a disposal cost that should be charged against an animal enterprise. Economic budgets were dependent on assumptions made regarding how to account for management costs. Overall, developing farmer-researcher partnerships was an effective method for evaluating alternative farming systems.

Methods and Materials

This study was conducted using measured and farmer-supplied information from four adjacent 40-acre fields in Boone County, Iowa. Cropping sequences used during the past 10 yr are summarized in Table 1. Conventional practices consist of a 2-yr corn and soybean rotation that has been followed since 1957. Prior to initiating the study (1932 through 1979), tillage consisted of moldboard plowing, disking, and harrowing for seedbed preparation. Hog manure was applied to the corn crop as a nutrient source. Based on experience and an occasional soil-test, an additional 0-18-33 (N-P-K) lb/acre of commercial fertilizer was applied every other year. Similarly, from 1960 through 1981, an additional 100 lb N/acre, generally as anhydrous ammonia, was also applied to the corn crop. Since 1981, the farm has been part of a custom-farming operation, soil tests were made approximately every 5 yr, and tillage practices included chisel plowing to incorporate corn stover and two passes with a field cultivator to apply herbicides and prepare the seedbed. Soybean stover was generally not incorporated until the following spring when a field cultivator was used to incorporate herbicide and

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broadcast P and K fertilizer. Based on experience, soil-test values, and local recommendations, inorganic fertilizer rates applied to the corn crops have averaged 130–80–100 (N-P-K) lb/acre since 1981. No additional fertilizer was applied for the soybean crop.

The alternative farming practices that have been followed since 1967 were described in detail (Karlen and Colvin, 1992; Logadon et al., 1993), but can be summarized as follows. A 5-yr, corn, soybean, corn, oat and hay rotation is used on each field. From 1967 through 1984 no commercial fertilizer was applied. Nutrients were provided to the row crops during the first 3 yr of each rotation by applying 20 tons/yr of swine and beef manure. Municipal sewage sludge from Boone, Iowa, has been mixed with the manure since 1984. The manure and sludge mixture was incorporated during a ridge-till planting operation within 48 h after application. Some K fertilizer has been applied to the oat and hay crops, and small amounts of starter N have occasionally been used for the corn since 1988. Nutrient application rates from the manure and sludge were based on application rates and lab analyses provided by our cooperators, who had submitted replicated samples to a commercial lab for several years (Rodale Institute, 1990). Inorganic fertilizer application amounts were also provided by our cooperators from their farm records. This information was used to calculate nutrient inputs for 1984 through 1993 for each farming system (Table 2).

Crop yields were measured for 5 yr in the two south fields and for 4 yr in the north fields. For row crops, a modified commercial combine (Colvin, 1990) was used to measure grain yield for 240 (±20) plots along eight transects within each field. Individual plots were 40 to 50 feet long and three to four rows wide depending on row spacing. Corn and soybean stover were not harvested. Yields for the oat and hay crops were estimated by hand-harvesting 16 to 28, 1550-sq-in. samples. Oats were dried and threshed before calculating yields at 11% water content. Average crop yield for each 40-acre field was computed using the individual measurements. The calculated values were within 8% (±3%) of the yields obtained from our cooperators’ sales receipts and weight records. This agreement enabled us to expand our crop yield database to 10 yr (Table 3) by using farmer-supplied estimates for 1983 through 1988. The larger database enabled us to evaluate crop yield for the alternative rotation for two 5-yr cycles and for five 2-yr cycles for the conventional rotation. Labor, energy, and economic records were not available for 1983 to 1988, so those factors were evaluated for only the years when research data were being collected (1989 to 1993).

Nitrogen concentrations in corn grain samples, collected from both farms in 1992, were measured by using dry combustion techniques with a Carlo Erba NCS 1500 analyzer. Nutrient concentrations in hay samples from both 1990 and 1991 were determined by having samples analyzed in a commercial lab. Nutrient concentrations for soybean and oat were estimated from information presented by Tisdale et al. (1993, Table 12.1). The N, P, and K concentrations in Table 4 and crop yield data (Table 3) were used to calculate the nutrient removal presented in Table 5. Nutrient application and crop removal data were then used to compute 10-yr nutrient budgets for all four fields.

