Production Practices and Systems in Sustainable Agriculture

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Abstract

Interest in sustainable agriculture probably had its roots in the concept of sustainable development. There exist no agricultural production technologies or farming systems that are environmentally benign. The question thus becomes "what is sustainable and what is not?" The two underlying themes that appear in most definitions of sustainability and sustainable farming systems deal with (1) the economic profitability of the farming system over a long period of time; and (2) long-term benefits to the environment. To the extent that the proposed (sustainable) farming system provides greater off-site benefits than the farming system currently in place, federal, state and even local governments may have an interest in assuring that the alternative is implemented. Any regulations placed on U.S. farmers in an effort to achieve environmental goals cannot be so onerous such that U.S. farmers will no longer be able to produce commodities profitably at world market prices.

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Production Practices and Systems in Sustainable Agriculture

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Introduction

Interest in sustainable agriculture probably had its roots in the concept of sustainable development. From an international perspective, the sustainability of production systems in agriculture is a very important component. Interest in environmental issues has been a longstanding concern, In the 1950s, increased interest in outdoor recreation stimulated interest in maintaining and improving the environment (Batie, p. 1083). Environmental issues and their linkages to agriculture are not only of recent concern. The 1930s was a period of time in which problems associated with wind and water erosion were causing considerable concern for the future of American agriculture, and led to government policies directed toward agriculture that were specifically aimed at environmental issues. The Soil Conservation Service came into being 1935, but actually started much earlier as the Soil Erosion service (Tweeten, pg. 96).

"Sustainable development is a concept based on intergenerational equity--that is, the current generation must not compromise the ability of future generations to meet their 'material needs' and to enjoy a healthy environment" (Batie, p. 1084). If we apply an analogous definition to sustainable agriculture, then sustainable agriculture is also based on intergenerational equity, that is, the current generation of farmers must not compromise the ability of future generations of farmers to meet their material needs and continue to enjoy a healthy environment. That is, farmers have an "intergenerational obligation" to choose production practices and farming systems that maintain the ability of agriculture to produce agricultural commodities and products, maintain a decent standard of living for the farmer, yet jeopardize neither the ability of future generations of farmers to produce and maintain a decent standard of living, nor the quality of the environment for either the current or future generations.

As recently as 1991, the concept of sustainability still concentrated on the need to reduce the use of purchased inputs in agriculture, but in 1991, Ikerd argued that the "low input" aspect of sustainable agriculture was becoming less important as public policy began to focus on the broader sustainability issues. He suggests (p. 43) that the long run sustainability of agriculture could have far different implications for southern farms than those implied by a simplistic restriction, ban or even lowering of commercial agricultural inputs.

Technology in agriculture moves ahead at a steady pace over the long term. Technological progress also occurs with respect to society's ability to detect possible consequences to the environment of specific production practices and farming systems in agriculture. Therefore, a production practice or farming system that, during one period of time, is thought to be environmentally benign, in a future time period made be found to have some consequences to the environment that are of long- run concern. Thus, the technologies employed within a specific sustainable farming system can only be judged in relation to our ability at the same point in time to detect the probable consequences of the technologies on future generations. Batie (1988, p. 1) argues that there continues to remain a what she terms a "denial" among many agricultural scientists that technological advances could be part of "the problem" as easily as they could be a part of "the solution to the problem."

Science has created problems in other areas as well. Lead in gasoline was once thought to be a simple, cheap, and environmentally benign way of increasing the octane of gasoline. DDT was thought of as a "miracle pesticide" that could alleviate a number of diseases transmitted by insects and thus make future generations better off. Asbestos was the material of choice for adding fire retardant properties to the interiors of public buildings, and good choice for the homeowner was asbestos siding that would give fire-retardant properties to the exterior of frame structures. These products were endorsed by scientists, produced by manufacturers and used by the public because they appeared to be effective, cost-efficient solutions to known problems. All of these products of technology were ultimately shown to have serious harmful long-term effects on the environment. The lead used in gasoline saved oil for future generations. DDT saved lives from insect-borne disease: asbestos saved lives because of reduced incidence and severity of fires in homes and public buildings. In short, at one time, these appeared to be technologies broadly consistent with the concepts underlying sustainability.

There exist no agricultural production technologies or farming systems that are environmentally benign. All have some potential consequences on the environment. Our ability to judge the probable consequences to the environment of a specific production practice or farming system is only as good as the technology in place to evaluate the probable environmental consequences. Scientists can and frequently do make mistakes in conducting these assessments, particularly assessments involving inter-temporal consequences. They err not only in calling some technologies inconsequential to the environment when indeed they are not, but also occasionally in finding environmental harm when, in reality, no harm exists.

To the extent that cost-efficient technologies are abandoned because scientists identify harmful effects that, in reality, do not exist, future generations are also harmed. They are harmed because cost-effective technologies are replaced with higher-cost technologies. Many of these higher-cost technologies require the use of additional resources that instead could have been saved for use by future generations. The choice of a particular production technology or farming system thus becomes a judgement call with regard to the probable consequences on future generations.

Multiple criteria are necessary to determine the probable consequences of a particular farming system on the environment. It would be nice if all probable environmental consequences (benefits and damages) of a particular farming system could somehow be collapsed into a single measure or indicator measuring the degree of environmental benefit or harm, but, because of the diverse array of potential benefits and damage, this is very difficult to do.

How should a specific reduction in soil loss due to erosion be valued (weighted) in comparison to a change in the amount of surface a ground water contamination? The environmental consequences of various reduced-tillage farming systems further illustrate this point. It may appear that any farming system that can significantly reduce water and wind erosion is broadly consistent with the goals of sustainability. At the same time however, many of the reduced-tillage farming systems (i.e. minimum-tillage or no-till) require increased use of pesticides, pesticides whose increased use will undoubtedly have *some* negative consequence on the environment.

Potential advances from biotechnology too may pose serious dilemmas. The public is concerned with respect to the potential risks associated with releasing into the environment genetically altered plants or animals. This is true even though, for example, the biotechnology has the potential for long-term environmental benefits, for example, by genetically altering non-legume plants to reduce or eliminate the need for fertilization employing chemical nitrogen.

The question thus becomes "what is sustainable and what is not?" In agriculture, specific production practices and farming systems that at first appear to be broadly consistent with the concept of sustainability may not ultimately be sustainable. Other production practices and farming systems thought to be inconsistent with sustainability concepts may ultimately be found to be sustainable.

The quest for sustainability stems from the idea that the limits of growth are about to be reached. As a consequence, sustainability overrides allocative optimality of conventional Economics (Daly). There is quite a variety of sustainability notions, differing according to the basic questions of sustainability of what, for whom, where and when.

Sustainability is an ecological concept that stems from the predator with "prudent behaviors" that avoids overexploiting its prey to ensure an "optimum sustained yield"

(Odum). Income, then can be defined as the maximum value that can be consumed during a period of time and still expect to be as well off at end of that period as ....at the beginning. Depending on the source of supply of welfare-relevant goods and amenities, three categories of sustainability can be distinguished. They are, the economic, ecological and social sustainability (Bartelmus). However, many other factors may influence the supply-production process. Some of these, as alternative production processes and technologies or discovery of natural assets may increase the scope of sustainability. Others, such as natural and/or man-made disasters may reduce sustainability. Strong sustainability, calls for the maintenance of each category of initial capital, assuming its complementarily (non- substitutability) in production (Bartelmus, Daly). Strong sustainability assigns, an "existence value" to each capital category. Weak sustainability focuses on maintenance of income or production, allowing for substitution and technological progress. Weak sustainability refers to the maintenance of the overall capital base, rather than of each of its components.

