A MULTIPLE OBJECTIVE APPROACH TO EVALUATE ECONOMIC AND ENVIRONMENTAL IMPACTS OF AGRICULTURAL MANAGEMENT SYSTEMS FROM A SUSTAINABLE DEVELOPMENT PERSPECTIVE

by

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(ABSTRACT)

This dissertation develops a systems theory perspective of the concept of sustainable development, and explores a systematic approach to employ this concept to an economic analysis. An examination of interpretations, foundations and the framework of the concept of sustainable development is conducted; and an empirical application of this concept through a multiple criteria evaluation of agricultural management systems in Richmond County, Virginia is presented.

Various interpretations of the concept of sustainable development are found to be based on Six "E" considerations: Economic, Energy, Environmental, Ecological, Equity, and Ethical. These interpretations with their different foci constitute a three dimensional view of economic development while neo-classical economics has a one dimensional view. The concept of sustainable development recognizes absolute resource scarcity, which is represented by the limited quantity of resources for inputs to economic systems; and is represented by the limits of the assimilative capacity of the environment for waste discharges. Advocates of the capacity of the environment for waste discharges. Advocates of the absolute quantity limit of resources generally employ the second law of thermodynamics, but a close examination indicates that this application of the second law is incorrect. The inapplicability of the second law thus widens the range of alternative choices that can be included in the design of a sustainable development path. For example, low-input sustainable agriculture loses its self-evidence meaning of sustainability. Its sustainablity should depend on its economic, environmental, and social values in different areas.

To employ a multiple criteria approach to evaluating economic and environmental impacts of agricultural management systems in Richmond County, Virginia, a multi-objective dynamic programming model; coupled with the Chemical, Runoff, and Erosion from Agricultural Management Systems simulation model; is developed. The results of the model suggest an improvement in economic and environmental benefits can be achieved through use of a mixture of legume and non-legume cover crops rather than use of poultry litter as fertilizer source or simply lowering fertilizer application rates. The results also indicate there is no possibility of achieving a 40% reduction of nitrogen loading as required by Chesapeake Bay Agreement by employing the any of 14 agricultural management systems analyzed in this study.

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Chapter 1 Introduction

Many disciplines have been challenged by the concept of sustainable development, and also contributed to this concept with various interpretations. These interpretations, thus, could be thought of as the projections of the concept of sustainable development on different disciplinary and public "screens" with different "color." These "colored projections" complement each other and constitute a "hologram" of this concept. The vitality of an individual interpretation is determined by its compatibility with other interpretations. The realization of sustainable development in a society depends on the compatibility of the concept with social ideology, the social environment, and social relationships; which are changed with time; human knowledge; ethics; and economic conditions in different stages of socioeconomic development. This dissertation demonstrates a systems theory perspective of the concepts of sustainable development, and explores a way to employ this concept in an empirical economic analysis.

1.1 Several Points on the Concept of Sustainable Development

"Sustainable development as a concept represents the latest step in a long evolution of public concerns with respect to both natural resources and to the environment (Batie, 1989, p.1083)." The concept of sustainable development evolved in the late 1980's. The global challenge of environmental decline and the new understanding of the environment contributed to the formation of this concept. Environmental trends, including desertification; deforestation; acid precipitation; and global warming, threaten to radically alter the planet and the lives of many species upon it, including humans. It became impossible to separate economic development issues from environmental issues (World Commission on Environment and Development, 1987). In terms of humans' reaction to these environmental trends, "the call for sustainable development resonates with the rise of new understanding of environmental systems, technology, social organization, knowledge, value, and their interplay (Norgaard, 1988, p.614)." Therefore, formation of the concept of sustainable development is the product of evolution of the global system, which includes human societies, biosystems, and physical systems.

One of the important features of the concept of sustainable development is pluralism; pluralistic concepts and pluralistic forms of knowledge. One definition of sustainable development that is commonly accepted is economic development which "meets the needs of present without compromising the ability of future generations to meet their own need (World Commission on Environment and development, 1987, p.8)." However, interpretations of the nature of sustainable development are varied. Debate on the implications of sustainable development have been broadly extended from its original economic concern to environmental, ecological, social, political, and ethical concerns. The hypotheses and philosophical bases of these interpretations are so different that the desire for sustainability may be the only overlap among these interpretations. In terms of forms of knowledge, the concept of sustainable development, originally in the form of "scholarly knowledge"[1], is strongly influenced and affected by the "folk knowledge"[2] of individuals in human societies. The benefit from pluralism is potential new avenues of inquiry into sustainable development (Castle, 1990).

Two ambiguities of the concept of sustainable development are: what is the direction of sustainable development, and how can sustainable development be measured? A co-evolutionary process does not necessarily result in sustainable development for all societies (Norgaard, 1988). There is no evidence that evolution of human societies and ecosystems has a direction, called a "time's arrow," which can be measured. Therefore, the direction of evolution can not be said to go "up" or "down" (Boulding, 1978).

One of the important values of the concept of sustainable development is as a guide to the decision and policy making processes related to environmental and natural resources management. For example, Norgaard and Dixon (1986) suggested modified benefit-cost analysis for pluralistic project design. Improved traditional techniques of economic analysis and new evaluation techniques are needed to analyze the empirical problems under the guidance of the concept of sustainable development.

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[1] "Scholarly knowledge is what is acquired and transmitted by specialists in the acquisition and transmission of knowledge (Boulding, 1983, p.7)."

[2] "Folk knowledge is what we acquire in the ordinary business of life (Boulding 1983, p.7)."

1.2 Objectives of this Study

This study includes two basic parts: a theoretical study on the concept of sustainable development and an empirical application of multiple-criteria evaluation to agricultural management systems in Richmond County, Virginia.

The objectives of the first part are:

- to briefly review various aspects of the sustainable development concept with emphasis on exploring the pluralistic characteristic of the concept of sustainable development;

- to present a systems theory perspective of the concept of sustainable development and neoclassical economics, and to appeal for inter-disciplinary research;

- to employ a cognitive systems approach to analyze the applicability of the second law of thermodynamics, one of the foundations of the concept of sustainable development, to the conclusion of absolute limits to growth; and

- to analyze low-input sustainable agriculture production systems with emphasis on exploring the multi-objective characteristics of these agricultural production systems.

The objectives of the second part are:

- to develop empirical techniques to evaluate the economic and environmental impacts of low-input agricultural management systems, which are assumed to represent a step towards sustainable agriculture, in Richmond County, Virginia;

- to develop parameters for the CREAMS simulation model in order to be able to predict and compare non-point source pollution and crop yield response of agricultural management systems; and
- to employ a multi-objective dynamic model to quantitatively determine consistent and inconsistent relationships between economic and non-point source pollution impacts of conventional and low-input agriculture.

1.3 A General Outline of this Dissertation

The remainder of this dissertation is organized in following manner. Chapter 2 presents a theoretical study on the concept of sustainable development. Chapter 3 develops a general multi-objective dynamic programming model for empirically evaluating economic and environmental impacts of the agricultural management systems. Chapter 4 presents the results of the general model and discusses results under several scenarios. Chapter 5 summarizes the dissertation, offers some conclusions, discusses the limitations of the study, and suggests further research.

Chapter 2

Examination of the Concept of Sustainable Development: Interpretation, Foundations, and Framework

In this chapter, various interpretations of the concept of sustainable development based on different foci are first discussed. Then, a systems theory perspective of the concept of sustainable development and neoclassical economics is presented. Finally, two applications of systematic analysis, including examination of the foundation of sustainable development and features of low-input sustainable agriculture, are presented.

2.1 A Brief Review of the Sustainable Development Concept: The Six "E" based Considerations

"Sustainability appears to be accepted as the mediating term designed to bridge the gulf between 'developer' and 'environmentalists'. Its beguiling simplicity and apparently self-evident meaning have obscured its inherent ambiguity (O'Riordan, 1988, p.29)." The concept of sustainable development has been interpreted in numerous forms with different foci. These various interpretations of sustainable development are generally based on six "E" considerations: Economics, Energy, Environment, Ecology, Equity, and Ethics, and will be discussed below.

2.1.1 Economic Considerations of Sustainable Development

The concept of sustainable development is economically oriented. The World Commission on Environment and Development (1987, p.8) pointed out that the economic implications of the Commission's definition of sustainable development described in chapter one are: (1) "the present generation can not borrow environmental capital from future generations with no intention or prospect of repaying," that is, the decline in the endowment of natural resources could limit a future generations' economy if a repayment is not given by the present generation; (2) these limits are "not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effect of human activities," and (3) in terms of future economic growth, "technology and social organization can be both managed and improved to make way for a new era of economic growth."

Conceptually, this definition of sustainable development can be accepted by either neoclassical economists and some advocates of sustainable development even though their interpretations of the definition may be different. The neoclassical economics view of sustainable development is basically defined in terms of efficiency, including temporary and intertemporal efficiency. For example, Hotelling (1933) argued that the net price (prices minus marginal cost of extraction) of a given resource should be used over time at rate equal to society's discount rate. The neoclassical view of sustainable development includes the concepts of that: (1) price of a natural resource can be a measurement of scarcity of the natural resource; (2) scarcity of natural resources can be mitigated by substitutes, technological development, and exploration, which are activated by using price levers (Randall, 1987);

(3) limits to economic growth can be avoided through expert management of technology at least in the near future; and (4) inter-generational equity will be realized because the "repaying" of resource uses by the present generation to future generations could include knowledge, expanded research capacity, improved technology, reproducible capital goods, improved social institutions, as well as environmental and natural resource assets (Veeman, 1989).

Batie (1989) pointed out that within this definition, some advocates of sustainable development defined several paths of sustainable development such as maximizing subject to constraints (Pearce, 1987) and enoughness (Sachs, 1989). The former path pursues economic growth subject to environmental constraints. The latter path requires greatly reducing rates of economic growth and minimizing the use of natural resources.

2.1.2 Energy Considerations of Sustainable Development

Some advocates of sustainable development challenge the basic point of unlimited substitutes. They believe that resources, in terms of workable energy are absolutely limited and their use will lead to their exhaustion in the near future. The last 400 year boom in the world economy has led to population increase and exploitation of non-renewable resources. Vitousek et al. (1986) estimated that nearly 40 percent of potential terrestrial net primary productivity[3] is used directly, co-

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[3] "Net primary productivity is the amount of energy left after subtracting the respiration of primary producers (mostly plants) from the total amount of energy (mostly solar) that is fixed biologically (Vitousek, 1986, p.368)."

opted, or foregone because of human activities even though *homo sapiens* is only one of about 5 to 30 million animal species on the earth. Therefore, the existence of absolute energy based limits to economic growth will come to play in the near future, maybe in the next generation. Controlling population and the scale of the economy is necessary (Daly, 1990). Advocates of energy considerations of sustainable development believe that it is the given amount of low entropy energy that limits the economic growth and can lead to extinction of human societies. A detailed discussion of the energy considerations of sustainable development can be found in section 2.2.3.

2.1.3 Environmental Considerations of Sustainable Development

Public concerns relating environmental problems arose from damage caused by the rapid economic growth following the Second World War (World Commission on Environment and Development, 1987). Unlike prior to the War, these public concerns increasingly emphasized on aesthetic and amenity uses of environmental resources due to a rapid growth of interest in outdoor recreation in the 1950's (Batie, 1989). Environment has been recognized as a scarce resource, which has the functions of: (1) supplying useful material and energy inputs for the economic processes, (2) providing certain utility through aesthetic or amenity uses, and (3) assimilating the wastes generated by economic processes (Barbier, 1990).

In terms of the first function of environmental resources, environmental considerations of sustainable development are similar to the economic considerations of sustainable development above. The second function leads to evaluating the environmental value of resources based on the private preferences of individuals or public preferences. Individuals have private preferences and public preferences. Private preferences assign non-market values to environmental services in terms of willingness to pay and willingness to be compensated. Public preferences involve opinions and beliefs about what ought to be the case rather than individual desires or wants, which are the basis of social norms and legislation. Consideration of the assimilative capacity of the environment is, in a sense, similar to the ecological consideration of sustainable development. "These advocates are concerned with limits to growth posed by the pollution of the environment (Batie, 1989, p.1089)." Since entropic throughput from economic process is discharged to the environment, environmental constraints could ultimately cease the economic growth (Daly, 1990; Georgescu-Roegen, 1971).

2.1.4 Ecological Considerations of Sustainable Development

Discussion relating to ecological considerations of sustainable development occupies a large percentage of sustainable development literature. Basic topics of ecological considerations of sustainable development involve ecological carrying (or assimilative) capacity, species diversity, ecosystem resilience, and the rights of non-human species. Assimilative capacity of ecosystems has been argued as an alternate limit to economic growth. Ecological economists, as representatives of ecological considerations of sustainable development, aim to extend the modest area of overlap between economics and ecology and to find new ways of thinking about the linkages between ecological and economic systems (Costanza, 1989).

Furthermore, deep ecologists purport to speak more directly for the biosphere as a whole and seek a better relationship between humans and other forms of life to save the earth and to create more ecologically sound ways to live upon the earth. They celebrate individual personal relationships with the ever-shrinking world of "wild" nature and embrace a wide variety of political, artistic, and philosophical approaches for expressing and deepening those relationships (Tokar, 1988). From this point of view, ecological considerations of deep ecologists are close to ethical considerations of sustainable development.

Another type of ecological consideration of sustainable development came from social ecologists. Social ecology emphasizes the historical unity of ecological and social concerns. For example, merging of ecological and anti-militarist concerns led to the foundation of the Green party in Europe (Tokar, 1988). This type of ecological consideration is politically colored and is close to equity considerations of sustainable development.

Proponents of ecological considerations of sustainable development may represent the biggest group of sustainable development advocates. Failures in managing the human environment and in spreading benefits associated with economic growth to all members of societies, as well as the dynamic evolution of human knowledge lead to different groups of people in society preferring ecologically sound development paths. The complexity of ecosystems also attracts humans' curiosity of exploration, and plays an important role in the development of ecological considerations of sustainable development.

2.1.5 Equity Considerations of Sustainable Development

Equity considerations of sustainable development include emphasis on: (1) intra-generational equity, (2) inter-generational equity, and (3) extending equity to non-human species. The first two considerations are mostly based on Rawls' (1971) theory of Justice which stated that only a just society is sustainable. Originally, Rawls' (1971) theory of justice concerned intra-generational justice. Individuals in an original position, where they face a "veil of ignorance" about their exact location in society, such as rich or poor and advantaged or disadvantaged, will secure the greatest protection possible against the risk of being the poorest members of society. Rawls' (1971) results suggested maximizing primary goods[4] available to the most disadvantaged individual in society. Rawls' (1971) justice law was extended to an inter-generation context by Page (1977). Changes from the intra-generational to inter-generational analysis include: (1) individuals who face the "veil of ignorance" can come from different generations, instead of coming from contemporary society; and (2) extending Rawls' law to suggest that natural resources availability to the poorest generations should be maximized, instead of primary goods to the poorest individuals. The extension was suggested because if the endowments of natural resources vary between generations,

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[4] Primary goods are rights and liberties, opportunities and powers, income and wealth (Rawls, 1971).

primary goods will vary between generations. To maximize the natural resources available to the most disadvantaged generation in human history, an individual will choose equal generational use of natural resources (Pearce, 1987). Therefore, the extension of Rawls' justice to the inter-generational consideration is implicitly built on the assumption of existence of absolute limits to natural resources.

Extension of equity to non-human species argues for the rights of non-human beings, which is similar to ethical considerations of sustainable development. That consideration will be discussed below.

2.1.6 Ethical Considerations of Sustainable Development

Ethical considerations of sustainable development search for new environmental ethics, apart from utilitarianism that is the ethical bases of the traditional approach to economic decision making and policy making. These new environmental ethics include ethics for justice of human society and ethics for non-human beings. The former concerns intra- and inter-generational justice. The later concerns non-human species rights.

Since neither utilitarianism nor libertarianism can support an ethical basis for the principles of intra- and inter-generational justice requiring equal treatment for all persons as well as non-human beings, environmental ethicists need a new theory of justice. As mentioned above, Rawls' theory of justice is commonly used as the framework of ethics for intra- and inter-generational justice. However, Rawls' theory is not free from criticism. The dual nature of Rawls' theory results in conflicts as soon as the analysis moves away from a self-contained society of contemporaries (Wolff, 1977). When Rawls' theory of justice is applied in an inter-generation context, a permanent livability criterion is suggested, which states that the only justification for unequal resource endowments for each generation is if all generations can made better off as a result of this inequality. Not too surprising, intertemporal efficiency and intertemporal justice are likely to be in conflict (Pearce, 1987).

Collectivism also has been suggested to be the basis of the environmental ethic. Given a collectivist position, the principle of inter-generational equity can be interpreted in terms of a "justice as opportunity" argument and a "Lockean Standard". Each generation should leave enough and as good for others that follow on. The sustainability principle of collectivism relies on keeping a constant natural capital stock. That is, the present generation compensates for any reduction caused by their access to easily extracted resources and conveniently located investments designed to offset the impacts of depletion.

Ethics for non-human beings include: (1) anthropocentric environmental ethics, (2) ecocentric ethics, and (3) biotic egalitarianism. Anthropocentric environmental ethics is also called an extended stewardship ideology. The basic idea is that humans should act as natural stewards and practice careful husbandry of natural resources, for their own sakes and protection of other creatures. As a result of this perspective, the total economic value of a resource includes three parts: (1) actual use value, (2) option value, and (3) existence value. Where, actual use value is market value; option value is the value of environmental amenity or resource as a potential benefit measured as the willingness to pay or willingness to accept. Existence value is an intrinsic value and is different to "indirectly use value" (Pearce, 1987; Hargrove, 1989).

Ecocentric ethics state that non-human species are inherently valuable and possess moral rights. The class of morally considerable being should be extended to systems and not just individuals. The anchor point for this position is Leopold's 'Land Ethic'. The *summum bonum* of the land Ethic is the integrity, stability and beauty of the biotic community (Hargrove and Callicott, 1990)

Biotic egalitarianism argues equal rights for all species must be recognized, at least in theory. Deep ecologists believe that only biotic egalitarianism can offer adequate environmental protection.

Obviously, there is difficulty in going beyond saying that ethical standards apply to non-human beings, to empirically applying these ethics. Two major problems are: (1) how to discover the intrinsic value of non-human species, and (2) what the principles or rules for adjudication of cases where human and non-human moral interests come into conflict is.

Different considerations of sustainable development contribute alternate ways of thinking about sustainable and development. A systems theory perspective of these considerations is given in the next section.

2.2 Systems Theory Perspectives of the Concept of Sustainable Development and Neoclassical Economics: A One Dimensional Versus A Three Dimensional Approach

General systems theory was first developed by Ludwig Von Bertalanffy (1956). One of the distinguishing properties of the systems approach is that system scientists prefer an interdisciplinary consideration of phenomena. A systems approach uses either qualitative or quantitative analysis as the basic vehicle to: investigate concepts, laws, and models in various fields; encourage the development of adequate theoretical models in the fields which lack them; minimize the duplication of theoretical effort in different fields; and promote the unity of science through improving communication among specialists (Von Bertalanffy, 1968). In this section, the definitions, classifications, and functions of systems are first presented. Then, systems theory perspectives of neoclassical economics and the concept of sustainable development are compared. Finally, discussions on appropriate interdisciplinary research, cybernetic and cognitive systems approaches, and applicability of the concept of sustainable development are presented after exploring the complementarities and contractions of relevant disciplines.

2.2.1 Definitions, Classifications, and Functions of Systems

A system has various definitions. Von Bertalanffy (1968) defined a system as a complex of interaction elements. F.J. Kast and J.E. Rosenweig (1969) defined a system as an organized or complex whole: an assemblage or combination of things or parts forming a complex or unitary whole.

Sutherland (1975) thought that a proper system would be an entity that substantially meets the following: (1) a system must be in a state of integration sufficient to separate it from its environment; (2) a system must contain differentiable subsystems, where the differential may be either structural, functional, or spatial; and (3) a system must be capable of constrained animation among its subsystems, such that their behavior is not entirely autonomous.

A system can be classified in several ways. Von Bertalanffy classified systems as either closed systems or open systems based on their relationships with their environment. An open system is a system that depends, to a lesser or greater extent, on interchanges with its environment and other systems that might be present. For example, economic systems, social systems, and biosystems are examples of open systems. A closed system, on the other hand, tends to be self-contained or only minimally responsive to outside influences. Clearly, no system exists in the real world that is totally closed to outside influences for any significant interval of time (Von Bertalanffy, 1956).

Another approach to classifying systems is more oriented to engineering and sometimes is confused with the above classification. Using such an engineering orientation, Forrester (1968) divided systems into two categories, open systems and feedback systems. An open system is one characterized by outputs of the system that respond to its inputs, but the outputs are isolated from and have no influence on the inputs. That is, in an open system, past action does not control future action. A feedback system, which is sometimes called a "closed" system, has a closed feedback loop that brings results from past actions of a system back to influence future action. There are two classes of feedback systems, negative feedback systems and positive feedback systems. A negative feedback system seeks a goal and responds as a consequence of failing to achieve the goal. A positive feedback system generates growth processes wherein action builds results that generate further greater action.

Thus, the confusion generated by these two definitions is compounded by the fact that the definitions are not comparable. What Von Bertalanffy (1956) defined as an open or closed system may be either a closed or open system by Forrester's (1968) definition and vice versa. For example, man, as a system, has energy exchanges with the environment and is also influenced by past behavior, so man is an open system by Von Bertalanffy's (1956) view, but a closed system by Forrester's view (1968). To avoid confusion, Sutherland (1975) suggested that Forrester's open system be referred to as an open-loop system and Forrester's closed system as a closed-loop system.