Information on seed, pesticide, and nutrient inputs, as well as the specific farming operations performed on the four fields from 1989 through 1993, were provided by the cooperators. This information, with the assumptions outlined in Table 6, was used to compute 5-yr labor, energy (Table 7), and economic (Table 8) budgets for the two farming systems. Energy use was computed as a sum of the equivalent gallons of diesel fuel attributed to the fertilizer and pesticides applied, machinery used, and drying costs for the conventional farming practices. Energy costs for manufacture of pesticides and fertilizers were included, but not for manufacture of the equipment. Therefore, for each lb of N, P, and K, respectively, energy charges equivalent to 0.24, 0.13, and 0.044 gal of diesel fuel were assessed. Labor charges for delivery and handling were built into the
estimates of variable costs. Machinery costs were taken from Iowa State University Extension Publication No. 1712 (Iowa State University, 1992).

RESULTS AND DISCUSSION

Nutrient Budgets

Ten-year (1984 through 1993) total nutrient applications averaged 735, 169, and 421 lb/acre N, P, and K, respectively (Table 2) for the two 40-acre, conventionally managed fields. Total applications averaged 1644, 456, and 1574 lb/acre, respectively, for the two 40-acre alternatively managed fields. The total application for all three macronutrients was much higher with the alternative system because manure and sewage sludge were applied to the two corn and one soybean crops during the first 3 yr of each 5-yr cycle. When expressed as a percentage of the total amount applied for each macronutrient, this organic material provided 96% of the N, 98% of the P, and 63% of the K required for crop production. These nutrients may have been less available than from commercial fertilizer, but for a simple mass-balance budget we chose to examine total inputs and outputs rather than to estimate seasonal availability.

Estimated nutrient removal by corn and soybean grain, produced on conventionally managed fields over the 10-yr from 1984 through 1993 (Table 5), averaged 1152, 202, and 393 lb/acre N, P, and K, respectively. The corn and soybean stover was not harvested, therefore nutrients contained in those plant parts were assumed to be recycled. Nutrients removed by the corn, soybean, oat and hay crops during the 5-yr rotation on alternatively managed fields averaged 254, 481, and 891 lb/acre, respectively. Nutrient application and removal by crops from each of the two 40-acre fields under each management system differed by less than ±2% over the 10 yr, except for P removal, which differed by ±4% in the two alternatively managed fields (Table 5). Because of these small differences, nutrient input and removal amounts were averaged for the two fields in each management system to develop the nutrient budgets.

The 10-yr nutrient mass balance shows a deficit of 417 lb N/acre and a deficit of 29 lb P/acre for the conventional system. There was a slight surplus of 31 lb K/acre for this system. The alternative system received N, P, and K applications that exceeded crop removal by an average of 490, 244, and 844 lb/acre, respectively. Excess P applications associated with the manure (and municipal sludge since 1984) increased Bray P1 soil-test values from 19 lb/acre in 1967 to 132 lb/acre in 1989 (Rodale Institute, 1990). Exchangeable K levels increased from 21 lb/acre to 400 lb/acre during the same 22 yr.

A simple nutrient application minus grain removal mass balance for N does not account for all inputs or losses, because in addition to using residual nutrients from the fertilizer applied to each corn crop, soybean obtains additional N through symbiotic fixation. The exact amount of N2 fixation by soybean in a 2-yr rotation with corn on Midwestern soils is variable and may be as low as 40%, with the remaining 60% being taken up from the soil (Heichel, 1987). To estimate the minimum amount of fixation required to prevent mining of N from the soil organic matter, the 417 lb N/acre deficit for the two conventionally managed fields was divided by the amount of N used (791 lb/acre), which was the average amount removed by soybean grain (Table 5). This calculation indicates that soybean grown in conventionally managed fields had to obtain at least 53% of its N through N2 fixation to prevent loss of the soil organic matter or depletion of other soil nitrogen pools.