Sustainable national income has been defined as Net National Product with adjustments for the degradation of renewable and non-renewable capital. It reflects the implicit conditions for sustainable development: intergenerational equity, ecosystem resilience, and equity in opportunity and human development. Implementation of these three conditions leads to environmental and equity constraints on economic optimization. Tests of sustainability require defining and measuring changes (depletion or increase in stock) in critical natural capital (Pearce and Atkinson). Resource accounting treats natural capital in a similar manner to reproducible capital in accounting terms. If a correct value can be placed on natural capital under an accounting system, then if stocks of natural-capital are depleted to increase stocks of reproducible capital then under a strong sustainability rule, the ability to generate future income will be maintained. Natural capital changes and their measurement have been discussed by Hartwick and Maler.

Net national product becomes the traditional gross product less a rental defined as the price less marginal cost multiplied by the change in the stock of capital.

Thus the modified NNP can be calculated as being the aggregate consumption plus the change of the pollution stock multiplied by its rental value, minus the change in stocks of renewable and exhaustible resources (net of their mean annual natural increments) multiplied by their respective rental values.

In the case of a farmer or a farming system then a detailed account of each natural resource used in the production process should be made and according to the modified NNP definition about keeping track of decreases or increases in the modified NNP so defined.

$$\text{Modified NNP} = C + \Delta Km - (Pe - MCe)\,\Delta(Qe - De) + (Pr - MCr)\,\Delta(MAI - Qr) + (Px - MCx)\,\Delta X$$

Where

C = aggregate consumption
Km = reproducible capital stock
Pe = price of exhaustible resources
MCe = marginal cost of extraction of exhaustible
Qe = extraction of exhaustible resources
De = discoveries of exhaustible resources
Pr = price of renewable resources
MCr = marginal cost of renewable resources
MAI = growth of renewable resources (mean annual increment)
QR = harvest of renewable resources
Px = price of pollution
MCx = marginal cost of pollution
X = pollution stock
Δ = change

Sustainable Agriculture: Basic Definitions and Concepts

Defining sustainable agriculture should be a simple task, but as the broad set of issues surrounding the concept of sustainability suggests, the task may be somewhat more arduous. Johnson characterizes a sustainable agricultural system as one that is economically viable, environmentally sound and socially acceptable (p. 75). He argues that "...beginning with the Agricultural Adjustment Act of 1933, we as a society must have felt that the American Agricultural System as it now exists is not sustainable and have legislated numerous laws in an attempt to make it such"(ibid). He argues that agriculture largely succeeded in reducing food costs, releasing labor from the farm, stabilizing prices for farmers and consumers, and feeding an increasing population, but only recently has attempted to seriously address environmental concerns linked to agriculture's exploitation of natural resources. One widely accepted definition of sustainable agriculture comes legislation, specifically that contained in the 1990 Farm Bill, technically the U.S. House of Representative's conference report on the Food, Agriculture and Trade Act of 1990 (p. 1055). The conference report defines sustainable agriculture as

"An integrated system of plant and animal production practices having a site-specific application that will, over the long term: (1) satisfy human food and fiber needs; (2) enhance environmental quality and the natural resource base on which the agricultural economy depends; make the most efficient use of non-renewable resources and on-farm resources, and integrate, where appropriate, natural biological cycles and controls; (4) sustain the economic viability of farm operations; and (5) enhance the quality of life for farmers and society as a whole."

The National Research Council, (cited in Ray, et al., p. 51) suggests that the numerous definitions of sustainable agriculture share the common elements of retaining natural resources, minimizing environmental damage, providing adequate farm profits and optimizing farm production with a low level of fertilizer and other inputs.

The Science Council of Canada (p. 15) reports that the definition adopted by Canada's federal department of agriculture is

Sustainable agri-food systems are those that are economically viable, and meet society's need for safe and nutritious food, while conserving and enhancing Canada's natural resources and the quality of the environment for future generations.

They argue that by simply deleting the word "Canada," the definition would apply anywhere in the world.

Ikerd suggests that the difference between sustainable and conventional agriculture is more due to a difference in what he terms "farming philosophy than due to what he terms farming practices and methods (p. 45). In order to satisfy long-term (intergenerational) needs of a society, sustainable agriculture must employ a farming system comprised of a collection of interrelated and integrated agricultural production practices that can be continued (or "sustained") over a long period of time. The period of time is at least many production seasons, perhaps as long as the remaining years a farmer intends to farm, or perhaps even longer, assuming that the farm is passed on to another generation.

A key element of sustainability is that the farming system in place must be sufficiently profitable such that it is economically viable over the long term. If a farmer is to continue farming over a long period of time and ultimately transfer ownership of the farm to the next generation, the specific farming practices employed over the period of time must be profitable, at least in most years. Therefore, a key element of sustainable agriculture is *long-run profitability* of the set specific sustainable production practices comprising the farming system. Dicks (p. 53) argues that *any* family owned farm that has been passed through several generations is, somehow, economically viable, but may not be ecologically sound.

Sustainable agriculture involves the *long-run maintenance and improvement of soil fertility while minimizing the undesirable effects of wind and water erosion*. This suggests that if a farmer employs sustainable agriculture practices, at the time the farm is transferred to the next generation, the farm will at least have maintained, and perhaps even increased in "real" value over the period, even when the effects of inflation have been considered. In part, this is because the topsoil depth and soil fertility level is maintained to the extent possible through the production practices employed.

Thus, sustainable agriculture practices often appeal to farmers who adopt as a goal a long-run strategy of attempting to maximize net worth over many production seasons, rather than a short run strategy of profit maximization in one or two production periods. Land tenure (ownership) considerations enter here, as farmers who are owners rather than renters would more likely be willing to make choices regarding farming systems that are consistent with building net worth over a long time horizon.

Sustainable agriculture practices show a *concern for the environment*. Hoag et al. (p. 2) suggest that while most definitions of sustainable agriculture mention enhancing environmental quality as a major goal, what is meant by this is often ambiguous. They note that the 1990 Farm Bill definition (pp. 391-2) of environmental quality includes wildlife habitat, soil conservation, water quality, air quality and preservation of natural resources. Pearce and Turner (as cited in Dicks, p. 53) identify four basic rules that must be followed for a system to be environmentally sustainable. They are:

1. Use renewable resources at a rate less than the natural rate of generation.

2. Maintain wastes from production at a level below the assimilative capacity of the environment.

3. Ensure that the reduction of stock resources is compensated for by increases in renewable resources.

4. Depletion of stock resources should occur with an increased standard of living.

Any agricultural production activity will have some impact on the environment. However, people need to eat, and the only way to produce food is to engage in an activity that somehow changes (in some manner harms) the environment. This is true whether food comes from agricultural production on farmland or from the ocean. Even sustainable agriculture practices change the environment in some way, but sustainable agricultural practices attempt to *minimize* the harmful effects on the environment from pollution, wind and water erosion and other types of environmental damage arising from agricultural production.

Evaluating Alternative Sustainable Farming Systems

A sustainable farming system is not simply a series of production practices that can each be evaluated independently from one another, but rather a series of production practices that are integrated and interrelated with each another. Ikerd suggests that sustainability is determined by the system as a whole, not its individual components (pg. 46). He argues that what he calls "synergism" is the key to sustainability. The interdependent linkages between production practices comprising a farming system makes evaluation of the profitability and environmental benefits attributed to a specific practice difficult.

A specific production practice, say a particular type of tillage, when taken alone, may appear to be inconsistent with the goals of sustainable agriculture. However, it is the farming system in place, that is, the integrated system of interrelated production practices that ultimately determines the sustainability of the farming system.

Any sustainable farming system may include some specific production practices that might not appear to be consistent with the goals of sustainable agriculture, and yet, when integrated with other specific production practices, the entire farming system in total might be quite sustainable.

Identifying Specific Farming Systems Consistent with Sustainable Agriculture

The two underlying themes that appear in most definitions of sustainability and sustainable farming systems deal with (1) the economic profitability of the farming system over a long period of time; and (2) long-term benefits to the environment. Environmental benefits are sometimes not measured as an overall improvement in environmental quality over time, but instead compared with what would have happened to the environment over time had conventional (previously-employed, non-sustainable) production practices been continued.

