

Sustainable Agriculture:

Making Money, Making Sense





Twenty Years of Research and Results

LITERATURE REVIEW

FIRES OF HOPE

By Kristen Corselius, Suzanne Wisniewski, and Mark Ritchie

THE INSTITUTE FOR AGRICULTURE AND TRADE POLICY

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THE FIRES OF HOPE INITIATIVE

Fires of Hope was established in 1997 by the W. K. Kellogg Foundation to use state-of-the-art communications techniques and public policy innovations to foster and promote sustainable food systems in critical regions of the United States. In 2000, Fires of Hope was transformed into a nonprofit, 501(c)3 organization focused on impacting the public policy arena, generating marketplace opportunities, and stimulating partnership development around sustainable food systems. Driven by an experienced and knowledgeable team of communications, public policy, and sustainable agriculture professionals, Fires of Hope is marshalling the tools of strategic media and communications, public policy innovation, partnership development, and impact evaluation to pursue and catalyze changes in the way food is grown, processed, distributed, and marketed. This initiative is supporting diverse efforts nationwide to reconstruct the food system into one that is economically viable, ecologically sound, and socially just.

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HOW TO ORDER

Copies of this report are available on-line at www.firesofhope.org and www.iatp.org.

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FOREWORD

Over twenty years of research by land grant universities and other scientific institutions demonstrates repeatedly that sustainable farming is, on average, more profitable than conventional agriculture. Through a combination of factors that include lower costs, higher yields, and, in some cases, price premiums, farmers who use one or more sustainable practices (as defined by the National Academy of Sciences) make a larger profit in the marketplace than do growers who rely solely on conventional practices.

The research analysis that follows bears these statements out, drawing some important conclusions about sustainable farming in the process. The first derives from the consistency of results documented by studies conducted during the last two decades in most agricultural regions of the United States. Across a range of crops, sizes, geographic areas, and sustainable farming practices, researchers found that in almost all cases farmers using non-conventional practices made more money by lowering their costs, increasing their yields, or receiving higher market prices for their goods.

The second is that more research is needed. While the scientific studies reviewed during this analysis have yielded valuable insights that are already helping farmers, it is clear that major research gaps exist which additional and newer studies could ameliorate. For example, very little research has examined the impact of value-adding mechanisms like on-farm processing and direct marketing, and no studies have evaluated the kinds of price premiums and increased market share that are enjoyed by producers who participate in sustainable farming labeling initiatives. Additional analysis of these factors would provide a valuable foundation upon which future agricultural decisions could be made.

Third, the crucial role of management and labor in making sustainable agriculture more profitable is clear. Almost all of the research cited in this report focuses on farms that are very well designed and managed. These ingredients play a crucial role in any farmer's ability to cut costs and boost yields. For farms hoping to transition to sustainable practices (such as integrated pest management), several studies indicate that additional skills and labor power are even more essential. As in any endeavor, economic success in the utilization of sustainable farming techniques requires a significant level of knowledge, skill, and hard work.

Finally, in times of low overall market prices, it appears that farming sustainably can mean the difference between profit and loss. The lower costs and higher yields that sustainable farms frequently enjoy can provide a margin of profit that today's conventional producer might not be able to achieve. While this is a very important benefit for many sustainable farmers, a number of studies indicate that not all sustainable farms are thriving economically. Many sustainable farmers operate within the global market system, in which prices can fall to unfathomably low levels, as they did with hogs just a few winters ago—bottoming out at less than a dime a pound. These extreme price depressions can put even the most efficient farmers at risk. (See page 4 for definitions of sustainable and conventional agriculture.)

Over the past twenty years, the quality and quantity of research on sustainable farming has steadily increased. This survey of results provides one of the first attempts to compile a body of data that will help farmers discern larger patterns, lessons, and opportunities. While much remains to study and learn—especially about profitability impacts on both conventional and sustainable growers of the so-called new economy—one thing is clear: sustainable agriculture can be good for a farming family's bottom line. Mounds of data prove that sustainable agriculture improves the soil, protects wildlife, safeguards water quality, and enhances rural communities. Proof is now mounting that sustainable practices are also good for the producer's pocketbook. That's good news for all of us.

Mark Ritchie, *President, Institute for Agriculture and Trade Policy*

INTRODUCTION

Sustainable and alternative farming were both productive and profitable almost as soon as researchers began studying them. In 1984, the National Research Council's Board on Agriculture set out to study the science and policies that have influenced the adoption of alternative agricultural production systems (National Research Council 1989) in the United States. The findings concluded that, "Farmers who adopt alternative farming systems often have productive and profitable operations, even though these farms usually function with relatively little help from commodity income and price support extension." Similarly, Charles Benbrook, Chair of the Board of Agriculture at that time, concurred with the above findings (National Research Council 1991). He argued that U.S. agriculture faced a diverse, dynamic, and complex set of natural resource, economic, and food safety problems, but that "a common set of biological and ecological principles, when systematically embodied in cropping and livestock management systems, can bring improved economic and environmental performance within the reach of innovative farmers."

This issue brief reviews the current economic and agricultural research on the financial impact of sustainable farming on farmers in the United States. If profitability means the measure of return to the farmer, is sustainable farming profitable? Have specific types of sustainable agriculture systems been found to decrease the cost of production and thus raise farm income? Do certain practices enhance farm productivity and thus profitability? How does income vary over time? Is it fair to compare conventional and sustainable agriculture? These are some of the inquiries explored throughout this literature review.

DEFINING SUSTAINABLE AGRICULTURE: A BRIEF INTRODUCTION

In the interest of placing this synthesis in a common framework (and not to provoke debate), sustainable agriculture will be defined according to the National Research Council's statements in the 1991 *Sustainable Agriculture Research and Education in the Field: A Proceedings*.

Sustainable agriculture, which is a goal rather than a distinct set of practices, is a system of food and fiber production that

- improves the underlying productivity of natural resources and cropping systems so that farmers can meet increasing levels of demand in concert with population and economic growth;
- produces food that is safe, wholesome, and nutritious and that promotes human well-being;
- ensures an adequate net farm income to support an acceptable standard of living for farmers while also underwriting the annual investments needed to improve progressively the productivity of soil, water, and other resources; and
- complies with community norms and meets social expectations.

The National Research Council also makes the distinction between sustainable agriculture and alternative agriculture, whereby alternative agriculture is the process of on-farm innovation that works toward the goal of sustainable agriculture. The same National Research Council report defines alternative agriculture as *any system of food or fiber production that systematically pursues the following goals*:

- more thorough incorporation of natural processes such as nutrient cycling, nitrogen fixation, and beneficial pest-predator relationships into the agricultural production process;
- reduction in the use of off-farm inputs with the greatest potential to harm the environment or the health of farmers and consumers;

- productive use of biological and genetic potential of plant and animal species;
- improvement in the match between cropping patterns and the productive potential and physical limitations of agricultural lands; and
- profitable and efficient production with emphasis on improved farm management, prevention of animal disease, optimal integration of livestock and cropping enterprises, and conservation of soil, water, energy, and biological resources.

For the purposes of simplification, the terms "sustainable agriculture" and "alternative agriculture" may be used interchangeably in this paper.

MEASURING THE PROFITABILITY OF SUSTAINABLE AGRICULTURE

The examination of the profitability of sustainable agriculture is complex and presents important challenges. For example, sustainable agriculture is site-specific by nature, therefore generalizations are difficult to make, especially across different geographic regions. Early research by the National Research Council found that, "farm surveys do not provide conclusive evidence regarding the advantages and disadvantages of farming methods because many factors are randomized or not constant"(National Research Council 1989).

Second, differences in climate and soil types may affect the cost of implementation and results of the practice of a specific sustainable agriculture system. For example, research may find that crop rotation can be cost effective for controlling weeds for certain crops in certain climates, but for crops in other agro-climatic regions, herbicides may be a more efficient alternative (National Research Council 1989).

Third, a systems perspective is essential to understanding sustainability in agriculture (Feenstra 2000). Evaluating only one aspect of the system, such as economic profitability, may not give a complete assessment of the benefits of a sustainable agricultural practice. The emphasis on the system rather than the part allows a larger and more thorough view of the consequences of farming practices on human communities and the environment. Along the same lines, evaluating one system (rotational grazing) on a sustainable farm that also organically grows feed and cash crops using crop rotation makes it difficult to assess the profitability impacts of any one practice on the whole farm.

In light of these complexities, this paper has been divided into several categories representing the different practices or system characteristics of sustainable agriculture. These include specific farming *practices* to build soil, manage soil fertility, and control pests. Also addressed are three alternative farming *systems*: small farms, organic production, and alternative livestock operations. Within this framework, the paper is organized into four sections. First, the paper reviews the research that has examined the profitability of sustainable agriculture as a whole, without regard to a specific production practice or system. The second section reviews research studies that focus on specific practices of crop rotations, conservation tillage, low external inputs, cover crops, and integrated pest management. Third, the paper discusses the research conducted on specific systems of sustainable agriculture, including small-scale farming, organic production, and sustainable livestock. The concluding section offers suggestions for future research.


NRCS

SECTION 1: COMPREHENSIVE RESEARCH STUDIES COMPARING CONVENTIONAL AND SUSTAINABLE SYSTEMS

Before delving into specific sustainable farming practices and systems, it is important to note several comprehensive studies pertaining more broadly to the economics of sustainable farming as a whole, rather than specific farming practices. Each study brings to light different aspects of profitability in sustainable systems, such as: the comparable profitability of some sustainable farming systems to their conventional counterparts while generating additional non-economic benefits; the impact of government program involvement on farm income; the impact of time in transitioning to sustainable farming systems; the divergence of labor distribution in alternative and conventional farming systems.

The first two studies compared sustainable farming to conventional farming by using an index to classify real farms into either of the two categories. First, the Northwest Area Foundation (1994) initiated a series of research projects aimed at examining the widespread adoption of sustainable agriculture practices and their impact on the economic, social, and environmental health of rural agricultural communities. Their research compared sustainable farms to conventional farms in Minnesota, Iowa, North and South Dakota, Montana, Idaho, Washington, and Oregon. Farms were classified as sustainable or conventional by an index that measured the extent to which a farm reduced purchased inputs, increased use of certain ecological practices, and demonstrated long-term commitment to sustainable practices. In general, while the research did not uncover many significant economic differences between conventional and sustainable farms, it did find that sustainable farms generated "respectable net incomes and economic returns." In fact, the foundation's findings reported that the use of sustainable agricultural practices was able to explain only a small portion of the differences in profitability between conventional and sustainable farms. In other words, profitability seemed to be influenced by factors other than employing specific sustainable farming practices.