This simple nutrient budget assumes no net N loss for either farming system through denitrification, volatilization, or leaching to or below the tile drainage lines. Denitrifica-
Table 6. Assumptions used while computing five-year energy, labor, and economic budgets for a conventional and alternative farming system in central Iowa.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional</th>
<th>Without charges</th>
<th>Chemical prices</th>
<th>Yearly average prices were used if available. If not, the prices supplied by the cooperators were used.</th>
<th>Alternative</th>
<th>With charges for manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed costs</td>
<td>Prices used were those supplied by cooperating farmers.</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Interest and miscellaneous expenses</td>
<td>None were used for either farming system.</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Land charge</td>
<td>Cash rent equivalent for both farms was taken from ISU Extension Publication no. 1712 (ISU, 1992).</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Crop prices</td>
<td>Yearly average prices were used for 1989 through 1992. The 1982 prices were used for 1993.</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Labor charges</td>
<td>Labor charge for delivery and handling of grain were included in the variable costs.</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Manure nutrients</td>
<td>The value of the nutrients contained in the manure was charged at commercial fertilizer rates as provided by ISU Extension Publication no. 1712 (ISU, 1992).</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Manure spreading</td>
<td>Spreading was charged at 2.42 loads/acre, assuming an 8.25 ton/acre application rate.</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Machinery costs</td>
<td>Preharvest and harvest machinery costs were taken from the ISU Extension Publication no. 1712 (ISU, 1992).</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Corn harvesting charges</td>
<td>Rates for the alternative system were those associated with picking ear corn. A shelling charge was added, but drying was not charged since the crop was air-dried. Rates for the conventional system were those for combining the corn. Drying charges were based on grain moisture at harvest with fuel charges for liquid propane taken for each year from ISU Extension Publication no. 1712 (ISU, 1992).</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>Equipment charges</td>
<td>Charges for cost of production and energy summaries on the alternative system included using sweeps on the planter and disk-hillers on the cultivator.</td>
<td>------------------------------</td>
<td>-----------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>------------</td>
<td>-------------------------</td>
</tr>
</tbody>
</table>

Table 7. Energy summaries for two conventionally managed and two alternatively managed fields in central Iowa from 1989 through 1993.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>North</th>
<th>South</th>
<th>North</th>
<th>South</th>
<th>North</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemicals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer</td>
<td>7494</td>
<td>7256</td>
<td>9020</td>
<td>9038</td>
<td>3474</td>
<td>3547</td>
</tr>
<tr>
<td>Machinery</td>
<td>5824</td>
<td>5762</td>
<td>6601</td>
<td>6745</td>
<td>6614</td>
<td>6782</td>
</tr>
<tr>
<td>Drying grain</td>
<td>342</td>
<td>340</td>
<td>335</td>
<td>336</td>
<td>337</td>
<td>337</td>
</tr>
<tr>
<td>Total</td>
<td>8570</td>
<td>8588</td>
<td>12004</td>
<td>12172</td>
<td>12654</td>
<td>12557</td>
</tr>
</tbody>
</table>

Table 8. Economic summaries for two conventionally managed and two alternatively managed fields in central Iowa from 1989 through 1993.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>North</th>
<th>South</th>
<th>North</th>
<th>South</th>
<th>North</th>
<th>South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fixed cost</td>
<td>21.18</td>
<td>19.00</td>
<td>20.70</td>
<td>18.08</td>
<td>20.70</td>
<td>18.08</td>
</tr>
<tr>
<td>variable cost</td>
<td>9.71</td>
<td>8.87</td>
<td>9.65</td>
<td>7.65</td>
<td>9.65</td>
<td>7.65</td>
</tr>
<tr>
<td>Seed</td>
<td>19.05</td>
<td>22.52</td>
<td>19.74</td>
<td>18.31</td>
<td>19.74</td>
<td>18.31</td>
</tr>
<tr>
<td>Chemicals</td>
<td>15.65</td>
<td>20.15</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Cover crop</td>
<td>0.00</td>
<td>0.00</td>
<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>Manure</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>19.46</td>
<td>27.88</td>
<td>20.70</td>
<td>15.76</td>
<td>20.70</td>
<td>15.76</td>
</tr>
<tr>
<td>Labor @ $6/h</td>
<td>6.32</td>
<td>6.47</td>
<td>11.21</td>
<td>11.57</td>
<td>11.21</td>
<td>11.57</td>
</tr>
<tr>
<td>Land</td>
<td>108.00</td>
<td>108.00</td>
<td>108.00</td>
<td>108.00</td>
<td>108.00</td>
<td>108.00</td>
</tr>
<tr>
<td>Expenses/acre</td>
<td>242.39</td>
<td>245.64</td>
<td>228.55</td>
<td>252.47</td>
<td>290.00</td>
<td>291.87</td>
</tr>
<tr>
<td>Return to management</td>
<td>32.84</td>
<td>25.11</td>
<td>46.78</td>
<td>77.52</td>
<td>14.84</td>
<td>10.42</td>
</tr>
</tbody>
</table>