For example, it is generally recognized that any type of agricultural land use will result in a significant loss in topsoil. Even idle land in grass steadily loses topsoil. An environmental goal of a sustainable farming system might not be to actually increase the quantity of topsoil on the farm, but rather to employ a farming system that minimizes the amount of topsoil loss over time, especially when compared with alternative farming systems that might instead have been continued.

Thus, farming systems cannot simply be divided into two dichotomous categories, labeled either conventional or sustainable. Instead, there are degrees of sustainability. An existing farming system—one that might be described as conventional—may be profitable even over a long time period, consistent with one of the primary goals of sustainability. Furthermore, a farming system labeled as sustainable because the probable benefits to the environment over the long term are great may incorporate a number of specific production practices that, if taken individually, would be called conventional. A sustainable farming system does not necessarily employ an entirely different set of specific production practices and does not necessarily preclude the use of some specific practices that might be labeled "conventional."

Sustainable farming systems are, indeed, systems. In this context, a sustainable farming system must consist of a series of related and integrated production practices. In some instances, it may be possible to determine if a specific production practice incorporated into a farming system is more or less sustainable than another alternative production practice. For example, a specific production practice that makes better use of green manure crops than chemical fertilizers to improve soil fertility might result in environmental benefits arising from decreased ground and surface water contamination. Such a production might be labeled as sustainable based on perceived environmental benefits.

Furthermore, differences in profitability that occur might be directly attributed to differences in the specific production practices that are employed. The farmer who reduces purchased chemical fertilizer use by relying more heavily on green-manure crops in a rotation to improve soil fertility will likely experience some change in the pattern of profitability over time. Presumably, to the extent that profits change, the change occurred because of the modification in the specific production practice that was employed.

From the perspective of sustainability, an ideal situation would be one in which profits increase as a result of shift from chemical fertilizers to green manure in a rotation, and the environment is also significantly enhanced because of reduced nitrate pollutants in ground and surface water. Further, this could actually happen. A farmer who reduces chemical fertilizer use will likely decrease out-of-pocket expenses, enhancing profitability. But output levels may not remain constant, either, since profit is the net of revenue over costs. Moreover, the improvements to the quality of ground and surface water by reducing or eliminating chemical fertilizer use may not be significant or even measurable.

In most cases, however, the concept of a sustainable farming system suggests forgoing some profit (in comparison with the production system previously employed) over the short run (the first few years a farming system is in place) with the expectation that benefits will be achieved over a longer period of time. Long-run profitability may be increased *relative to what would have occurred* if the conventional farming system had continued indefinitely. While the ideal would be improved environmental quality over time, the sustainable farming system may be justified (and considered successful) if the benefit is only that the environment is less harmed than would have been the case if the conventional farming system had continued to be employed.

Thus, environmental benefits from alternative, sustainable farming systems must be evaluated not only in terms of absolute improvement in environmental quality, but also in relative terms, that is, relative to what would have occurred had the new, sustainable farming system not been implemented. Similarly, the consequences of such a sustainable farming system on profitability must be evaluated not only over a multi-year time horizon, but also relative the likely profitability of the conventional system over the same, multi-year time horizon.

Environmental Considerations

The environmental benefits associated with sustainable farming systems can thus be categorized into four major groups:

1. Benefits accruing from a reduction in soil erosion due to wind and water

2. Benefits accruing from a reduction of pollutants in ground and surface water linked to chemical fertilizers, primarily nitrates, but also phosphates.

3 Benefits accruing from a reduction in pollutants in ground and surface water and in the air arising from herbicides and insecticides.

4. A larger and more nebulous category of benefits that occur because, for example, soil structure might be maintained and enhanced with certain crop rotations, the use of animal manure, and other similar benefits arising from specific farming practices that help maintain and improve the productivity of the land over a long period of time.

Heimlich argues that improvement of wildlife habitat should be am important goal. Among advocates, this category of benefits is quite important. For agricultural scientists, rationalizing sustainable farming systems based on these kinds of benefits is controversial. In many instances, the scientific evidence in support of these benefits is inclusive, or has not been conducted over a sufficient period of time such that the benefits, if any, can be measured.

It is tempting to define as sustainable only those farming systems that produce environmental gain. However, as earlier indicated, the diverse array of environmental benefits and damages makes it difficult to compress the various facets of environmental quality into a single measure or indicator. Each alternative farming system whether labeled as sustainable or not will generate a unique combination of environmental benefits and damages. A new farming system, for example, may significantly reduce soil erosion, but at the cost of additional ground water contamination relative to a farming system that had been previously employed. Questions arise that are not easily answered. Is such a farming system sustainable? Must all environmental consequences of a new farming system at least be no worse than what existed under the previously employed system?

Other questions pose additional difficulties. Are there tradeoffs between various categories of environmental benefits? If so, in valuing environmental benefits, what weights should be employed for each type or category of benefits? Should these weights be constant across states and regions? Is a ton of soil loss from erosion in an area where the topsoil is several feet thick as serious an environmental concern as a similar amount of loss from an area where the topsoil is fragile and only a few inches thick? Should greater weight be placed on reducing pollutants in instances where scientific evidence exists that a pollutant is harmful to human health, or should a reduction in any kind of pollutant be equally valued? These are difficult questions to answer.

Environmental benefits (and damages) can be categorized with respect to whether the benefits (and damages) occur on-site or off-site. A farmer who implements a production practice that reduces nitrate pollution in drinking water from a farm well is realizing an on-site (benefit to the farmer) environmental benefit, whereas, if the production practice reduces nitrate contamination in wells of neighboring farms, an off-site benefit (benefit to others) occurs. If additional costs (and perhaps a reduction in profitability) are incurred from a particular production practice that also provides environmental benefits (or reduces harm to the environment), farmers would likely be more interested in implementing practices that provide primarily on-site benefits (benefits to them) than primarily off-site benefits (benefits to others).

A farming system that reduces soil erosion from water provides long-term on-site benefits to the farmer in the form of a reduced rate of loss of soil productivity over time. However, the reduction in silting of rivers arising from reduced water erosion may be highly beneficial to others, including taxpayers who must pay for the cost of dredging silted rivers. In this instance, the private interests of the farmer and the public interest of others coincide. In general, sustainable farming systems that reduce soil erosion provide considerable private on-site benefits. The public off-site benefits may be noticeable, however, only if a comparatively large number of farmers adopt production practices that lead to a significant reduction in soil erosion in an area.

Aside from the water well example, the on-site benefits to farmers of reducing the use of chemical fertilizers and pesticides may be somewhat less clear. Some farmers and soil scientists have argued that monocultures employing chemicals ultimately lead to a deterioration of the soil structure over time, with consequent negative effects on the long-term productivity of land. The long-term safety of certain agricultural chemicals to farmers their families and hired employees is another concern. Agricultural scientists who deal with pesticides are equally convinced of the current safety of the products, if applied in the manner and in the amounts as labeled.

Categorizing Sustainable Farming Systems based on Short and Long Run Profitability

This section outlines a procedure for categorizing specific farming systems according to the likely willingness of farmers to implement them in the short and long run. An ideal sustainable farming system is one that is highly beneficial to the environment, costs very little to implement, improves profitability immediately from the time of implementation, and for which the long-run profitability is greater than for the farming system it replaces. At the other extreme, another farming system may enhance environmental quality only slightly, be costly to implement, and substantially reduce profitability in both the short and long run.

Four categories of sustainable farming systems can be defined. Category I consists of those farming systems that reduce harmful effects of agriculture on the environment and increase the profitability of the farm in both the short and long run. Category II includes systems that reduce farm profitability in the short run but increase long-run profitability. This, in turn, leads to an increase the value of the farm over the long run. Category III includes systems that reduce profitability and the short and long run, but increase the long run value of the farm (and perhaps, the farmer's net worth). Category IV includes systems that reduce the harmful effects of agriculture on the environment but reduce profits in the short and long run. Unlike Category III practices, however, Category IV practices have no impact on the long-run value of the farm. Table 1 summarizes consequences for various categories of sustainable farming systems.