In Figure 2.2.1, a simple feedback system borrowed from Machol (1965), is used to present the fundamental elements of a feedback loop. A feedback loop has at least a monitor element and a comparator element. With a feedback loop, the feedback system can react to its own output. In the beginning, the system is given a desired output, DO. An initial input based on the desired DO enters the system and produces an output, RO. The output is measured by a monitor in which information, MO, is produced. Since neither the system nor monitor is likely to be perfect, in general

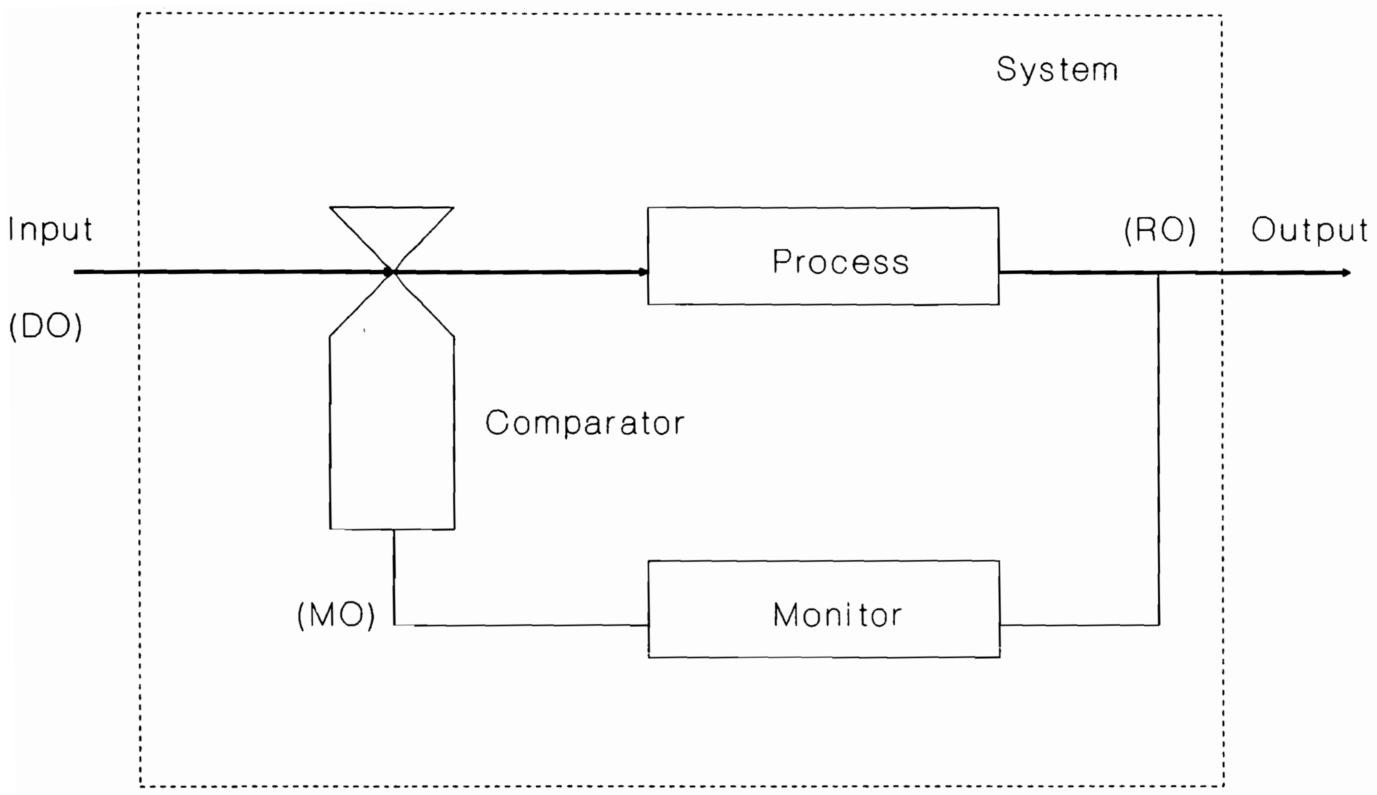


Figure 2.2.1 A Simple Feedback System

Source: Machel (1965)

MO is biased and not equal to DO. Like a decisionmaker, the comparator adjusts the input based on error E, which is equal to DO minus MO, $E = DO - MO$. Then an input adjusted by the error enters the system, as a new input, and the process will continue as long as system works. In a negative feedback system, which has a negative feedback loop, input adjustment is always toward the direction of eliminating error, E. Most engineering systems have negative feedback loops since engineering systems are commonly designed for specific purposes.

Forrester (1968) pointed out that output of the negative feedback system can smoothly achieve the goal that the system is seeking or wildly fluctuate in search of the goal. The former is called a first order negative feedback system, which has only one system level variable, and the latter a second order feedback system, which has two system level variables. Furthermore, an n^{th} order feedback system has n system level variables. Figure 2.2.2 presents the dynamic behavior of the first and second order negative feedback loop system. It should be pointed out that the desired output of the negative feedback system could vary with time.

Positive feedback systems have a positive feedback loop. Positive feedback systems do not seek an externally determined goal as do negative-feed back systems. Action within the positive loop system increases the discrepancy between the system's level and the "goal" or reference point. The rates of increasing discrepancy depend on the feedback loop and the system themselves. Figure 2.2.3 represents an "exponential" growth rate of a positive feedback system, smooth versus fluctuations in searching the goal. In this case, the output to which the level of system has already

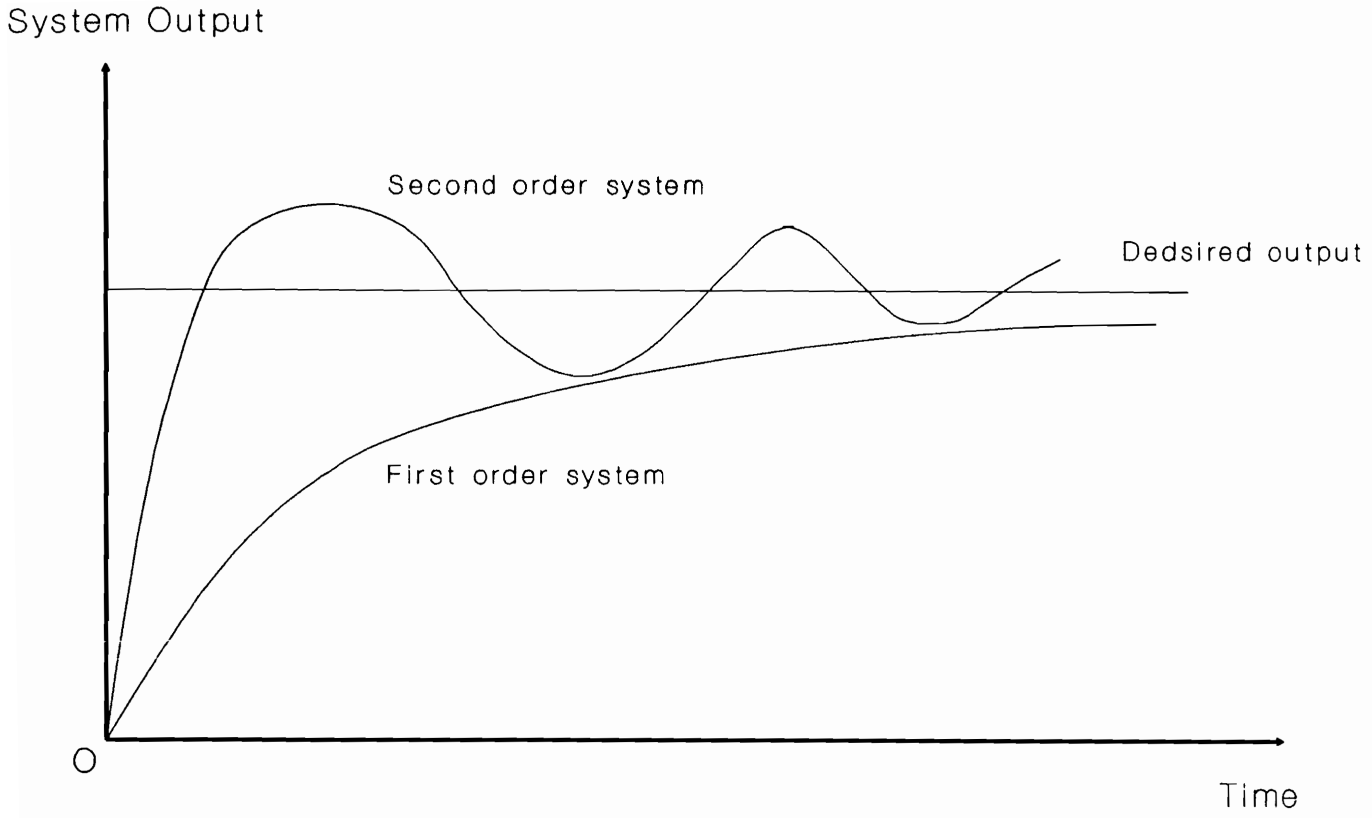


Figure 2.2.2 Dynamic Behavior of the First And Second Order Negative Feedback Systems

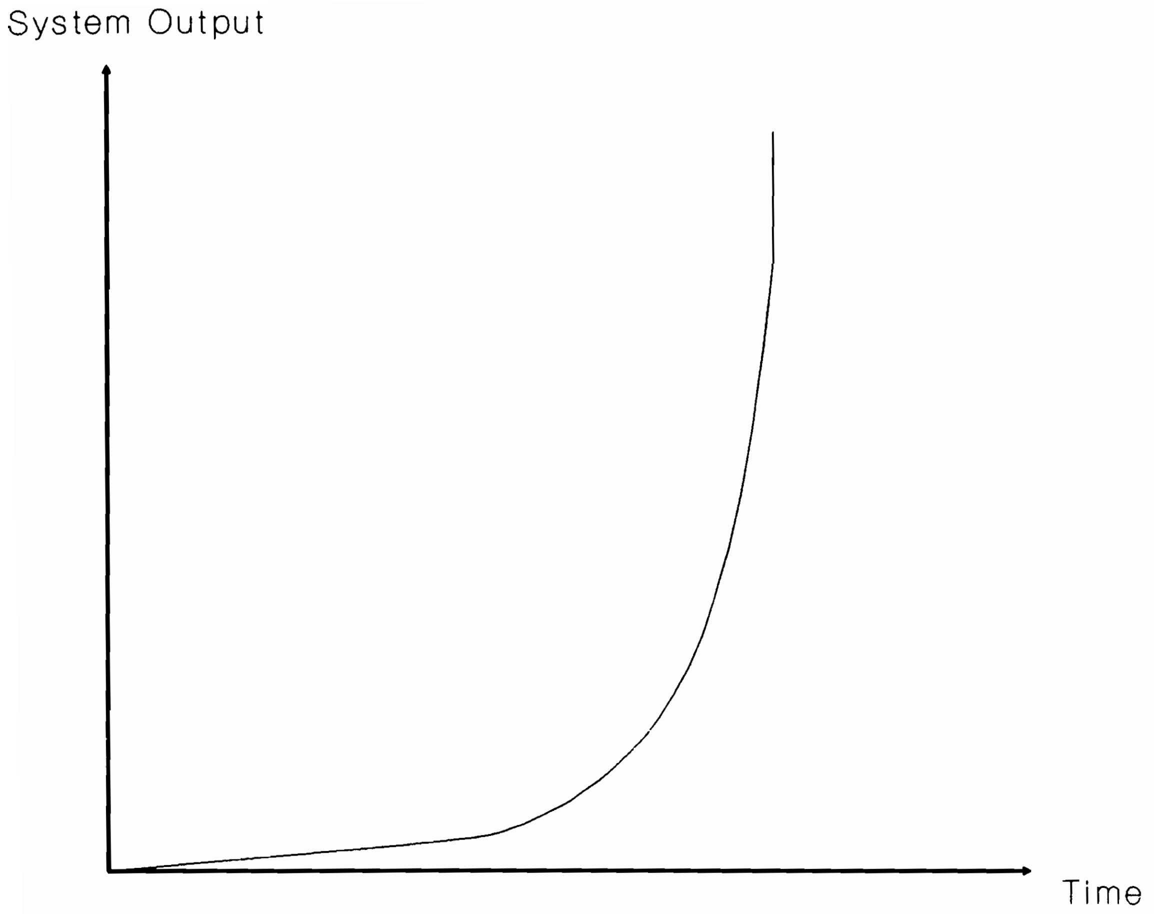


Figure 2.2.3 Exponential Growth rate of a Positive Feedbck Loop System

risen determines the rate of further increases. The bigger the output is, the faster the output grows, until something happens to alter the parameter values in the positive feedback loop (Forrester 1968).

Human ecological systems include two kinds of independent subsystems on the earth, human social systems and ecosystems. Ecosystems consist of biosystems and physical systems. Coexisting on the earth, human social systems, referred to as social systems in the remainder of this dissertation and biosystems have been constraining each other and co-evolving for millions years. The economic system is a subsystem of the social system and has many subsystems such as industries. Economic activity, as one of the activities of humans, has a shorter history than human beings, but it is the foundation of much of the social organization, institutions, and ethics of modern society. Economic activity is also affected by social organizations, institutions, and ethics. Sustainable development is an economically oriented concept and is a synthesis of the concept of sustainability and development. Sustainable development can be reached only if it is associated with sustainable: economic systems; social systems; and ecosystems. Thus these three systems are discussed in more depth below. Here, the social system is defined to include many subsystems except economic subsystems, such as, political systems, legal systems, historical systems, and psychological systems.

2.2.2 A One Dimensional Versus A Three Dimensional View of Economic Development

2.2.2.1 A neoclassical economic approach

An economic system, from the neoclassical point of view, could be abstracted as a closed-loop system as in Figure 2.2.4, which includes production and consumption processes and a feedback loop. Resources pass from the non-economic set into the economic system in the process of production, and products pass out of the economic system as their value becomes zero (Boulding, 1966). Inputs of the economic system are resources, labor, and capital and outputs are the level and characteristics of the economic system, such as GNP; GDP; income distribution; and zero value matter and energy, that is wastes, which are discharged by the economic system and mostly have adverse impacts on the ecosystem. In an economic system, most of the outputs are directly consumed; parts of the output are used in maintaining the economic system itself and are reinvested; parts of material goods and services are exported from the system; and small parts of the output have been used to conserve or preserve some non-human systems including biosystems and physical systems. Biosystems and physical systems may still be thought of as having at least an indirect use for humans.

There is one major feedback loop and one auxiliary feedback in a market oriented economic system. The former is a market feedback loop between production and consumption processes "controlled" by Smith's "invisible hand." The latter is a policy feedback loop, which has contradictory roles in a market economy. The policy feedback loop consists of a monitor element and a decision element. The monitor element detects system levels, which include the dimensions of the system, for example as indicated by GNP, GDP, system structure, and system efficiency. Economists play the most important role as monitors. The decision element

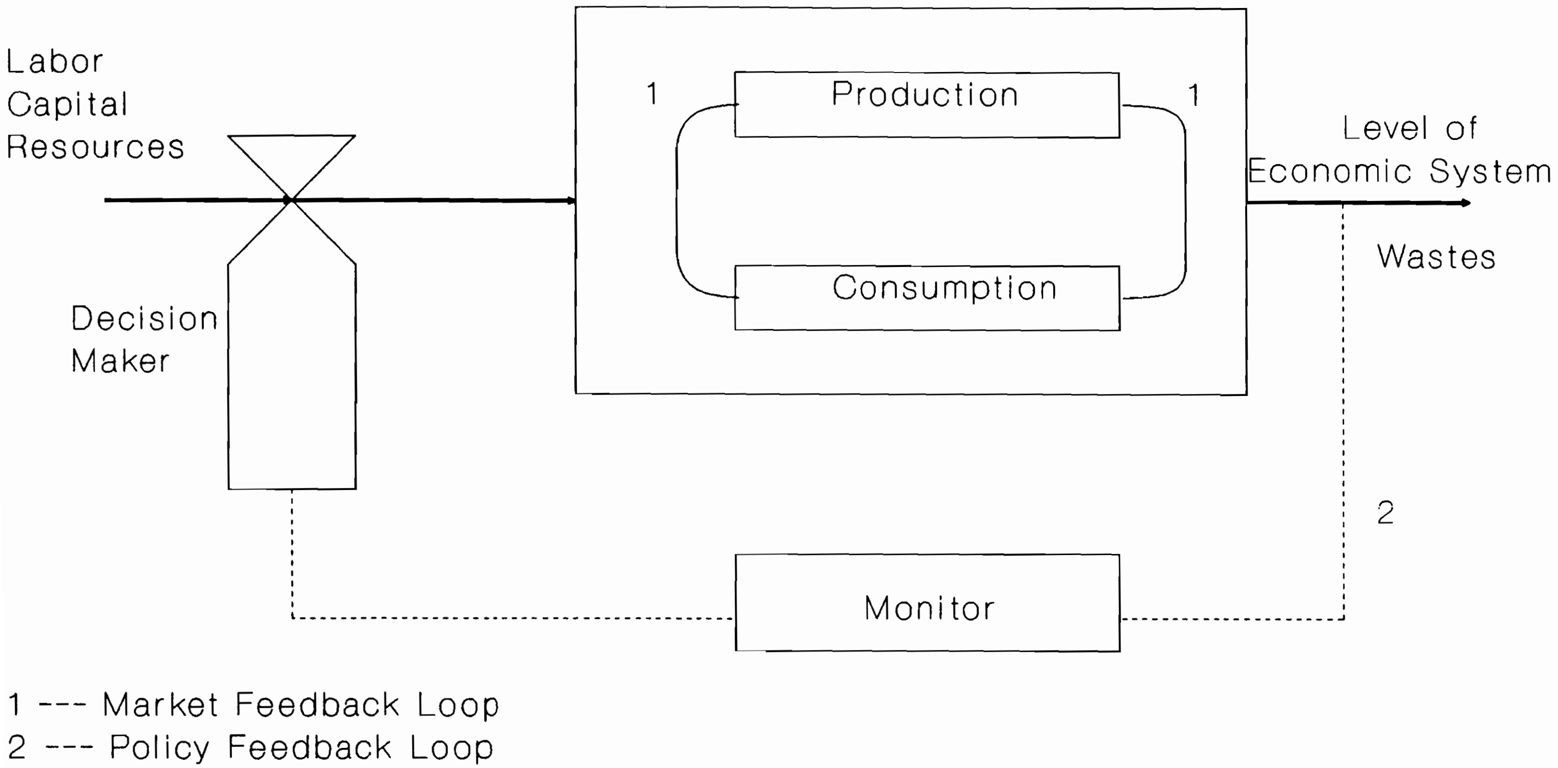


Figure 2.2.4 A Neoclassical Economics View of Economic Approach

includes the political and legal subsystems. Legislation and policies constrain the functioning of the economic system. The monitor element and the decision element, however, have limited roles in a market economy. Norgaard and Dixon (1986, p.307) argued that in a market economy system, "Market forces play an important short-run role in the description, but predictions and prescriptions stemming from economic and planning models play an incidental role relative to phenomena which were neither predicted nor prescribed. And this is entirely appropriate for U.S. agricultural development was not planned. Individual farmers made independent decisions. Even the institutional scheme within which individuals made decisions evolved in an ad hoc manner rather then in the context of philosophy and theory of agricultural development. Unplanned evolution characterized the most successful development story ever told." That is, the strong market feedback loop plays the major role in a market economy and the policy feedback plays a minor role. The policy feedback loop is basically positive since it has to be in accord with the market feedback loop which is considered positive in the following discussion, but can be negative sometimes in order to adjust the structure and dimensions of the economic system.

The market system has an inherently positive market feedback loop between production and consumption processes. Growth is a process in which capital is accumulated and the physical dimensions of an economic system expand, and is a process in which production stimulates consumption and vice versa. Georgescu-Roegen called this neoclassical paradigm of economic growth a pendulum movement between production and consumption within a *closed system* (1971). Note that the closed system referred to Georgescu-Roegen (1971) is not a closed system as defined by Von Bertalanffy (1956), but a closed-loop system, or a positive feedback loop system, defined by Forrester (1968). The "pendulum movement" between production and consumption "pumps" resources from the environment and discharges wastes into the environment. Gradually the increasing dimensions of the economic system accelerate natural resource use and cause resource scarcity. The neoclassical view of the economic system is a system which is open to its environment and has two feedback loops. In Figure 2.2.5, the resource inputs and waste output are "open ends" from and to the environment. Therefore in the neoclassical view, resources are "infinite." This conclusion does not mean infinite individual resources, but that the total amount of resources is infinite at least within a meaningful time frame. The perfect market system is a completely *open system* with infinite markets for the priced inputs and outputs, including "markets" for wastes with negative prices. Thus, resource scarcity is only an economic concept, not physical one. Scarcity could be mitigated by technical innovation and substitution induced by price changes, an automatic marketing adjustment, so there is only relative scarcity, rather than absolute scarcity (Randall, 1987). The market system is, therefore, an adaptive system in a sense, self-controlled by the "invisible hand." What is important in economics is efficiency, including contemporary and intertemporal efficiency. The neoclassical paradigm is a one dimensional approach, a pure economic approach.

One of the important common features is their multiple dimensional consideration of the environmental and natural resource problem facing human in the world although their foci are different.

2.2.2.2 A sustainable development approach

Growth oriented economic sustainability has been questioned many times. Boulding (1966, p.4) thought that "economists in particular, for the most part, have failed to come to grips with the ultimate consequences of the transition from the open to closed earth. The open system, indeed, has some similarities to the open system of Von Bertalanffy, in that it implies that some kind of structure is maintained in the midst of a throughput from inputs to outputs. In a closed system, the outputs of all parts of the system are linked to the inputs of other parts." Later, Boulding (1966) defined an economic system as an "open system" since there are energy exchanges between the economic and non-economic "environment," but a "closed system" that in a "closed earth" economic impacts should be internally considered. Thus, Boulding's (1966) statement could be understood as a mixed use of Von Bertalanffy (1956) and Forrester's (1968) definitions of open and closed systems. Here, the "closed system" implies existence of feedback between economic systems and other systems on the earth. Misunderstanding the meaning of the "closed system" could lead to the incorrect conclusion that an inevitable trend of increasing entropy will ultimately extinguish every thing in a "closed" earth. This concept will be discussed in section 2.3. What is important here is that Boulding (1966) challenged the circular flow of economic processes, an infinite flow of production to consumption.

The concept of sustainable development challenges the two "open ends" of the neoclassical paradigm. The argument of intergenerational equity arises from the belief in two absolute limits: the limit of the quantity of resources and the limit of assimilative capacity of ecosystems, which is a measurement of pollution of the environment. Since the former limit relates to Malthusian limits, the concept of sustainable development is called neo-Malthusian by Randall (1987). The latter limit is relatively new and is concerned with irreversible changes in biosystems or physical systems that will lead to limits to economic growth and ultimately could eliminate biosystems and humans. These two limits lead to consideration of the scale of the economy and intergenerational and intragenerational equity. Recognizing the two limits, sustainable development proponents argue that ecosystems and social systems must be explicitly combined in economic processes.

