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

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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.

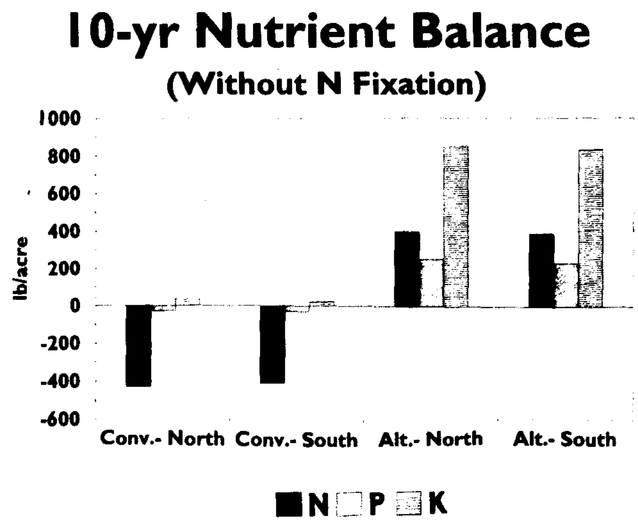

Fig. 1. A 10-yr N, P, and K balance, without including N fixation, for two conventionally managed (Conv.-North and Conv.-South) and two alternatively managed (Alt.-North and Alt.-South) farming systems in central Iowa.

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_2 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.

FARMERS AND RESEARCHERS are continually striving to develop soil, crop, animal, and nutrient management practices that are productive, environmentally safe, economically sound, and socially acceptable. One method to help ensure these goals are attained is to examine effects of alternative farming systems in situ by forming farmer-researcher partnerships. This approach was used to evaluate effects of organic and conventional farming systems on soil tilth and soil erosion losses in the Palouse area of eastern Washington state (Reganold, 1988).

Development of farmer-researcher partnerships and systems approaches (Oberle and Keeney, 1991; Alessi et al., 1994; Oberle, 1994), in conjunction with reductionist approaches (McRae et al., 1989), will improve our understanding of the complex interactions occurring between farming systems and the environment. Together, reductionist and systems methods can be used to guide development of more efficient and sustainable farming operations (Karlen et al., 1994). These ideas were also expressed in the Alternative Agriculture report (National Research Council, 1989), which showed that alternative farming methods were feasible and could be profitable. One criticism of that report was that the case studies were not supported by quantitative data (CAST, 1990).

Studies were initiated in 1989 on two adjacent 80-acre tracts in central Iowa that have been managed using either conventional or 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). Both 80-acre tracts are managed as two 40-acre fields (north and south) and have provided a field-research site for quantitative evaluations of profile N (Karlen and Colvin, 1992), water infiltration (Logsdon et al., 1993), earthworm activity (Berry and Karlen, 1993), water stability of soil aggregates (Jordahl and Karlen, 1993), and crop yield (Steinwand et al. 1996).

The initial studies provided important and previously unavailable information for comparing environmental and agronomic impacts 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) for the two farming systems. For those assessments, a substantial amount of information was needed from each of the cooperators. This required us to establish and implement a farmer-researcher partnership to quantitatively evaluate the effects of alternative farming practices.

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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Table 1. Ten year cropping history on four 40-acre fields in central Iowa managed with conventional or alternative farming practices.

Crop year	Conventional North	Conventional South	Alternative North	Alternative South
1984	Corn	Soybean	Oats	Corn
1985	Soybean	Corn	Hay	Oats
1986	Corn	Soybean	Corn	Hay
1987	Soybean	Corn	Soybean	Corn
1988	Corn	Soybean	Corn	Soybean
1989	Soybean	Corn	Oats	Corn
1990	Corn	Soybean	Hay	Oats
1991	Soybean	Corn	Corn	Hay
1992	Corn	Soybean	Soybean	Corn
1993	Soybean	Corn	Corn	Soybean

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; Logsdon 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 cooperator, 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

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or Iowa State University and does not imply its approval to the exclusion of the other products or vendors that may also be suitable.

Table 2. Ten year N-P-K application history for four 40-acre fields in central Iowa managed conventionally with commercial fertilizer or alternatively with manure-municipal sludge as the primary nutrient source.