Table 1. Categories of Sustainable Agriculture Farming Systems.

Category:	Impact on the Environment	Impact on Short-Run Profits	Impact on Long-Run Profits	Impact on Farm Value (Net Worth)
I	⇑	⇑	⇑	⇑
II	⇑	⇓	⇑	⇑
III	⇑	⇓	⇓	⇑
IV	⇑	⇓	⇓	⇔

Patterns of Profitability and Environmental Benefits over Time

A widely held belief is that the only sustainable farming systems that we can expect farmers to implement those that are profitable. A conclusion could be that no farming system consistent with the overall goals of sustainable agriculture should be considered unless it is profitable immediately after implementation. But many desirable farming systems that are consistent with the environmental goals of sustainability may not be profitable in the first or even the first few years of implementation. Over a period of 10 to 20 years or even longer, however, these practices may be quite profitable when compared with conventional practices and also prove increasingly beneficial to the environment. This section illustrate alternative patterns of profitability and discusses the complex issues involved when one attempts to determine if a specific sustainable agriculture production practice is profitable.

Figure 1 illustrates profits over time for four hypothetical farming systems. Suppose that the first farming system, labeled here as "conventional," represents some existing technology currently employed. Even this farming system may incorporate some specific production practices broadly consistent with the goals of sustainability. Such a conventional farming system might be representative of a tillage- monoculture cropping system that tends to deplete soil organic matter (requiring increased amounts of chemical fertilizer to sustain output levels over time, and ultimately reducing profitability), and leading to a loss of topsoil due to erosion from wind and water. Even if yields can be maintained over time with increased applications of chemical fertilizers, the cost of these additional units of fertilizer over time ultimately decreases profits. Thus, this "conventional" farming system illustrates a pattern of decreasing profitability over the ten year period.

In contrast, the option labeled as sustainable option 1 represents a nearly ideal farming system. Profits exceed the profitability of the conventional system in all years of the ten-year time horizon being evaluated, and greatly exceed the profitability of the conventional system in years 5-10 of the time horizon. Unless such a system requires a large up-front capital outlay, farmers easily will be convinced that such a system should be implemented. Only a basic educational program is needed to acquaint farmers with specific production practices to be employed within the system.

The line labeled as sustainable option 2 perhaps represents a more typical, "textbook" case with respect to a sustainable farming system. In this hypothetical farming system, profitability in the early years is considerably below the profitability of the conventional system. This reduced profitability could be due to a number of reasons. Perhaps the new system requires a large up-front cash outlay in order to implement. Further, the possibility may be that either output is reduced or other (variable) costs are higher than under the conventional system. By year 4, however, the benefits (perhaps due to improved soil fertility or reduced erosion) are such that profits exceed the profitability of the conventional farming system. This option clearly has an advantage over the conventional option in sustaining profitability over time.

The line labeled sustainable option 3 represents yet another pattern of profitability over time. Although profitable, profits for this option remain below the conventional system in all years of the time horizon. This example might be most closely associated with a series of production practices incorporated into the farming system that, from a sustainability perspective, primarily yield off-site benefits to the environment. An example might be a farming system that employs specific production practices designed to reduce surface or groundwater contamination from nitrate pollutants by decreasing the use of chemical nitrogen fertilizers. Option 3 as illustrated here is clearly sustainable in that it is profitable over the time horizon, but profits to the individual farmer are considerably reduced relative to the other systems over the long term. At the same time, however, off-site environmental benefits under this option may be greater than for the other options.

Option 3 would be the most difficult to convince most farmers to implement, since the benefits of implementing such a practice or farming system largely accrue to those other than the farmer. If the environmental benefits are sufficiently great, however, the government may decide that a cost-sharing strategy might be appropriate.

In the example illustrated in Figure 1, all options were shown to be profitable in all years of the time horizon. This is, perhaps, an unrealistic assumption, and profits might be negative for some options in some years. Part of the issue centers on whether or not, when calculating profits as returns over costs, all costs are covered. For example, should a charge be levied for the farmer's own labor and capital? Depending on answers to such questions, the profitability and sustainability of the various options is in question.

Figure 2 is based on the profit scale illustrated in Figure 1, but instead compares the profitability of the various sustainable options with the conventional farming system. The profit measured on the vertical axis in Figure 1 is represented as a deviation from the profit obtained from the conventional system, as represented by the zero axis. Values above the zero axis represent profits above the conventional system, whereas values below the zero axis represent profits below that of the conventional system.

To the extent that the profits represented here are negative, they represent the implicit or imputed costs associated with attainment of the environmental benefits. If profits are positive, then the imputed cost of the environmental benefits (whatever he benefits might be) is negative. Farmers would likely be pleased if environmental benefits could be attained at no cost as measured by foregone profits. They would be even more pleased if a sustainable farming system that generated greater environmental benefits while generating more profit than the conventional system.

Figure 3 is identical to figure 1 but assumes an increase in fixed costs of $42,000 per year. The patterns for the various options are the same as in Figure 1, except that the vertical axis labeled profit has been adjusted. This might occur, for examples in instances where more of the true economic costs are accounted for. Examples include opportunity costs of owners’ equity capital, chargers for labor supplied by the farmer and other, similar, non-cash costs.

With this adjustment, the conventional option remains profitable only until year 4. The profitability of sustainable option 1 drops to zero in year 5. Sustainable option 2 is profitable for only a few years, whereas sustainable option 3 is not profitable in any year. Even though the profitability pattern for each option remains the same over time, the consequences of this adjustment might lead to dramatically different conclusions with respect to farmers' willingness to implement the various options. Clearly, option 3 is not now sustainable. Even the sustainability of option 2 is questionable, given that profits are positive in only a few years. The conventional production practice (system) is no longer profitable after year 4.

In (farm) business analysis, profits represent the return to all inputs that are not specifically deducted as individual cost items. In a normal farm business analysis, profits are defined as the return to the farm operator's managerial skills, entrepreneurship (that is, willingness to assume risk), farmer-supplied labor and the farmer's own equity capital. The definition of profit frequently used in farm business analysis differs significantly from an economic definition of profit. Using the economic definition, a charge for the farmer's own labor and equity capital would definitely be made. Profitability of the various options depicted in Figures 1 and 3 thus depends heavily on the whether the farm analysis or the economist's definition of profit is employed.

Each of the farming system options presented in these graphs will different types of environmental benefits and damages, and will occur as a stream of benefits or damages over time. Figure 4 simplifies the problem by collapsing a variety of environmental benefits and damages into a single environmental index (sometimes called an environmental indicator) that varies for each option over time. Such an indicator might include the effects of the option on wind and water erosion, surface and ground water contamination, and other measures. Similar techniques are widely used to rank cities with regard to the quality of life based on weighted average of a variety of individual indicators.

Figure 4 thus illustrates some hypothetical patterns for environmental indicators over time for the various farming system options over time. Under the conventional option, after initially rising for a short period of time, the indicator then steadily decreases. For sustainable option 1, the indicator increases slowly but steadily over time, although over the time period it does not achieve the levels illustrated for options 2 and 3. Under option 2, the environmental indicator is higher than for either conventional option or option 1. Option 3, the least profitable option, results in the highest environmental index, and the environmental index remains nearly constant over time as well. Each farming system option will potentially generate a different stream of environmental benefits over time. Furthermore, each will have a different stream of benefits and damages with respect to soil erosion, fertilizer and pesticide leaching and potential for ground and surface water contamination.

As suggested by these illustrations, tradeoffs frequently exist between the environmental benefits to a particular production practice or farming system, and the profitability of the practice or system over time. Neither the profitability nor the environmental benefits to practices broadly consistent with sustainability remain constant over time.