A similar study from North Dakota State University by Sell et al. (1995) also compared sustainable to conventional farms using a similar index to classify farms. This time, farms were indexed by farming practices (non-use of herbicides, non-use of commercial fertilizers, use of natural fertilizers, and high cropping diversity), self-identification as a sustainable farmer, and farmer attitudes. Overall, the research found that conventional farms had greater equity, assets, and gross farm income than sustainable farms, and that conventional farms had net farm income that was nearly twice that of sustainable farmers. However, when the size of the farming operation was taken into consideration (the average size in acres of sustainable farms was lower than conventional farms), there was not a statistically significant difference in either gross farm income or net farm income between sustainable and conventional farms. Interestingly, both sustainable and conventional farms earned the largest source of their income from the sale of crops, yet the second largest source of income for sustainable farmers was from the sale of livestock and the second largest source of income from conventional farmers was from agricultural program payments. This suggests that diversification of sustainable farming has a positive impact on profitability.

The next two studies examined the potential community-wide financial impact of sustainable farming. First, in 1992, Dobbs and Cole looked at the potential economic effects on the local economy of converting a farm from a conventional to a sustainable system. The researchers conducted five case studies in five regions of South Dakota to estimate local economic effects by examining changes in off-farm purchased inputs and sales associated with the conversion. Overall, the total on-and-off farm personal income (returns to labor and management) effect of converting to a sustainable system was found to be higher in only one case without organic premiums, and in only one additional case with price premiums. (As will be discussed later in the section on organic

systems, a price premium is often awarded to organic agricultural products.) However, this study was limited in that it compared five real sustainable farms with a hypothetical conventional farm in all but one case. Yet, the conclusions argued that given more time for changes in sustainable production techniques and in the structure of farms and the rural economy, the overall effects of conversion to sustainable farming were likely to be more positive than the study's estimates suggested.

Second, Ikerd, Devino and Traiyongwanich (1996) evaluated the potential economic, environmental, and social performance of sustainable farming on a community in Putnam County, Missouri. The authors used a theoretical scenario of returning currently enrolled Conservation Reserve Program acres to either a conventional farming system or an alternative farming system, which assumed crop rotations, intensive management of inputs, reduced tillage, and intensively managed, pasture-based beef production. Applying data to these scenarios, the results found that the total positive community economic impact of returning land to an alternative system was 25 percent greater than a conventional system. Much of the economic differences arose from the livestock sector in the alternative farming system, where production and direct income potential were found to be significantly higher for the intensively managed grazing system. Yet the results do seem to correlate with that of Sell et al. (1995), in that both studies suggested the positive economic impact of sustainable livestock production.

The next three studies focused on comparing various combinations of cropping systems. First, Hanson et al. (1990) conducted a whole-farm analysis of a representative mid-Atlantic 750-acre commercial grain farm under conventional and low-input scenarios from 1981 to 1989. The four cropping schemes included: conventional grain without government programs (corn, soybeans, corn and soybeans); conventional grain with government programs (corn, soybeans, and 50 acres of set-aside); a low-input grain farm (small grain/forage legume, corn, small grain/forage legume, corn and soybeans) without commercial herbicides or fertilizers; a low-input grain farm participating in government programs (corn, wheat/red clover, and 38 acres of set-aside). They found that the conventional and low-input farms participating in the government programs were the most profitable scenarios. However, the low-input farm schemes had the lowest degree of income variability. Also, the low-input scenarios noted a dramatic increase in returns following the first four years. As with Dobbs and Cole (1992), it was suggested that it takes time for soil to develop positive attributes associated with a low-input approach. In this study, the low-input base scenario averaged a 46 percent increase in profit after the transition period. In addition, the study found that it took at least five additional years for the farm to recoup the lost profits from the transition period, such that the farmer would be as well off as if no change had been made.

Second, Ikerd et al. (1993) estimated and compared the farm level costs, returns, chemical use and soil loss for conventional and alternative systems of production for corn, soybeans, milo, small grains, cotton, peanuts, and tobacco for nine major crop-producing regions in the United States, using crop budgets from state extension specialists and data from the National Resource Inventory (NRI) of the Soil Conservation Service. Alternative crop production systems used different crop rotation patterns, tillage methods, and pesticide and fertilizer input levels based on soil erodibility identified by the NRI. In comparing the two types of systems, the study found that cash production costs for the alternative practice fell while total production and returns remained unchanged. In addition to reduced soil loss, the results also found decreased fossil fuel-based energy consumption, decrease in use of commercial herbicides, reduced use of nitrogen fertilization, but increased crop labor.

Third, Olsen (1998) conducted a study in eastern Nebraska to determine the profitability of five alternative farming systems: conventional, modified conventional, agro-forestry, organic, and a pasture-based beef farm. The conventional farm included a rotation of corn and soybeans with standard application of chemical fertilizers and herbicides. The modified conventional farm consisted of corn and soybeans, with sorghum and alfalfa added to the rotation using chemical fertilizers and herbicides. The agro-forestry system included the modified conventional system in addition to shelterbelts and tree crops. The organic system included the modified conventional system without chemical inputs. Vegetable crops were also added to the system. The pasture-based beef farm consisted of a completely grass system. The economic results showed that net farm income from the agro-forestry and organic systems exceeded the two conventional systems, even though the systems used a third less land. Their results suggested that farming systems could be developed to allow smaller farmers to be economically and environmentally competitive with larger conventional farms.

Finally, case studies were conducted by the Minnesota Department of Agriculture to examine the profitability of five integrated crop and livestock farms in Minnesota (Chan-Muehlbauer et al. 1994; Dansingburg and Gunnick 1996). These farms had diversified farming practices of raising livestock and growing crops, mostly for animal consumption. In general, the results found that “family-sized farms, employing environmentally sound, humane farming practices, can provide returns well above the average achieved by more conventional operations” (Chan-Muehlbauer et al. 1994). All five farms reported a higher net income return per animal (hog and dairy) and per acre as compared to other farms in the area, as well as reduced costs from external inputs.

Summary

Available studies suggest that sustainable agriculture systems may be just as profitable as, if not more profitable than, their conventional counterparts on a per-animal and per-acre basis. These studies also show that the passage of time can positively influence profitability results of farms transitioning to alternative farming systems, and therefore needs to be considered in assessing the impacts of agriculture.

SECTION 2: RESEARCH STUDIES EXAMINING PRACTICES OF SOIL BUILDING AND FERTILITY MANAGEMENT

Agricultural chemicals, especially nitrogen, phosphorus, and pesticides, have been linked to surface and ground water contamination, residue on food, and air pollution. Alternative systems have been utilized to mitigate the impacts of conventional agriculture (Faeth 2000). Soil building and fertility management include farming practices that combine the reduction of synthetic herbicides and fertilizers with soil building and nutrient management techniques such as cover crops and green manure, crop rotation, and tillage practices. The following section reviews some recent research on five sustainable agriculture practices under the umbrella of soil building and fertility management: crop rotation, conservation tillage, low-external-input farming, cover crops, and integrated pest management (IPM).

CROP ROTATION

Crop rotation is the annual or biannual variation in plant species within a given field and is basic to the manner in which farmers practice low-input, sustainable agriculture. Crop rotation serves a variety of purposes in the field, including effectively reducing disease, insect pests, and prevalence of particular weed species (Zimdahl 1993; Karlen et al, 1994). Crop rotation can also have a beneficial effect on soil fertility, since different rooting structures extract nutrients at varying depths, and legume species (when included or in the case of cover crops) can add nitrogen to the cropping system (Cruse and Dinnes 1995). Looking at profitability of crop rotations is complicated and can be difficult to measure.

According to Gebremedhin and Schwab (1998), "Profitability of a rotation system needs to be compared with the profitability of a continuous cropping system, taking into account the yields of the new crops in the rotation. Also, alternative systems may have different effects on production costs and yields of crops involved, requiring the computation of the comparative profitability of each system."

The following studies assess the potential economic impact of adding additional crops to a cropping system as compared to a mono-crop or two-crop rotation for grains, soybeans, and potatoes.

In 1982, McQueen et al. used a linear programming model to look at the effect of seven different crop rotations and four management practices (fall plowing only, spring plowing only, cover cropping, and no-till) on Arkansas farm profitability. The most profitable system they found was a double cropping of soybeans and wheat with spring plowing only. However, they generally concluded that net returns to Arkansas farmers would increase by 28 percent by changing to crop rotations that lowered soil loss.

A number of studies have looked at the effects of diversifying a continuous corn or corn-soybean crop rotation. First, Hesterman et al. (1986) compared the economic viability of different two-year crop rotations that included alfalfa-corn, soybean-corn, and corn-corn in Minnesota. The study showed that an alfalfa-corn sequence, with the alfalfa under a three-cut system, was the optimum rotation when compared to continuous corn or soybean-corn systems.

Second, Diebel et al. (1995) conducted an economic comparison of conventional and alternative cropping systems for a northeastern Kansas farm. They compared seven different cropping systems ranging from conventional continuous corn, and corn-soybean, to alternative rotations containing alfalfa/oats/alfalfa/alfalfa-wheat-soybeans. They found that an alternative system of wheat-clover-sorghum-soybean was the most profitable system with or without government programs. They also found that the profitability of the systems containing alfalfa depended on the volatility of the alfalfa market.

Third, Jones (1996) examined the short-term economic returns of a combination of corn-based rotation and cover crops using different fertility sources. He compared the returns over variable costs of continuous corn and corn-corn-soybean-wheat rotations. Based on three years of data, he found also that the profitability of the crop rotation was dependent on market prices, in this case of wheat and soybeans relative to corn.

Fourth, Ghaffarzadeh (1997) looked at the economic benefits of adding oats intercropped with berseem clover to corn-soybean rotations to enhance the crop diversity of a corn-soybean rotation. The researchers found that berseem clover enhanced both oat and corn yields and profitability while having no significant effect on soybeans. They attributed the increase in production to the nitrogen contributions and enhanced soil quality provided by the berseem clover.

Fifth, in North Carolina, King and Hoag (1998) compared the economic profitability of different cropping systems for continuous corn, a two-year corn soybean rotation, and four-year rotation (corn-wheat-soybean-corn-clover-hay). The results found that the four-year rotation was more economically profitable. The researchers added that the increased return in more extensive rotations was due primarily to the presence of more profitable crops in the system rather than an increase in yields due to a more lengthy rotation, as was the case with Ghaffarzadeh (1997).

Finally, a longer-term study run by the Center for Integrated Agricultural Systems in Wisconsin (2000) compared the profit margins of three cash-grain cropping systems from 1992 to 1998 ranging in species diversity from: continuous corn, corn-soybean, and corn-soybean-wheat/clover system. The study found that the diversified grain system had consistently better returns than the continuous cropping of corn (for two of the three trial sites). However, they also concluded that economic profitability was contingent on changes in market prices.