Figure 2.2.5 represents a three dimensional approach to sustainable development, which simultaneously considers the economic system, social system, and ecosystem. In this figure, the economic system is examined more elaborately, while the social system and ecosystem are only partly examined. There are two feedback loops which connect the economic system to the ecosystem and the social system: an ecological feedback loop and a social feedback loop. As discussed above there are two feedback loops in the economic system, the market feedback loop between production and consumption and the policy feedback loop. The national system as defined by the three dimensional approach is an open system to the world outside of the nation, through exchanges with other nations and global ecosystems, but it is a closed-loop system since there are feedback loops inside and

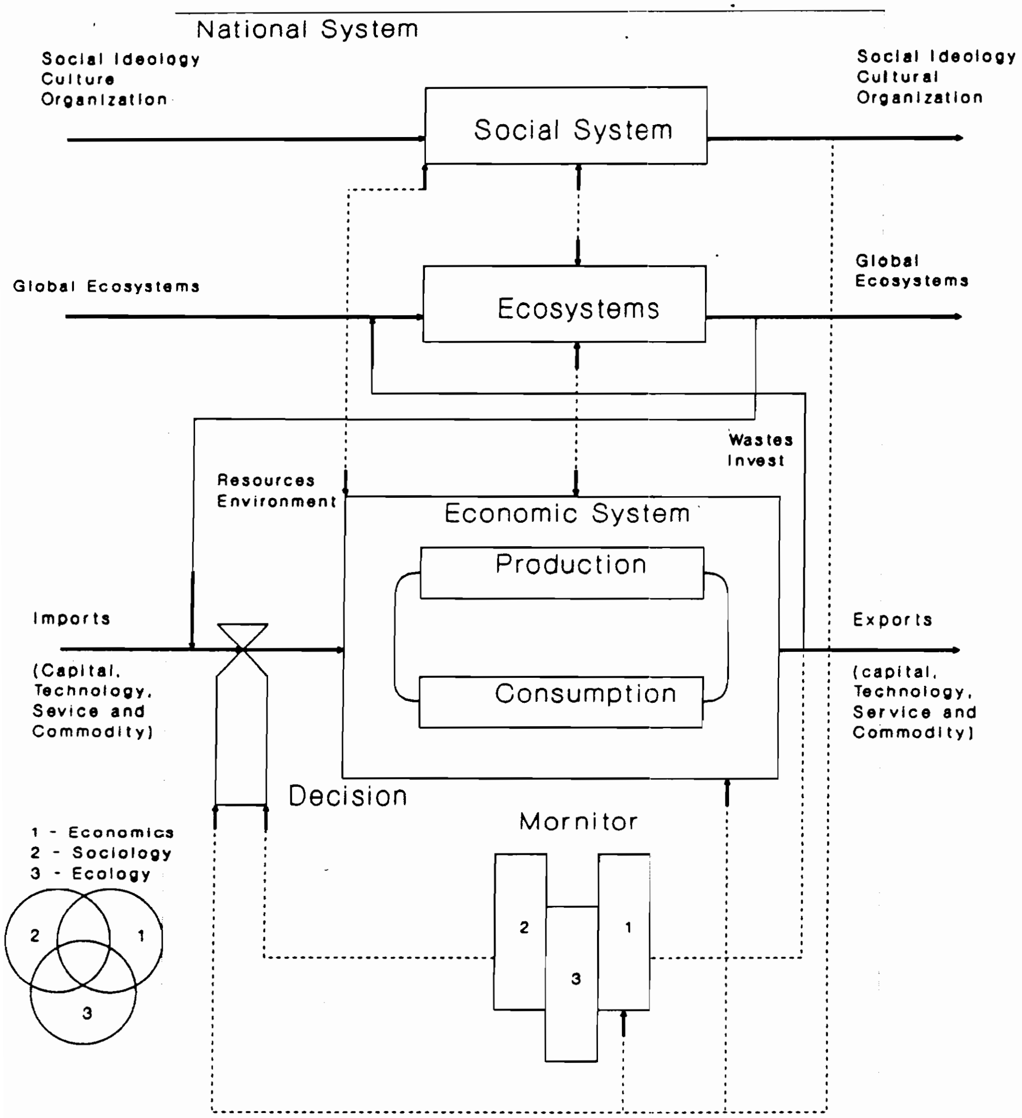


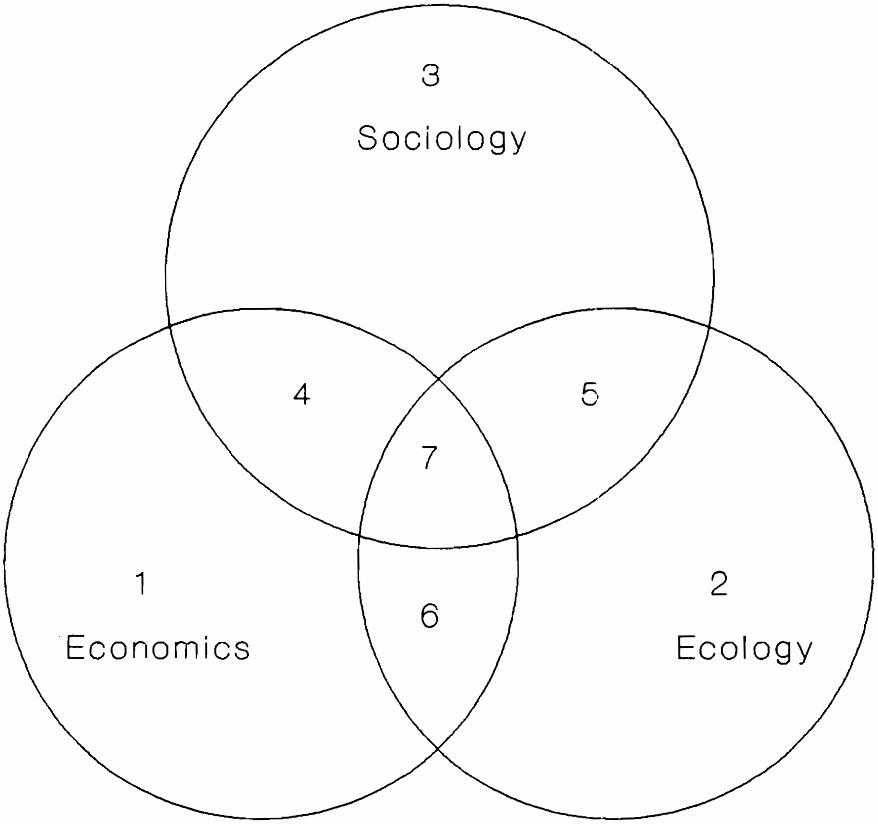
Figure 2.2.5 A Three Dimentional Sustainable Development View of Economic Approach

outside. The inputs and outputs of the economic system are connected to the ecosystems. That is, resources and environmental inputs from the ecosystem enter the economic system; wastes from the economic system are discharged to ecosystems, which in general has adverse impacts on the ecosystems. The social causes of economic behavior and the social consequences of economic behavior are also directly addressed in the three dimensional approach.

A major change in the policy feedback loop in the economic system in terms of the concept of sustainable development is the function of monitor and decision elements. Sustainable development proponents argue that the monitor element should reflect a pluralistic view, or a "hologram" of economic performance, of different disciplines and different schools in disciplines including: minority schools of economics, sociology, and ecology, and should serve as an "interdisciplinary filter" of information. They also argue that the decision element should play more of a role in resource and environmental issues.

Ascher (1990) argued that the policy development process should consist of two steps: (1) exploring economic performance of policies by passing them through the "interdisciplinary filter" and producing processed information, then (2) making decisions based on the processed information. Ascher called the first step the policy process and the second step the policy science approach. He mentioned that two different types of expertise are required in the policy selection process. One is the expertise of specialists in mono-disciplines such as economists, ecologists, and sociologists. The another concerns how policies and strategies are formulated so as to produce the best outcomes. In Figure 2.2.5, the specialists play the role of the "monitor" element and the formulation of policies and strategies play the roles of the decision element in the feedback loop. According to Ascher (1990), policy science should be: problem oriented, value committed rather than value free, interdisciplinary, multi-method, sensitive to process as well as substance, comprehensive, behavioral rather than formal, and sensitive to context. Conducted in this manner, policy science has the possibility of dealing with the "hologram" produced by the "interdisciplinary filter."

The "interdisciplinary filter" consists of three major mono-disciplines relative to the concept of sustainable development, economics, sociology, and ecology. Their relationship is expressed in the Venn diagram of Figure 2.2.6. Three mono-disciplines, economics; sociology; and ecology, are numbered from 1 to 3. Three pairs of bi-disciplines, socioeconomics and economic sociology; ecological economics and economic ecology; and ecological sociology and social ecology, are represented in the overlap of pairs of disciplines and are numbered from 4 to 6. The overlap of the two economic dominated bi-disciplines, socioeconomics and ecological economics, is a tri-discipline and numbered as 7, through which sustainable development oriented issues should be analyzed, and on which interdisciplinary communication should dominate all individual disciplinary studies. Depending on the policies to be considered, the policy selection process could use the processed information passed thought any area from 1 to 7. For example, policies involving social economic issues use the processed information through area 4. Policies



4 -- Socioeconomics and Economic Sociology
5 -- Ecological Sociology and Social Ecology
6 -- Ecological Economics and Economic Ecology
7 -- Sustainable Development

Figure 2.2.6 Venn Diagram of Three Disciplines involving ecological economic issues use the processed information through area 5. Sustainable development involves sustainability of the economic system, the social system, and the ecosystem so the policies involving sustainable development use the processed information through area 7.

2.2.3 Complements and Contradictions among Disciplines

Neo-classical economists think of economics as the study of the use of limited resources for the achievement of alternate ends (Henderson and Quandt, 1980). Resource economics and environmental economics as derivatives of neoclassical economics apply neo-classical economic theory as a major vehicle to analyze resource and environmental issues (Costanza 1989). Institutional economists study the changing pattern of cultural relations which deal with the creation and disposal of scare material goods and services by individuals and groups in the light of their private and public aims (Pettman, 1977).

Sociology systematically explains regularities and variations in individual orientations and behavior, group orientations and behavior, social structure, sanctions, norms, and values. More specifically, sociology studies the causal and interactive processes that relate these factors to one another (Smelser, 1976). Ecology is the science of studying interrelations between living organisms and their environment (Odum, 1971). It is well known that humans cannot exist in isolation. Interacting with living and non-living systems, humans have special relationships to ecosystems. Human ecology is the study of ecosystems as they affect and are affected by human beings (Sutton, 1973). Human ecology therefore must be involved in the study of the concept of sustainable development.

Bi-disciplines usually arise for explaining phenomena or solving problems which can not be explained or solved satisfactorily in either mono-discipline. Two relevant bi-disciplines, social economics and ecological economics are discussed next. Hagenbuch (1965) considered social economics as: (1) a branch of applied economics, that is, the application of economic theory to social problems; (2) a branch of applied statistics, that is, the numerical measurement of the extent and constitution of social problems; (3) the study of social causes of economic behavior, that is, how economic behavior changes with changes in the social environment in which people play their part as producers and consumers; and (4) the study of the social consequences of economic behavior, that is, the relationship between individual economic decisions and social welfare. The fourth aspect of social economics is close to the content of welfare economics. Welfare economics, however, is concerned with those social consequences of economic behavior, which can be in principle objectively measured with the analytical tools of economic theory. Social economics is concerned with much broader social consequences, whether measurable or unmeasurable, than welfare economics.

Ecological economics addresses the relationships between ecology and economics. Costanza (1989) pointed out that environmental and resource economics cover only the applications of neo-classical economics to environmental and resource problems, and that ecology deals with human impacts on ecosystems and sticks to "natural" systems. What ecological economics aims to do is to encourage new linkages between ecology and economics.

Pearce (1987) pointed out the deficiencies of welfare and environmental economics. He argued that the economy designed by welfare economists such that it maximizes some measure of social (human) welfare subject to biophysical constraints will assist in, but will not be sufficient for, attainment of intergenerational equity. Environmental problems in terms of optimal externalities as defined by neoclassical welfare economics will not achieve sustainability. The optimal externality defined by environmental economics, which is justified by balancing costs and benefits of pollution control, implies a non-zero level of externality to the ecosystems, since there does exist some positive level of pollution. Peace (1987) suggested that only if prices were formulated to reveal *infinite marginal prices* when pollution reaches some critical level in terms of ecosystem functioning, could price be used to reflect the sustainability objective.

A tri-discipline, where various concepts of sustainable development are active, has been developing, and serves as an alternate way of thinking about economic development. A major difficulty comes from inter-disciplinary communication. As summarized in the preceding section, the various interpretations of sustainable development are based on six "E" considerations: *Economic; Ecological; Environmental; Energy; Equity; and Ethical*, thus sustainable development has different foci that are different from the foci of the three major mono-disciplines, ecology, sociology, and economics. For example, although the roots of the names of economics and ecology are the same and their fundamental concerns are deeply intertwined, the concepts and principles of either discipline are still not easily adaptable to their sister disciplines.

In general, the primary objective of economic activity is the self-preservation of human species (Georgescu-Roegen, 1971), the strategy of "maximum protection"; that is, trying to achieve maximum support of a complex biomass structure, however, often conflicts with man's goal of "maximum production", trying to obtain the highest possible yield (Odum, 1969). While more and more economists have been taught that ecosystems provide humanity with an absolutely indispensable array of services, Ehrlich (1989) appealed to economists to reform their discipline and begin to interact more with ecologists so that economists would lose their blissful ignorance of important ecological concepts, and become more receptive to the contributions of their sister science.

On the other hand, the careless use of "infinite marginal price" for ecosystem damage may lead to no economic solution to environmental and ecological problems. Thus, ecologists need to deliberate the ecological impacts and ecosystem damage of economic activity. One ecologist, Eugene Odum (1989, p262), pointed out that: "Most ideas pertaining to the development of ecological systems are based on descriptive data obtained by observing changes in biotic communities over long periods, or on highly theoretical assumptions; very few of generally accepted hypotheses have been tested experimentally. Some of the confusion, vagueness, and lack of experimental work in this area stems from the tendency of ecologists to regard "succession" as a single straightforward idea; in actual fact, it entails an interacting complex of processes, some of which counteract one another."

Despite these differences, the two bi-disciplines, social economics and ecological economics, do move towards addressing resource and environmental issues. Pettman (1977) proposed that social economics is a quadro-discipline including economics, sociology, politics, and law. Social economics conceives of social development as comprising two, complementary, inseparable, and of equal weight pursuits: (1) maximizing human satisfaction (2) minimizing the disturbance to the earth and to humanity. Pettman's description of quadro-disciplines can be divided into two parts as in Figure 2.2.5. Economics and sociology are in the monitor element and subsystems of the political and legal systems, which relative to the economy, are in the decision element. It is interesting to note that Pettman's perspective of social economics includes "minimizing the disturbance to the earth," explicitly extending social economics to ecology, although he did not mention ecology as a fifth discipline. Like social economics, institutional economists are interested in the role of institutions in achieving change, but have tended to emphasize institutions apart from nature (Batie, 1989).

2.2.4 Systems Approach for Interdisciplinary Research

Sustainable development, as concept viewed by a tri-discipline, can be deliberately analyzed only through communication among economists, ecologists, and sociologists. Systems theory could provide the framework for these interdisciplinary communications because "when we raise our consideration of systems to a sufficiently high level of abstraction, real differences among subjects sorted into traditional disciplinary classification schemes often tend to disappear, and so the differences between the methodological procedures of the various fields often tend to become gratuitous." (Sutherland, 1975, p.6) Systems theory could establish an appropriate network of science communication and lead to the unity of sciences, including unity in diversity or unity through diversity (Tchon, 1984).

2.2.4.1 Selection of an appropriate form of co-ordination among disciplines

The major problem of empirical interdisciplinary research is how to develop various systems to order the principles of different disciplines to solve various environmental problems. To classify the form of various interdisciplinary efforts, Jantsch (1972) used a systems approach to describe five forms of co-operation and co-ordination among disciplines from the lowest "organic" coupling to the highest coupling. They are multi-disciplinarity, pluridisciplinarity, crossdisciplinarity, interdisciplinarity, transdisciplinarity. Multi- and pluridisciplinarity are comprised of rigid disciplinary "modules," in which there is not any "organic" connection among disciplines. Crossdisciplinarity implies a "brute force" approach to reinterpreting disciplinary concepts and goals or axioms in the light of one specific discipline or goal and to impose a rigid polarization across disciplines at the same level. Interdisciplinarity has common axioms for a group of related disciplines, which is selected at the next higher hierarchical level. Transdisciplinarity has generalized axioms for all involved disciplines so the whole system pursues a set of common purposes.

Selection of the form of co-ordination depends on the features of the problem to be analyzed. In general, there are two major obstacles, which are: (1) the rigidity of disciplines and disciplinary concepts and axioms developed at the lower levels; and (2) the application of lower-level concepts and axioms to higher levels (Jantsch, 1972). As an example of the second obstacle, in section 2.3, a cognitive systems approach will be employed to analyze the foundations of sustainable development.

2.2.4.2 Combining quantitative and qualitative systems approaches

Two major systems approaches are occasionally used in socioeconomic research: a cybernetic systems approach and a cognitive systems approach. The cybernetic systems approach is quantitative. Quantification of the phenomena under consideration is a prerequisite in the cybernetic systems approach. In contrast, the cognitive systems approach only employs the concept of "system" or style-model of a socio-economic system to interpret the causal relationships of socioeconomic phenomena. The cognitive systems approach focuses on understanding a socioeconomic system in a comprehensive and realistic way though comprehending the social psychology that pervades the system. In general, the cybernetic systems approach could sometimes be applied to a technical refinement of socioeconomic theories. The cognitive systems approach however could provide a broader context in which to interpret socioeconomic theories and make these theories more accessible [Ischboldin and Sharp, 1980]. Empirically, the two approaches have limits in their applicability to multi-dimensional and complex socioeconomic problems. Combining the use of these two systems approaches, that is, using quantitative analysis results for non-quantitative analysis, could lead to a significant advancement in the development of more comprehensive analyses. An effort to combine these two systems approaches will be made in chapter 3 in an empirical evaluation of agricultural management systems in Richmond County, Virginia.

2.2.5 Applicability of the Concept of Sustainable Development

The viability of the concept of sustainable development, to a great extent, depends on the communication among three major disciplines: economics, sociology, and ecology. Furthermore, it depends on the compatibility of the concept of sustainable development with major social ideologies. Pettman (1977) defined the social relationship as the output of the social economic system, which can be expressed in a form of an equation indicating the major components that are involved in producing the output of social relations:

$$SR = f(s, e, i) \tag{2.4.1}$$

where: SR is social relations, s is social structure, e is social environment, and i is social ideology. Social structure plays an important role, integrating human society as an entity and holding the major social ideas and beliefs in congruence.

Pettman's equation can be inverted as follows:

$$I = F(s, e, sr, t) \tag{2.4.2}$$

Here, t explicitly expresses the dynamic characteristic of social ideologies, which implicitly exists in Pettman's original equation. The inverted equation indicates social ideologies are a function of social structure, social environment including the natural; political; and economic environment, social relations, and time t. Thus, the concept of sustainable development, as a part of social ideology, is influenced by social structure, social relations, the social environment, and time. As a subsystem of the social system, the economic system could have its own ideology, but if it does, it must be consistent with major social ideology. So, realization of sustainable development, to a great extent, depends on three factors: (1) compatibility with social ideology; (2) the proper social environment; and (3) the harmonious social relationships, which are changed with time, human knowledge, ethics, and economic conditions in different stages of socioeconomic development.

2.3 The Second Law of Thermodynamics and Sustainable Development: An Application of Systematic Analysis

In this section, a cognitive systems approach is employed to identify if an absolute limit to growth stemming from the second law of thermodynamics can be used as a foundation for the concept of sustainable development. Alternative perspectives of limits to growth by sustainable development advocates are first reviewed. Then, after a brief description of the laws of thermodynamics, the applicability of the second law of thermodynamics to limit to growth is examined.

2.3.1 Alternative Perspectives of Limits to Growth

The concept of limits to economic growth as stemming from the laws of thermodynamics was probably first introduced into economics by Boulding in 1966 and more fully elaborated on and integrated into economic theory by Georgescu-Roegen in 1971 (Daly, 1990). In discussing limits to growth, Boulding (1966) found that, from a material point of view, objects pass from a "non-economic" set into an "economic set" in the process of production, and products pass out of the economic set as their value becomes zero. From an energy point of view, he noted that the economic system uses inputs of available energy to move matter from the non-economic set into the economic set, or out of it again; as a consequence, energy is given off by the system in a less available form, mostly in the form of heat. Boulding (1966) thus concluded that there is no law of increasing material entropy[5], thus it is quite possible to concentrate diffused materials[6] if energy inputs are allowed. However, in regard to the energy system, there is, no escape from the grim second law of thermodynamics[7].

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[5] The term "entropy" was first defined by Clausius in the middle of nineteenth century as a thermodynamic measurement of dispersion of energy. The higher the entropy is, the lower is the energy concentration.

[6] Concentration of diffused materials is a process of using energy inputs to reduce matter entropy. For example, the processes for fixation of nitrogen from the air and for the desalinization of sea water are considered anti-entropic processes (Boulding, 1966).

[7] The original Kelvin-Planck statement of the second law is that "no process is possible whose sole result is the absorption of heat from a reservoir and conversion of this heat into work" (Zemansky, 1968, p.178). More commonly, the second law of thermodynamics translates into the conclusion that the transfer of energy is never 100 percent efficient. A

When predicting the results of economic growth, Georgescu-Roegen (1971) thought it unfortunate that economists had failed to pay attention to the thermodynamic laws. He thought that, while some economists had carefully emphasized the point that man can create neither matter nor energy, few realized the constraint imposed by the second law of thermodynamics. He noted that things are scarce, in a sense, because, "first the amount of low entropy within our environment decreases continuously and irrevocably, and second, *a given amount of low entropy can be used only once* (p.278)." He explicitly pointed out that economic growth and human societies are constrained by the second law, and that ultimately there will be extinction because of increasing population and extravagant wants of human beings. "We can say that every baby born now means one human life less in the future. But also every Cadillac produced at any time means fewer lives in the future. The sun will continue to shine on the earth, perhaps, almost at bright as today even after extinction of mankind and will feed with low entropy other species, those with no ambition whatever (Georgescu-Roegen, 1971, p.304)." If this predicted extinction will occur then the problem of intergenerational equity arises. The effect of one generation's choices on another becomes important. Pearce (1987) interpreted the objective of sustainable society to be one in which a Rawls-style concept of distributive justice is applied in an intergenerational context, and he suggested an extension of Rawlsian justice to non-human species. He noted that if natural resource

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more detailed discussion of the second law of thermodynamics will be found latter in this section.

endowments vary between generations, then primary goods will vary between generations, where the primary goods are rights and liberties, opportunities and powers, and income and wealth. Thus the concept of sustainable development based on intergenerational equity requires that the resource base be kept intact. He concluded that the rate of resource extraction will be limited either by the assimilative capacity of the environment or by the rate of regeneration of renewable resources. Thus the particular relevance of the second law of thermodynamics for sustainability is likely that of rule-making relative to the use of the receiving environment.

Daly (1990) and other economists continue to question the basic premise of economics, that is, the optimal allocation of scarce resources. Daly (1990) noted that three conceptual issues are critical for clear thinking about economic development and the environment, they are: (1) the basic conceptual starting point of economic analysis: the circular flow of exchange value versus the one-way entropic throughput of matter-energy; (2) alternative uses of the resource flow: optimal allocation versus optimal scale; and (3) the normal healthy condition of an economy: growth versus steady state. Daly (1990) thought that neoclassical economics: fails to recognize that the economic approach is a process of irreversible entropy change stemming from the second law of thermodynamics; fails to realize that markets can not find an optimal scale of total resource flow, but only optimal resource allocation under ideal conditions; and falls to understand that growth beyond the optimal scale is "anti-growth". Daly's (1990) first conceptual issues give rise to the second and third conceptual issues. He stated that "Although the three issues are separable they are also related. Once throughput is recognized as a fundamental and indispensable concept, then the question of its optimal scale within a finite ecosystem naturally arises, along with the recognition that the question is different from that of optimal allocation. The discussion of sustainable development will not get far without the recognition of throughput and the problem of its scale (Daly, 1990, p.4)." After calculating the percentage of human appropriation of total world products of photosynthesis as a index of the scale, Daly (1990) concluded that operation of the second law is ultimately the limitation of the economic system and human society:"unless we awaken to the existence and *nearness* of scale limits then the greenhouse effect, ozone layer depletion, and acid rain will be just a preview of disasters to come, not in the vague distant future, but in the next generation (Daly, 1990, p.11)."

The concept of absolute limits, ultimately, challenges the neoclassical concept of "infinite substitution". Recently, Underwood (1989) criticized the metaeconomic foundation of the neoclassical economics paradigm, that is, relative scarcity as a first principle. He suggested that, instead, the laws of thermodynamics should be the metaeconomic first principle of economics. According to this perspective, the laws of thermodynamics, which are immutable, guide the interaction of energy-matter on the earth, and impose absolute scarcity upon economic activity within a near time perspective.

Therefore, the acceptance, or rejection, of the laws of thermodynamics as guides for economic activity becomes the basis of some important divergences between neoclassical economics and sustainable development concepts. That is, sustainable development advocates generally believe that the absolute limits of entropy throughput that are imposed by the second law of thermodynamics are relevant and within some meaningful time frame will make irrelevant the neoclassical concept of relative scarcity. Furthermore, the problems posed by irreversible decisions loom large to sustainable development advocates. Concern about irreversibilities leads many sustainable development advocates to propose limiting or stopping economic growth. As an alternative to "growth", which refers to expansion in the scale of the physical dimensions of the economic system, Daly (1990) suggested the concept of "development", which refers to the qualitative improvement of a physically non-growing economic system in a state of dynamic equilibrium maintained by its environment.