Figure 5 illustrates possible hypothetical impacts on farm value (real value, that is, net of inflation) of various production systems over time. A conventional system, employing production practices such as conventional tillage systems that result in high rates of wind and water erosion and chemicals instead of crop rotations (leading to a potential reduction in soil organic matter and the deterioration of soil structure over time) results in a declining real farm value. As the benefits from reduction in wind and water erosion accumulate over time, sustainable options 1 and 2 result in an increase in the value of the farm over time. Sustainable option 3, however, merely maintains the real value of the farm over time.

The Need for Public Support to Encourage Sustainable Agriculture

This section discusses the need for public support (such as federal- or state-funded educational programs and subsidies) to encourage farmer adoption of specific sustainable agriculture production practices and integrating them into overall farming systems. The type of public support may vary depending on the particular farming practice or system under consideration.

In some instances, a particular production practice may be beneficial to the environment and profitable from the first year of adoption. Public support in this instance might be limited to (1) research aimed at identifying and developing such specific practices and farming systems, and (2) educational programs aimed at making farmers aware of the specific practice or even an entire farming system. There may be other practices or integrated farming systems that are expensive to adopt, and the cost of adoption may pose a significant deterrent to adoption by farmers. Such practices and systems might produce beneficial long-run impacts on the environment and still be quite profitable for farmers.

To the extent that the proposed farming system provides greater off-site benefits than the farming system currently in place, federal, state and even local governments may have an interest in assuring that the alternative is implemented. For example, if the alternative, proposed system requires a capital outlay by the farmer in order to implement, the federal government (through agencies such as the Soil Conservation Service) might agree to share part of the initial start-up cost. The greater the off-site benefits, and the greater the ratio of off-site to on-site benefits, the more interest government an any level should be in assuring that the alternative farming system is adopted.

With a few exceptions, pollution from agricultural activities is classified by resource economists as "non-point" That is, it does not arise from a specific identifiable site such as a manufacturing plant. An exception would be pollutants arising from a facility such as a livestock feedlot. The Environmental Protection Agency historically has largely had regulatory authority to deal with pollution from point sources, such as the site of a manufacturing plant. Point pollution is comparatively easy to regulate in that the source and cause of the pollution and the identity of the polluter is usually easy to determine. Regulation often involves requirements to install devices capable of controlling the pollutants of concern, with fines and orders to stop manufacturing processes that are causing the pollution in extreme cases.

Pollution from agricultural activities largely arises as a result of the collective consequences of decisions made by many individual producers. Batie, for example, wonders if farm-level solutions to non- point environmental problems even exist (1994, p. 75). If a farming system is chosen that results in high nitrate or pesticide runoff, each individual farmer will be responsible for only a small, perhaps not even measurable, proportion of the environmental pollution. Significant pollution problems only occur if many (perhaps most) farmers in an area *all* choose farming systems that generate high nitrate or pesticide pollutant levels. Furthermore, to have a significant impact on reducing the pollution load, many farmers will need to adopt farming systems that each, taken individually perhaps has little impact.

Regulatory strategies commonly used for dealing with point pollution problems are often much less effective when applied to non-point pollution. Without a specific site, who should be regulated or fined? Other, more creative approaches may be needed for dealing with non-point pollution arising from agricultural production. Generally, these solutions require other-than regulatory strategies. Some possible strategies include the following:

1. *Research*. Research is needed to determine if there are alternative, economically viable production systems capable of doing less environmental harm than those currently in place. The U.S. private and public agricultural research system has proven very capable in designing new crop varieties, improving the genetics of livestock, and in designing pesticides capable of effectively controlling a specific weed or insect pest. This research system has been far less successful in developing research capable of dealing with questions that must be answered on a farming system basis. Many of these questions can only be answered with research projects involving many different specialists, and these projects in many instances, must be conducted over a period of at least 5-7 years. An additional issue is that of tracking the economic viability of alternative systems over several years, and comparing the results with conventional systems.

Funding of agricultural research largely proceeds on a year-to-year basis. As a consequence, academic researchers are anxious to show results from their research activity in a comparatively short period of time, at most a year or two. The prospect of a research project involving researchers from a number of different disciplines with the measurable outcomes only available over of a period of 5 to 7 years may not hold a great deal of appeal to agricultural scientists and administrators.

2. *Education*. Once the alternative farming systems have been identified as being economically viable and environmentally beneficial, programs need to be developed to enable farmers to make the changes necessary in order to implement the alternative farming system. Crop and enterprises differ markedly in the knowledge and technical skills required. This suggests that farmers might select enterprises in part, by assessing their own knowledge an skills about each enterprise.

   Sustainability to some carries a connotation of somehow returning agriculture to a simpler time, a time in which success at producing crops and livestock was less information dependent, and a time in which farming practices such as crop rotations and the use of green-manure crops substitute for technology-intensive chemical fertilizers and pesticides. It does not necessarily follow, however, that a sustainable farming system will require less knowledge or technical skills than conventional production systems. For a long time, farmers who adopt sustainable farming systems will still be competing with farmers who do not choose to do so. In order to be profitable over the long in competition with farmers opting for conventional farming systems, greater knowledge and technical skills, not less, may be needed. The extension service and the Soil Conservation Service are two publicly-funded agencies that will become increasingly involved in providing educational programs designed to farmers with the requisite knowledge and technical skills needed to enable them to adopt sustainable farming systems.

3. *Cost-Sharing.* The requisite research and farmer education programs are important to the adoption of alternative sustainable farming systems. However, even if the research and educational programs are in place, farmers still may choose to not adopt sustainable farming systems. Farmers generally have a good understanding of the risks associated with the set of production practices they are currently using. Even if some farmers are convinced that an alternative farming system could be as profitable as the one they are currently using, they may be reluctant to adopt because of a fear that the variability in profit over time will be greater than under the conventional farming system that are currently using. Further, in order to change farming systems, some capital items

> will need to be disposed of, and other capital items will need to be purchased. The up-front costs of disposing partially depreciated machinery such as tillage equipment while purchasing other items to accommodate the specific production practices making up the new, sustainable system could be large.

To the extent that off-site environmental benefits of the alternative farming system are large (with benefits to the non-farm public as well), it may be reasonable for the government to share in at least some of the start-up costs associated with the implementation of the alternative system. Such a program might function similar to programs employed by the Soil Conservation Service for implementing environmentally sound practices aimed, for example, at reducing soil erosion. A program like this recognizes that there are both public and private benefits from farmer adoption of production practices with considerable environmental benefits.

Green Support Programs and Sustainable Agriculture

Few farmers will likely adopt sustainable farming practices and systems that significantly reduce profitability in the short and long run, even if the benefits for the environment are high. If such practices and farming systems are to be adopted, there will likely be a need for additional government involvement beyond the publicly-funded research, educational programs and cost-sharing suggested above. A number of authors have argued that the current system of government price and income support payments for a number of major crops--payments that increase as the volume of the commodity produced increases-- encourages farmers to employ production techniques designed to increase crop production possible, even if attaining this goal results in other, undesirable consequences. Such government programs might, for example, depend heavily on historical yields, and, as a result, (1) encourage farmers to apply more fertilizer than would be deemed adequate in the absence of government payments, and (2) encourage farmers to continue to keep in production land only marginally suited to crop production, because if such land were put into other non-crop uses, the volume of output would be reduced, and the government payments as well.

One approach that has been suggested is called a Green Support Program (GSP), A GSP is a voluntary program that provides monetary payments to farm operators or farmland owners in return for the provision for environmental benefits (Lynch and Smith). Those advocating such an approach would revamp the current commodity price support program to focus more heavily on environmental goals. Environmental goals entered starting with the swampbuster and sodbuster provisions of the 1985 Farm Bill with the swampbuster and sodbuster provision, and extending to the additional environmentally- oriented programs including the Wetland Reserve

Program, the Water Quality Incentives Program, and the Integrated Farm Management Program (Batie, 1994, p. 74).