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remained relatively constant in the conventional fields. The increase in soil organic matter is good with respect to soil structure, but it may create a less manageable N pool. However, based on previous studies (Karlen and Colvin, 1992) the two farming systems do not differ in their risk for groundwater contamination.

Labor Budgets

The labor required as a result of using either of these farming systems was compared by making a series of assumptions (Table 6) and then calculating the number of fieldwork hours (Williams and Ayers, 1976) that were required for each acre farmed. Fieldwork hours do not account for travel time to and from the homestead or other management activities.

Average fieldwork hours for the conventional system for 1989 through 1993 were 1.05 and 1.08 h/acre per year for the north and south 40-acre fields. For the alternative system, fieldwork hours during this period averaged 1.87 and 1.93 h/acre per year for the north and south fields, respectively. Increased labor was required for the alternative system because (i) more time was required to spread the manure and sludge than to apply commercial fertilizer, (ii) more cultivations were required to avoid the use of herbicides, and (iii) multiple harvests were required to include hay in the 5-yr rotation.

Energy and Economic Budgets

Energy and economic budgets for the alternative farming system were computed two different ways to account for use of the manure and municipal sludge mixture as the primary nutrient source. Calculations were made with (+) and without (−) manure nutrient charges. For the (−) manure calculations, the crop production portion of the diversified operation was not charged for the nutrient benefits of the manure and sludge. This approach assumes that the entire nutrient value would be charged to the animal enterprise and municipality because of the need to dispose of the manure and sludge as a waste. For the (+) manure calculations, the crop production enterprise was charged for the total nutrient value of the manure plus sludge. For a whole farm economic analysis (which was not done), nutrient values associated with animal manures (plus municipal sludge for this farm) should be charged an amount that would reflect the cost difference between using the material as a fertilizer resource and disposing of it as a waste. This case study included only two farms, so we chose to provide the extremes rather than to impose an arbitrary distribution of costs associated with crop production for the two farming systems.

Differences in how corn grain was handled were thought to introduce some inequality into our energy and economic comparisons (Tables 7 and 8) because fuel costs for drying the grain were charged against the conventional farming operation while nothing was charged for crib drying on the alternative farm (Table 6). The fuel cost charged was the normal amount required to reduce the grain moisture content from the measured harvest value to 15.5% for storage and marketing (Iowa State University, 1992). This survey also lists an average charge of $0.01/bu per month for ear corn storage. The storage period generally lasts until April, thus increasing costs incurred by the alternative farming operation by $0.06/bu. This storage cost, however, is more than offset by the normal price rise following harvest. Central Iowa corn prices increased an average of 7.4% from October to April for the 12 crops between 1980–1981 and 1991–1992. Assuming a base price of $2.15/bu, this indicates there would have been a $0.15/bu increase in price to offset a $0.06/bu cost. Assuming the conventional operation stored the corn until April, there would be an additional $0.03/bu charge for drying and shrinkage, plus a $0.02/bu per month storage fee (Iowa State University, 1992). The conventional operation would thus break even.