However, a close examination of the second law of thermodynamics reveals that its applicability to economic growth is not certain; thus, its use as a metaeconomic first principle may be inappropriate. If the second law of thermodynamics is not directly applicable to economic growth processes within some meaningful time frame, the conclusion is *not* that improvement of environmental quality and the protection of life-processes ceases to be important. But the inapplicability of the second law would widen the range of alternative choices that can be included in the design of a sustainable development path. Four questions can be used in an examination of the second law. First, what are the thermodynamic laws and to what systems do they apply? Second, which systems are concerned with the relationship between economic growth and the second law? Third, are the thermodynamic laws applicable to these systems? Fourth and finally, can the foundation of sustainable development concepts be built on the belief that economic growth and human society are constrained by the second law of thermodynamics?

2.3.2 Thermodynamic Laws

From its foundation in the 1850's, thermodynamics has gradually evolved as a independent branch of physics. The three laws of thermodynamics can be stated as follows. The first law of thermodynamics states that energy may be transformed from one type to another but is never created or destroyed. While the second law can be described in a variety ways, only two of these descriptions will be discussed here. The first form of the second law of thermodynamics states that no process involving an energy transformation will spontaneously occur unless there is a degradation of the energy from a concentrated form into a dispersed form. In other words, the energy transfer must be a process of increasing entropy. The second form of the second law of thermodynamics states that entropy of a *closed system* will continuously increase until the closed system losses the capacity of "work". Note that the first form of the second law of thermodynamics can be used for any process of energy transfer, but the second form of the second law of thermodynamics is only relevant for a closed system in which there are no inputs from outside and no outputs to the outside. The third law is the principle of the unattainability of absolute zero (Zemansky 1968). For the purposes of this discussion, the second law of thermodynamics is of interest.

In 1839, before the laws of thermodynamics were formulated, Seguin, a French engineer, proved that heat is a form of energy. This assertion was reenforced by Mayer, a German physician, in 1842. However, no conclusive experiments were performed by either researcher. In 1850, Rudolf Clausius formulated the laws of thermodynamics in his work, _The Mechanical Theory of Heat_. Clausius' approach, called the classical approach to the laws of thermodynamics, provided a macroscopic view of thermodynamic phenomena (Tribus 1978). Studies of thermodynamics, just as other branches of physics, hypothetically separate a restricted region of space or a finite portion of matter from its surroundings. The portion which is hypothetically set aside and on which attention is focused is called the "system", and everything outside the system that has direct bearing on its behavior is known as the "surroundings" (Zemansky, 1968). Almost all devices used for thermodynamic experiments represent such ideal systems. These devices are physically different from each other, but they have several common features. Among their common features are that those devices called "systems" are thought of as "nearly closed systems", "confined systems", and "non-living systems". It is important to notice that the three basic thermodynamic laws are induced from experimental results of operating these "systems".

The first law of thermodynamics allows for the existence of the scientists "dream" of a perpetual machine, that is, a perpetually existing system, but the "dream" was shattered by the discovery of the second law. A closed system will never be perpetual because of increasing entropy.

The second law has caused interesting reactions from scientists. The concept of entropy, initially used in engineering and physics, now has been loosely used in a variety disciplines, which include natural sciences and social sciences. In general, natural sciences which study "non-living systems", "closed" or "nearly closed" systems, and "confined systems" could apply the second law appropriately, but debates about the appropriateness of applying the second law to "living systems" and "open systems" frequently arise. In these latter cases, it is doubtful that the second law of thermodynamics can be used, even approximately.

2.3.3 Systems and the Applicability of the Second Law

Applying the second law to carelessly defined systems will result in incorrect conclusions. The second law has a number of corollaries for different systems. For example, when the second law is applied to an adiabatic[8] system which includes reservoirs[9], then the entropy change that results from any process within the system, may be *greater than or equal to zero.* The *equal* sign refers to the case with reversible processes and the inequality sign refers to the case without reversible processes (Zemansky 1968). A reversible process is defined as a process which results in entropy decline. Note that *"equal to zero"* means no entropy change, a situation which could never happen in a closed system without a reservoir.

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[8] Adiabatic is defined as occurring without loss or gain of heat.

[9] Reservoirs are suppliers of low entropy.

Georgescu-Roegen (1971), Daly (1990), and Underwood (1989) did not explicitly define the systems they were analyzing nor the forms of the second law of thermodynamics they used. But their concepts of absolute limits on economic activity, absolute scarcity imposed by the second law, and extinction of human society by entropy throughput indicate that they used the second form of the second law of thermodynamics.

There are two kinds of possible constraints on an economic system imposed by the second law of thermodynamics: a structural constraint and an environmental constraint. The structural constraint emingates from the structure of system. Every system has some of its components devoted to maintaining the coherence or integrity of the system as a whole, while other components actually do work or perform functions (Sutherland, 1975). Assuming the economic system[10] has plentiful inputs of low entropy energy sources available from the environment but is structurally outmoded, then, with changes in human and biosystems, it will gradually increase its own "structural entropy". That is, the outmoded economic system increasingly disperses "energy" on maintaining its structure, until the whole system loses work capacity. For example, throughout history, there have been economic systems which were not sustainable such as the Mayan Culture. Some of these systems can be thought of as victims of structural constraints, rather than limited by natural resources and environmental quality. After all, these systems were succeeded by other economic

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[10] For illustration, the working of an economic system is assumed to be a process in which the energy "pumped" into the economic system from the environment in a state of low entropy. It is released from the economic system returning to the environment in a state of high entropy.

systems which existed under almost the same resource and environment conditions.

The second type of possible constraint is an environmental constraint. If the environment has limited inputs of low entropy energy to provide to the economic system or if it has limited capacity to assimilate high entropy energy from the economic system, then the entropy of the environment will be continuously increasing. Eventually, the environment can not supply enough low entropy energy to the economic system, and the economic system loses work capacity. In this article, we will focus on this latter environmental constraint as it appears to be the constraint of interest to sustainable development advocates.

An economic system is a non-natural system, a subsystem of human social systems, and a sub-subsystem of the global system. Inside of the global system, there are the human social systems, biosystems, and physical systems. The global system can also be defined as a subsystem bounded by the earth's atmosphere, which is part of the solar system. Outside of the global system is outer space, which is called the environment of the global system. The environment of the economic system is defined as the whole global system except for the economic system. Therefore, the discussion of whether an economic system has environmental constraints imposed by the second law of thermodynamics could be reworded to: is the functioning of the global system constrained by the second form of the second law of thermodynamics?

The answer lies first in describing the energy exchanges between the global system and its environment. Energy can be conveniently divided into three basic forms: kinetic energy, material energy, and information energy. Kinetic energy is the energy arising from matter in motion and is roughly considered as including all energy other than matter and information. The concept of matter and information as energy was, directly or indirectly, demonstrated by Einstein's famous work, The Principle of Equivalence. The relationship between energy and matter was firmly established by Einstein in 1905 with his classic equation: $E=mc^2$ where E is energy, m is mass, and c is the velocity of light. The relationship between energy and information is not as clear as energy and matter, but recent studies indicate that information processing is restricted to living systems. Receiving; storing; or effecting, information processing in living systems is electrochemical in nature. Furthermore by means of informational energy processing, living systems learn to direct kinetic and material energy processing (Curtis, 1982).

Energy exchanges between the global system and its environment involve all three forms of energy. Kinetic energy exchanges have long been recognized. Solar radiation, as one type of kinetic energy, travels through space and reaches the earth's atmosphere, the boundary of the global system. There it is partly reflected back into space. Other parts are absorbed by the atmosphere or reach the ground where some is absorbed by the earth's ecological systems and physical systems, such as forests, grasslands, cultivated fields, greenhouses, lakes, oceans, mountains, deserts, and ice sheets. Some is reflected back to space. Ecologists estimate that about 37 percent of the solar radiation reaching the earth's atmosphere is reflected into space and 63 percent of solar energy remains in the global system at midday (Sutton and Harmon, 1973). It is reasonable to treat solar energy as a constant flow to the earth, a constant supplier of low entropy energy.

The solar system has been observed for thousands of years, but the process of exchanging information as a kind of energy exchange process has been only recognized for decades and is not well-examined. Brillouin (1949) revealed the relationship between entropy and intelligence and pointed out that scientific information represents a sort of negative entropy for scientists, who know how to use it for analysis and prediction. For example, the "information value" of the formation and development of the earth from space research could provide information on energy on the earth, which was assumed either from sun or *the earth itself* and used as the base of analyzing available energy by Boulding (1966). Except for meteorites, matter-energy exchange between the global system and its environment was impossible until the development of the space industry. Such matter-energy exchange will probably be limited in physical size in the near future. But these two newly-recognized forms of energy exchange will definitely effect the state of future global entropy.

Energy exchanges exist not only between the global system and the sun, but also between the global system and the whole universe. The existence of energy exchanges between the global system and its environment means the global system is an *open system*. This conclusion is crucial in selecting the appropriate corollary of the second law of thermodynamics to analyze the global system.

Furthermore, the existence of reversible processes in the global system is also important for analyzing the possibility of a non-positive change in the global system's entropy. Research on this problem has been conducted by many researchers in a variety of fields. The following examines the controversy surrounding this issue.

The global system consists of the human system, biosystems, and other physical systems. Human and biosystems are living systems. Scientists note that humans as well as the entire biosphere possess the unique thermodynamic characteristic of being able to create and maintain a high state of internal order, that is, a condition of low entropy (Odum, 1971). It is commonly recognized that plants' photosynthesis can transfer solar energy into organic substances. These substances contain potential energy with low entropy and are food for humans and other organisms as well. This transfer process can be thought of as a reversible entropy process, that is, the transfer reverses the tendency toward increasing entropy. The inputs of photosynthesis are solar energy, carbon dioxide (CO_2), water, and nutrients. Carbon dioxide is commonly thought of as high entropy as it is pumped out by the economic system. Many plant nutrients also are the product of the death of living systems, normally thought of as being of high entropy. So, in a sense, a plant's photosynthesis functions to produce low entropy energy and absorb high entropy "disorder". On the other hand, in managed economic production such as agriculture, water and nutrients are partly transferred from energy inputs, and a plant's photosynthesis is also a energy consuming process. The contradictory effects of these reversible processes on the entropy of the global system are widely debated in biology and ecology.

In the early twentieth century, some biologists realized that the theory of closed systems must be supplemented by a theory that encompasses open systems and steady states. In the late 1920's and early 1930's, Von Bertalanffy developed a number of the principles for open systems and discussed their significance for biological phenomena. Von Bertalanffy (1949, p.127) summarized: "Whereas in closed systems the trend of events is determined by the increase of entropy, irreversible processes in open systems cannot be characterized by entropy or another thermodynamic potential; rather the steady state which the system approaches is defined by the approach of minimal entropy production." The conclusion is that within an open system there is a tendency for entropy decline and a spontaneous transition to a state of higher heterogeneity and complexity. Since the global system consists of human and biosystems, and if Von Bertalanffy's perspective is accurate, then the theory of open systems should be applicable to the global system. A "steady state" for the global system is more appropriate as the standard of sustainable development then is the second law of thermodynamics.

Not all biologists and ecologists accept Von Bertalanffy's (1949) views of the steady state. Some scientists agree that photosynthesis appears to negate the tendency toward increasing entropy imposed by the second law, but a complete accounting of all consequences soon reveals that the entropy of the global system may still increase (Sutton and Harmon, 1973). Three major points these scientists make are: reversible processes of entropy exist, however the reversible process itself is an energy consuming process so the entropy of the global system could ultimately increase, and there is no evidence of an existing steady state.

Some biologists and ecologists argue that the evolution of the ecosystem as a whole is an irreversible process subject to the second law of thermodynamics and is therefore constrained to go in a direction of increasing entropy (Kemp, 1985). For example, Wicken (1981, 1984) argued that the increasing complexity of organisms generated via evolutionary processes corresponds to a decrease in potential energy and an increase in information entropy. Wicken's view indicates that the evolutionary processes of organisms indirectly provide the evidence of the increasing tendency of global entropy. The biologists and ecologists that favor this argument thus believe the second law of thermodynamics can be used for biological and ecological systems.

Nevertheless, it is known that some biosystems such as green plants possess the special functions of reversing the tendency to increasing entropy and absorbing some of the "disorder" of the globe. From a thermodynamic perspective, those processes, at least in part, improve the state of global entropy. Some man-made systems have similar reversible functions if solar energy is assumed to be a constant energy flow. Hydroelectric stations are an example of such man made systems. That is, due to gravity water flows from uplands to lowlands along rivers and aquifers. From an energy point of view, this flow is a process of increasing entropy since the potential energy of water is transferred to dispersed frictional heat. Also as part of the water cycle, the absorption of solar energy by land and water results in the evaporation of water, against the force of gravity. Solar energy is transferred to the potential energy of water vapor. When water vapor moves above upland, condenses, and precipitates to the ground, the water thus regains the potential energy characterized by lower entropy. Solar energy continuously adds to the reversible process of the water cycle and disperses into heat energy with a state of higher entropy. The water cycle is roughly an isoentropic[11] process, but it is an increasing entropy process of solar radiation. From a thermodynamic view, since solar energy is an external energy source of the global system, the disperse of solar energy is not accounted for in the change of global entropy. Hydroelectric stations can thought as the man-made "green plants", which transfer solar energy to electric energy. In a sense, they have the same function of reversing the tendency of global entropy as do natural green plants although they have other contradictory effects on the environment. Similar alternative energies transferred from solar energy are wind energy and sea wave energy.

2.3.4 The Sustainable Development Concept and the Second Law

The global system is thus an open system with an external solar energy source and internal reversible processes. Since the second form of the second law of thermodynamics can be used only for a closed system, directly using the second form of the second law of thermodynamics for analysis of the global system appears to be incorrect. Solar energy, as a reservoir in the system, continuously supplies the global system with

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[11] Isoentropic process is a process in which entropy is unchanged.

low entropy energy; the *possibility of a non-positive change* of the global system's entropy does exist. If so, the global system should not be subjected to the second form of the second law of thermodynamics, but only the first form of the second law of thermodynamics. The important difference is, if the solar energy can totally compensate for the energy dispersed from global energy transfers, the conclusions of absolute limits and the ultimate extinction of human society within a meaningful time frame argued by Georgescu-Roegen (1971), Underwood (1989), and Daly (1990) are not correct.

Proof of the possibility of "total compensation" mentioned above is complex and beyond this analysis. But as Georgescu-Roegen realized: "In terms of low entropy, the stock of mineral resources is only a very small fraction of the solar energy received by the globe within a single year. More precisely, the highest estimate of terrestrial energy resources does not exceed the amount of free energy received from the sun during *four days*. In addition, the flow of the sun's radiation will continue with the same intensity for a long time to come. For these reasons and because the low entropy received from the sun cannot be converted into matter in bulk, it is not the sun's finite stock of energy that sets a limit to how long the human species may survive. Instead, it is the meager stock of the earth's resources that constitutes the crucial scarcity (1971 pp.303-304)". Does not this quote indicate that the conclusion of "the absolute limits" comes from an "incorrectly used the second form of second law of thermodynamics", but not from the estimation of possible total compensation? Furthermore, as Georgescu-Roegen's quote implies if the global system is redefined to include solar energy within the system, and thereby obtain a "closed system", the existence of the sun's reservoir of low entropy energy extends the conclusions of human extinction to the far distant future, conceivably even to the end of the sun itself.

The second form of the second law of thermodynamics is a physical law applied to closed system. The global system, as an open system with an external energy source and internal reversible processes, is unnecessarily constrained by the closed system assumption. Theoretically, the change of global entropy could be non-positive. What is important for humankind's future is conservation of the natural reversible processes and development of artificial reversible processes.

2.4 Low-input Sustainable Agriculture

In this section, the concept and features of low-input sustainable agriculture (LISA) are discussed. One of the objectives of this section is to prepare the conceptual basis for the development of an appropriate model for evaluating economic and environmental impacts of agricultural management systems in Richmond County, Virginia, in the chapter 3.

2.4.1 Concept of LISA

LISA production systems have been thought of as a step to sustainable agricultural production and they have become a popular topic of research and publication. As alternative agricultural production systems, LISA farming practices are not well defined. The boundary between LISA and conventional agriculture is unclear and standards of lower input rates may never be identified. LISA production systems are not the systems that simply revive old agricultural production systems with lower off-farm inputs and lower outputs, nor are they based on suspicions about modern technology and science, but they are developed to seek the goals of sustainable production and sustainable environmental quality. LISA can be treated as "a vision of future agriculture, a vision of what could be if we choose a different set of objectives (Luna, 1988, p.8)." In this research, LISA production systems are systems "in which the direct or indirect use of purchased petrochemicaly-based inputs are reduced relative to conventional agriculture (Batie and Taylor, 1989, p.2)." They are a subset of alternative agriculture production systems. Three basic features of LISA production systems are discussed below.

2.4.2 Multiple Objectives of LISA

Alternative agriculture pursues the goals of: (1) incorporating natural processes such as nutrient cycles, nitrogen fixation, and pest-predator relationships into agricultural production; (2) reducing the use of off-farm inputs with the greatest potential to harm the environment and human health; (3) using the biological and genetic potential of plant and animal species; and (4) improving the match between cropping patterns and the productive potential and physical limitations of agricultural lands to ensure long-term sustainability of current production levels. It strives for profitable and efficient production with emphasis on improved farm management and conservation of soil, water, energy, and biological resources (National Research Council, 1989). Arising from these goals, proponents of alternative agriculture often incorporate the values of agricultural fundamentalism: family and group self-reliance, harmony with nature, a global village view of the world, a respect of nature and ecosystems, a voluntary simplicity, the goal of sustainable economic growth, and a belief in the "goodness" of the family farm (Dahlberg, 1985).

As a subset of alternative agricultural systems, LISA suggests a different way of thinking and an alternative set of benefits which include economic benefits such as profit and non-economic benefits such as protection of the natural environment. Economically viable, ecologically sound, and socially just and humane are, more or less, recognized as the general objectives of sustainable agriculture (Luna 1988).

Among three general criteria mentioned above, measurement of economic viability is familiar to economists. Even so, previous LISA research showed that to determine whether or not low-input agricultural systems are economically viable produces a mixed bag of answers. Research is mostly case study based and its results are generally sensitive to marketing factors, such as the prices of the products in the study area and the existence of or lack of markets for some crops such as hay and byproducts such as poultry litter (Taylor, 1989). These results are also affected by the natural conditions of agricultural production systems such as weather, pests and diseases, and the soil-crop ecosystems. The most important aspect of LISA is that benefits arise from taking advantage of naturally occurring beneficial interactions, such as using crop rotations to control pests through seasonal change in the pests' food sources; and considering regional production conditions, such as weather and/or temperature. These characteristics make results of case study based research more variable than that of conventional production practices, and the evaluation of LISA performance at an aggregate level more difficult. LISA's economic viability requires not only profitable production, but also production which is comparable in profitability to conventional agricultural systems. Furthermore, to be sustainable, LISA needs to be comparably profitable to non-agricultural industries in the economy as a whole, otherwise, LISA will only amount to a temporary experiment.

"Ecologically (environmentally) sound" is an indistinct criterion. Some deep ecologists think nature has a right to exist separate and apart from a utilitarian appraisal by humans, so that any non-market valuation of environmental goods and services is absurd and irrelevant. But ecological economists try to deliberately consider the environment within the neoclassical paradigm (Batie, 1989). The major difficulty faced by environmental economists arises from the fact that environmental criteria are non-commensurable with the profitability criteria.

Combining economic and ecological criteria to measure the performance of LISA production systems is much more difficult than the use of a single criterion. In general, agricultural production systems are often in conflict with environmental quality, even if some agricultural practices can be modified to improve one or more measures of environmental quality.

Socially just and humane is a difficult question not only for LISA production systems but for any form of human endeavor. Such an evaluation reflects society's perspective of the new systems, a vision of what could be. Social valuation of economic systems is far beyond the concerns of this study. Only some social restrictions on individual's decision making will be considered in this study, without considering whether they are socially just or humane. In the following, the relationships among three objectives will be discussed.

2.4.2.1 Three ranges of the relationship between economic and environmental criteria

The relationship between profit from off-farm inputs and adverse environmental impacts of a particular agricultural production system is represented in Figure 2.4.1. For illustration, let the net revenue (NR) from agricultural production, a function of off-farm inputs, be a concave function; and the adverse environmental impacts (AEI) a convex function.

Range one is the range in which a continuous increase in off-farm inputs has positive effects on both profit and environmental quality. The economic criterion and the environmental criterion are compatible in range one. The LISA concept contributes nothing in this range. The main feature in this range is that "more is better." The limitation of increasing economic and environmental values comes from the production capacity.

Usually, range one is either narrow or non existent, especially for most developed areas. It may, however, exist for some developing areas, for example, in an area where there is no vegetative cover and which is suffering from severe soil loss, the establishment of a grass cover will decrease the adverse environmental impacts of soil erosion. The base

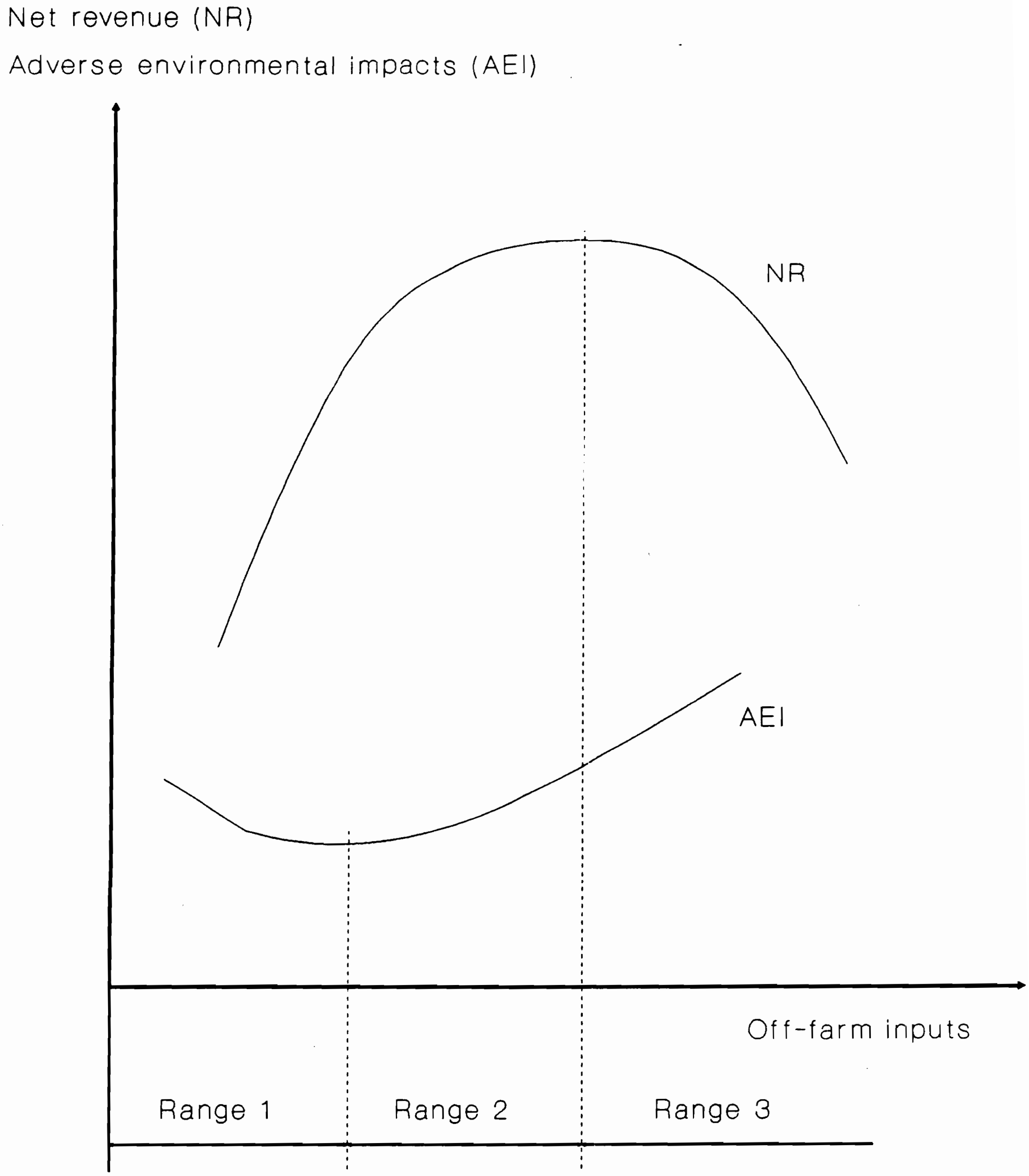

Fig. 2.4.1 Three Ranges of Relationship between Economic and Environmental Criteria

point for evaluating the environmental impacts of agricultural activities in such areas is the current environmental situation. Where and how the current situation came about are not a concern of this study. Range two is much more interesting. In this range, both the economic profit and adverse environmental impacts increase with increasing off-farm inputs. It indicates that LISA production systems could be still profitable, but they are less profitable than conventional production systems, since more intensive use of inputs will get extra profits. Technological progress, which is one of implicit goals of USDA's LISA program, could narrow the size of range two by moving the RN curve to the left and flatting or lowering the AEI curve, which means reducing the conflicts between economic benefits and adverse environmental impacts. But in most, if not all cases, the AEI is unknown or imperfectly known, which, on the other hand, indicates it is difficult to convert the environmental benefits to the monetary value.