Several studies were also reviewed for the impact of crop rotation on potato production. Lazarus et al. (1984) conducted a study in Long Island, New York, to determine the economic impact of crop rotations that reduce potato acreage. They compared the return from continuous potatoes with those from potato-based rotations that included corn, wheat, safflowers, soybeans, dry beans, and cauliflower. They found that potato-cauliflower would be a viable alternative to continuous potatoes.

Later, a Maine study by Westra and Boyle (1990) looked at the profitability of continuous potatoes compared to several alternative potato rotations. The rotations included: three years of potato–one year of oats, two and three years of potato–one year of oats/underseeded with clover, a potato–oat rotation/underseeded with clover and processing peas, three years of potato–one year of barley, two and three years of potato–one year of barley/underseeded with clover, a potato–barley rotation/underseeded with clover, a potato-processing peas rotation, and three years of potatoes–one year of processing peas. The study found that with the exception of the three-year potato-oats and three-year potato-barley rotations, all other potato-based rotations had higher returns than continuous potatoes. The three-year potato-processing peas had over twice the returns as continuous potatoes.

Finally, a central Alabama study by Guertal et al. (1997) analyzed the effect of various rotations on yield and quality of sweet potatoes. The rotation systems considered were continuous sweet potato, sweet corn-sweet potato, soybean-sweet potato, two-year sweet corn-sweet potato, two-year bahia grass-sweet potato, and soybean-sweet corn-sweet potato. They concluded that sweet potatoes in rotation had, on average, a 40 percent higher marketable yield than continuous sweet potatoes. Further, sweet potatoes rotated with two-year bahia grass gave the highest annual yield and cumulative yield that was as high as continuous sweet potatoes.

Summary

While crop productivity is generally enhanced under different crop rotations as compared to continuous cropping within one field, profitability of employing certain crop rotations, especially those involving corn, was more directly an effect of prices of the crop at the time of marketing. Potato yield and profitability tended to be higher in potato-based rotations than in continuous potatoes. Differences in capital investments in machinery and possible infrastructure on the farm, plus off-site beyond the farm boundaries (e.g. societal welfare) should also be considered in influencing optimal crop rotations (Gebremedhin and Schwab 1998). Also, environmental aspects that are accrued to society were not considered in most of the studies. More advanced work on methods to quantify the value of these environmental benefits is needed to more accurately depict farm profitability.

CONSERVATION TILLAGE

Conservation tillage is a reduced-tillage system in which crop residues are left on the soil to minimize water runoff and soil erosion (Foth 1990). Conservation tillage can reduce production expenses for labor, fuel, oil, and repair costs associated with machinery use. Reduced-till and no-till practices can improve soil quality by increasing water infiltration and reducing water loss due to evaporation. Conservation tillage can also enhance yields by reducing soil loss and minimizing soil compaction that results from machinery use (Grebremedhin and Schwab 1998). The conservation tillage studies reviewed focus primarily on corn, sorghum, and cotton.

Several studies have examined the economics of conservation tillage on grains and soybeans. First, Doster et al. (1983) looked at economic returns of various tillage practices (fall plow, spring plow, spring disk, ridge-till, and no-till) for corn and soybeans on three different soil types in Indiana. They found that the ridge-till systems produced equal or greater returns than other systems on all soil types. They also found that on lighter soils in Indiana, reduced-tillage (tillage-plant and fall chisel) systems were more profitable than conventional tillage. The no-till system produced net returns comparable to those with reduced tillage on well-drained sloping soils. (In contrast, Hesterman et al. (1988) found no significant difference in corn yield in Michigan between conventional-tillage and no-till systems on both poorly drained and coarser soils.)

Then, Domanico et al. (1986) modeled a 300-acre crop (1/3 corn and soybeans, 1/3 hay, 1/3 small grains) and livestock (beef) farm under alternative management practices in Pennsylvania. The alternative practices included: conventional, organic, and no-till production—all with and without the use of overseeding and cover crops. They also compared profitability with and without the constraints of soil erosion. Prior to constraining soil erosion, no-till was found to be the most profitable, with conventional, then organic, falling behind. No-till also remained the most profitable at low levels of soil erosion (under five tons per acre). However, the organic system was more profitable than the conventional at low levels of soil erosion.

Fletcher and Lovejoy (1988), as cited by Fox et al. (1991), found that no-till corn produced higher net returns per acre than conventional tillage, but profitability was more dependent on the previous crop than the soil type. Ridge-till had an even higher net return than the no-till plots.

Next, a North Carolina study looked at the longer-term effects of continuous conventional tillage, continuous no-tillage, and alternating conventional tillage with no-tillage practices on yields in continuous corn and corn-soybean rotation (Wagger and Denton 1992). Over a five-year period, they found that corn yields from no-till were 4 percent—27 percent higher than continuous tillage. They attributed the increase in yield to the higher soil moisture that was the result of greater residue cover.

Two studies were reviewed from South Dakota. First, Dobbs, Leedy and Smolik (1988) compared conventional ridge-till and an alternative production system for grain farms (small grain and corn–soybeans) in South Dakota. No synthetic fertilizers or herbicides were used in the alternative system. In one study, ridge–till was most profitable, followed by conventional. In the second study, incomes from all the systems were substantially lower and differentials among the systems were smaller; however, alternative systems had the highest net profit.

Second, Smolik and Dobbs (1995) compared the economic performance of a low input system (no commercial fertilizers or pesticides, no moldboard plowing), a conventional system, and a reduced tillage system in both a row crop and small grains system in South Dakota over five years. They found that the alternative systems were economically more competitive. The five-year average net income after overall costs, except management, was highest for the alternative systems in both studies. Also, the overall net returns provided less-variable returns compared to the more conventional systems.

Lui and Duffy (1996) compared tillage systems and profitability, using farm data from the Iowa MAX program (Farming for Maximum Efficiency) for 1992 and 1993. They compared conventional till, no-till, reduced-till, ridge-till and mulch-till systems for continuous corn and a corn and soybean rotation. For corn in both years, no-till and ridge-till were equally profitable and significantly more profitable than conventional tillage. For soybean, reduced-till, ridge-till, and no-till had higher profits than conventional till. No-till was most profitable in 1993. Operating costs were a major factor in profit-per-acre differences between conservation tillage and plowing.

Kelly et al. (1996) examined the environmental and economic tradeoffs of different crop rotations on the USDA's Beltsville Agricultural Research Center. They collected field data comparing a conventional two-year corn-winter-wheat/soybean rotation, a no-till rotation similar to the conventional, a zero tillage rotation using cover crops, and organic crop rotations with varying levels of manure applications. They also used the EPIC (erosion-productivity impact calculator) model to simulate economic and environmental effects over a 30-year period. They found that the no-till rotation provided the greatest net returns, dominated in regard to loss of nitrogen, and was also high in phosphorus and erosion loss prevention. However, the pesticide hazard was very high, suggesting the trade-off between pesticide hazard and environmental considerations.

Several studies have looked at the impact of conservation tillage on profitability in sorghum production. Williams et al. (1987) took price data from 1973–1983 and coupled it with 1984 production costs to determine expected returns of different cropping systems on a 2,000-acre dryland farm in Kansas. They found that net returns were highest for a reduced-tillage wheat-sorghum-fallow system whereas the conventional wheat-fallow system had negative net returns. The reduced-till wheat-sorghum-fallow system also had the lowest coefficient of variation in economic returns. And Harman et al. (1985), cited by Fox et al. (1991), concluded that both dryland and irrigated sorghum were more profitable using no-till as compared to conventional tillage.

Roth and Classen (2000) also looked at the profitability of alternative production strategies for dryland wheat and grain sorghum in Kansas in 1995 and found that a rotation of reduced-till sorghum-no-till wheat provided the highest yields for sorghum while maintaining average yields for wheat. This system also had the lowest input costs as compared to the continuous crops of conventionally tilled and reduced-till wheat and sorghum fields.

Effects of conservation tillage on cotton have also been frequently studied. First, Kelling et al. (1989) reported that conservation-tillage systems for cotton and terminated wheat with cotton in the Texas southern highland plains were more profitable than conventional-tillage systems in both irrigated and dryland systems.

A fourteen-year study in Tennessee on no-till versus conventional tillage found that cotton lint yields in no-tilled fields were as high as conventionally tilled cotton (Hart 1996). Huskins and Gwathmey (1996) also looked at effects on cotton in Tennessee and found no-till cotton averaged higher cotton lint levels. Over a four-year period there was an average increase of 7 percent in average cotton lint for no-till cotton when compared to conventional tillage.

A study of thirteen no-till cotton producers in Mississippi found that ultra-narrow-row cotton production could result in larger net returns per acre than conventional production practices (Parvin et al. 2000). The researchers added that profitability was more notable on marginal lands without the highest yield potentials. The researchers also associated dry weather with enhanced yield. Parvin and Cook (2000) conducted a second Mississippi study of ten no-till cotton producers and found that no-till cotton production could result in larger net returns per acre than conventional tillage. However, the researchers suggested that soil quality could be a factor on effects of profitability in conservation tillage and suggested additional analysis on a larger sample of commercial no-till growers on better cotton soils.

Finally, Bryant (2000) reviewed the economic results from several studies of conservation tillage on cotton in Arkansas, Louisiana, Mississippi, and Tennessee. Bryant found that the results of the studies were mixed, but most of the research studies found only small differences in costs between conventional and no-till cotton production. While some of the studies found no differences in yields, others found increases associated with no-till, especially over time. He concluded that no-till cotton showed the most promise in Louisiana, Mississippi, and Tennessee, while ridge tillage showed promise in Missouri. In Arkansas studies, however, he found no clear economic advantage or disadvantage associated with any of the tillage systems. From this comprehensive literature review, Bryant concluded that the primary economic benefit of conservation tillage is the reduction in labor and machine hour use while having minimal impact on crop yields.

Summary

Research studies have shown that conservation tillage can result in either equivalent or higher yields as compared to conventional tillage, especially in corn and cotton in certain geographic locations, while reducing costs due to savings in energy and equipment expenditures. As with the other practices, benefits of conservation tillage are site-specific and depend on soil type, topsoil depth, choice of cropping system, level of management, and local climate conditions (Fox et al. 1991). Conservation-tilled crops do particularly well on coarsely textured soils and in areas with lower weed populations. Conservation tillage has also been shown to be even more effective on marginal lands and in areas with drier climates.

LOW EXTERNAL INPUT FARMING

Low-input farming refers to purchasing fewer off-farm or external inputs, typically fertilizers and pesticides, while increasing on-farm inputs such as manure, cover crops, and management (Norman et al. 2000). This category refers to research studies that compared crop productivity with reduced and more concise applications of synthetic fertilizers and herbicides, thereby reducing production costs. The following studies have looked at specific farming practices that reduce nutrient use, be it through the type of application or the amount of fertilizer applied in corn and soybeans, small grains, and potatoes.