One way of looking at a Green Support Program is as a logical extension of the current sodbuster and swampbuster programs of the 1985 Farm Bill and the additional environmental goals articulated in the 1990 Farm Bill, designed to encourage farmers to implement a variety of production practices that provide environmental benefits. Critics of the current system of farm program payments argue that the emphasis on tying program payments to output levels provides economic encouragement for farmers to use production practices and adopt farming systems that are likely to be harmful to the environment over the long run.

Under a GSP, government payments to farmers would be linked to the adoption of production practices and farming systems that produce significant environmental benefits. Thus, the system of federal farm program payments would no longer be based entirely on acreages and production levels. Rather farmers who adopted practices that are environmentally beneficial would, in part, be compensated for the potential reduced long run profitability of such practices through a revamped system of farm program payments. Those who choose not to adopt these production practices would be ineligible for such payments.

Batie argues that a GSP provides specific incentives or penalties, voluntary adoption may be difficult. She argues that a successful GSP, if voluntary--that is, without government incentives-- must (a) identify and target the location of the environmental problem (b) have access to and make available the requisite technologies needed to enhance environmental quality, and (c) producers must be somehow encouraged to make the adjustments needed on a voluntary basis.

The threat of losing government payments from commodity price support programs has been an important policy "tool" for "encouraging" farmers to comply with the environmental provisions of the 1985 and 1990 Farm Bills. Much of the current discussion about reducing and eventually eliminating commodity price support programs in an effort to reduce federal outlays has ignored the fact that once the commodity price support programs are eliminated, the government will no longer have this tool to discourage farmers from implementing farming systems and specific production practices that are harmful to the environment. In the face of reduced, unsubsidized commodity prices at world market price level, and without acreage allotments, farmers may have economic incentive to maintain income by returning fragile lands--land not in production when acreage allotments were in effect--to production.

The idea of using money that was once used to support prices of basic agricultural commodities instead to encourage farmers to adopt production practices beneficial to the environment sounds highly desirable. Skees, however, suggests that major problems may occur in designing specific mechanisms used for developing an implementation strategy designed to achieve this kind of change in government policy (p.102).

Skees points out that politicians are primarily interested in funding programs that result in obvious short-run benefits, and a GSP designed to encourage farmers to adopt production practices that are environmentally beneficial will, by definition, provide the bulk of the benefits in the long run (p. 96). In this case, the long run is a period of time in which the environmental benefits of the GSP are obvious that is longer than the period of time to the next election. From a political perspective, there must be some short-run benefits to a GSP that politicians who support such a program could identify with as a basis for reelection.

Policymakers within the federal government are interested in reducing and eventually eliminating price support payments on commodities such as wheat and feed grains. Promises to cut spending in order to reduce the budget deficit combine with the political position of the U.S. government in international trade negotiations in which the U.S. is encouraging governments worldwide to eliminate subsidies to specific industries, thus "leveling the playing field" for all traders in world markets.

Any federal program aimed specifically at encouraging farmers to adopt farming systems and specific production practices consistent with the goals of sustainable agriculture must compete with policy designed to achieve the dual goals of deficit reduction and free trade worldwide. Any regulations placed on U.S. farmers in an effort to achieve environmental goals cannot be so onerous such that U.S. farmers will no longer be able to produce commodities profitably at world market prices.

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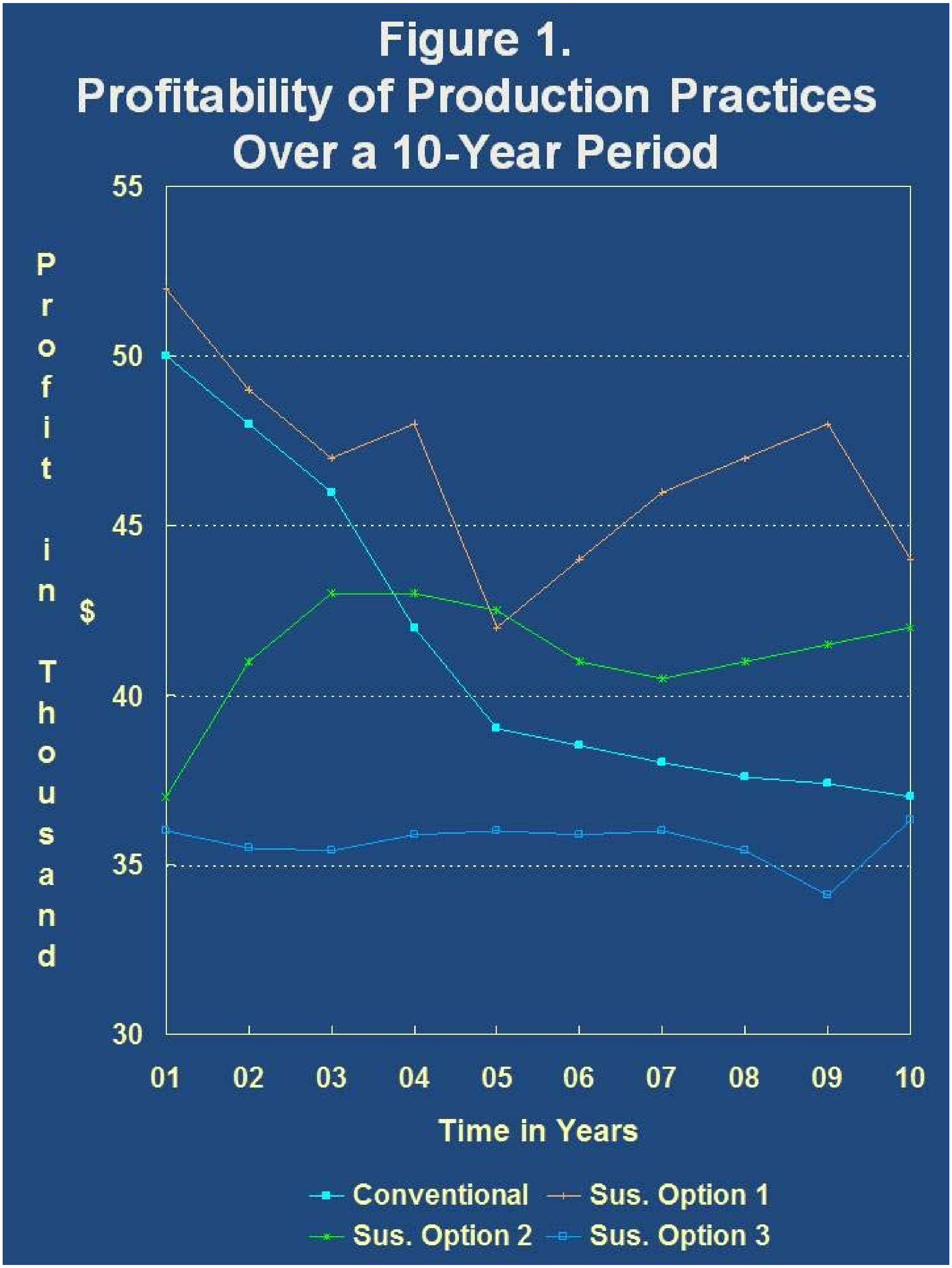
Figure 1.
Profitability of Production Practices
Over a 10-Year Period
55
50
45
40
35
30
Profit in Thousand $
01
02
03
04
05
06
07
08
09
10
Time in Years
Conventional
Sus. Option 1
Sus. Option 2
Sus. Option 3