The trade-off between economic and environmental objectives is the main feature of this range. Range two is probably common in agricultural production systems. "Worth" of production is clearly a mix of monetary benefit and non-monetary environmental benefit, which is referred to as surrogate worth. Decisions about which production system to employ in range two involve human behavior and preferences. Social structure including economic and political systems may have an important influence on the decision.

The existence of range three has been recognized for a long while, but was attached importance only recently. Determination of this range involved interdisciplinary co-operation, information transfer, and public recognition. The message of range three is that lower inputs are better from both an economic and environmental perspective. For the farm level problem, LISA is one way to move from range three to range two even if barriers to LISA adoption, which could come from psychological factors, farm and farmer characteristics, labor requirements, and other factors, exist (Taylor, 1989).

2.4.2.2 Compatible and incompatible environmental criteria

An example of incompatible relationships is that some soil conservation practices such as no-till may affect the protection of groundwater by inhibiting runoff and sediment containing chemicals and nutrients, which may lead to their percolation through the soil and perhaps into groundwater (Diebel, 1990). The simulation results of this study will also demonstrate an incompatible relationships between protection of surface water quality and groundwater quality in the study area. On the other hand, it is possible that one conservation practice can improve several aspects of environmental quality. For example, it will be shown that cover crop in Richmond County protect wind erosion, water erosion, and nitrate leaching. In that case, the criteria are compatible.

2.4.2.3 Social Value of LISA and the Decision Makers

Confronted with multidimensional and multidirectional objectives, society and decision makers, usually farmers, may select different "optimal" solutions. Previous research found that society is interested in alternative farming systems because they are viewed as a way to reduce health and environmental hazards and to foster a commitment to natural resource stewardship. Farmers considering a change in farming practices to LISA are, however, likely to emphasize economic criteria in their decision (National Research Council, 1989). It is therefore difficult to determine the optimal management of natural resources with consideration of both their social value and farmers' benefits.

It is widely recognized that the sum of individuals' interests may not be the same as the interest of society. In a market economy, most agricultural production decisions are typically made by farmers based on their own criteria including net revenue, utility, and risk attitudes. One farmer's decision may affect another farmer's revenue and also the non-farm environment, by producing externalities such as the run-off of fertilizers which pollute streams and lakes, the raising of watertables through irrigation resulting in salt intrusion in soils, resistance of pests to pesticides, and so forth (Kennedy, 1986). Therefore, social value of individuals' production activities is judged not only by the value of products, but also the nature of the activities themselves.

The measurement of social value in models is a controversial problem. A more fruitful approach for resource modeling is using the social value measures directly in criterion functions and imposing ancillary constrains to protect a farm's income. Measurement of social values is, however, a nebulous task, at best (Burt, 1969). Furthermore, social value, as a representation of collective preferences in society, changes over time. Changes in social values reflect changes in peoples' desires of environmental improvement at different stages of socioeconomic development.

Abstracting from the problem of social value, the farm level analysis of LISA production systems is still possible because farm level decision making and social values are two different types of decision problems, representing a regulatory type and an institutional type of decision making, respectively. Regulatory decision problems are generally concerned with the proper specification of a flow of variables taking as given a particular institutional or environmental structure. Such problems concentrate on periodic decisions that must frequently be made under a given institutional design, such as interseasonal and intraseasonal decisions about agricultural production. Farm level decision problems, at least in the short term, thus can be considered as a decision process constrained by the given institutions, policies, and many other factors. In contrast, institutional decision problems allow institutional structure to vary and thus the proper organization of the general system within which the agricultural subsystem operates are explicitly considered (Rausser and Hochman, 1979).

2.4.3 Dynamic Features of LISA

The second basic feature of LISA production systems is dynamic management of these systems. As mentioned above, successful LISA production systems must take advantage of naturally occurring beneficial interactions to improve their economic and environmental performance by lowering per unit expenditures on petrochemical-based inputs or increasing output per unit of those inputs. These interactions could take place with in a crop's growing season, or several seasons, or over many years. Most interactions are a function of time.

Crop rotation is an important LISA farming practice and it is commonly considered as one of the methods to encourage beneficial interactions. Crop rotation is the successive planting of different crops in the same field as opposed to continuous cropping which involves successively planing the same crop. Crop rotation could provide many economic and environment benefits to agricultural producers. Experiments have demonstrated the so called rotation effect, which is the fact that in most cases rotation will increase yield of a crop beyond yields achieved with continuous cropping under similar conditions. This effect could be caused by many factors, such as increasing soil moisture, nutrient carry over, insect and disease control, weed control, and nitrogen fixation if there are legumes in the rotation (National Research Council, 1989). All of these influences occur over time. Rotation itself means a dynamic production process. From this point of view, dynamic decision making is a distinct feature of LISA.

Environmental benefits of LISA are also a function of time. In most cases, adverse environmental impacts of agricultural activities occur slowly over time and it thus takes time for them to have a significant impact. Soil loss and accumulated contaminants in groundwater usually occur so slowly that people do not become concerned about them for long periods of time. Reversing adverse environmental impacts usually takes a longer time and in some cases they are irreversible. Here, irreversibility could mean that the impacts on natural resources may be technically reversible, but are economically irreversible because the costs of reversal are unacceptably high.

Decision making is also time based. That is, decisions must be made over time. Decision makers have experiences from the past to draw on; are constrained by contracts, certain policies, or information received; employ subjective observation and forecasting; and vary in their understanding of the decision environment around them, all of which influences their decisions over time. Good decision makers benefit from observations made over time.

2.4.4 Stochastic Features of LISA

The relationship between outputs and inputs not only changes through time, but also is somewhat uncertain in any agricultural production system. To manage natural resources, the need to measure, to control, to aggregate, to devise criteria, and to trade off the present with the future is faced. The inherently stochastic nature of the decision making process must be addressed (Denardo, 1982). Agricultural production inherently has more random variables, which include economic variables such as input and output prices, weather variables such as temperature and rainfall, and technical parameters particular to the resource system such as growth rates for biological systems, than many other decision making processes (Kennedy, 1986).

LISA production systems may face new sources of uncertainty related to taking advantage of naturally occurring beneficial interactions. The general level of uncertainty is, however, not necessarily higher than that of conventional agricultural systems. For example, organic fertilizers improve soil quality by increasing the organic matter content in the soil, but their slow release of nitrogen may cause more nitrate leaching, especially in the period between harvest and the next crop growing season (Diebel, 1990). In order to take deliberate advantage of natural interactions, deliberate management practices and observations are required. Increased management requirements are part of the costs of LISA systems. Those costs vary with natural conditions, such as weather, topography, soil type, and the crop-soil system, in addition to human activities.

Chapter 3

Empirical Evaluation of Agricultural Management Systems in Richmond County, Virginia: An Effort to Employ Multiple Criteria

This chapter employs multiple criteria to evaluate the economic and environmental impacts of agricultural management systems in Richmond County, Virginia through a multi-objective dynamic programming model. To match the multiple objective, dynamic, and stochastic features of low-input agricultural production systems, the surrogate worth trade-off method was first selected as a solution approach. After a brief description of the study area and the scope of this research, parameters of CREAMS simulation model were developed to estimate the environmental impacts of these agricultural production systems. The simulation results were then coupled to a multi-objective dynamic programming model to simultaneously evaluate the environmental and economic impacts of these systems.

3.1 The Surrogate Worth Trade-off Approach to Multiple Criteria Evaluation

In this section, the functions, type, and features of the model selected for this study are first discussed. Then, the surrogate worth trade-off method is introduced. Finally, the advantages and extensions of the surrogate worth trade-off method are presented.

3.1.1 Modeling the Study's Problem

Models are generally constructed to provide information about systems of interest. To address the complexity of agricultural systems, representing them in a mathematical model is particularly useful. Following Rausser and Hochman (1979), the functions of the model in this study are: (1) accounting quantitatively for interdependencies and relationships between the factors of interest; (2) forcing analysts or other interested parties to be precise about their perceptions and to examine possible inconsistences in those perceptions; and (3) representing a way of formalizing thought processes and testing these processes with available evidence.

Depending on research objectives, models can generally be classified as four types: descriptive, explanatory, predictive, and decision making. For this study, the model that will be employed is regulatory decision making model.

The performance of agricultural management systems in Richmond County, Virginia is empirically evaluated in this study. The evaluation consists of a multi-objective, dynamic, and stochastic decision making analysis.

Basically, three types of approaches can be used as solution methods for multi-objective problems. The first finds the preferred solution directly; the second weighs objectives and transforms the multi-objective problem to single objective problem; and the third starts from generating a non-inferior solution[12] set and then finds a preferred solution from the non-inferior set.

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[12] A non-inferior solution is one in which no improvement can be obtained in any of the objectives without a cost to at least one of the other objectives (Haimes et al. 1975).

The first approach is a utility function approach, which considers all the objectives in a utility function; and then optimizes the utility function. The major difficulty with this approach is that a utility function may not be satisfactorily determined.

The second approach includes lexicographic approaches, parametric approaches, goal programming and so forth. The major feature of this approach is that objectives need to be ranked in order of their importance by analysts and/or decision makers, which is not an easy task for a problem with conflicting multiple objectives, especially if some of them have irreversible effects. The first and second approaches were used at the start of the analysis to explorate decision makers' preferences and to identify the compatibility or incompatibility of objectives in the case of incomplete information.

The third approach has the advantages of separating objective analyses from subjective choices and excluding inferior solution sets, which could be a subset of feasible solution sets. In a sense, this approach approximates decision making processes of human activity, which are a thought process of developing logical bases for eliminating further consideration of a large number of otherwise possible decisions with reasonable assurance that the most desirable decisions are not inadvertently lost (Haimes et al., 1975). Analysis through modeling and decision making are separated into two steps in this approach, though feedback exists. The third approach is also convenient for considering dynamic and stochastic features of agricultural management systems. The surrogate worth trade-off (SWT) method is one of these approaches, and it is chosen for this study. A detailed discussion of the SWT method will follow. The major disadvantage of the third approach are higher computational burdens.

Features, other than multiple objectives; dynamics; and stochasticity, that need to be considered in the modeling are: *discrete versus continuous time model, analytical versus numerical analysis, adaptive versus nonadaptive approach, and perfect information versus imperfect information*. Based on the problem addressed in this study and the data available, these other features are considered as follows:

(1) discrete versus continuous time models

Discrete time models are probably the best choice for the empirical analysis of decision making processes since available data usually conform to such a model and decision mechanisms in agricultural production models must be discontinuous (Burt and Cummings, 1977). These decisions include input decisions, output decisions, and replacement decisions. In this research, the input decisions are used as control variables which include crop rotation; tillage; fertilizer type; and nutrient quantity, timing, and method of application. All of those decisions are made at the beginning of a stage. All of them are discontinuous with respected to time. Revenues from crops are accounted for annually. The processes of soil loss and nitrate leached to groundwater are inherently continuous, but can be calculated annually, monthly, or daily by CREAMS (chemicals, runoff, and erosion from agricultural management systems (Knisel, 1980), simulation model[13] and can be treated as discrete.

(2) Numerical versus analytical approaches

An important advantage of the analytical approach is overcoming the curse of dimensionality[14]. The solution procedure for the analytical problem with vectors of control variables and state variables is the same as for the problem with a single control variable and state variable in dynamic programming. Another advantage is that the time taken to compute an analytical solution is about one fifth of that for the numerical solution. But the limitation of the analytical approach is that it may not be easily applied if each solution stage is constrained by restrictions on the control variables and state variables (Kennedy, 1986). Another important obstacle of using an analytical approach for this study is that it is difficult to develop a general state transition function for soil loss and nitrate leaching associated with various agricultural production systems. In contrast, some simulation models, such as CREAMS, can numerically show the soil loss and nitrate leaching of individual agricultural management system. Thus, a numerical approach is used in this study.

(3) Perfect versus imperfect information and adaptive versus nonadaptive approach

For a class of optimal control problems in which some of the key

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[13] The CREAMS simulation model will be discussed in section 3.3.

[14] Given the amount of computer memory available, the curse of dimensionality limits the maximum number of state variable since computer memory required increases exponentially with the number of state variable.

information is not known exactly, these problems are considered as optimal control problems under imperfect information and may be solved by adaptive optimal control. In that kind of a problem, at least one of the unknown parameters is contained in a transition equation, an observation equation, various probability densities of the noises, the initial conditions and/or in the description of the input (Aoki, 1989). The adaptive control model observes the occurrence of the random events over a number of stages and uses a conditional probability distribution to improve the estimation of unknown parameters.

For agricultural production systems, uncertainty and imperfect information are the rule rather than exception. Random variables could exist in the economic variables, the weather variables, or the technical coefficients. Conceptually, adaptive control provides a preferred approach. However, the conditional probability distribution observed from past stages contributes little information in this analysis since the distribution of the weather index, which is the only random variable in this study, is historically based and relatively stable. Observations from several past stages provide limited information for predicting future events of the random variable. Employing the perfect information and non-adaptive approach is some what insufficient for this study's problem, but they are employed as a compromise due the lack of available data.

In summary, the features of a discrete analysis; numerical approach; and assuming perfect information and a non-adaptive approach, are combined with three major features of the agricultural production system: multiple objectives; dynamic; and stochastic in a multi-objective dynamic programming model. This multi-objective dynamic programming model will be developed in section 3.4.

3.1.2 The Surrogate Worth Trade-off Method

The SWT method was developed by Haimes and Hall (1974) for large systems, which usually have several conflicting and non-commensurable objectives. In such a situation, there is generally no single optimal decision because of the existence of more than two non-commensurable and/or conflicting objectives. The SWT method evaluates the relative value of an additional increment of the various non-commensurable objectives, at a given value of each objective function, rather than their absolute values. The SWT method focuses on searching for a *best decision* in the sense that no other decision can be demonstrated as superior.

3.1.2.1 SWT for a two objective problem

The SWT method may be explained more directly by using a simple example. The following is an example of a problem with two conflicting commensurable objectives and two decision variables borrowed from Haimes et al. (1975).

Problem 3.1

Minimize $f_1 = x_1$ (3.1.1)

Minimize $f_2 = 10 - x_1 - x_2$ (3.1.2)

Subject to: $0 \leq x_1 \leq 5$, and (3.1.3)

$$0 \le x_2 \le 5. \qquad (3.1.4)$$

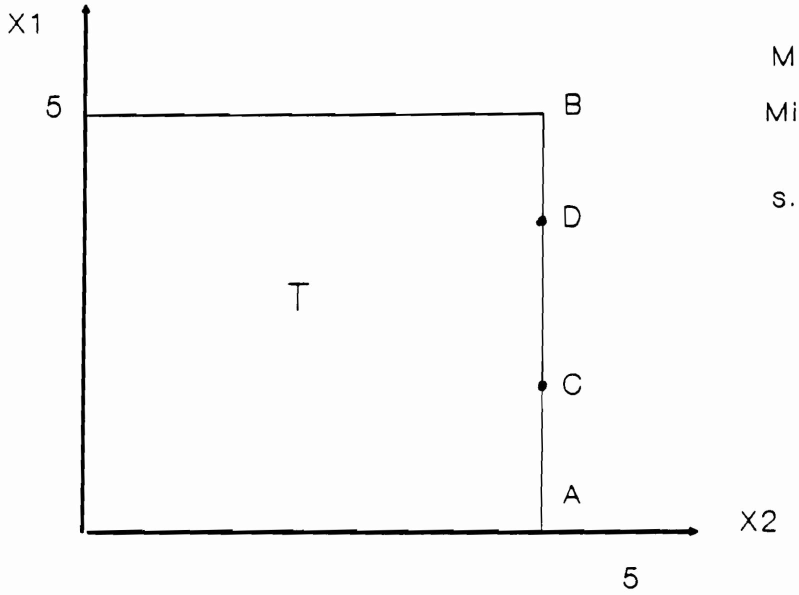
where: f_1 and f_2 are objectives; and

x_1 and x_2 are decision variables.

The feasible decision set T is expressed in Figure 3.1.1a and the feasible objective function set S is expressed in Figure 3.1.1b. Several important points can be made with this example. First, no optimal solution exists since the minimum of f_1 and f_2 can never be reached simultaneously. Decreasing in f_1 will cause an increase in f_2 in the non-inferior functional set. In multi-objective programming, the optimal solution is usually defined as the solution that optimizes all the objectives simultaneously.

Second, non-inferior solutions can only be arrived at the boundary AB of the feasible functional set S. This is because for any point in the interior of S a reduction could be achieved in one objective without changing the others by moving in a negative direction parallel to that axis as far as possible until the boundary is reached.

Third, the non-inferior solution is not unique. All the points on the boundary AB belong to the non-inferior set. This indicates that additional criteria are needed to decide the best combination of objective function values from the non-inferior functional set. Those additional criteria reflect the decision maker's preference. The best decision can be obtained by mapping the best combination of objective functions to the decision space. For example, if D is a point on the non-inferior set



Min F1 = X1

Min F2 = 10-X1-X2

s.t. 0 =< X1 =< 5

0 =< X2 =< 5

Fig. 3.1.1a Feasible Decision Space

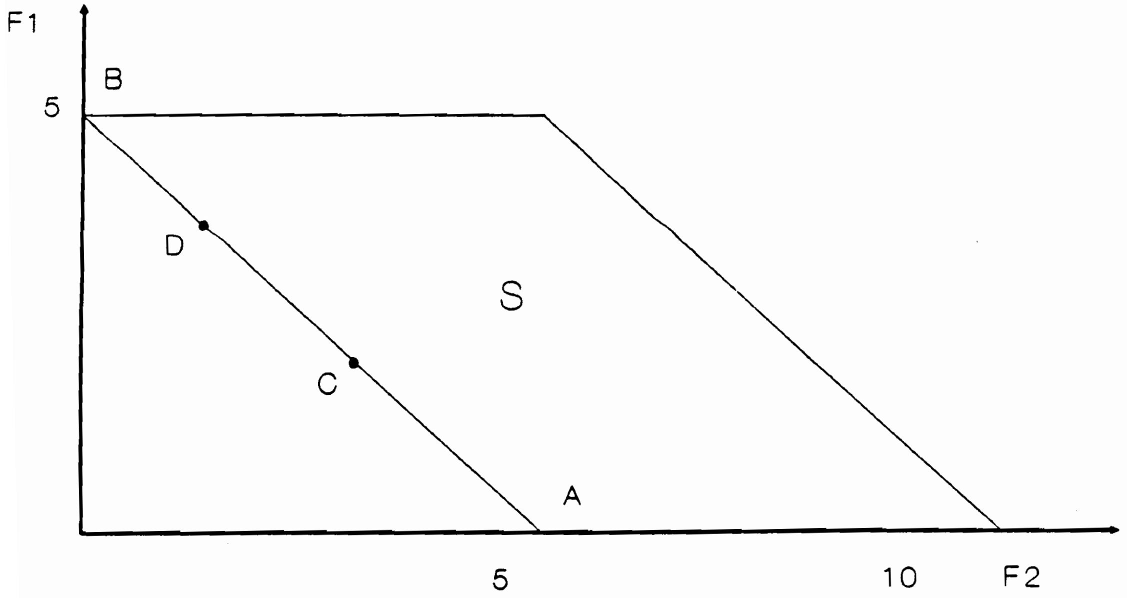


Fig. 3.1.1b Feasible Functional Space

AB is selected as the best combination of f_1 and f_2 by the decision maker, $f_1 = 3$ and $f_2 = 2$, then $x_1 = f_1 = 3$ and $x_2 = 10-x_1-f_2 = 5$.

Fourth, there exists a trade-off function $f^*_1(f_2)$ which shows how much the value of f_1 must be changed to stay in the non-inferior set when the value of f_2 is changed, which is $f^*_1(f_2) = 5 - f_2$ in this example. This functional relation between f_1 and f_2 can be also expressed in a form of ratio, that is, the trade-off rate which is defined as:

$$T_{12} = df_1 / df_2 \tag{3.1.5}$$

The trade-off rate is only related to the value of a small increment in f_2 to the resulting increment in f_1, that is the relative value of increments, but not the objective function itself.

The trade-off rate is identically equal to minus one when f_1 and f_2 are fully commensurate units (Haimes et al. 1975). In this example, $T_{12} = df_1 / df_2 = -1$.

As an extension of this example, if two objectives are measured in different units or dimensions, but commensurable, the real trade-off rate T_{12} is no longer equal to minus one. Let T_{12} be multiplied by W_{12}, the ratio of the true per unit worth of any increment of f_1 to the true per unit worth of any increment of f_2. If it can be determined, W_{12} is a worth coefficient for the trade-off rate T_{12}. For example, if f_1 has the unit value of a thousand dollars and f_2 has the unit value of one dollar, the W_{12} is equal to a thousand. That is: $T_{12}W_{12} = df_1 / df_2 = -1$; and the trade-off rate $T_{12} = 1/W_{12} = 1/1000$. When two objectives are commensurable, W_{12} is constant no matter whether two objectives have the same units.

Fifth and finally, in the case of non-commensurable objectives, W_{12}

cannot be determined. Otherwise, the objective function could be transformed as commensurate objectives and the analysis process above can be used to decide the trade-off rate. For example, assume that the environmental effects of some conservation practices are evaluated; that there are two objectives, minimizing soil loss and nitrate leaching; and that they are in conflict. In this case, the value of increments of the two objectives are non-commensurable, that is, it is not known how much the value of decreasing soil loss by one unit is worth compared to the value of increasing nitrate contamination of the groundwater by one unit. Therefore only an ordinal number, rather then a cardinal number, can be identified for W_{12}. Furthermore, W_{12} is not constant as it is in the commensurable objectives situation. W_{12} will change at different levels of f_1 and f_2, therefore $W_{12} = W_{12}(f_1, f_2)$. W_{12} is called surrogate worth function.