Energy Budgets

Five-year average energy budgets, based on the assumptions outlined for the two farming systems in Table 6 and data collected for the 5-yr period (1989 to 1993), are presented in Table 7. The energy requirements for individual years ranged from 768 to 9568 KBtu and from 963 to 9292 KBtu for the conventionally managed north and south fields, respectively (data not presented). The difference in average values for the two fields (Table 7) occurred because two corn crops were grown on the north field and three were grown on the south field during the past 5 yr. For the (−) manure calculations, yearly energy costs for the 5-yr rotation ranged from 552 to 93816 KBtu and from 601 to 3063 KBtu for the alternatively managed north and south fields, respectively (data not presented). With energy charges (+ manure), yearly values ranged from 1245 to 16605 KBtu and from 1409 to 15852 KBtu for the north and south fields, respectively (data not presented).

The 5-yr average energy budgets (Table 7) show that without charging for the energy associated with the manure nutrients, the alternative farming system required approximately half the energy required for the conventional system. If energy costs for the nutrients were included, however, the alternative system used twice as much energy for crop production as the conventional system. We assume the actual energy cost for crop production with the alternative system will lie somewhere between the two extremes of charging or not charging for the nutrients provided by the manure and sludge. To validate that assumption, additional information about the animal production enterprise would be required, and a whole farm economic analysis would have to be calculated. That was beyond the scope of this study, so no effort was made to obtain the additional information from our cooperator.

Economic Budgets

Five-year average economic budgets based on assumptions outlined for the two farming systems in Table 6 are presented in Table 8. Yearly returns to management for the 2-yr conventional corn and soybean rotation ranged from −$67.53 for soybean in 1993 to $98.93 for corn in 1992 in the north field and from −$93.47 for corn in 1993 to $91.62 for corn in 1989 in the south field (data for remaining years not presented). The high financial losses in 1993 were caused by very low average yields in all of the 40 acre
fields. The low yields were attributed to major portions of
the fields being flooded and either killed or severely
stressed by the excessive rainfall that occurred throughout
the upper Midwest. The difference in average return to
management values for the two fields (Table 8) was
primarily caused by the high losses associated with the 1993
corn crop, although return to management for the corn crop
grown in the north field in 1990 was only $9.70/acre (data
not presented). For the (−) manure calculations, yearly return to
management for the 5-yr rotation ranged from −$121.01 for corn
in 1993 to $166.41 for hay in 1990 in the north field and
from −$5.16 for soybean in 1993 to $139.31 for corn in
1992 in the north field. In the north field, yearly return to
management with charges for nutrients in the manure
ranged from −$232.10 for corn in 1993 to $166.41 for hay
in 1990. In the south field they ranged from −$116.36 for
soybean in 1993 to $134.54 for hay in 1991. These data
show that without including deficiency payments for the
corn, the hay crop provided the best economic return for the
5-yr rotation. Oats, which had a yield of 136 bu/acre in
1989 and was valued at $1.50/bu, provided a close second
in the north field with a return to management of $128.91. However, because of much lower yields in 1990 (92.6
bu/acre) and a lower price ($1.20/bu), oats returned only
$5.47/acre on the south field.

The 5-yr average economic summary (Table 8) shows
that return to management averaged $32.84/acre and
$25.11/acre for the conventionally managed 2-yr corn and
soybean rotation in the north and south fields. Without
charging for nutrients in the manure, the 5-yr rotation in the
north and south alternatively managed fields returned an
average of $46.78 and $77.62/acre, respectively, for the
1989 through 1993 period. If nutrient costs were included,
however, the return to management averaged −$14.84/acre
and $10.42/acre for the north and south fields, respectively.

The actual return to management for the 5-yr rotation
presumably lies somewhere between the values computed
with and without the nutrient charges. Therefore, to
compare net return to management for the two farming systems,
we chose to average the values for both conventionally
managed fields and for the two alternatively managed fields
with and without nutrient charges. This procedure showed
that the return to management, without government
deficiency payments for corn, averaged $28.97 and $30/acre
for the central Iowa conventional and alternative farming
systems, respectively.

When most economic comparisons made at less than the
whole farm scale, such as when fertilizer rates, varieties,
raisons, additives, and herbicides, are compared, it is
reasonable to assume that the management and labor
requirements across treatments are essentially the same.
Scientists therefore present the results by reporting the
return to "family labor and management." However, in this
study, differences in management and labor may be relative-
ly important issues. The alternative system may have
required more management time because more crops were
included, manure was used instead of commercial fertilizer,
and more timely cultivations were used to avoid using
herbicides. Management, however, is difficult to quantify.
Direct crop labor can be quantified, and the alternative
system did require 78% more (1.90 vs. 1.065 h/acre).