Crop year	Conventional North	Conventional South	Alternative North	Alternative South
	Seasonal nutrient applications (N-P-K), lb/acre			
1984	130-35-82	--	0-0-98	263-75-164†
1985	--	130-35-82	0-0-98	0-0-98
1986	130-35-82	--	263-75-164 +0-0-57	0-0-98
1987	--	130-35-82	263-75-164 +0-0-49	263-75-164 +0-0-57
1988	130-35-82	--	263-75-164 +0-0-57	263-75-164 +0-0-49
1989	--	120-0-0 +31-35-82	0-0-98	263-75-164 +0-0-57
1990	140-0-0 +26-29-0 +0-0-90	--	0-0-98	0-0-98
1991	--	148-0-0 +31-35-100	263-75-164	0-0-98
1992	138-0-0 +29-33-0 +0-0-90	--	263-75-164	263-75-164 +50-7-62
1993	--	130-0-0 +27-30-0 +0-0-87	263-75-164 +26-8-28 +55-0-0	263-75-164
10-yr total	723-167-426	747-171-415	1659-456-1570	1628-455-1579

† The 263-75-164 (N-P-K) rates are estimated nutrient applications from animal manure plus municipal sludge. These are based on application rates and laboratory analyses provided by our cooperator (Rodale Institute, 1990).

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[1] 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

Table 3. Ten-year crop yield history for two 40-acre fields in central Iowa managed with commercial fertilizer and two 40-acre fields receiving manure-municipal sludge as the primary nutrient source.†

	Conventional		Alternative	
Year	North	South	North	South
	lb/acre			
1984	(corn) 6 867	(soy) 1 957	(oats) 3 140‡	(corn) 4 940
1985	(soy) 2 351	(corn) 8 606	(hay) 9 990‡	(oats) 4 060
1986	(corn) 8 350	(soy) 2 580	(corn) 6 646	(hay) 9 990‡
1987	(soy) 3 053	(corn) 6 705	(soy) 3 150	(corn) 7 190
1988	(corn) 5 976	(soy) 1 946	(corn) 6 540	(soy) 2 515
1989	(soy) 2 550	(corn) 8 245	(oats) 4 345	(corn) 7 780
1990	(corn) 6 875	(soy) 2 515	(hay) 10 540	(oats) 2 780
1991	(soy) 2 640	(corn) 8 340	(corn) 6 040	(hay) 11 820
1992	(corn) 9 605	(soy) 2 745	(soy) 3 150	(corn) 9 680
1993	(soy) 1 407	(corn) 4 533	(corn) 3 200	(soy) 2 145

† Moisture content of corn, soybean, and oats are reported at 15.5, 13.0, and 11.0%, respectively. Hay yield is expressed as dry matter per acre.
‡ Estimated yield based on the weighted distribution of soil map units across the field and productivity estimates for each soil (Steinwand et al., 1996).

Table 4. Nutrient concentrations used to estimate crop removal from farms using conventional and alternative management practices in central Iowa.

Crop	N	P	K
	%		
Corn	1.10†	0.40	0.50
Soybean	7.66	0.60	2.20
Oats	1.86†	0.40	0.60
Mixed hay	2.50†	0.31†	2.26†

† Measured values for samples collected from both farming systems in 1992 (corn) or the alternative farming system for oats (1991) and hay (1990 and 1992). The P and K values for corn and oats and N, P, and K values for soybean were estimated using values in Table 12.1 from Tisdale et al. (1993).

Table 5. Ten year N–P–K removal history for four 40-acre fields in central Iowa managed with commercial fertilizer or manure-municipal sludge as the primary nutrient source.†

	Conventional		Alternative	
Year	North 40	South 40	North 40	South 40
	lb/acre (N–P–K)			
1984	64–24–29	130–11–38	52–11–16	46–17–21
1985	157–12–45	80–30–36	250–32–226	67–15–21
1986	78–29–35	172–15–49	62–23–28	250–32–226
1987	203–16–58	62–23–28	210–17–61	67–25–30
1988	56–21–25	130–11–37	61–22–28	168–13–48
1989	170–14–49	107–40–48	72–16–23	72–27–33
1990	64–24–29	168–13–48	264–33–238	46–10–15
1991	176–14–61	78–29–35	56–21–25	296–37–267
1992	89–33–40	183–15–53	210–17–61	89–33–41
1993	94–8–27	42–16–19	28–11–13	143–11–41
10-yr total	1151–194–393	1152–202–396	1265–202–727	1244–221–752

† Nutrient removal based on dry matter for corn, soybean, oat and hay and nutrient concentrations presented in Table 4.

estimates of variable costs. Machinery costs were taken from Iowa State University Extension Publication No. 1712 (Iowa State Uuniversity, 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, 198, and 390 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 1254, 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 211 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 N_2 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 N_2 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.

Parameter	Assumption
Chemical prices	Yearly average prices were used if available. If not, the prices supplied by the cooperators were used.
Seed costs	Prices used were those supplied by cooperating farmers.
Interest and miscellaneous expenses	None were used for either farming system.
Land charge	Cash rent equivalent for both farms was taken from ISU Extension Publication no. 1712 (ISU, 1992).
Crop prices	Yearly average prices were used for 1989 through 1992. The 1992 prices were used for 1993.
Labor charges	Labor charge for delivery and handling of grain were included in the variable costs.
Manure nutrients	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).
Manure spreading	Spreading was charged at 2.42 loads/acre, assuming an 8.25 ton spreader and a 20 ton/acre application rate.
Machinery costs	Preharvest and harvest machinery costs were taken from the ISU Extension Publication no. 1712 (ISU, 1992).
Corn harvesting charges	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).
Equipment charges	Charges for cost of production and energy summaries on the alternative system included using sweeps on the planter and disk-hillers on the cultivator.