Since the surrogate worth function W_{12} is ordinal, at certain levels of f_1 and f_2, a decision maker assigns a positive value to W_{12}, such as +10 to +1, if the decision maker considers that the true worth of an increment of f_1 is greater than the true worth of decrement of f_2. The larger the assigned value is, the more unequal the decision maker feels about the value of f_1 and f_2. A negative value such as from -1 to -10 might be applied to W_{12}, if the decision maker considers the relative worth of f_1 and f_2 to be reversed. The smaller the negative number is, the more unequal the decision maker feels about the value of f_1 and f_2; A value zero is assigned to W_{12} if the decision maker is indifferent about trade-off between f_1 and f_2. Thus, the best solution is the solution that is in the non-inferior solution set and the surrogate worth function equals zero for the decision maker.

3.1.2.2 SWT for the general n-objective problem

The general n-objective problem is an extension of the two objective problem and can be expressed as:

Problem 3.2

Minimize $\{f_1(\underline{X}), \ldots, f_j(\underline{X}), \ldots, f_n(\underline{X})\}$ (3.1.6)

Subject to: $g_k(\underline{X}) \leq 0$, and (3.1.7)

$\underline{X} \geq 0$. (3.1.8)

Where: $\underline{X}$ is an N dimensional decision vector;

$f_j(\underline{X})$ is the j^{th} objective function; $j = 1, 2, \ldots, n$; and

$g_k(\underline{X})$ is the k^{th} constraints; $k = 1, 2, \ldots, m$.

In vector form, it can be expressed as:

Problem 3.3

Minimize $\underline{f}(\underline{X})$ (3.1.9)

Subject to: $\underline{g}(\underline{X}) \leq \underline{0}$, and (3.1.10)

$\underline{X} \geq 0$. (3.1.11)

where $\underline{X}$ is an N dimensional decision vector;

$\underline{f}$ is an n dimensional objective function vector; and

$\underline{g}$ is an m dimensional constraint vector.

It was proved by Haimes et al. (1975) that in the n objective case, the non-inferior functional set of $\underline{f}(\underline{X})$ is still on the boundary of the feasible functional set of $\underline{f}(\underline{X})$, S, and that it is a surface in R^n dimensions. In terms of mathematical expressions, the trade-off function and the trade-off rate function of the n-objective problem are defined the same as in the two objective problem 3.1. But the contents of these functions are different since both the trade-off function and the trade-off rate function now include not only two trading objectives, but the other objectives. That is, in the n objective problem, the ith trade-off function is a function of all objectives except for the ith objective.

$$f^*_i = f^*_i(f_1, \ldots, f_{i-1}, f_{i+1}, \ldots, f_n) \qquad (3.1.12)$$

As a result, the trade-off rate between the ith and the jth function, $T_{ij}(f_1, \ldots, f_n)$, is:

$$T_{ij} = df_i(\underline{X}) \;/\; df_j(\underline{X}); \qquad (3.1.13)$$

Where: $df_i(\underline{X}) = \Sigma\, [\partial f_i(\underline{X}) \;/\; \partial x_k]\, dx_k$; and

$df_j(\underline{x}) = \Sigma\, [\partial f_j(\underline{X}) \;/\; \partial x_k]\, dx_k$.

The direct use of this formula is impractical and computationally prohibitive, especially with non-commensurable objectives. Haimes et al. (1975) used an alternating approach, the ε-constraint approach, to find the trade-off rate function. They reformulated the general n-objective problem as:

Problem 3.4

Minimize $f_i(\underline{X})$ (3.1.14)

Subject to: $f_j(\underline{X}) \le \varepsilon_j \quad j = 1, 2, \ldots, i-1, i+1, \ldots, n,$ (3.1.15)

$g_k(\underline{X}) \le 0 \quad k = 1, 2, \ldots, m,$ and (3.1.16)

$\underline{X} \ge 0.$

where: $f_i(\underline{X})$ and $f_j(\underline{X})$ are the objective functions;

$\varepsilon_j = f_{j\,min} + \Delta\varepsilon_j$;

ε_j is the allowed value for the j^{th} objective, which is determined by the empirical problem and $\varepsilon_{j\,min} \ge 0$;

$f_{j\,min}$ is the minimum value of the j^{th} objective when all other objectives are ignored;

$\Delta\varepsilon_j$ is the deviation of ε_j from $f_{j\,min}$; and

other notation is the same as in problem 3.3.

This approach chooses an objective, the i^{th} objective, as a reference objective, the rest of the objectives are treated as constraints. There is no rule for selecting the reference objective, but usually the one in familiar units such as dollars is recommended. Using familiar units in the reference objective will lead to a meaningful trade-off analysis later. In the derivation below, the first objective is arbitrarily selected as the reference objective without loss of generality. The problem becomes minimizing the first objective restricted by n+m-1 constraints, which are the n-1 objectives and the m constraints in the original problem. For this reformulated problem, the generalized Lagrangian can be used to find the trade-off rate function. The Lagrangian function, L, is:

$$L = f_1(\underline{X}) + \Sigma \, \mu_k g_k(\underline{X}) + \Sigma \, \lambda_{1j}(f_j(\underline{X}) - \varepsilon_j) \qquad (3.1.18)$$

where μ_k and λ_{1j} are the generalized Lagrangian multipliers. The subscript 1j on λ denotes that λ is the Lagrangian multiplier associated with the first objective and the j^{th} constraint, which is the j^{th} objective in the original problem.

The derivation of Kuhn-Tucker necessary and sufficient conditions, which are analogous to the classic Kuhn-Tucker conditions for optimality of a single objective problem, are based on Kuhn and Tucker's well-known 1951 paper and later works by Cohon and Mark (1975) and Cohon (1978). A summary of the development of these conditions can be found in Chankong and Haimes (1983). Several Kuhn-Tucker conditions are of interest to this discussion as follows:

$$\lambda_{1j}(f_j(\underline{X}) - \varepsilon_j) = 0 \qquad j = 2, 3, \ldots, n \qquad (3.1.19)$$

$$\lambda_{1j} \geq 0 \qquad j = 2, 3, \ldots, n \qquad (3.1.20)$$

Equation (3.1.19) holds only if: (1) $\lambda_{1j} = 0$, (2) $f_j(\underline{X}) - \varepsilon_j = 0$, or (3) both equal zero. In the first situation, $f_j(\underline{X}) - \varepsilon_j < 0$ and the j^{th} constraint is not binding. The associated solution would belong to the inferior solution set since deceasing the first objective can be achieved without degradation of the j^{th} objective. The third situation is defined as being associated with the inferior set by Haimes et al. (1975) based on previous studies.

In the second situation, the j^{th} constraint is binding. The Lagrangian multiplier λ_{ij}, is positive and indicates the marginal benefit (or cost) of the first objective due to an additional unit of j^{th} objective, which is the same concept as the trade-off rate function. Mathematically, the following can be derived:

$$\lambda_{1j} = - \partial L \, / \, \partial \varepsilon_j \ .$$

When the Kuhn-Tucker necessary conditions are satisfied and the constraints are binding:

$$\mu_k g_k(\underline{X}) = 0, \ \lambda_{1j}(f_j(\underline{X}) - \varepsilon_j) = 0, \text{ and } f_j(\underline{X}) = \varepsilon_j \quad \forall \ j, \ k$$

so $L = f_1(\underline{X})$,

$f_j(\underline{X}) = \varepsilon_j$, and

$$\lambda_{1j} = - \partial f_1(\underline{X}) \, / \, \partial f_j(\underline{X}), \qquad (3.1.21)$$

which is the trade-off rate that was defined above.

This formula can be generalized when the i^{th} objective is selected as the reference objective rather than the first one. In that case, the subscripted index 1 should be replaced by i and the rest of the derivation is the same, providing:

$$\lambda_{ij} = - \partial f_i(\underline{X}) \,/\, \partial f_j(\underline{X}) \quad i \neq j \ ; \ i,\ j = 1,2,\ldots,n \qquad (3.1.22)$$

where: λ_{ij} is the marginal benefit (or cost) of i^{th} objective due to the additional unit of j^{th} objective. In other words, when $\lambda_{ij} > 0$ there is a degradation in the j^{th} objective function for an improvement in the i^{th} objective function. The minus one in the formula indicates the conflicting relationship between objectives.

Note that the above derivation is based on the artificially selected value of ε_j. λ_{ij} is a function of the selected ε_j's, which can be represented as the trade-off rate function:

$$\lambda_{ij} = \lambda_{ij}(\varepsilon^{P}{}_{j}) \qquad (3.1.23)$$

where: p = 1, 2,..., P and $\varepsilon^{P}{}_{j}$ is the P^{th} value selected for j^{th} objective, which results in the j^{th} constraint being binding with a positive λ_{ij}. Empirically, these ε_{ij}'s could come from physical knowledge of the j^{th} constraint such as the allowed soil loss, nitrate leaching, or nitrogen runoff to the surface water. For every selected ε_{ij}, a corresponding λ_{ij} can be found. The trade-off rate function can be determined by regression analysis, interpolation, or curve fitting. The trade-off rate is not unique and it changes with different levels of the objectives. A best solution can be decided only using additional criteria, which usually depend on decision makers' preferences, ethics, knowledge, and judgement.

As in the two objective case, the final surrogate worth functions W_{ij}'s are decided subjectively by the decision maker. But in the n objective case, the possible non-inferior solutions developed with the objective analysis will increase tremendously with increases in the dimensions of the objective function.

3.1.3 Advantages and Extensions of the SWT Method

The major advantages of the SWT method were summarized by Haimes et al. (1975) and Chankong et al. (1984) as it being able to:

(1) handle multidimensional and multidirectional objectives, in both the commensurable and non-commensurable cases, quantitatively;

(2) separate the objective trade-off analysis and subjective decision choice without loss of the connection between the analysts doing the modeling and the decision makers;

(3) provide decision makers with additional quantitative information on the non-inferior frontiers, which are the trade-offs between any two objectives of interest at various levels of the objectives;

(4) provide a logical framework for the decision makers to assess and evaluate heir own preferences rationally and simply;

(5) make decisions on functional space, which is more familiar and meaningful to decision makers, compared to decision space; and

(6) provide the opportunity to incorporate other operational methodologies or even the pattern of thinking about the systems with multi-objectives.

Extensions and applications of the SWT method are numerous. Major extensions include: (1) the SWT dynamic method by Haimes et al. (1975), which incorporates dynamic programming in the SWT method; (2) the Multi-objective statistical method by Haimes et al. (1980) and Haimes (1980), which integrates statistical attributes with the SWT method; (3) the uncertainty/sensitivity index method By Haimes et al. (1975), Haimes and Hall (1977), and Haimes (1981), which treats risk and sensitivity as separate objectives rather than as the overall index of model performance; (4) the interactive SWT method by Chankong and Haimes (1978), which allows the complex details of the internal, quantifiable, structure of the multi-objective decision making problem to be effectively exploited and, at the same time, provides an effective mechanism for treating other important "subjective" elements; and (5) the SWT method with multiple decision makers by Hall and Haimes (1976), Haimes (1980), Zwick (1981), and Zwick and Haimes (1981), which involves a group of decision makers rather than single individual.

The SWT method has been extended to a multi-objective problem that has discrete objective functions and/or constraints. The first part of the SWT, the objective trade-off analysis, is one class of vector objective optimization problems, which consists of mathematical programming with multiple objective functions. Just as is the case with the single objective optimization problem, the Kuhn-Tucker necessary conditions for the vector objective optimality problem require that all of the objective functions and constraints have first and second derivatives; and the sufficient conditions for existence of the non-inferior solutions require convexity of all functions with at least one objective function being strictly convex (Chankong et al., 1984). Conceptually, the non-inferior solution approach can be used only for continuous functions to satisfy the Kuhn-Tucker conditions, but approximately, this approach is commonly used for discrete functions under the assumption that the interval represented by the discrete functions is "small enough." All interpretations of non-inferior solution in the discrete function case are the same as in the continuous function case. For example, the ratio of the value of a small increment of f_i with respect to the value of small decrement in f_j can be interpreted as the trade-off rate between objectives f_i and f_j. A more detailed derivation of the discrete maximum principle with economic interpretations can be found in Dorfman (1969), Benavie (1970), and Clark (1976).

3.2 The Study Area and Scope of Analysis

In this section, the natural conditions influencing agricultural production in the study area are first discussed. Then, the agricultural practices of the 14 currently employed and potentially employable agricultural management systems are described. The scope of the multiple criteria evaluation of agricultural management systems in the study area is presented after examining the current environmental impacts of agricultural production, measured as soil loss and nitrate leaching.

3.2.1 Natural Conditions Influencing Agricultural Production

Richmond County is on the Coastal Plain of Virginia between the Potomac and the Rappahannock rivers. It abuts the Rappahannock River which flows into the Chesapeake Bay. Richmond County covers a total area of 129,920 acres, including 7,040 acres of water and 122,880 acres of land. There are 23 soil types in Richmond County. About 55,082 acres, or nearly 45 percent, of Richmond County's land is prime farmland[15]. Suffolk sandy loam, at 19.2 percent of Richmond County land, is the primary soil type used for crop production. Typically, the surface layer of Suffolk sandy loam in Richmond County is about 9 inches thick and the subsoil 32 inches thick. Suffolk sandy loam soil is well suited to crop and hay production. This soil has a moderate to medium permeability, and a slow to medium runoff. This soil can be very strongly acidic or strongly acid in unlimed areas and the surface layer is low in organic matter (United States Department of Agriculture, 1982).

Richmond county has a warm, continental climate. Data in the period of 1951-1978 indicates that the average annual precipitation is 42.61 inches and the average number of days with 0.1 inch or more rainfall is 77. Both the hazard of wind and water erosion are management concerns in the county (United States Department of Agriculture, 1982). The average annual value of the rainfall erosion index in Richmond County is 250 (Wischmeier and Smith, 1978). The average daily temperature is 57.5 °F, which facilitates leaching of plant nutrients from the soil and oxidation of organic matter in the surface layer of the soils. Generally, Richmond County has suitable natural conditions for crop production (United States

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[15] Prime farmland, as defined by the U.S. Department of Agriculture, is the land that is best suited to producing food, feed, forage, fiber, and oilseed crops. It has the soil quality, growing season, and moisture supply needed to economically produce a sustained high yield when it is managed using acceptable farming methods (United States Department of Agriculture, 1982).

Department of Agriculture, 1982).

3.2.2 Agricultural Production Systems in Richmond County

Richmond County is the second largest county in the Northern Neck of Virginia. Major crops are corn; soybeans; wheat; and barley, which rank the 17th; 15th; 10th; and 5th in cash receipts in Virginia, respectively (Virginia Agricultural Statistics Service, 1990). In 1987, Richmond County had 31.7 percent of its total land in farms, of which about 67.5 percent, or 26,395 acres, was crop land. There were 148 crop farms, out of which 81 had annual sales of $10,000 or more and had 90.9 percent of total crop land, that is, 23,997 acres. The average farm size of these 81 farms was 296 acres and the average value of agricultural products sold from the 81 farms was $71,551. From 1982 to 1987, harvested acreage of corn, soybeans, wheat, and barley dropped about 41 percent, 19 percent, 30 percent, and 46 percent, respectively (United States Department of Commerce, 1987).

Information on current agricultural management systems in Richmond County came from a survey of Richmond County farm operators conducted in 1989 (Giuranna et al., 1991) and from the Richmond County Extension Agent (Liddington). An agricultural management system (AMS) is a combination of various agricultural practices, such as, tillage, nutrient management, weed control methods, disease control methods; and crop rotation. Farming practices of the 14 AMSs used in this study will be discussed below. The schedules of field operations, including planting; tillage; nitrogen applications; and harvesting, of these 14 AMSs are listed in Table 3.2.1. The numbering of the AMSs is consistent with Diebel (1990) to facilitate the reader's evaluation of supporting material. AMSs having the same number represent the same basic management practices except the type of fertilizer applied: commercial nitrogen versus poultry litter. An AMS followed by the suffix L uses poultry litter as an organic fertilizer source.

Four basic crop rotations are currently commonly used in Richmond County. They are: a two year rotation with corn followed by double-cropped small grains[16] and soybeans (C/D-SG); a two year rotation with corn followed by double-cropped small grains and soybeans with a winter rye cover crop (C/D-SG-R); a two year rotation with corn followed by double-cropped small grains and soybeans with winter cover of rye mixed with crimson clover (C/D-SG-M); and a four year rotation with corn followed by double-cropped small grains and soybeans in the second year, full-season soybeans in the third year, followed by double-cropped small grains and soybeans in fourth year (C/D-SG/FS/D-SG). They most commonly use a medium level of inputs.

Tillage methods for these four rotations are based on the current production practices in the county. Four tillage methods are used for the rotation C/D-SG. They are: (1) moldboard plowing for corn, moldboard plowing for small grain, and no-till for soybeans in AMSs 1, 1L, and 4; (2) no-till for corn, moldboard plowing for small grains, and disking for

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[16] Small grains consist of barley and winter wheat.

Table 3.2.1 Fourteen Agriculturual Mangement Systems Used for Analysis

AMS	Crop	Tillage Date	Tillage Method	Plant Data	Nitrogen Date	Nitrogen Method (a,b)	Nitrogen Amount Commer. (lb/ac)	Nitrogen Amount PL	Cultivate Data	Harvest Data
1	Corn	3/25	MB		3/25	1, 4	30			
				4/15						
					5/10	3, 5	100			
										9/20
	Wheat	9/27	MB	9/27	9/27	1, 4	15			
					2/20	3, 2	65			
										6/10
	Soybean		NT	6/15						
										11/15
1L	Corn	3/25	MB		3/25	1, 4		130		
				4/15						
										9/20
	Wheat	9/27	MB	9/27	9/27	1, 4		80		
										6/10
	Soybean		NT	6/15						
										11/15
2	Corn		NT		3/25	1, 4	20			
				4/10						
					5/10	3, 5	130			
										9/20
	Wheat	9/27	MB		9/27	1, 4	57			
				10/5						
					2/20	3, 2	61			
										6/10
	Soybean	6/15	DISK	6/15						
										11/15
2L	Corn		NT		3/25	1, 4		150		
				4/10						9/20
	Wheat	9/27	MB		9/27	1, 4		118		
				10/5						6/10
	Soybean	6/15	DISK	6/15						
										11/15

Table 3.2.1 Fourteen Agriculturual Mangement Systems Used for Analysis
(Continued)

AMS	Crop	Tillage Date	Tillage Method	Plant Data	Nitrogen Date	Nitrogen Method (a,b)	Nitrogen Amount Commer. (lb/ac)	Nitrogen Amount PL	Cultivate Data	Harvest Data
3	Corn	3/25	CHIS		3/25	1, 4	30			
				4/10						
					5/10	3, 5	70			
										9/20
	Wheat	9/27	MB		9/27	1, 4	16			
				10/5						
					2/20	3, 2	61			
										6/10
	Soybean		NT	6/15						
										11/15
3L	Corn	3/25	CHIS		3/25	1, 4		100		
				4/10						
										9/20
	Wheat	9/27	MB		9/27	1, 4		77		
				10/5						
										6/10
	Soybean		NT	6/15						
										11/15
4	Corn	3/25	MB		3/25	1, 4	30			
				4/10						
					5/10	3, 5	100			
										9/20
	Wheat	9/27	MB		9/27	1, 4	15			
				10/5						
					2/20 3/20	3, 2 3, 2	35 30			
										6/10
	Soybean		NT	6/15						
										11/15
5L	Corn	3/25	DISK		3/25	1, 4		130		
				4/10						
									4/30 5/15	
										9/20
	Wheat	9/27	MB		9/27	1, 4		77		
				10/5						
										6/10
	Soybean		NT	6/15						
										11/15

Table 3.2.1 Fourteen Agriculturual Mangement Systems Used for Analysis (Continued)

AMS	Crop	Tillage Date	Tillage Method	Plant Data	Nitrogen Date	Nitrogen Method (a,b)	Nitrogen Amount Commer. (lb/ac)	Nitrogen Amount PL	Cultivate Data	Harvest Data
8	Corn		NT	4/15	4/15	1, 4	30			
					5/10	3, 5	100			
									5/15	
										9/27
	Rye		AO	9/15						
										4/5
	Wheat	9/30	MB		9/30	1, 4	15			
				10/5						
					2/20	3, 2	65			
										6/10
	Soybean		NT	6/15						
										11/15
8L	Corn		NT	4/15	4/15	1, 4		130		
										9/27
	Rye		AO	9/15						
										4/5
	Wheat	9/30	MB		9/30	1, 4		80		
				10/5						
										6/10
	Soybean		NT	6/15						
										11/15
11L	Corn		NT	4/15	4/15	1, 4		130		
									4/30 5/15	
										9/27
	Rye		AO	9/15						
										4/5
	Wheat	9/30	MB		9/30	1, 4		80		
				10/5						
										6/10
	Soybean		NT	6/15						
										11/15
15	Corn	4/15	DISK		4/15	1, 4	30			
				5/15						
					6/10	3, 5	100			9/27
	Mix	9/15	AO							4/5

Table 3.2.1 Fourteen Agriculturual Mangement Systems Used for Analysis
(Continued)

AMS	Crop	Tillage Date	Tillage Method	Plant Data	Nitrogen Date	Nitrogen Method (a,b)	Nitrogen Amount Commer. (lb/ac)	Nitrogen Amount PL (lb/ac)	Cultivate Data	Harvest Data
	Wheat	9/30	MB		9/30	1, 4	15			
				10/5						
										6/10
	Soybean		NT	6/15						
										11/15
15L	Corn	4/15	DISK		4/15	1, 4		130		
				5/15						
										9/27
	Mix	9/15	AO							
										4/5
	Wheat	9/30	MB		9/30	1, 4		80		
				10/5						
										6/10
	Soybean		NT	6/15						
										11/15
16L	Corn	4/15	DISK		4/15	1, 4		130		
				4/25						
									MAY	
										9/27
	Mix	9/15	AO							
										4/5
	Wheat	9/30	MB		9/30	1, 4		80		
				10/5						
										6/10
	Soybean		NT	6/15						
									July	
										11/15

Notation:

Tillage:
MB --- Moldboard
DISK --- Disk
NT --- No-till
CHIS --- Chisel
AO --- Aerial overseed

Timing and method of N application (a, b):
a = 1 --- Preplant
3 --- Post-emergence
b = 2 --- Ground spray
4 --- Ground broadcast
5 --- Trickle

soybeans in AMSs 2 and 2L; (3) chisel plowing for corn, moldboard plowing for small grains, and no-till for soybeans in AMSs 3 and 3L; and (4) disking for corn, moldboard plowing for small grains, and no-till for soybeans in AMS 5L. Two tillage methods are used for the rotation C/D-SG-R. They are: (1) no-till for corn, moldboard plowing for small grains, no-till for soybeans and aerial overseeded rye in AMSs 8, 8L and 11L; and (2) no-till for corn, moldboard plowing for small grains, no-till for soybeans, and cultivation for weed control in AMS 11L. Two tillage methods are used for the rotation C/D-SG-M. They are: (1) disking for corn, moldboard plowing for small grains, and no-till for soybeans in AMSs 15 and 15L; and (2) disking for corn, moldboard plowing for small grains, no-till for soybeans, and cultivation for weed control in AMS 16L; the rye and mixed rye and crimson clover cover crop are aerial overseeded. Only one tillage method is used for the rotation C/D-SG/FS/D-SG. That is, moldboard plowing in the first year's corn, moldboard plowing for small grains and no-till soybeans in the second year, no-till for full season soybeans in the third year, and moldboard plowing for small grains and no-till for soybeans in the fourth year. The four year crop rotation (C/D-SG/FS/D-SG) is not included in the AMSs to be analyzed due to a lack of adequate simulation data.