First, in a broad study looking at the profitability of low-input systems, Madden and O'Connell (1990) reported on an eleven-year study of Illinois farmers that examined records from 161 farms. They found that farmers using the highest amounts of purchased inputs per acre harvested more bushels but earned less profit per acre compared with farmers using less purchased inputs per acre. The farms were ranked according to their per-acre expenditures on commercial fertilizers and cultural chemicals. On average, the high-input group had $37 per acre more gross income than the low-input group, but their net income per acre was $29 lower than the low-input group.

Second, a number of studies have examined the profitability of low-input practices on corn and soybean farms. In Iowa, research by Chase and Duffy (1991) conducted an economic comparison of conventional and organic (reduced chemical) farming systems from 1979 to 1989. Specifically, it compared three cropping systems: a two-year corn-soybean rotation, continuous corn, and reduced chemical input corn-oats-alfalfa rotation. The results indicated that the returns to the reduced chemical practice were lower than the corn-soybean rotation, but they were still competitive and outperformed the continuous corn system. This result was partially based on a lower cost of production for the reduced chemical system.

A study at the University of Wisconsin examined the effectiveness of reduced-rate applications of soil-applied herbicides on corn and soybeans for 1990 and 1991 at four different Wisconsin experiment stations (Doll et al. 1992). The study found that lowering the pre-emergence application rate of broadcast sprays by 50 percent, followed by one timely row cultivation, resulted in no difference in corn yields as compared to the regular rate, but it did reduce input costs. The net result could make the practice more profitable. Similarly, the research found that banding applications at a reduced rate of 50 percent of the standard herbicide application with timely cultivation caused no decrease in yields. However, researchers noted that increased management is necessary when experimenting with reduced applications and may be less effective depending on weed type.

In Ohio, Munn et al. (1998) compared conventional practices using fertilizers and herbicides for corn, wheat, and soybean crops with a low-input system using no synthetic fertilizers. The low-input practices included crop rotation (corn, soybean, and wheat—with medium red clover green manure). The alternatively grown wheat was more profitable than that grown conventionally; however, the alternative systems of corn and soybeans were not. The researchers suggested that without a price premium for using a reduced input system for corn and soybeans, low-input practices were not financially worthwhile.

Most recently, Funk et al. (1999) also conducted an economic analysis of a corn-soybean crop rotation under different input combinations of commercial fertilizer and insecticides in South Central Texas. The combinations of fertilizer-insecticide-no herbicide, fertilizer-no insecticide-herbicide, and fertilizer-no insecticide-no herbicide provided the next highest returns over the two-year rotation. The researchers noted the importance of nitrogen in the corn rotation. Researchers concluded that limited-input crop rotations, which fall between the two extremes of conventional agriculture (which utilizes all three inputs) and organic agriculture (which strives to use none of the inputs), deserve further attention as possible production alternatives. As a result, the study's authors recommended

that future research explore varying degrees of input combinations, other than the recommended amount and none at all, as was done in their study.

Another set of studies has focused on small grains. Goldstein and Young (1987) compared conventional and low-input systems for grain and legume production in the Palouse region of the northwestern United States. The low-input system used no synthetic fertilizer and no pesticides on medic or winter wheat. Recommended rates of pesticides were applied to peas only. The conventional system was a four-year wheat-barley-wheat-pea rotation with fertilizers and pesticide inputs each year. The low-input system was more profitable than the conventional system when crops were valued at current market prices, but when target prices were used, the conventional system was more profitable.

Jacobson et al. (1997) looked specifically at the response of no-till wheat to fertilizer sources and placement methods in Montana. They examined different standard and experimental nitrogen and phosphorus sources at two rates and in different placement methods. The results found that banding nitrogen and phosphorus together at lower rates provided the greatest wheat yields (as compared to broadcasting nitrogen), thereby providing an economic incentive to band fertilizers. Like Doll (1992), they added that precipitation timing and quantity were geographically dependent and greatly influenced fertilizer use and other agronomic management strategies.

Finally, a few of the studies reviewed have examined profitability of low-input farming on vegetable farms. In Connecticut, Bravo-Ureta et al. (1995) evaluated nitrogen application on yield in sweet corn production and found that the most profitable rate of nitrogen application on sweet corn was 112 kg/ha (compared to the state average of 169 kg/ha). The study noted that changes in application are highly variable depending on location, prior crops, and variations in precipitation, but reducing nitrogen applications does offer economic incentives for farmers to change their current practices. Alvarez and Sanchez (1995) also compared banding versus broadcasting of phosphorus on sweet corn and lettuce. They found that banding phosphorus not only reduced costs dramatically in both crops, but also increased yields. The researchers concluded that banding phosphorus would be even more profitable if the effect of reduced nutrient loading on the water supply was able to be quantified.

Bellinder et al. (1996) looked at reduced rates of herbicide use, following tillage, in conventional and reduced-tillage potato production in New York State. They found that half the standard rate of two different herbicides provided control to the standard recommended amount in both the conventional and reduced tillage systems, thereby increasing the potential profitability of potato production in reduced-input systems.

In a longer-term and more comprehensive study, Gallandt et al. (1998) compared alternative pest and soil management strategies of three different Maine potato production systems. The study contrasted amended (using beef manure and culled potato compost and extended crop rotation) and unamended soil strategies and conventional vs. reduced-input vs. bio-intensive pest management strategies. The economic analysis indicates that from 1993 to 1996 the reduced-input system had greater returns over variable costs than the conventional and bio-intensive pest management systems. Overall, the conventional system had greater returns than the reduced-input system; however, the greater returns were not high enough to offset the conventional system's higher variable costs. In addition, the reduced-input practice saw improvements in soil quality, and, similar to Bravo-Ureta (1995), a decrease in phosphorus overloading in the low-input system.

Summary

The main objective of low-input farming is to reduce the amount of off-farm, purchased inputs, typically herbicides and fertilizers, while increasing overall profitability. The studies reviewed found that reduction of inputs through banding of fertilizers (versus broadcasting) and decreased application rates of pesticides can be economically profitable, depending on geographic location, precipitation, and crop and weed species, as well as the farmer's willingness to experiment within his or her farming system. The studies also indicate a need to value environmental externalities, such as reductions in nutrient loading (nitrogen and phosphorus) in water sources, for a true assessment of profitability of the low external-input systems.

COVER CROPS

Cover crops are living ground covers grown between periods of regular crop production. They offer a number of benefits to the soil, such as the reduction of soil erosion, the addition of organic matter, improvements in soil conditioning and improved water-use efficiency. Legume cover crops also provide soil with nitrogen in their decomposition of organic matter. The benefits from cover crops may increase farm profitability by reducing costs, such as reducing the need for commercial fertilizer, or by increasing yield through their effect on soil quality and fertility (Gebremedhin and Schwab 1998). Many of the profitability studies assessing the effectiveness of cover crops have been in field corn, fresh market tomatoes and other miscellaneous horticultural crops.

The following four studies looked at the use of vetches as cover crops in no-till corn production. First, Ott and Hargrove (1989) examined the profitability of using different cover crops (crimson clover, hairy vetch, winter wheat and winter fallowing) in no-till corn production in Georgia. They found that the substitution of hairy vetch for nitrogen in a no-till system was as economically profitable as conventional no-till corn with nitrogen inputs, but was contingent on mild winter temperatures,

so as to not reduce the hairy vetch's stand. The researchers also added that the leguminous cover crop reduced soil erosion and improved soil structure and fertility over time. Although difficult to quantify, the researchers argued that such factors needed to be considered in economic assessment.

Several years later, Hanson et al. (1993) looked at the profitability of no-till corn following three different cover crops in two geographic locations (the Coastal Plain and the Piedmont) of Maryland between 1986 and 1988. When comparing hairy vetch, winter fallow and winter wheat, they also found hairy vetch to be the most profitable on the Coastal Plain. However, yield advantages were not as great in the Piedmont. Researchers hypothesized the harsher Piedmont climate reduced the hairy vetch's top growth. The higher level of organic matter (therefore residual nitrogen) already available in the Piedmont soils reduced the impact of the cover crop's contributions. Their findings were similar to that of Ott and Hargrove (1989)—hairy vetch in no-till corn can be potentially valuable, depending on geophysiographic factors.

Ess et al. (1994) then examined the economics of legume cover crops (hairy vetch and big flower vetch) in corn production in Virginia. They compared conventionally grown corn with no-till or disked cover-cropped treatments. Based on their two-year results, the researchers concluded that the winter-annual cover crops in no-tillage and reduced-tillage systems provided adequate nitrogen to equal the "standard" corn production practices using manufactured nitrogen fertilizer. They also added that use of the cover crops significantly lowered the energy expenditures in corn production as compared to the cropping systems that relied on manufactured nitrogen.

A fourth study compared the profitability and economic risk of four corn-soybean rotations over three years at the USDA Sustainable Agriculture Demonstration Site in Beltsville, Maryland (Lu et al. 1999). Each system consisted of a rotation of corn-winter wheat/soybeans with varying types of tillage and inputs: no-tillage with commercial fertilizers and herbicides; no-tillage with a crown vetch living mulch; no-tillage with a winter annual cover crop (hairy vetch); and a reduced tillage, manure-based system without chemical inputs. Overall, they found the cover crop system to be most profitable, followed by the no-till in a given year. However, the no-till system was consistently more profitable than the cover crop system. Like prior research studies, they noted that in areas of colder winters or drier climates cover crops may not be as profitable.

Only one study examining the economics of cover crops for small grains was reviewed. Painter (1991) conducted a case study comparing conventional to low-input cropping systems using cover crops in the dryland wheat region of eastern Washington. The conventional system consisted of a winter wheat/spring barley/summer fallow rotation; conventional tillage was used, as were synthetic fertilizers and herbicides. The low-input cropping system rotation consisted of a wheat/pea/green manure rotation with occasional rotations of grass, and used green manure crops for fertilizer and minimal herbicides for the dried peas. Without crop subsidies and deficiency payments, the alternative, low-input system was productive; however, crop subsidies on barley and summer fallow made conventional crops more economically profitable. They also added that the low-input system significantly reduced erosion (because of the heavy emphasis on green manure crops) and a limited potential for environmental pollution because of the lack of chemical fertilizers and limited pesticide use.

Two reviewed studies looked at the impacts of cover crops on tomatoes. Abdul-Baki and associates looked at cover crop mulch in alternative low-input systems for fresh market tomato production in Maryland (Abdul-Baki and Teasdale 1993; Adbul-Baki et al. 1996). They compared the effects of cover crops (hairy vetch, crimson clover, rye, and subterranean clover) to no cover and the black polyethelene in conventional systems. The cover-crop systems used the winter annual cover crops to fix nitrogen, recycle leftover nutrients, produce biomass, and prevent soil erosion. They found that tomato systems using the cover crops were consistently and significantly more productive than those using conventional black polyethylene or no cover at all.