The $28.97/acre and $30/acre estimates for "return to
management" reported in Table 8 for the two farming
systems were computed by subtracting estimates of all costs,
including an arbitrary labor charge of $6/h. In this case,
"management" would be referred to as the "residual
claimant." By this measure, the difference in average
economic return per acre across the two farming systems is
small. This could be interpreted as an indication that, if
government programs are ignored, the two systems have
nearly equivalent income generation potential per unit land
area. The family's income, however, will depend upon the
number of acres managed.

Labor rather than management could be treated as the
residual claimant. For example, rather than placing an
arbitrary charge of $6/h for direct crop labor, the analysis
could have been conducted by placing an arbitrary charge
of $10/acre as a management fee for both farming systems.
In that case, the return to direct crop labor would be
$25.37/acre for the conventional system and $31.40/acre for
the alternative system. Dividing by the hours of direct crop
labor for each farming system reveals that the return is
$23.82/h for conventional and $16.53/h for alternative
farming practices. By this measure, the return to "direct
crop labor" is 44% greater for the conventional farming
system.

For simplicity, the same management fee per acre was
charged for both systems. This resulted in negligible
differences. If the management requirement is greater for
the alternative system, the return to direct crop labor would
be more than 44% greater for the conventional system.
The assumptions made with regard to computing the
economic return for the two systems will undoubtedly
reflect personal preferences. Furthermore, although this case
study was not replicated, it generally supports the con-
clusion reached by Chase and Duffy (1991) that any
farming system is often only as good as the farmer. Our
experience suggests that all cooperators involved in this
farmer-researcher partnership are very good stewards of the
land, and that differences in their choices of farming
practices primarily reflect the differences in their manage-
ment styles.

SUMMARY AND CONCLUSIONSNutrient, labor, energy, and economic budgets were
developed for adjacent farms using alternative and conven-
tional practices in central Iowa. To balance crop N removal
with N application over a 10-yr period, our calculations
suggest that soybean grown in conventional fields had to
obtain 53% of its N from fixation. Nitrogen applied through
manure and municipal sewage sludge in excess of that
removed by the crops could be accounted for by differences
in soil organic matter (total C) or total N content. The 2-yr
conventional rotation required 1.06 fieldwork hours/acre per
year, while the 5-yr alternative rotation required 1.90
fieldwork hours/acre per year. This labor difference may be
a factor influencing a farmer's decision on adopting
alternative farming practices, especially if the operation
involves large amounts of land or if the operator is also
dependant on off-farm employment.

Overall, the projected energy and economic budgets for
crop production were highly dependent on whether the
nutrients in the manure plus municipal sludge were considered as (i) an input cost for the crop, or (ii) a disposal cost that should be charged against an animal enterprise. Economic assessments made for 1989 through 1993 by treating ‘‘management’’ as the ‘‘residual claimant’’ showed that the return to management, without government deficiency payments for corn, averaged $28.97/acre per year for the conventional system and $30/acre per year for the alternative farming system. With this assumption, the difference in average economic return per acre for the two farming systems is small. However, if the management requirement is greater for the alternative system and ‘‘labor’’ is treated as the ‘‘residual claimant,’’ the return to direct crop labor would be more than 44% greater for the conventional system.

Farming systems are often only as good as the farmer and since the two farming systems compared for this study were not and could not be precisely replicated, not all aspects will be directly transferable to other farming systems comparisons. We conclude, however, that by developing farmer-researcher partnerships, complex farming systems and environmental questions can be addressed in an efficient and scientifically sound manner.

Finally, we recognize that substantial averaging was required for these analyses, but for systems-level questions this is not unusual. A critical factor, however, is to be sure that all assumptions made are clearly documented. Ideally, this type of study would be replicated, designed to include a wider variety of managerial skills, and to include whole-farm economic analyses.

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