Nutrient rates, type, timing, and method of application for each activity basically follow Diebel (1990). Fertilizer rates are, however, adjusted to three levels in order to more easily compare the impacts of tillage, cover crop, and nitrogen application timing on the simulation results. These three fertilizer nitrogen application rates are: (1) 150 pounds per acre for corn and 118 pounds per acre for wheat in AMSs 2 and 2L; (2) 130 pounds per acre for corn and 80 pounds per acre for wheat in AMSs 1, 1L, 4, 5L, 8, 8L, 15, 15L, and 16L; and (3) 100 pounds per acre for corn and 77 pounds per acre for wheat in AMSs 3 and 3L. These three fertilizer rates represent high, conventional, and low fertilizer applications, respectively. The required rates of phosphorus and potassium are assumed to be the same for all AMSs. Nitrogen in crop residues is not deducted from the recommended fertilizer rate for all AMSs, but is accounted for in the CREAMS simulation modeling.

Fertilizer types include commercial nitrogen and organic poultry litter. The application rates of poultry litter are established so that the mineralizable nitrogen in the poultry litter is equal to those levels in the commercial nitrogen. A detailed formula of litter application rates will be given in section 3.3. The litter is assumed to be shipped from Rockingham County in the Shenandoah Valley, Virginia. Note that at the time of this study, poultry litter was not being shipped from the Shenandoah Valley to Richmond County (Norris, 1988; Napit, 1990; Diebel, 1990).

The timing of nutrient application includes pre-planting, post-emergence, and at planting. Nutrient application methods include ground spraying, ground broadcasting, and trickle. Winter cover crops are currently used in Richmond County. In AMSs 8, 8L, and 11L, rye is the cover crop; and AMSs 15, 15L, and 16L use rye mixed with crimson clover as their cover crop.

For analyzing and comparing various agricultural management systems in Richmond County, the 14 combinations of crop rotation with different tillage, weed control method, nutrient rates, time, type, and method of application are selected as management systems or potentially employable management systems, which are listed in Table 3.2.1. A detailed description of these 14 AMSs can be found in Diebel (1990).

3.2.3 Current Environmental Quality and the Chesapeake Bay Agreement

Non-point pollution from agricultural production is charged as one of the major non-point pollutants of the Chesapeake Bay, and has led to declines in water quality and productivity. Richmond County contributes to the non-point source pollution through the Columbia aquifer and Rappahannock river.

In 1987, the Chesapeake Bay Agreement, which was approved by Virginia, Pennsylvania, Maryland, and the District of Columbia, requires the EPA and the Chesapeake Bay Commission to establish goals and mechanisms to clean-up and prevent further degradation of the Bay. The water quality goal of the Agreement, requires the reduction of point and non-point sources of pollution to attain a water quality condition necessary to support the living resources of the Bay. This water quality goal includes protection of groundwater from agricultural discharges of contaminants such as nitrates and pesticides. A 40 percent reduction of nitrogen and phosphorus entering the main stem of the Chesapeake Bay is required by the year 2000 (Chesapeake Bay Commission, 1987).

Evaluation of non-point pollution resulting from farmers' decisions on land use is necessary, but difficult. In this study, a simulation model, CREAMS is used to estimate the non-point pollution of agricultural activities. A brief description of CREAMS and its application to this study are contained in section 3.3.

3.2.4 Government Policies

The major government programs in Richmond County, which affect land use, include the: federal commodity programs; federal Conservation Reserve Program; and state buffer strip requirements of the Chesapeake Bay Local Assistance Board (Diebel, 1990; Giuranna, 1991). The commodity programs have the largest number of participants. The major products in Richmond County, which are eligible to join in the federal commodity programs, are corn; wheat; and barley. About 47 percent of farmers join wheat and corn programs and 34 percent of farmers join barley program (Giuranna, 1991). In general, the rate of enrollment in other government programs are much less than that in the commodity programs in Richmond County (Pease, 1991). A survey of Richmond County farm operators indicates that 95 percent of farmers practiced crop rotation and 74 percent of farmers practiced no-till land with little or no aid from the federal or state governments (Giuranna, 1991).

Including the federal commodity programs in the model is clearly helpful and realistic when economic and environmental impacts of agricultural management systems are evaluated. The commodity programs will affect the farm's net returns through government deficiency payments as well as the environmental impacts of AMSs since parts of the crop land are required to be set side to join the commodity programs. The deficiency payment is equal to the eligible product times deficiency payment rate. At the time of the 1990 Farm bill, the eligible product was determined by the allowable planted portion of the base acreage, which is equal to the five year average of base acreage minus the reduction acreage and required and optional flex acres, and the yield, which is a moving five year average of the historical yield and is frozen at the 1990 level through 1995. The percentage of acreage reduction will be established based on the ratio of ending stocks to total disappearance annually, but will not be higher than 20 percent. The deficiency payment rate is the difference between the target price and market price. The target prices for corn; wheat; and barley are frozen at 1990 level, which are $2.75; $4.00; and $2.36 per bushel, respectively. Beginning in 1994, calculation of deficiency payment rate will based on the target price and the 12 month average market price or the 5 month average market price plus 10 cent for wheat or 7 cents for corn and other feed grains, whichever is smaller (Pease, 1990). To include the commodity program in dynamic programming model, these patterns of target price, market price, acreage reduction percentage, and decisions of alternative crops in the required and optional flex acres have to be considered appropriately.

3.2.5 Scope of Analysis

This study evaluates and compares the performance of the 14 agricultural management systems in Richmond County, including LISA production systems and conventional production systems, on a per acre basis. The economic objective, represented by farmer's discounted net return per acre over a 10 year planning horizon, and two environmental objectives, represented by soil conservation and groundwater protection from nitrate contamination; are simultaneously evaluated in a multi-objective model. Any non-inferior solution sets gained from the model will quantitatively show the trade-offs, if any exist, between pairs of the three objectives at different levels of the three objectives. Compatibility and incompatibility of these objectives and different trade-offs will provide policy makers with important information on LISA production systems in the study area.

3.3 CREAMS: A Model for Estimating Environmental Impacts of Agricultural Management Systems

Estimation of soil erosion and non-point source pollution caused by various agricultural systems is necessary as the multiple objective evaluation of these systems is the concern of this research. While observed data from various field experiments are a more realistic evaluation of these environmental impacts, they are very costly. Simulation is a cost effective alternative. Tanji (1982 p.721) stated that "simulation modeling may have quite diverse objectives: testing existing or new concepts and hypotheses, obtaining greater conceptual understanding of complex problems, obtaining more quantitative evaluation or prediction of observed phenomena or experimental data, identifying research needs, and helping develop guidelines for best management practices." Therefore, a well developed simulation model for estimating effects of agricultural management systems on non-point source loading of nitrates and pesticides could be considered as an extensive use of information from experiments and surveys of soil scientists, agronomists, hydrologists, and environmental scientists.

A number of models have been developed and used as management tools to predict the response of the physical system to various AMSs. Among these models, CREAMS (Knisel, 1980) has been widely distributed and used since it has great strength in predicting surface runoff constituents, including sediment; nutrients; and pesticides, as well as nitrate leaching, and evaluating comprehensive cropping systems and rotations (Heatwole, 1991). CREAMS was used for this research.

3.3.1 Introduction to the CREAMS Model

CREAMS is a physically based daily simulation model that estimates runoff, erosion and sediment transport, and nutrient and pesticides loadings of land management systems from field sized areas (Knisel, 1980). The CREAMS simulates surface water movement to the edge of the field and groundwater movement to the bottom of the root zone. Therefore, the levels of pollutants predicted by CREAMS must be viewed as potential levels of pollution only. Assuming CREAMS is accurate with its predictions, they probably represent an over estimation of the actual levels of ground and surface water pollution.

The inputs of CREAMS can be divided into three categories of information[17]: (1) climate information on precipitation, solar radiation,

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[17] In the following discussion this information will be referred to as categories one, two, and three of information.

and temperature; (2) watershed system information on geology, topography, and soil properties; and (3) management information on land use, cultural practices, plant nutrients, and pesticides. The main outputs of CREAMS are runoff; sediment; and percolation, carried with nutrients and pesticides, associated with various management systems.

CREAMS has three submodels: hydrology; erosion and sediment; and nutrient and pesticides. Since water is the carrier of sediment and agricultural chemicals including nutrients and pesticides, central to the simulation of pollutant movement is the simulation of the amount and rate of water movement on the surface and through the soil. The simulation procedure, thus, starts from the hydrologic submodel, proceeds through the erosion and sediment submodel, to the nutrient and pesticide submodel recursively.

The hydrology submodel uses the all three categories of information except information on plant nutrients and pesticides. The outputs of the hydrology submodel are summaries of rainfall, runoff, evapotranspiration, percolation, and average soil water content in daily, monthly, or annual increments depending on the form of input and output required. The outputs of the hydrology submodel are transmitted to the erosion and sediment submodel in a form of pass file[18].

The erosion and sediment submodel uses the first category of information through the pass file from the hydrology submodel, and the second and third categories of information except plant nutrients and

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[18] A pass file sends useful parts of outputs from one sub-model to a subsequent sub-model.

pesticides. The outputs of the erosion and sediment submodel are the sediment yields of all types of particles and soil loss. The outputs of the erosion and sediment submodel are transmitted to the nutrient and pesticide submodel in a form of pass file.

The nutrient and pesticide submodel has two independent components: a nutrient component; and a pesticide component. The inputs of the nutrient component, which are of interest to this study, include the first and second categories of information through the pass file from the erosion and sediment submodel and certain information on land use, schedule of field operations, cultural practices, and nutrient management practices. Inputs and outputs of nutrients are balanced in the nutrient component. The outputs of the nutrient component relative to nitrogen are: (1) nitrogen and phosphorus in runoff; (2) nitrogen in sediment; (3) mineralized nitrogen; (4) nitrogen uptake by plants; (5) nitrate leaching; (6) denitrification; (7) nitrogen in rainfall; (8) soil nitrates; and (9) potentially mineralizable nitrogen (POTM) in the soil. The first seven are summarized in daily, monthly, or an annual time steps depending on the form of input and output required. The last two are the temporal values at the end of a specified time segment. Note that the three submodels use all three categories of information, but their foci are different. Transformation of information among the three submodels is forward recursive. That is, there is no feedback from the later submodel to the former submodels. For example, nitrogen uptake by crops from the nutrient component will not affect the water balance in the hydrology submodel although plant growth does affect the evapotranspiration and water content of the soil. A detailed description of inputs and outputs of CREAMS simulations can be found in Knisel (1980).

3.3.2 Simulation of Nitrogen Balance

Many studies on the nitrogen cycle have been conducted by agronomists, soil scientists, environmentalists, and economists. Here, the focus is placed to how CREAMS simulates the nitrogen cycle and what components of the nitrogen cycle are not considered by CREAMS.

The interactions among the various forms of nitrogen in soil, plants, and the atmosphere constitute the nitrogen cycle. Brady (1990) diagrammed a *practical* management of soil nitrogen in Figure 3.3.1. Gains of nitrogen include commercial fertilizer, crop residues, manure, nitrification, nitrogen fixation, and nitrogen in rainfall. Losses of nitrogen include crop removal, leaching losses, erosion losses, denitrification, and volatilization. Brady used the widths of the arrows to roughly indicate the magnitude of the losses and the gains often encountered. Therefore, major gains are fertilizer applied and nitrification of soil organic matter when nitrogen fixation does not exist, and major losses are plant uptake and nitrate leaching.

The nitrogen cycle is simulated by CREAMS in a form of nitrate balance represented in Figure 3.3.2 (Frere et al., 1980). Here, the losses of other forms of nitrogen[19], which includes nitrogen in runoff and

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[19] Other forms of nitrogen include all forms of nitrogen except soluble nitrates.

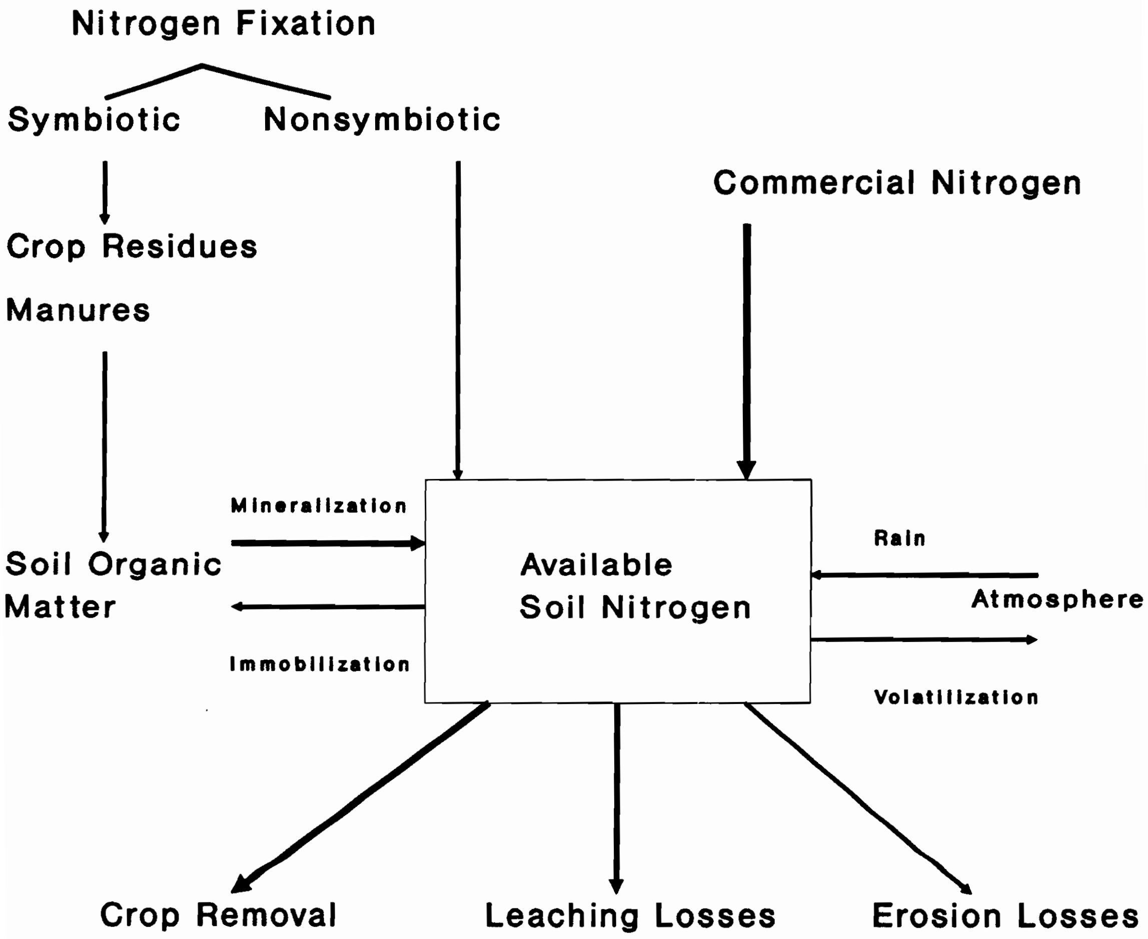

Figure 3.3.1 A Practical Management Flowchart of Soil Nitrogen

Source: Brady (1990) p.337

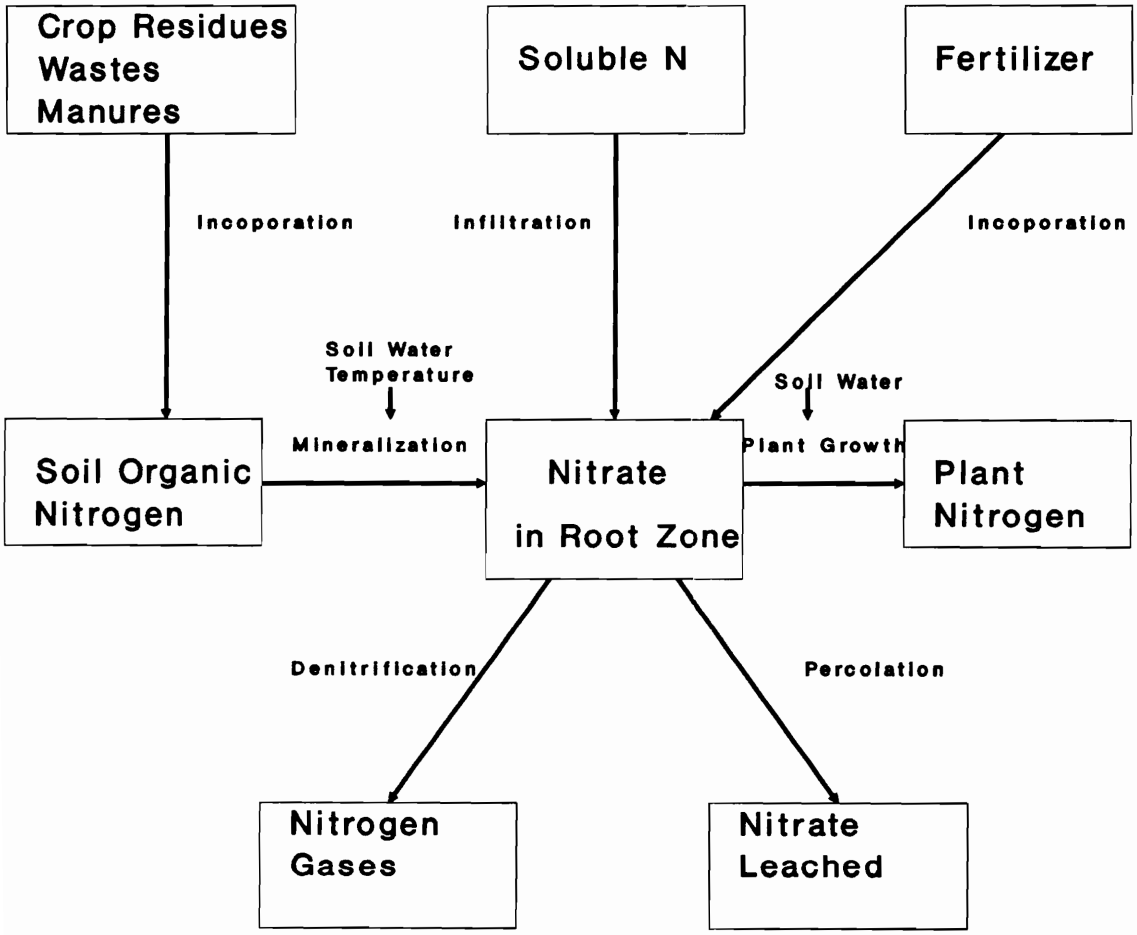

Figure 3.3.2 Diagram for Estimating Nitrogen Leaching

Source: Frere et al. (1980) p.67

nitrogen with sediment, are considered separately (Frere and Nowlin, 1980).

Three main differences between Brady's diagram and the CREAMS' diagram are the consideration of: (1) biological nitrogen fixation; (2) immobilization; and (3) mineralization, denitrification, and volatilization. These three differences and their effects on this research are discussed below.

3.3.2.1 Estimation of biological nitrogen fixation of soybeans and crimson clover

Biological nitrogen fixation is a biochemical process by which elemental nitrogen, N_2, is combined into organic forms. Although biological nitrogen fixation can be accomplished by a number of different organisms, the general process is to reduce nitrogen gas to ammonia. Legume symbiotic systems provide the major biological source of fixed nitrogen in agriculture (Brady, 1990). The lack of a component for considering nitrogen fixation in CREAMS will definitely affect the simulation results since all the 14 AMSs in this study include soybeans and three of them include crimson clover. The nitrogen fixed by soybeans and crimson clover, thus, can only be estimated in this study.

The nitrogen metabolism of legumes can be divided into two parts: symbiotic nitrogen fixation and nitrate metabolism. The nitrogen fixation of legumes is a process of symbiosis of legumes and bacteria of the genus *Rhizobium*. *Rhizobium* bacteria invade the root hairs and the cortical cells of plants, ultimately inducing the formation of nodules that serve as a home for the organisms. The host plant supplies the bacteria with carbohydrates for energy, and the bacteria reciprocate by supplying the plant with fixed nitrogen compounds (Brady, 1990). The nitrate metabolism of legumes also takes up nitrates from the soil solution by their roots. Although the two nitrogen input processes have independent pathways, inhibition of nodulation by nitrates has been known for many years. That is, the residual nitrogen in the soil will decrease the amount of symbiotic nitrogen fixation. In most of the soybean production areas in the United States, soils have appreciable levels of residual nitrogen. The symbiotic nitrogen fixation, thus, is generally functioning at less than maximum rates, due to inhibitory effects of nitrates. Under typical conditions nitrogen fixation by soybeans ranges from 71 to 89 pounds per acre in Corn Belt soils (Johnson et al., 1975) to a high of 277 pounds per acre in a sandy loam soil (Harper, 1987). Therefore, it is recognized that soybeans are nonresponsive or less responsive to the application of nitrogen fertilizer than other crops except where the organic matter content in the soil is very low (Harper, 1987; Welch, 1983).

Although no fertilizer is applied to soybeans or cover crops in the 14 AMSs in this study, Harper (1987) and Welch's (1983) conclusions indicate that the nitrogen metabolism in terms of the uptake of mineralized nitrogen in the soil will not substantially affect the total nitrogen metabolism of soybeans and crimson clover in the 14 AMSs. That is, the effects of previous AMSs on soybeans or crimson clover through variation in the POTM at the beginning of soybeans or cover crop growing season are ignored in this study. For example, based on simulation results of this study the average mineralized nitrogen in the soybean season varies from 7.3 to 40.2 pounds per acre for the 14 AMSs while the total nitrogen in the biomass of soybeans is about 126.5 pounds per acre associated with a soybean yield of 23 bushels per acre. Therefore, it is assumed that the yield of soybeans and clover will not be affected by the mineralized nitrogen or the POTM at the beginning of soybean and clover season. An average yield of 23 bushels per acre based on the soybean yields from 1970 to 1988 in Richmond County (Virginia Agricultural Statistics Service, 1989) is used as the soybean yield. Nitrogen contributed by N fixation of soybeans or crimson clover is considered through adjusting the POTM of soybean and crimson clover residue as discussed below.

3.3.2.2 Immobilization

Immobilization is a process of converting inorganic nitrogen ions (NO_3^- and NH_4^+) into organic tissue of microorganisms. It occurs mostly when plant and animal residues, especially those low in nitrogen, are added to soils. When the organisms die, some of the organic nitrogen in their bodies may be converted into NO_3^- and NH_4^+ ions again, a process of mineralization. Mineralization and immobilization are the conversion processes between the organic nitrogen pool and inorganic nitrogen pool in the soil (Brady, 1990). Organic nitrogen is not available to plants or leaching while inorganic nitrates are available. The rate of decomposition and the rate of immobilization are influenced by environmental factors such as temperature; soil moisture; and PH as well as by management practices such as the position on or in the soil where plant residues or animal manures are decomposed. Surface residues are subject to rapid drying and thus tend to decompose more slowly than residues that are plowed in. Mulch crop residues may not contain sufficient nitrogen to facilitate decomposition. Residues that are plowed in and surrounded by the soil supply much more nitrogen than residues on the surface of the soil (Parker et al., 1957). Therefore when different activities are considered, *the "actual" mineralized nitrogen* of a crop's residue *should not be identical* across the AMSs even through the total nitrogen content of that crop is approximately same because of different tillage and methods of incorporating crop residues and manures. CREAMS has no explicit element for accounting for nitrogen immobilization. In this study, nitrogen immobilization is accounted for by adjusting the POTM values of crop residues in the nutrient component and soil moisture through water balance in hydrology submodel.