Chellemi et al. (1999) also compared productivity and input costs of conventionally grown market tomatoes in Florida to an alternative low-input system that used cover crops with reduced amounts of plastic mulch and methyl bromide. The alternative system transplanted tomatoes into a strip-tilled bahia grass pasture, with sod in between the rows as a living mulch. They found that while yields were 6.5 t/ha greater under the conventional system, net return was $568/ha greater in the alternative system in Florida due to lower input costs.

Finally, two studies examined the profitability of different cover crops on brassicas and muskmelon. Schonbeck et al. (1993) studied the profitability of cover crops on brassicas in the northeastern United States. They found that the cover crops of vetch and vetch plus rye consistently produced higher broccoli and cabbage yields than rye alone as a cover, or no cover at all. However, profitability was contingent on soil type. Crop yields were not as productive under cover crops on silty loam soils as they were on sandy loam soils. Singogo et al. (1996) looked at the effects of four cover crops (alfalfa, hairy vetch, Austrian winter pea and winter wheat) on muskmelon production in Kansas. They found muskmelon to be equally profitable under legume cover crops as compared to muskmelon grown with synthetic fertilizers.

Summary

Cover crops have been found to be profitable in grain crops and a limited number of horticultural crops. Studies of legume cover crops have found that the nitrogen from legumes, as compared to purchased nitrogen, is equally if not more effective in improving yields in some crops. However, overall success is contingent on weather, particularly winter climate, moisture, and soil type.

INTEGRATED PEST MANAGEMENT

Integrated Pest Management (IPM) is not always considered to fall under the umbrella of sustainable agriculture. For example, research by Jaenicke (1997) for the Henry A. Wallace Institute for Alternative Agriculture argued that typical research studies conducted on IPM do not necessarily address the issue of reducing pesticide use. Jaenicke cited the example that in January 1997 the USDA's Animal Plant Health Inspection Service approved more biotechnology field trials for breeding herbicide-tolerant plants than for breeding insect-resistant plants. He argued that such research serves pesticide manufacturers, but not the general public, who wants farmers to rely on fewer pesticides. However, in a recent commentary on IPM, entomologists argued that "Integrated" Pest Management was still a "farce" after three decades of research experience (Center for Integrated Agricultural Systems 2000). The center contended that federal policies need to promote a more integrated understanding of IPM, address how its adoption can be measured in the field, and provide incentives to encourage such adoption. The center also recommended improving broad-based training in land-grant institutions, increasing long-term financial support for IPM research, and increased emphasis on true pesticide reduction. As such, it is worth briefly noting some research that has attempted to evaluate its economic impact on farming.

IPM is a management approach that emphasizes biologically based pest controls, such as establishing natural predators and beneficial insects and breaking pest cycles. It is an approach that encourages natural control of pest populations by anticipating pest problems and preventing pests from reaching high levels of economic damage. Some IPM techniques include enhancing natural enemies, planting pest-resistant crops, adapting cultural management, and using pesticides judiciously (Fernandez-Corenjo and Sans 1996). For insect control, IPM systems rely on the precise application of specific pesticides. For disease control, IPM relies more heavily on the use of rotations, planting dates, weather monitoring, and resistant varieties as its most common components. IPM is a complex, knowledge- and information-

intensive technology that is less precise than many of the farming methods already discussed in this paper. Assessing the effects of IPM programs is difficult because of the differences across regions, time, and types of crops grown.

Because of this complexity, limited research projects have looked at the profitability of IPM. It has been suggested that the difficulty in measuring and valuing IPM impacts may account for the scarcity of studies estimating the economic returns in IPM. Furthermore, many forms of IPM involve information use or slight changes in rationale for management practices, making it more difficult to quantify (Swinton and Day 2000). It has also been argued that because IPM programs are grounded in economic threshold principles, they almost always result in increased returns for growers. IPM is thought to be inevitably achieved through better knowledge of pest and predator relationships, more accurate times, better measured pesticide applications that reduce overall pest control costs, and improved crop quality.

Madden and Dobbs (1990) conducted a literature review of integrated pest management in 1990 and also found that it was economically promising, but IPM did not always decrease the use of chemical pesticides. Their review concluded that rotating legumes and minimizing or eliminating synthetic chemical inputs offered profitable components of an IPM system.

In 1998, Fernandez-Cornejo et al. summarized the research literature exploring the impact of IPM on pesticide use, yields, and profits, to update a review previously completed by Norton and Mullen in 1992. Norton and Mullen first reviewed the economics of IPM programs in cotton, soybeans, vegetables, fruits, peanuts, tobacco, corn, and alfalfa in order to determine the link between adopting IPM and reducing pesticide use. Pesticide use decreased on average for seven out of eight of these commodities or commodity groups (corn was the exception). Yields and net returns increased on average in each of the eight groups. Fernandez-Cornejo summarized 51 studies (including the work of Norton and Mullen) and found that IPM adoption was associated with a reduction in pesticide use by 15 percent and an increase in net returns. The author noted that results were not uniform. Like Madden and Dobbs (1990), he found that when scouting was used alone, pesticide use tended to increase in many cases. However, when scouting was used in combination with other IPM techniques, decreased pesticide use was more often the case. Yields and profits, especially in the case of cotton and corn, also tended to increase.

Summary

Integrated Pest Management profitability is site-specific and contingent on the type of crop grown, pests faced, and time available. Differences in the crop value, pests, the availability of reliable IPM techniques, and necessary time demands have all been found to influence profitability (Fernandez-Cornejo et al. 1998). Some studies have indicated that IPM offers potential to increase net returns of farmers. In order to do so, an increased understanding of IPM, as well as research methodologies to measure IPM benefits, are necessary in order to increase applicability in sustainable agriculture communities.

SECTION 3: RESEARCH STUDIES EXAMINING SYSTEMS OF SMALL FARMS, ORGANIC FARMING, AND SUSTAINABLE LIVESTOCK PRODUCTION

Beyond specific sustainable agricultural practices, such as various forms of crop rotation and conservation tillage, sustainable farms can also be characterized by an alternative farm system. Small-scale farming or family farms, organic production systems, and sustainable livestock production systems are all examples of alternative sustainable farming systems. The following section will review the recent literature on the profitability of these systems.

SMALL FARMS

A common characteristic of sustainable farms is that they tend to be smaller in size, or at least family farms. Several studies have found this size tendency to be true. Research from the Northwest Area Foundation (1994) found that overall, sustainable farmers tend to farm less land than conventional farmers. Also, Sell et al. (1995) found in a study comparing sustainable farms to conventional farms in North Dakota that the average size of sustainable farms, in terms of acres, was smaller than conventional farms. The same seems to be true for dairy farms. Jackson-Smith, Douglas et al. (1996) found in their survey of dairy systems in Wisconsin that most farms employing intensive grazing have much smaller-scale farm enterprises (in terms of both cows and acres) than do confinement operators. The study noted that because smaller operators invest less in confinement buildings and equipment, they may be more likely to adopt an intensive grazing approach. However, sustainable farmers do come in all sizes. For example, in Minnesota, North Dakota, South Dakota, and Montana sustainable farms range in size from less than a few hundred acres to over a thousand acres.

There has long existed the proposition that large farms are more efficient than small farms, and many proponents of this proposition point to the growth in size and decrease in number of farms over the past half-century as evidence. Yet a growing body of literature points to the contrary. Hallem (1991) completed a review of empirical studies of farm size and efficiency and found that there do not seem to be significant economies of scale in the production of individual crops for, at least, average-size farms.

In 1997, Peterson examined the relationship between farm size and efficiency in the U.S. Corn Belt, where farm size was measured in terms of total sales. The results concluded that small farms are just as efficient as large farms and that as farm size increases, farms actually become *less* efficient. Factors that can influence the unit cost of agriculture, other than farm size, include quality of land and managerial skill, contributions of the farm dwelling to output, and the impact of off-farm employment on output and production costs.

Some studies, which examined the economics of sustainable agriculture, also looked at how farm size influences profitability. The results from the Minnesota Department of Agriculture's study of four sustainable farms in Minnesota found that the high net profits that were attained by the farmers were achieved on substantially less acreage than that of other area farms. In addition, the Northwest Area Foundation research mentioned above also found that among sustainable farms, farms with higher returns were not always found to be larger in size, in terms of acreage. In fact, not only do sustainable farmers tend to farm less land, but they also are more likely to own it. This key finding led to one of the report's conclusions that the ownership of farms can play an important role in adoption of sustainable farms. The report stated that short-term land rental could discourage long-term management strategies and encourage conventional practices that focus only on producing high yields. This finding also raises the question of whether or not it is farm size or farm ownership that influences the adoption of a sustainable agriculture practice.

Looking more specifically at the impact of small-scale systems on organic agricultural production, one recent study by Hanson, Lichtenberg and Peters (1997) compared the profitability of the organic and conventional cash grain rotations since 1982. Overall, it was found that the organic rotation could generate total returns per acre comparable to those of the conventional rotation. But interestingly, the study also found that the organic grain rotation becomes less profitable than the conventional rotation as the farm size, measured in acres, gets bigger.

Taking this analysis one step further, work on the economics of organic cropping systems by Smolik and Dobbs (1991) and Smolik et al. (1995) allowed Dobbs (1999) to conclude that organic farming can have potentially favorable effects on the farm size and structure of agriculture. Dobbs states that, "wide spread organic farming systems would tend to halt or at least slow the trend of ever increasing farm size." This work has shown that net returns to labor and management could allow organic farmers to meet family income goals with about the same or slightly less land than conventional farmers.

One of the major proponents of the argument that sustainable farms tend to be smaller is Peter Rosset (1999) at Food First/The Institute for Food and Development Policy, who argues that "small farms are 'multi-functional' —more productive, more efficient, and contribute more to economic development than large farms." He further states that small farmers make better stewards of natural resources, conserving biodiversity and better safeguarding the sustainability of production. He also argues that there is no reason to believe that large farms are more efficient than small farms (Rosset 1999 and Peterson 1997). He states, "the consensus position is probably that very small farms are inefficient because they can't make full use of expensive equipment, while very large farms are also inefficient because of management and labor problems inherent in large operations." Further, he states that the symbiotic relationship between farm size and productivity "constitutes a core argument for efficient management of natural resources and for policy design to remedy imperfections in agriculture and agriculture-related markets."

Summary

The reviewed research suggests two conclusions. First, there is a tendency for sustainable farms to be smaller in size. Second, small farms can be as economically efficient as large farms.