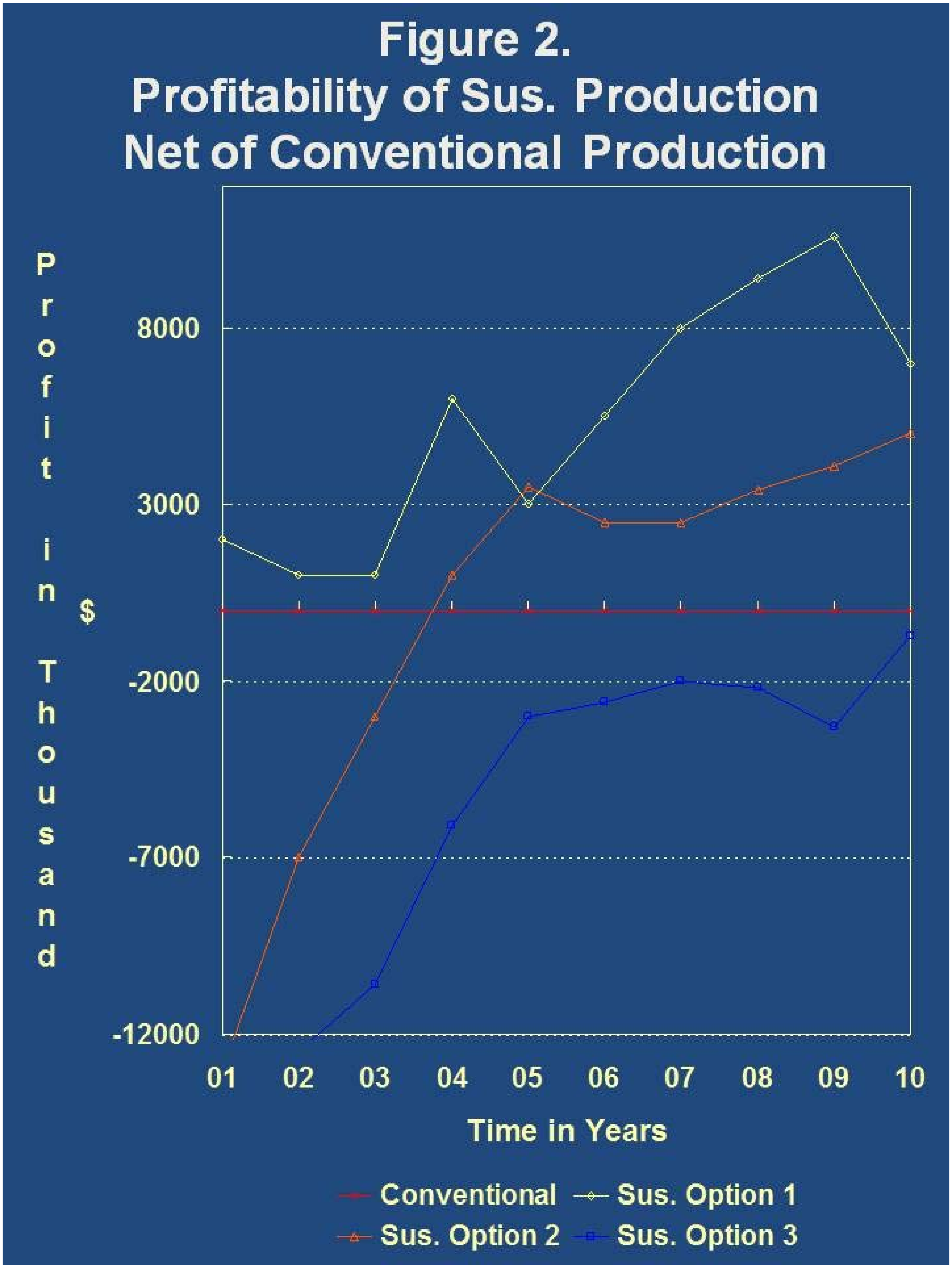
Figure 2.
Profitability of Sus. Production
Net of Conventional Production
Profit in Thousand $
8000
3000
-2000
-7000
-12000
01
02
03
04
05
06
07
08
09
10
Time in Years
Conventional
Sus. Option 1
Sus. Option 2
Sus. Option 3

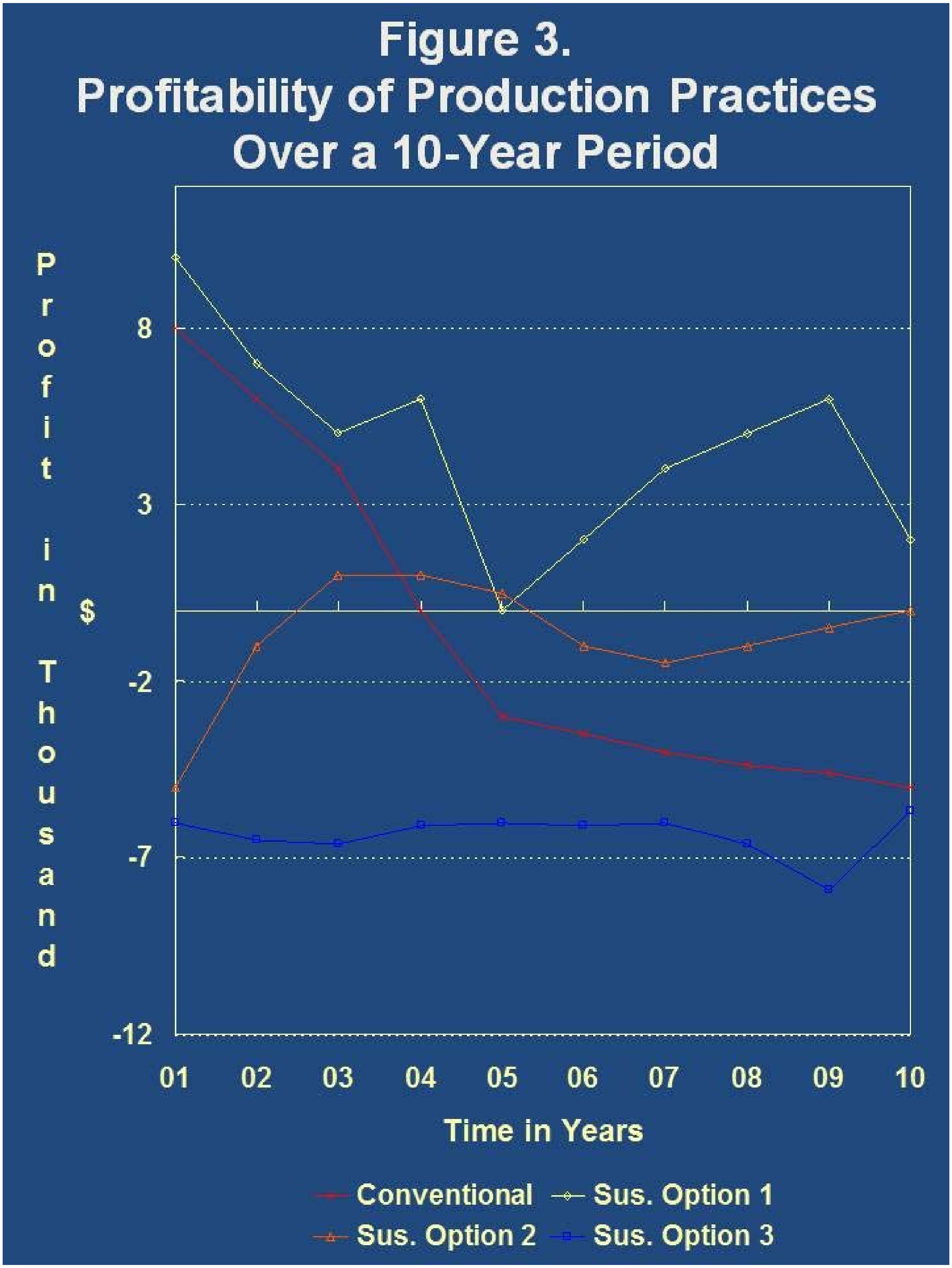
Figure 3.
Profitability of Production Practices
Over a 10-Year Period
Profit in Thousand $
8
3
-2
-7
-12
01
02
03
04
05
06
07
08
09
10
Time in Years
Conventional
Sus. Option 1
Sus. Option 2
Sus. Option 3