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

			Alternative			
	Conventional		Without charges for manure		With charges for manure	
Parameter	North	South	North	South	North	South
	KBtu/year					
Fertilizer	2846	4459	1362	797	9035	8471
Chemicals	241	315	0	0	0	0
Machinery	718	675	661	734	661	734
Drying grain	326	220	0	0	0	0
Total	4130	5670	2023	1532	9696	9205

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

			Alternative			
	Conventional		Without charges for manure		With charges for manure	
Parameter	North	South	North	South	North	South
	$/acre per year					
Machinery—						
fixed cost	21.18	19.00	20.70	18.08	20.70	18.08
variable cost	9.71	8.87	9.65	7.65	9.65	7.65
Seed	19.05	22.52	19.74	18.31	19.74	18.31
Chemical	15.65	20.15	0.00	0.00	0.00	0.00
Cover crop	0.00	0.00	0.72	0.72	0.72	0.72
Manure	0.00	0.00	0.00	0.00	61.64	67.20
Fertilizer	19.46	27.88	20.70	15.76	20.70	15.76
Labor @ $6/h	6.32	6.47	11.21	11.57	11.21	11.57
Land	108.00	108.00	108.00	108.00	108.00	108.00
Expenses/acre	232.49	245.54	228.36	224.67	290.00	291.87
Return to management	32.84	25.11	46.78	77.62	(14.84)	10.42

tion and volatilization have not been measured at these field sites. We considered estimating drainage losses, but concluded it was not possible because the exact origin and drainage patterns of tile drainage lines are no longer known. However, analyses of soil cores collected into the unoxidized glacial till, which is located approximately 14.5 ft below the soil surface, did not show major differences in profile N concentrations for the two farming systems (Karlen and Colvin, 1992). If N losses through these or other processes were significant, our approach would suggest that the amount of N that must be supplied by fixation would have to be higher or that soil organic matter levels would decrease. Soil C concentrations were measured in 1989 and 1990 (Berry and Karlen, 1993), but samples from the early 1980s were not available to determine if soil organic matter concentrations in conventionally managed fields were decreasing.

We assume that, in addition to the excess N applied with the manure and municipal sludge, some N was also added through fixation by the soybean and hay crops grown in the alternatively managed fields. Symbiotic N_2 fixation is generally reduced by high levels of available soil N, but nitrate- and ammonium-N concentrations for both farming systems were quite similar (Karlen and Colvin, 1992), therefore, we credited the soybean and hay crops in the alternatively managed fields with the same rate (i.e., 53%) of fixation as was required to balance N removal by soybean in the conventionally managed fields. This approach suggests that the two 40-acre alternatively managed fields had an average excess application credit of 472 lb N/acre from fixation plus 490 lb N/acre from manure and sludge or a total of 962 lb N/acre during the 10 yr.

Soil profile nitrate- and ammonium-N concentrations suggested there was essentially no difference in the potential water quality impact attributable to the two farming systems (Karlen and Colvin, 1992). Therefore, some mechanism for accounting for the excess N application must be proposed. We suggest that this can be done with the total C (Berry and Karlen, 1993) or total N measurements (Karlen and Colvin, 1992) that were reported previously for this experimental site.

Berry and Karlen (1993) reported a significantly higher total C content in the top 4 in. of the southern, alternatively managed field than in the southern conventionally managed field. Assuming a bulk density of 1.3 g/cu cm for this soil depth (Jordahl, 1991) and a 10:1 C:N ratio in the organic matter, the measured difference in total C content would account for approximately 854 lb N/acre. Similarly, using the significant differences in total N concentrations in the top 18 in. that were reported by Karlen and Colvin (1992), it is possible to account for 1695 lb N/acre by using typical (T.E. Fenton, 1994, personal communication) bulk density values of 1.3 g/cu cm for the 0- to 4-in. depth, 1.4 g/cu cm for the 4- to 8-in. depth, 1.5 g/cu cm for the 8- to 12-in. depth, and 1.5 g/cu cm for the 12- to 18-in. depth. These calculations show that using significant differences in either total soil C or N can account for all of the N applied in excess of crop removal, assuming that total soil C and N 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 3816 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, rations, 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 relatively 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 conclusion 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 management styles.

SUMMARY AND CONCLUSIONS

Nutrient, labor, energy, and economic budgets were developed for adjacent farms using alternative and conventional 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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