ORGANIC FARMING

One type of sustainable production system that is primarily based on producing products in an environmentally sound way is organic farming. As with the definition of sustainable agriculture, there is no single accepted definition of organic production in the United States. However, one aspect is clear: organic agricultural production is grounded in principles of environmental sustainability. The National Organic Standards Board (NOSB) adopted the following definition of organic agriculture at its April 1995 meeting in Orlando, Florida.

> "Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony."

Organic agriculture also differs from the other types of sustainable agricultural programs in that its product often earns the farmer a premium price. Thomas Dobbs (1998) recently collected information on the prices paid for organic corn, soybeans, wheat, and oats and found them all to be consistently higher than their conventionally grown counterpart. With this framework in mind, the following explores the extent to which organic agricultural systems have been found to be profitable across the United States. The review first examines a few select studies and then summarizes the findings of other literature reviews on the topic. (It is important to note that many of the studies reviewed did not distinguish between organic practices and certified organic production, and quite often studies used the word "organic" to describe the low-input system because it was thought to be consistent with the guidelines of most organic certification programs. Such studies often blurred the lines between organic and low, off-farm input agriculture. To the extent possible, the following studies refer only to those thought to be organic studies; low-input studies are summarized previously in this review.)

REVIEW OF SELECT STUDIES ACROSS THE UNITED STATES

Lockeretz et al. (1978) and later Shearer et al. (1981) sparked the debate over the profitability of organic agriculture. Both studies compared the profitability of organic and conventional farming in the 1970s and found that organic farms were just as profitable as conventional farms when the growing conditions were optimum, but that organic farms were less profitable when the growing conditions were optimum.

Later, in east central Nebraska, research by Helmers et al. (1986) estimated net returns for thirteen different cropping systems between 1979 and 1986. The systems compared included four-year rotations, two-year rotations, and continuous cropping systems. Within the four-year rotations, an organic alternative was compared to inorganic chemical treatments. The results found that rotations had higher average net returns than continuously cropped systems but that different chemical treatments, including organic, had little impact on profitability. It was found that the lower cost of inputs for organic systems was offset by the lower yields within the four-year rotation. In addition, the organic rotation did not include as high a proportion of soybeans as the other alternatives, and since soybean crops earned the highest net returns, this lowered the relative profitability of the organic system.

Three major studies were conducted in South Dakota. Smolik and Dobbs (1991) and Smolik, Dobbs and Rickerl (1995) summarized two of the three studies. From 1985 to 1992, two studies were conducted at the Northeast Research Station near Watertown, South Dakota. The first study compared row crops: a four-year rotation of oats/alfalfa-alfalfa-soybeans-corn (no commercial fertilizers, pesticides, or moldboard plowing); a three-year rotation of corn-soybeans-spring wheat (conventional tillage); and a three-year rotation of corn-soybeans-spring wheat (ridge tillage). The second study compared small grains: a four-year rotation of oats/sweet clover-red clover (as green manure)-soybeans-spring wheat (no commercial inputs, no moldboard plowing); a three-year rotation of soybeans-spring wheat-barley (conventional tillage); and a three-year rotation of soybeans-spring wheat-barley (minimum tillage). Each study had one organic system. Without price premiums, the organic system had the highest net return in study one, and net return was equal to that of the conventional system in study two. Net returns were also found to be less variable for the organic system than for the conventional systems, and the organic system was the least dependent on government programs for profitability. The authors also concluded that certain types of organic systems are attractive both on the basis of profitability and productivity, especially in the specific region of the transitional zone between the mesic region of corn, soybeans, and hogs and the drier region of cattle, wheat, and sorghum.

Dobbs and Smolik (1996) summarized the third study in South Dakota. Between 1985 and 1992, the study compared an organic and a conventional farm. The organic farm used a four-year crop rotation and the conventional farm used a two-year crop rotation. The results found that without price premiums, the conventional farm's net income was substantially higher and less variable than the organic farm. The authors suggested this was due to the higher soybean yields and greater portion of acreage in corn and soybeans on the conventional farm. Despite this, the authors argued that the organic farm still received "acceptable" profits, covering all costs and leaving a return to management. In addition, the study found that the conventional system was most profitable in the early years of the study, but the organic system was most profitable over the later years.

Two major studies were reviewed from Pennsylvania. First, Hanson, Lichtenberg and Peters (1997) compared the profitability of organic and conventional cash grain rotations since 1982 at the Rodale Institute Research Center in the southeastern part of the state. The results found that after a short period of investment in soil capital, organic crop rotations produced per-acre returns that were competitive with, and sometimes greater than, conventional grain rotations. The research also found that other factors could place significant barriers on adopting organic farming. First, the organic system required much more family labor than the conventional rotation, therefore the opportunity cost (foregone wages and benefits of off-farm work) of farmers converting to organic may be a barrier. Second, the economic cost of investing in the soil capital during the initial transition years may also be a barrier. These findings pointed to the author's conclusion that "differences in the transition costs farmers face and in how they value family labor may partially explain the conflicting opinions regarding the relative profitability of conventional and organic systems." These differences in farmers' perceptions about the relative profitability of organic and conventional farming systems were likely to be strongly influenced by differences in the opportunity cost of labor and transitional investment.

A second study was completed by the Rodale Institute in 1999, also at the Rodale Institute Research Center in Pennsylvania. This publication reviewed fifteen years of farming system trials comparing conventional and organic farming. Not including price premiums, the economic analysis of these fifteen years of research suggested that organic farms, after a transition period, can economically compete with conventional farms. In general, profits from the organic system varied from slightly below to substantially above conventional farming profits. In addition, due to the diversity of marketable crops in an organic system, organic farms are less likely to see income fluctuations than conventional systems. Yet another key finding indicated that the cost of the transition period, where yields are likely to be lower for organic production, could affect the farm's overall financial picture for quite some time. In addition, the management of a diverse organic farm system was also found to require significantly more labor and management skill.

A few studies were reviewed for organic production of fruits and vegetables in California. Research in California's Sacramento Valley by Clark et al. (1999) has compared conventional, low-input and organic farming systems, all using a four-year rotation during an eight-year study from 1989-1996. The rotation included tomato, safflower, corn, bean, and a winter grain and/or legume double-cropped with bean. Overall, the results suggested that the organic system was the most profitable, but only when price premiums were included; without price premiums, the organic system was unprofitable on average over the eight-year study. Yet, the results also strongly suggest that the economics of all three farming systems were highly dependent on the costs and profits associated with tomato production. The differences stemmed from the fact that the total tomato production costs were substantially greater than those of the conventional system. Increased costs for organic production were associated with increased planting costs, higher-cost cover crop and weed management practices, and use of purchased composted manure. Beans were the most profitable in the organic system with price premiums; without price premiums, beans were profitable in only five of the seven years. While conventionally grown beans were less profitable due to higher operating costs of fertility and pest management, the price premiums were the primary contributor to organic profitability. For corn, the organic system came in second, in terms of profitability, behind the low-input system when price premiums were included, but was unprofitable without the premiums. Because the profitability of organic farming was so dependent on price premiums, the study raised concerns over its long-term economic viability.

Another study in California by Swezey et al. (1998) suggests that certified organic apple production in California can be commercially profitable. Swezey led a three-year project, from 1989-1991, to compare units of transitional or certified organic and conventional-input production in each of the four major apple production regions of California. Despite the higher material and labor inputs, using price premiums of 38 percent and 33 percent respectively for 1990 and 1991, the certified organic apples received greater net returns per hectare than the conventional apples.

Summary of Previous Literature Reviews

Over the years, several literature reviews have attempted to draw some conclusions about the profitability of organic agriculture. Cacek and Langer (1986) first reviewed some of the earlier research in the central and northern states. They noticed that research using actual yield data from actual grain farms showed that organic farming equals or exceeds conventional farming in economic performance, but the models that used hypothetical data showed an economic disadvantage. The authors argue that the "future trends in commodity prices, input prices, pollution regulation and research can be expected to have mixed effects on conventional and organic farmers, but the net impact will favor organic farmers."

Fox et al. (1991) reviewed several studies—for example: Lockeretz et al. 1978; Shearer et al. 1981; Goldstein and Young 1987; Sahs, Helmers, and Langemeier 1986—which evaluated organic performance compared to conventional production systems from 1976 and 1989. (Here organic production systems are loosely defined as any system that does not use synthetic pesticides or fertilizers purchased from sources off the farm.) In general, the review concluded that neither the organic nor conventional system had consistently outperformed the other. It was suggested that part of the reason may be that many of the studies covered a limited time-frame of one to two years. This opens the door for year-to-year fluctuations in input prices, output prices, and weather, to skew the results. In addition, the author stated that profitability also varied with the type of production system studied in the comparison, soil type, price and cost assumptions, and crops produced.

In another review, Lee (1992) found that studies usually report that net returns for organic systems are lower than conventional systems and that organic farming usually results in lower yields per acre for corn, wheat, and soybeans. Interestingly, this paper also used an economic model to show what would happen in the event of a complete conversion of U.S. agriculture to organic. The results indicated that farm income and consumer prices would increase while yields and aggregate output would decrease.

Later, Dobbs (1994 and 1995) re-examined some of the literature reviews mentioned above, as well as others including Cacek and Langner (1986), Madden and Dobbs (1990), Crosson and Ostrov (1990), and Fox et al. (1991). He found that many of the reviews reported conflicting, confusing, and mixed results, yet when taken as a whole, Dobbs argued that the sustainable agriculture profitability comparisons were beginning to form a pattern. More specifically, agro-climatic area patterns are beginning to emerge such that sustainable organic systems appear more competitive with conventional systems in predominantly small-grain areas, or in transition areas between the Corn Belt and the small-grain areas.

One of the most current reviews of the profitability of organic agriculture was recently published by the Henry A. Wallace Institute for Alternative Agriculture (Welsh 1999). The report reviewed six land-grant university studies comparing organic and conventional grain cropping systems (generally crop rotation systems) in the Midwest (Kansas, Diebel et al. 1995; Minnesota, Olson and Mahoney 1999; South Dakota, Smolik and Dobbs 1991; Smolik et al. 1995; Iowa, Chase and Duffy 1991 and Duffy 1991; Nebraska, Helmers et al. 1986; and South Dakota, Dobbs and Smolik 1996). Overall, the central conclusion was that if farmers obtain the current market premiums for organic grains and soybeans, their organic production generally delivers higher profits than non-organic grain and soybean-production rotational systems. The results also showed that organic cropping systems were always more profitable, without price premiums, than continuous corn systems.

However, without the crops earning price premiums, the Welsh review found mixed results. Three of the studies showed that organic cropping systems, without earning a price premium, were found to be more profitable than common conventional systems (generally a corn-soybean system) in studies conducted in Kansas (Diebel et al. 1995), Minnesota (Olson and Mahoney 1999), and South Dakota (Smolik and Dobbs 1991 and Smolik et al. 1995). However, three of the studies showed that organic cropping systems, without earning a price premium, were not found to be more profitable in Iowa (Chase and Duffy 1991 and Duffy 1991), Nebraska (Helmers et al. 1986), and South Dakota (Dobbs and Smolik 1996).