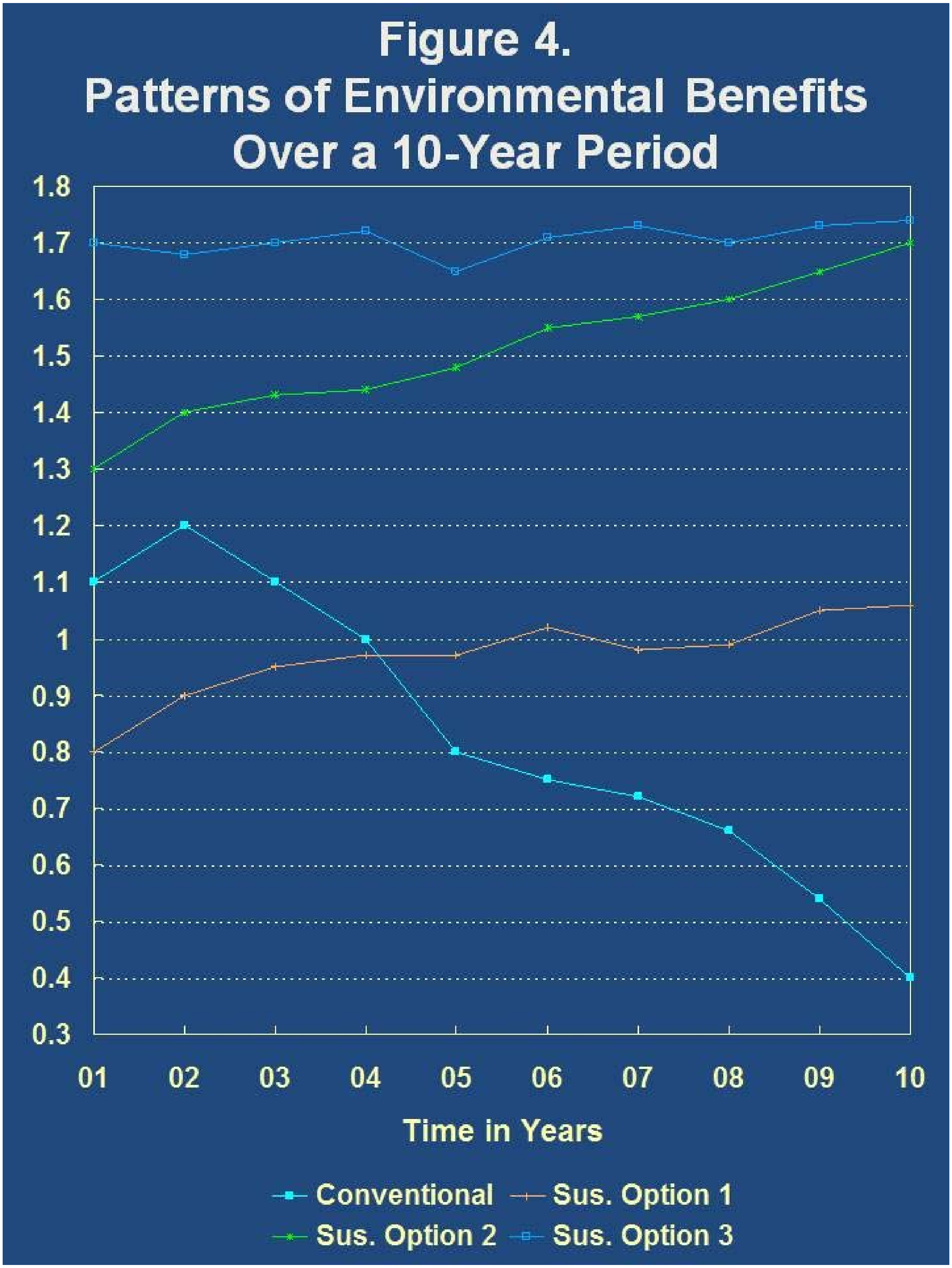
Figure 4.
Patterns of Environmental Benefits
Over a 10-Year Period
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
01
02
03
04
05
06
07
08
09
10
Time in Years
Conventional
Sus. Option 1
Sus. Option 2
Sus. Option 3

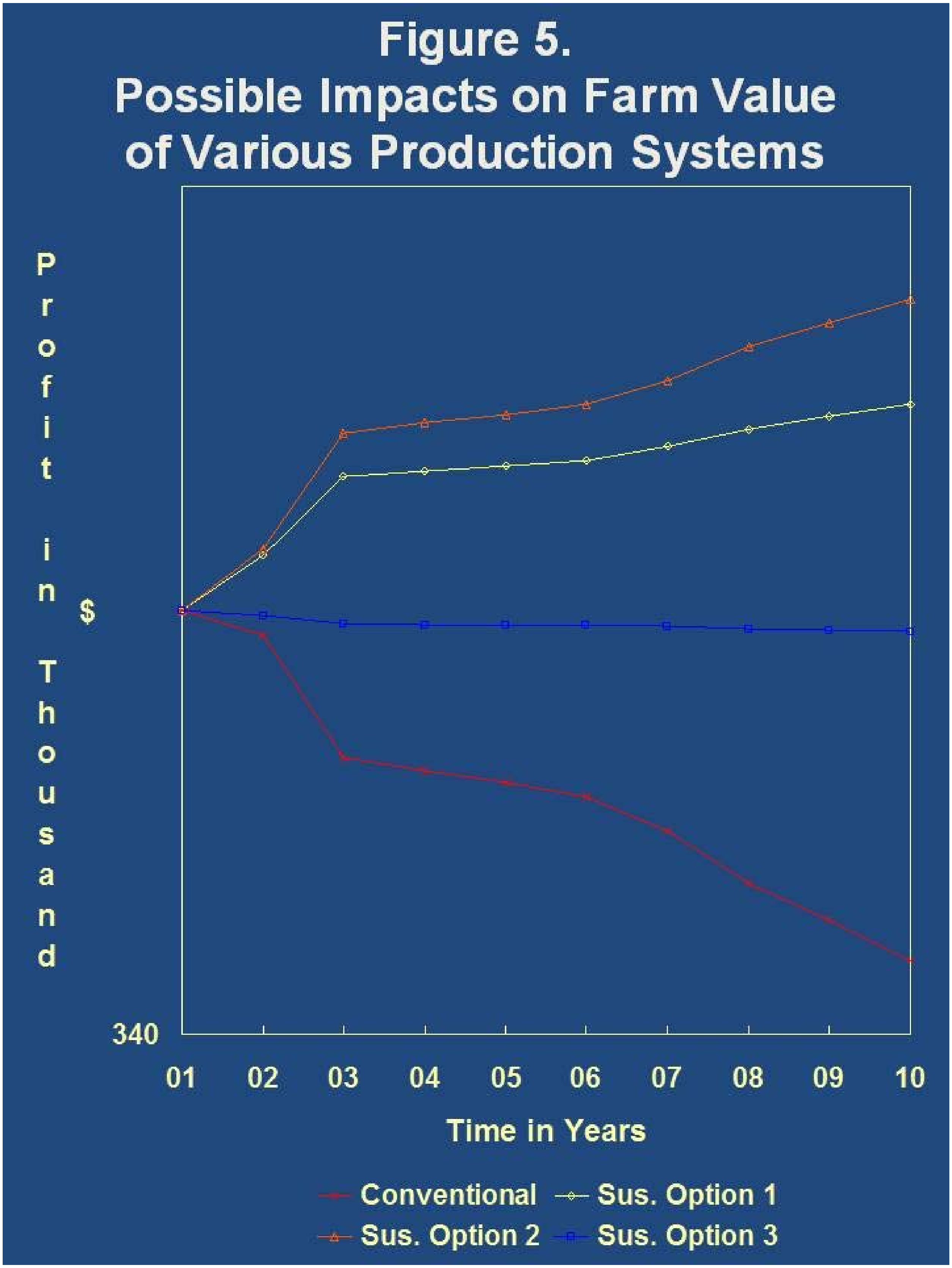
Figure 5.
Possible Impacts on Farm Value
of Various Production Systems
Profit in Thousand $
340
01
02
03
04
05
06
07
08
09
10
Time in Years
Conventional
Sus. Option 1
Sus. Option 2
Sus. Option 3