In cases where organic cropping systems were found to be less profitable than the conventional system, Welsh calculated the price premium that would allow organic production to "break even" with conventional. Data were available only for the Iowa State University study and the University of Nebraska studies. In both cases, the break-even annual average organic price premium was found to be less than the price premiums reported for those study years.

Welsh developed several important conclusions from his review. First, price premiums paid for organic products, although they increase profitability, are not always necessary for organic systems to be competitive with or outperform conventional farming systems. In fact, growing organic grain and soybeans may not always be the most profitable alternative for farmers. Second, organic cropping systems seem to be more profitable in drier conditions—either because of unfavorable growing conditions due to weather or increased moisture hoarding capacities of organic soils. And third, studies on the economics of organic systems should consider moving away from studies that compare organic systems to conventional systems. Rather, they should compare the economics of different types of organic systems for profitability.

Summary

Organic agricultural products generally earn a premium price, making organic farms more profitable than conventional. While economic performance without price premiums has been mixed, some general trends can be seen. In general, organic systems tend to lower the cost of production for commodities such as grains and soybeans in the Midwest and East. But profitability patterns seem to depend on the specific agro-climatic region; organic systems appear more competitive in the drier transition zone between the Corn Belt and small-grains areas. In fruit-growing regions like California, organic production increases the cost of production. Thus, the need for organic price premiums to become profitable becomes crucial for this type of production system.

SUSTAINABLE LIVESTOCK SYSTEMS: ROTATIONAL GRAZING

Sustainable farms also tend to be characterized by systems of sustainable livestock production. This may be the case for farmers in livestock production alone, or in diversification to other sustainable crop production systems. The following will review studies of rotational grazing for dairy and beef production.

In the last decade, there has been increasing interest in the use of low-input, pasture-based systems for dairy cow feeding in efforts to reduce the cost for machinery, housing, and feeding that results from confinement feeding. Some producers have been adopting intensive rotational grazing systems in order to do this. There are several different terms for this type of sustainable system including: controlled rotational system, management-intensive rotational grazing, intensive rotational stocking, and the New Zealand concept of rotational grazing. Essentially, they all refer to a system that relies on the intensive use of pastures for short time periods as a major source of feed for cows, whereby the animals are rotated among several small pasture sub-units called paddocks rather than continuously grazing one large pasture or feeding in confinement. Each paddock is grazed quickly and then allowed to re-grow for several days, until ready for another grazing. The lengths of the grazing periods and the rests between them are controlled by varying the size and number of paddocks and the number of animals. Confinement feeding, on the other hand is "an energy- and capital-intensive strategy involving mechanization of crop production and harvesting, extensive facilities for housing and feed storage, and grain feeding" (Rust et al. 1995). The following will summarize the literature on the economics of rotational grazing, grouping studies by state.

First, in a four-year study conducted in Missouri from 1986 to 1989, Gerrish (1990) evaluated the animal and pasture response of changing from a traditional, extensive management cow-calf system to a more intensive cow-calf pasture management program. The results found that animal output per acre can be dramatically improved through the implementation of intensive grazing management and that improved utilization of the forage being produced is an effective means of lowering the cost of production in a beef operation and increasing profitability.

Second, Welsh (1996) profiled a New York State dairy farm, which converted from a confinement feeding system to a rotational grazing system. While the profile was written from a qualitative, rather than quantitative perspective, the economic comparison found that feeding costs after grazing was adopted were reduced by about $30,000 per year.

Two studies were reviewed in Minnesota. Dittrich et al. (1993) reported on a study conducted from 1989 to 1992, which examined the economics of low-input, reduced-chemical and management alternatives of 45 western Wisconsin and southeast Minnesota dairy farms. In this particular report, Dittrich et al. compared enterprise and whole-farm based costs and returns collected on 16 single-family dairy farms over two years (1991-1992). Eight confinement dairy farms using mechanical methods to harvest forage were compared to management-intensive grazing during the growing season. On a whole-farm basis, the results did not find a significant difference in gross returns, net cash returns, and net returns. Interestingly, fixed costs on pasture-based farms increased over the study period and any anticipated reductions in labor costs were offset by higher cow numbers to increase whole-farm gross margins.

In the second Minnesota study, Rust et al. (1995) compared rotational grazing and confinement feeding of dairy cows from May to October in 1991 and 1992 in northern Minnesota, where permanent grass pastures are abundant and dairy herds are usually fewer than 50 cows. The confined cows were fed alfalfa hay and corn silage and housed in a tie-stall barn except for one hour per day. The rotationally grazed cows used pasture as the major source of forage, plus they were fed alfalfa hay in the barn at milking. The results found that the confined cows had greater milk production throughout the grazing season for both 1991 and 1992, but the net return for the grazing cows was $53 and $44 greater in 1991 and 1992 respectively due to lower cost of feeding, facilities, and labor. Overall, the study found the potential economic advantages of a rotational grazing system over confinement were that cows are fed less corn, grain, soybean meal, alfalfa haylage and corn silage, machinery usage is lower, and the system requires less expenditure for buying, operating, and maintaining equipment, silos, and housing.

Another predominant region of research on rotational grazing was Wisconsin; several studies were reviewed from that state. First, Tranel and Frank (1991) were one of the first to examine whether or not intensive grazing could work for Wisconsin dairy farmers. Using a computerized budget program, the study evaluated four cropping systems to provide feed to a dairy herd (conventional corn-hay system, corn-hay-pasture, no corn/all hay-pasture system, and rotationally grazed pasture/purchase feed system). The fundamental aim was to determine if a pasture enterprise would be economically competitive with other crops that could be grown. The authors found that it was difficult to accurately compare the alternatives with so many variables involved. The profitability of the alternatives depends highly on the ability of each farmer to manage each individual situation. Yet they did conclude that the potential net cash return per acre of the rotationally grazed pasture was significant.

After that time, much of what was learned about management-intensive rotational grazing (MIRG) as a dairy system in Wisconsin was discovered from case studies, simulation models, stories, and visits to farms, which all tended to indicate a potential viability of the system. However, it was not until Jackson-Smith et al. (1996), which used survey data from two large-scale random samples of dairy farmers in Wisconsin, could the results of previous work be generalized to the rest of the grazier population. The results found that "MIRG operations reported lower levels of net farm income, but higher economic returns to equity, when the cost of family labor was not considered." Interestingly, MIRG operators also reported higher levels of off-farm work than the other categories of dairy farmers. This may be due to the facts that the lower net farm income exerts pressure on farmers to pursue additional income from off-farm sources, and the less total farm labor required to operate the farm makes working off-farm more feasible. Overall, the authors concluded that this study supported the view that this system could be a viable approach to dairying in Wisconsin.

Jackson-Smith et al. (1996) also briefly reviewed other research on the economic performance of MIRG as a dairy farm strategy around the Midwest and Northeast (Michigan and Rotz 1995; Minnesota, Rust et al. 1995; New York, Emmick and Toomer 1991 and Nicholas and Knoblauch 1996a, 1996b; Ohio, Miller and Schnitkey 1992; Pennsylvania, Parker et al. 1991, 1992, Ford and Hanson 1994 and Elberhri and Ford 1995; Vermont, Winsten and Petrucci 1996; Virginia, Carr et al. 1994; Wisconsin, Tranel and Frank 1991, Klemme et al. 1992 and Frank et al. 1995, 1996). Together these studies found that the key to competitiveness of MIRG is the reduction in feed and labor costs. Most researchers have found that net economic returns tend to be higher among MIRG farmers than among comparable confinement operations. However, most of the research assumed that milk production per cow was comparable to the confinement herds and that if milk production per cow fell below 6 percent to 7 percent less than on a confinement system, the cost-reduction advantages of grazing might be negated by the lower production levels. On the other hand, Rust et al. (1995) did find that even with a 7 percent reduction from grazing, grazing still produced higher net returns per cow. (This study was conducted only during the grazing season.) In addition, many of the studies completed to date have not included the range of other factors that could influence long-term competitiveness (potential improvements in pasture quality and management skill and differences in capital expenditure associated with the two systems).

Just recently, Krigel (2000) completed the preliminary fourth-year summary of the Wisconsin Grazing Dairy Profitability Analysis. The study surveyed graziers over four years to better understand if grazing is economically viable, where the system works best, what practices make each system most viable, and how each system can be best managed for the benefit of the farmer operating it. From this study, several general conclusions were made. First, the results indicate that management-intensive rotational grazing (MIRG) is economically viable for most farm sizes and they compare favorably with conventional dairy farms when using a variety of financial measures. Second, MIRG is more economically flexible than conventional systems, in that farmers can easily recover most of the initial investment. Third, while many graziers are financially competitive at production levels that are lower than found in other systems, they will be more competitive if they find ways to not sacrifice production. In fact, herds transitioning from another system may not be able to afford much production decline. Fourth, the most financially successful graziers are those who focus on income generation, operating expense control, and investment control. A tendency to focus on any one or two components can lead to disadvantages. Lastly, the study points out that there will never be one study to determine once and for all, and for all conditions, that grazing is more or less profitable than conventional dairy farming. This is because the nature of production allows some practitioners of each strategy to be successful and because management continues to be the single most important factor in determining business success in farming.
Several studies were conducted in Pennsylvania. First, Brown (1990) summarized the experiences of intensive rotational grazing at four Pennsylvania dairy farms and

found that, when compared to conventional confinement systems, intensive rotational grazing earned higher profits due to lower feed and machinery costs.

Second, Parker, Muller and Buckmaster (1992) studied the effects of intensive grazing by dairy cattle compared to the drylot feeding system in Pennsylvania. The results found that, in part due to the reduction in operating expenses of the grazing system, the gross margin was higher per cow on the grazing system. However, overall income would not improve if production per cow fell below a specific level. The study also pointed out that despite this potential to improve profitability, the low use of intensive grazing would be likely to continue in the region until farmers could become confident that the grazing system would maintain a similar level of milk production.

Third, Parker et al. (1993) conducted a survey of Pennsylvania dairy farmers in 1990 to compare farmers using intensive grazing systems to those using traditional drylot feeding systems. The financial analysis was limited in this study, but it did find that the feed purchase cost in 1989 on the intensive-grazing farms were similar to the drylot systems, and the milk production levels were lower on the farms using grazing.

Fourth, the Grazing Lands Technology Institute of the U.S. Department of Agriculture conducted a study in 1996 to provide farm-level information on the profitability of intensive rotational stocking. The study analyzed farm costs and returns for 52 dairy farmers in northeastern Pennsylvania in 1992, comparing intensive grazing to continuous grazing, hay, and corn silage. The results found that intensive rotational grazing had the highest net returns or net profit for farmers sampled in the study. Direct cost for intensive grazing was also significantly lower than for corn silage and hay, but not for continuous grazing. Intensive grazing also had the lowest-cost feed source on the farms in the study. Overall, it was found that farmers could increase their reliance on intensive grazing because the result would lower labor expenses for feeding and manure handling, and a buildup of stored feed.

Finally, out of concern that previous studies comparing the economic benefits of grazing to conventional dairy production were limited by the use of a partial cost approach, Elbehri and Ford (1995) used a farm-level simulation model to evaluate the impact of intensive grazing on a representative Pennsylvania dairy farm. The results indicated that under the assumption of equal milk production, the annual net cash farm income for a typical dairy farm with intensive grazing increased by 14 percent to 25 percent, compared to farms without intensive grazing.

In addition, some farmers have been implementing an extended grazing system, whereby the usual grazing season is lengthened by using hay fields for pastures, as an alternative to conventional systems. D'Souza et al. (1990) attempted to quantify the farm-level impacts of extended grazing management on cow/calf production cost and profitability. Using primary data from four meadow-management systems over a three-year period from 1981 to 1984, the results found that extended grazing can be a more profitable option for beef cow/calf production. The study also noted that production costs and profitability also depend on the type of meadow, the hay baling method and the associated hay spoilage level.

Summary

Intensive rotational grazing systems for dairy production can be profitable, mostly due to a great reduction in the cost of production. However, studies suggest that intensive rotational grazing also tends to result in somewhat lower yields. Thus, the implication is that the farmer faces a management balancing act of ensuring that production levels (and thus gross sales) do not fall below a certain point. Doing so may negate the potential profits earned from reducing production costs.

RECOMMENDATIONS FOR FURTHER RESEARCH

As this brief shows, additional research into the economics of sustainable agriculture is needed.

Longer-term research. Much of the available research indicates that there is often a transition period for farms converting from conventional practices and systems to alternative methods. During this period, the profitability results for the alternative systems and practices may be less likely to be favorable. However, after this period—for example, after the soil has built up its own fertility and the farmer has learned better management skills—profitability is more likely to be competitive with conventional. For example, Parvin and Cook (2000) found that no-till yields tend to improve over time compared to conventional-till yields. Research has indicated that economic transitional periods from a conventional to an alternative system often exceed the biological transition period (Hanson et al. 1990). This transition factor is perhaps one major reason why studies limited to a one- to two-year period have been both criticized and less favorable to alternative systems. As such, there exists a continued need for more long-term studies on sustainable agriculture practices and systems, especially economic analysis.

Community research to assess the financial impact of sustainable agriculture. Diversifying a farmer's cropping system could potentially require access to different purchased inputs, labor demands, and organizations through which to market products. At the same time, established institutions are at potential risk of losing out financially if parts of the agricultural sector change. To date, very few studies have examined this trade-off. Such consequences need to be considered when assessing the costs/benefits to society as a whole.

Techniques to measure and then value the external costs/benefits of different agricultural systems to the environment. The National Research Council (1991) noted early on that efficient farm systems are generally associated with fewer environmental problems because cropping patterns, fertility, and pest control practices match the strengths and limitations of the resource base and follow sound biological and agronomic principles. While preserving the integrity of the nation's waterways is of tremendous economic benefit to society, farmers have yet to be financially rewarded for agricultural practices and systems that reduce nutrient loads and non-point source pollution. Research that can attempt to quantify the external costs of different farming practices would contribute to creating a system that rewards farmers for environmental farming practices.

Impact of government support programs on the relative profitability and subsequent adoption of sustainable agriculture. Early research by the National Research Council (1991) found that many federal policies discouraged the adoption of alternative practices and systems by economically penalizing those who adopted non-traditional rotations, employed certain soil conservation practices, or attempted to reduce pesticide applications. The studies reviewed to date still find that federal farm programs continue to make it difficult, if not impossible, for some sustainable agricultural practices and systems to be financially competitive with conventional. Likewise, this risk of losing government support payments may often prevent some farmers from adopting sustainable agriculture practices and systems. Future work could examine how altering federal support programs would impact the profitability of sustainable agriculture practices, or how they could be used to help eliminate the risk of transitioning from conventional to more sustainable systems.

Site-specific research to account for regional variation. The results of various farming practices and systems show differences across geographic regions. For example, economic research on low-input and organic farming of grains and oilseeds suggests that these systems can financially outperform conventional systems in drier regions, such as the Great Plains. Also, conservation tillage seems to be more effective in drier climates where soil moisture is at a premium. As these trends emerge, future work is needed to better define where and why specific practices perform better in some agro-climatic regions and not others. Follow-up questions would probe how various sustainable practices could be better adapted and transferred from one region to another.

"Real world" comparison of actual practices and systems. Studies on alternative systems tend to take an approach that highlights extreme cases of applying conventional amounts of herbicides and pesticides versus no purchased inputs at all. It is possible for some systems to operate at a higher level of profitability while still significantly reducing the amount of chemical inputs. This might also enhance the potential for greater adoption of the aforementioned farming practices.

Financial analyses that are focused on the net. In some cases where sustainable agriculture has been found to be profitable, one of the major factors leading to this result is a reduction in the cost of production, as opposed to an increase in total revenue from increased yields. As such, the net financial results can favor sustainable agriculture if the farmer can effectively balance a possible loss in gross revenue with cost savings of lower production costs from, for example, reduced or eliminated off-farm chemicals or capital equipment. However, many of the studies report that sustainable agriculture also can increase the amount of family labor required. Thus, if family labor requirements increase, the farmer must also balance the financial relationship between the reduction in chemicals and capital equipment with the value of family labor. For some farmers, an increase in family labor is not perceived as an increase in the cost of production, in which case sustainable agriculture practices could appear more profitable.

Beyond consideration of profitability. A recent USDA report by Hrubovcak et al. (1999) suggested three additional factors that present barriers to adopting sustainable agriculture practices. First, structural barriers such as a lack of financial capital and limits on labor availability may deter adoption. Second, the diversity of the natural resource base may make adoption of certain practices worthwhile in only some instances. Third, the perception of economic risk may prevent adoption. Since the research in this arena still appears to be limited, a key component to any future work should include an exploration of these, and possibly other, non-financial barriers to adopting sustainable agriculture practices.

Impact on horticultural crops. Finally, many of the studies reviewed in this paper have been limited to cereal crops, livestock, and to some extent cotton and a few fruits and vegetables. Less information is available on the sustainable production of horticultural crops, particularly in regions of the West Coast and Southeast. At a minimum, a more comprehensive review of the literature on horticulture crops is needed. The small amount of research reviewed suggests that horticultural crops require a higher degree of management and more intense cultural practices than do cereal crops; the transferability of conclusions from this paper to those crops may be extremely limited.

EPILOGUE

The examination of the profitability of sustainable agriculture is complex and presents many challenges. Foremost among them is the fact that researchers, academics, farmers, and policy makers will measure profitability in fundamentally different ways. One of the more pervasive methods is to compare sustainable agriculture to conventional agriculture. This presents the difficulty of measuring success based on failure. The $6 billion spent by the U.S. government in emergency aid in 1998 and the $9 billion in 1999 attests to the fact that conventional agriculture is not necessarily profitable for farmers.

Every year, however, the ecological, economic, and social track record for sustainable agriculture improves. After reviewing the past two decades of on-farm activity, it is clear that farmers who incorporate as little as one or more of the most common sustainable agriculture practices can benefit financially through some combination of cost savings, increased yields, and price premiums.

For example, farmers who switch to no-till or other forms of conservation tillage reduce their costs for labor and fuel by driving their tractors less, and often generate higher yields due to increased soil fertility and improved sub-soil moisture. Organic farmers in particular have enjoyed large price premiums that have boosted their income significantly. That's the good news.

There is some bad news, however, especially concerning the impact of some direct cash payment farm programs administered by the U.S. Department of Agriculture. Many of these federal initiatives *reward farming practices that are not sustainable*, making sustainable practices less financially attractive to producers who are already struggling in an economically depressed market.

For example, the federal government's current system of direct cash payments to farmers subsidizes primarily conventional, high-input production methods and high yields. In other words, the more a farmer produces, the more that farmer is paid by the government, no matter how much fertilizer is used to artificially boost yields. Farmers who rely on sustainable, low-input techniques to reduce environmental impact often do not receive the same level of federal subsidy, even though their practices improve soil and water quality and can earn farmers a premium in the marketplace.

Other examples of discrimination against sustainable farmers exist. Agencies that provide credit for growers from government sources often refuse to consider loan applications from organic or sustainable farmers. Even some anti-hunger programs, like WIC (which helps feed women, infants and children), specifically exclude organic products.

The impact of such practices is evident both on the farm and in the marketplace. These skewed lending and subsidy programs enable conventional farmers to compete against sustainable producers as if the playing field were level. Meanwhile, farmers who want to transition into a more sustainable operation face an unfair choice. Do they farm conventionally in order to receive the same level of subsidies that their competitors enjoy? Or do they farm sustainably, and hope they will reap a marketplace advantage that will replace lost government loans and payments?

Clearly, if the federal government were not subsidizing only one side of the equation, more farmers would be pulled into sustainable agriculture by the promise of the marketplace as well as the desire to be better stewards of the land. For now, at least, marketplace profits alone are not enough to convince conventional farmers to take the risk.

The research also yields a sobering reminder of one of the ironclad laws of farming—that market prices remain the single-most important factor in determining whether a farming family makes or loses money. Even the most productive and cost-efficient sustainable farmers cannot make a profit when farm gate prices fall to extremely

low levels, as they have over the past couple of years. No-till farmers and others who have reduced their energy dependency will do better than conventional growers when oil prices are high, but even they will lose money if the prices they receive for their crops remain at current record low levels.

More research is needed into the kinds of sustainable growing techniques and market mechanisms that can help sustainable farmers thrive in the United States. But we also need to act on what we already know. Farmers must receive the information contained in this study in order to make informed decisions about the opportunities awaiting them for higher yields and lower costs through sustainable farming. At a minimum county extension agents, the farm media, and land grant universities should begin promoting this approach to the same degree that they promote chemical- and energy-intensive growing methods.

At the same time, the federal government needs to re-set its priorities. The congressional subsidies that discriminate against organic and sustainable farmers must be abandoned; support for more environmentally sound practices must be increased.

This report documents what thousands of growers have learned over the past twenty years—that both sustainable and organic farming are better for the farmer's bottom line. The challenge now is to convince Congress to support policies that encourage farmers to embrace sustainable practices, not avoid them.

Timothy Bowser, *Executive Director*
Fires of Hope

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