3.3.2.3 Mineralization, denitrification, and volatilization

Borrowed from Patrick (1982), Figure 3.3.3 represents a nitrification and denitrification reaction. Organic nitrogen is first decomposed to NH_4^+ in a process of mineralization by microbes in the soil, then some of the NH_4^+ is oxidated to nitrite NO_2^- and nitrate NO_3^- in a process of nitrification by microbes in the soil; and some of the NH_4^+ volatilizes directly into atmosphere. Nitrates remaining in the soil may be take up by crops, leached, or diffuse downward and are denitrificated to the N_2 and N_2O gaseous forms, which are lost to the atmosphere. The magnitude and kinetics of the nitrification, volatilization, and denitrification will depend on the temperature, cultural practices, method of fertilizer application, and soil conditions (Brady, 1990).

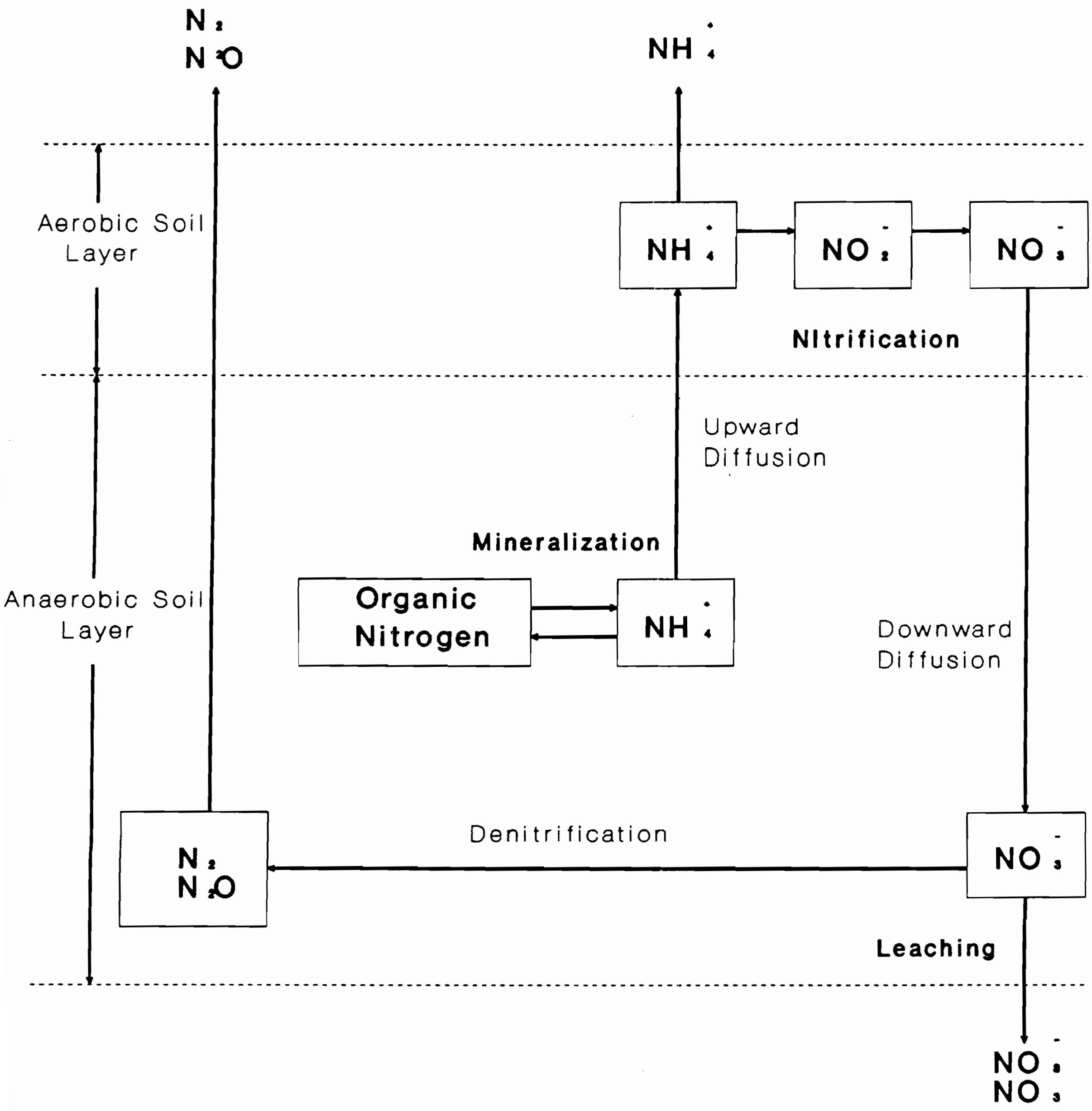

Figure 3.3.3 Nitrification--Denitrification Reaction

Source: Patrick (1982) p.451

The mineralized nitrogen in a certain period is sensitive to temperature, soil moisture, and potentially mineralizable nitrogen in soil. CREAMS assumes that the organic nitrogen pool in the soil is already very large and only nitrate or forms easily converted to nitrate, such as the POTM, are accounted for. CREAMS, thus, only gives the POTM of crop residues and manures credit by adding to a POTM pool and waiting for mineralization under favorable conditions when crops are harvested or manures are applied (Frere et al., 1980). Other forms of organic nitrogen in crop residues and manures are ignored.

The magnitude of denitrification of nitrates from mineralized organic fertilizer and the nitrates from commercial nitrogen is calculated in a single equation in CREAMS. Denitrification is sensitive to total nitrate content in the soil, organic carbon, temperature, and moisture (Frere et al., 1980).

Ammonia volatilization is not explicitly considered in CREAMS. Volatilization is serious when the manures and fertilizer are applied to the soil surface. Incorporating the manure and fertilizer into the top few inches of the soil can reduce volatilization by 25-75 percent (Brady, 1990).

The nitrate inputs considered by CREAMS are nitrates from fertilizer, mineralization, and rainfall. The overall nitrate outputs generated by CREAMS are nitrates in runoff, leaching, denitrification, and crop uptake. The nitrate balance in the model requires that the change of nitrate storage in soil is equal to the difference between total input minus total output (Frere et al., 1980).

These main deficiencies in the CREAMS nitrate cycle, that is, a lack of considering nitrogen fixation and immobilization, and of incompletely considering mineralization, denitrification, and volatilization, are ameliorated through adjusting parameters of nutrient components, which include the POTM values of crop residues and the distribution curves of nitrogen uptake discussed below. However, these updates may not comprehensively address these deficiencies. A comprehensive consideration of parameters in *all* of the three submodels may lead to more satisfactory simulation results.

3.3.3 Determination of Several Important Parameters in the Nutrient Component

In this research, the parameters of the hydrology and erosion and sediment submodels were developed by Davis (1991) and were modified by Heatwole (1991). The parameters of the nutrient component were developed by Davis (1991) and were modified in this study.

3.3.3.1 Poultry litter application rates of organic AMSs

Application rates of poultry litter for organic activities could be determined by various criteria. In this study, an equivalent criterion is used for calculating the application rates of poultry litter. That is, *the amount of inorganic nitrogen and the POTM in poultry litter applied should be equal to the amount of inorganic nitrogen of commercial fertilizer recommended.* This criterion does not consider long term effects of organic fertilizer on soil properties and productivity as well as environmental quality. As a practical criterion, the equivalent criterion is confirmed by Daniels (1991), Reneau (1991), Li (1991), and Ditsch (1991). Therefore, by the equivalent criterion the application rate of poultry litter should be:

$$ARPL = RN / \{TNPL * (INPL + ORPL * MN)\}, \qquad (3.3.1)$$

where:
ARPL is the application rate of poultry litter (ton/ac);
RN is the recommended commercial nitrogen rate (lb/ac);
TNPL is the total nitrogen in poultry litter per ton (lb/ton);
INPL is the percent of inorganic nitrogen in TNPL (%);
ORPL is the percent of organic nitrogen in TNPL (%);
INPL + ORPL = 1; and
MN (%) is the percent of mineralizable nitrogen in the organic nitrogen.

The TNPL, INPL, ORPL, and MN in equation (3.3.1) vary over large ranges. Norris (1988) used experimental data from the Department of Agricultural Engineering, Virginia Polytechnic Institute and State University (1988). In her study, average total nitrogen, P_2O_5, and K_2O of per ton poultry were 58, 40, and 30 pounds, respectively. That is, the total nitrogen, P_2O_5, and K_2O content of poultry litter are 2.9, 2, and 1.5 percent, respectively. Similar results were obtained from a study by Smith and Perteson (1982), indicating that fresh broiler manure contained 2.6 percent total nitrogen. Givens (1987) estimated 40 percent of the total nitrogen in poultry litter is inorganic and 60 percent is organic.

His estimate is used to develop nitrogen application rates of organic fertilizer AMSs in this study. The inorganic portion of nitrogen is approximately equal to a similar quantity commercial nitrogen. Since only mineralized nitrogen is available to plants, an organic nitrogen source needs to be divided into two components: mineralizable and non-mineralizable. The former is the POTM, and the latter is other forms of organic nitrogen. The mineralizable rate, or decay rate, of organic nitrogen in poultry litter varies with many factors including manure store age, handling, and method of application. Nitrogen loss in various storage, treatment and handling regimes can range from 10 to 84 percent. The decay rates of organic nitrogen in poultry litter, with immediate incorporation, were estimated at about 0.5, 0.12, 0.05, 0.02, and 0.02 (Givens, 1987). That is, 50 percent of the *initial* organic nitrogen is mineralized during the first year, 12 percent the second year, 5 percent the third year, 2 percent the fourth year, and 2 percent the fifth year. Thus, a total of 71 percent of organic nitrogen is mineralizable in a five year period. Using Givens' estimation, equation (3.3.1) becomes:

$$\begin{aligned} ARPL &= RN / \{ 58 * (0.4 + 0.6 * 0.71) \} \\ &= 0.021\ RN. \end{aligned} \tag{3.3.2}$$

Equation (3.3.2) was used for calculation of the application rates of poultry litter in this study.

3.3.3.2 Crop yield and nitrogen uptake by the crop

There are two options in CREAMS to calculate nitrogen uptake by a crop (Frere et al, 1980). Option two was used in this study[20]. Option two assumes nitrogen uptake by crop in a growing season follows a normal distribution. Therefore, only three parameters: (1) potential maximum uptake; (2) mean; and (3) standard deviation, of the distribution of nitrogen uptake need to be identified. In this study, these three parameters of nitrogen uptake by corn, wheat, and soybeans were determined using results from previous research. The distribution of nitrogen uptake by corn was developed by Martin et al. (1976); the distribution of nitrogen uptake by winter wheat was developed by Alley et al. (1987); and the distribution of nitrogen uptake by soybeans was developed by Hanway and Weber (1971). These curves of nitrogen uptake are in Appendix A.1. The distributions of nitrogen uptake by rye and rye mixed with crimson clover are not available, an updated wheat distribution was used as the distributions of rye and rye mixed with crimson clover (Ditsch, 1991). Note that since little experimental data from these 14 AMSs in the study area are available, distributions of nitrogen uptake by crops developed from other areas and similar AMSs were used as an approximation. Use of these parameters was confirmed by Ditsch (1991) and Evanylo (1991).

Crop yield is not a direct output of CREAMS. Nitrogen uptake by the crop, however, can be used as an indicator of crop yield (Knisel, 1991; Heatwole, 1991). A formula, which transfers the total nitrogen in biomass to crop yield based on the mass balance approach, is (Shibles et al, 1975;

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[20] Nitrogen uptake option one uses the ratio of actual plant evaporation to potential plant evaporation and cubic coefficients to estimate the nitrogen content in the crop dry matter (Frere, 1980). Little research has used option one due to a lack of data.

Norris, 1988):

$$CY = TNB * HINDEX / \{NB * DENSITY\}, \qquad (3.3.3)$$

where: CY is the crop yield (bu/ac);

TNB is the total nitrogen in biomass (lb/ac);

NB is the percent of nitrogen in biomass;

HINDEX is the harvest index, ratio of the weight of grain to the weight of total biomass; and

DENSITY is the weight of crop grain per unit volume (lb/bu).

The total nitrogen in biomass, TNB, is equal to the total nitrogen uptake by the crop, in the case of non-legume, which is simulated the CREAMS; and it consists of the total nitrogen uptake and nitrogen fixation by crop in the case of a legume, which is estimated in section 3.3.2. Harvest indices of corn, wheat, and soybeans are 56, 60, and 60 pounds per bushel, respectively. The percent of nitrogen in the biomass of corn, wheat, and soybean is 1.35, 1.52, and 2.75, respectively (Shibles et al, 1975; Norris, 1988). Note that the effects of disease on the crop yields is not considered in CREAMS. That is, all disease control practices, including use of chemicals or non-chemical alternatives, of the 14 AMSs are assumed to be effective. Also note that linear equation (3.3.3) is not a precise formula for converting nitrogen uptake by crop to crop yield, but only a approximation.

3.3.3.3 Mineralizable nitrogen in crop residue

Crop residue includes straw and roots of the crop. Nitrogen in the crop residue is equal to the total nitrogen in biomass minus the total nitrogen in grain, That is:

$$\mathrm{TNR} = \mathrm{TNB} - \mathrm{TNG}, \qquad (3.3.4)$$

where: TNR is the total nitrogen in crop residue (lb/ac);
TNG is the total nitrogen in grain (lb/ac); and
TNB is the total nitrogen in biomass (lb/ac).

Since the total nitrogen in the grain is equal to yield times percent of nitrogen in grain, NG, that is, $\mathrm{TNG} = \mathrm{CY} * \mathrm{NG}$, substituting equation (3.3.3) into equation (3.3.4), total nitrogen in crop residue is:

$$\mathrm{TNR} = \mathrm{TNB}\{1 - \mathrm{HINDEX}*\mathrm{NG}/(\mathrm{DENSITY}*\mathrm{NB})\} \qquad (3.3.5)$$

or

$$\mathrm{TNR} = \mathrm{CY}\{(\mathrm{NB}*\mathrm{DENSITY})/\mathrm{HINDEX} - \mathrm{NG}\} \qquad (3.3.6)$$

The percent nitrogen in grain of corn, wheat, and soybean are 1.6, 2.08, and 6.25, respectively (Shibles et al, 1975; Norris, 1988).

The 35 year average of seasonal nitrogen uptake by corn and wheat from preliminary simulation results with soybean yields of 23 bushel per acre were used to estimate the average total nitrogen in the residues of corn, wheat, and soybeans. Precise determination of POTM in crop residues is impossible. Previous research has identified various ranges for crops. The POTM of crop residue is the product of the total nitrogen in crop residue and a mineralizable coefficient. For corn, wheat, and soybeans, the mineralizable coefficient is about 0.2 when the crop residues are plowed in (Bortholomew, 1965; Smith and Peterson, 1982). That is, only 20 percent of the total nitrogen in the crop residue is mineralizable. An average POTM value of 9 pounds per acre is given to corn residue; 3.8 pounds per acre to wheat residue; 22.3 pounds per acre to soybean residue, which includes nitrogen fixation by soybean in this study (Evanylo, 1991).

Many researchers have identified that cover crops, especially legume cover crops, provide a significant amount of nitrogen to subsequent non-leguminous crops. Mcvay et al. (1989) found that crimson clover provided an average of 88 pounds per acre of nitrogen to a following corn crop in two Georga locations. Bruulsema and Christie (1986) observed that red clover plow down supplies the following a corn crop period between 80 to 111 pounds per acre nitrogen in their tracer experiments using ^{15}N in two Ontario locations. Hargrove (1985) conducted a field experiment to estimate the contribution of nitrogen from legume cover crops, including common vetch; crimson clover; and hairy vetch, to a following grain sorghum crop in Georgia. His findings were that an average of 64 pounds per acre of nitrogen was provided by these legume cover crops. Wagger (1989) estimated corn can recover 35.6 to 40 pounds of nitrogen per acre from a preceding crimson clover and hairy vetch crop, which amounted to approximately 30 to 36 percent of the total nitrogen content of these legume cover crops in two North Carolina locations. In this research, when these cover crops are plowed down, an average POTM value of 22.5 pounds per acre is given to rye; and 60 pound per acre to rye mixed with crimson clover when that rate of rye is equal to that of crimson clover. The rye of AMS 8L and 11L contributes no POTM to the soil since the rye is mowed, and is not incorporated in the soil (Meisinger et al. 1991; Hargrove, 1985; Wagger, 1988). The POTM value of the rye mixed with crimson clover includes nitrogen fixation by clover. A detailed list of parameter files of the nutrient component of the model can be found in Appendix A.2.

3.3.4 Results of CREAMS Simulation

Thirty five year (1/1/1951 through 12/30/1985) daily weather data from Richmond County, Virginia were used for CREAMS model simulations. A detailed exhibition of watershed information on the site to be simulated can be found in Davis' (1991) hydrology and erosion parameter files.

A seasonal summary of CREAMS output is developed in this study, which is a summary of simulation output over the period of a crop growing season. Several factors favor the use of a seasonal summary when crop rotations are simulated. First, a seasonal summary of simulation output provides more information on yield of the individual crop, which could be an alternate way to assess the validity of the simulation model since crop yield data are more available than data on environmental quality. County level aggregate yield data are available in most counties in the United States. Furthermore, experimental yield data are available in some areas. Second, since a crop rotation period usually includes several years, changes in simulation outputs in response to a change in a management decision; such as a decision on selection of winter covers; occur cross years. Usually, it is not easy for analysts to intuitively be responsive to these changes based on an annual summary. The seasonal summary of output can give an individual the ability to judge the validity of the impacts of these management changes when an individual is knowledgeable in the field related to the simulation outputs. Errors in modeling, for example errors in determining parameters, may be detected through directly observing changes in a seasonal summary. Third, the seasonal summary can provide information on the validity of water and nutrient balances, which are determined by a number of parameters in the three submodels. Unbalanced water and nutrients could result in a biased simulation. Fourth and finally, seasonal summaries of outputs may better lend itself to summary through regression analysis, which is necessary for the dynamic modeling, as discussed below. Magnitudes of changes in seasonal summaries associated with changes in management practices on individual crops is likely to be more significant than that of annual summaries since changes in simulation results could be masked across years in the latter case. Using a seasonal summary should be viewed as an exploratory way of using CREAMS simulation results and judging the validity of simulation results. A seasonal summary was used in this research.

A typical seasonal summary of outputs of simulations should be based on daily reports of CREAMS simulation. For example, Table 3.2.1 shows that the corn season of activity 1 is from March 25 to September 20. For simplification, seasonal summaries were developed based on monthly reports in this study. That is, the corn season is defined as running from April 1 to September 30; wheat from October 1 to June 30 of the second year; soybeans from July 1 to November 30; and winter cover from December 1 to March 30 of the third year. Therefore, a crop rotation period is defined from April first of the first year to March thirtieth of the third year. Outputs of 17 crop rotation periods from 4/1/1951 to 3/30/1985 that are included in simulation period from 1/1/1951 to 12/30/1985 were used to assess the impacts of the 14 AMSs on nitrate contamination of groundwater and soil erosion. The average of water percolation, runoff, erosion and outputs of the nutrient component of CREAMS for the corn, wheat, soybeans and cover crop seasons associated with 14 AMSs is presented in Table 3.3.1. Soil loss associated with the 14 AMSs ranged from 0.71 to 1.95 tons per acre in corn season, from 0.83 to 1.18 tons per acre in wheat season, from 0.50 to 0.85 tons per acre in soybean season, and from 0.02 to 0.28 tons per acre in cover crop season. Nitrate leaching associated with the 14 AMSs ranged from 5.59 to 22.98 pounds per acre in corn season, from 12.69 to 44.09 pounds per acre in wheat season, from 0.09 to 0.57 pounds per acre in soybean season, and from 0.68 to 6.30 pounds per acre in cover crop season. Simulation results in Table 3.3.1 show that the cover crops reduce the water percolation. In general, the AMSs with cover crops reduce water percolation by 50 percent in the cover crop season in the study area. For example, AMS 15 and 15L have the same tillage as AMS 5, but have cover crops. Water percolation is reduced by AMS 15 and AMS 15L by 47.4 percent in the cover crop season and 17.8 percent in the crop rotation period compared to AMS 5. The detailed reports are contained in Appendix A.3.

Table 3.3.1 The Average of Seasonal Outputs of CREAMS Simulation
(17 Crop Rotation Periods from 1951-1985)

(Corn Season 4/1-9/30)

AMS	RAIN	RO	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
1	23.91	1.32	3.78	1.95	0.56	11.52	35.42	13.65	10.54	4.33	125.23	18.40	6.20
1L	23.91	1.32	3.78	1.95	0.31	11.52	154.59	55.83	28.98	4.33	101.19	19.64	6.04
2	23.91	1.25	3.84	1.41	0.60	9.01	35.27	13.64	32.48	4.33	142.17	20.46	7.14
2L	23.91	1.25	3.84	1.41	0.34	9.01	190.59	65.90	40.32	4.33	117.90	22.98	7.12
3	23.91	1.25	3.84	1.54	0.30	9.40	35.27	13.64	9.90	4.33	100.13	16.58	5.16
3L	23.91	1.25	3.84	1.54	0.28	9.40	137.76	48.33	26.77	4.33	86.05	14.89	4.51
4	23.91	1.32	3.78	1.95	0.56	11.52	35.30	13.65	10.54	4.33	125.23	18.40	6.20
5L	23.91	1.32	3.68	1.61	0.31	9.84	140.22	50.39	27.24	4.33	97.28	18.40	5.72
8	23.91	0.98	2.44	0.80	0.26	5.20	34.46	13.51	15.42	4.33	130.39	5.59	2.19
8L	23.91	0.98	2.44	0.80	0.22	5.20	141.20	52.67	19.08	4.33	102.65	8.68	2.99
11L	23.91	1.02	2.31	0.93	0.23	6.08	143.78	53.49	19.17	4.33	106.14	9.16	2.96
15	23.91	1.00	2.43	0.75	0.28	4.94	95.44	40.57	24.43	4.33	142.98	8.99	3.59
15L	23.91	1.00	2.43	0.75	0.23	4.94	204.10	80.74	22.54	4.33	124.85	12.78	4.47
16L	23.91	1.04	2.30	0.71	0.25	4.86	205.09	80.45	22.83	4.33	125.01	12.10	4.34

(Wheat Season 10/1-6/30)

AMS	RAIN	RO	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
1	31.77	1.20	6.76	1.18	0.31	7.94	30.35	9.90	2.93	5.75	78.53	14.43	2.47
1L	31.77	1.20	6.76	1.18	0.28	7.94	121.07	43.12	10.22	5.75	49.70	31.87	5.43
2	31.77	1.13	6.82	1.03	0.31	7.07	30.27	9.89	4.62	5.75	90.87	35.20	5.97
2L	31.77	1.13	6.82	1.03	0.28	7.07	148.99	53.41	12.68	5.75	63.83	44.09	7.47
3	31.77	1.13	6.82	1.11	0.28	7.49	30.27	9.89	2.91	5.75	74.74	13.66	2.35
3L	31.77	1.13	6.82	1.11	0.26	7.49	108.57	38.59	9.15	5.75	45.87	29.59	4.99
4	31.77	1.20	6.76	1.18	0.33	7.94	30.31	9.88	6.30	5.75	76.89	12.69	2.16
5L	31.77	1.19	6.57	1.17	0.28	7.89	108.59	38.93	9.28	5.75	47.34	28.88	4.99
8	31.77	0.93	7.02	0.83	0.23	5.74	32.38	10.66	3.10	5.75	81.36	19.56	3.18
8L	31.77	0.93	7.02	0.83	0.21	5.74	130.20	45.95	11.06	5.75	49.67	30.85	5.11
11L	31.77	0.98	6.77	0.88	0.22	6.10	127.97	45.63	10.85	5.75	49.81	30.69	5.11
15	31.77	0.95	6.99	0.86	0.25	5.94	76.95	27.08	7.26	5.75	92.37	28.47	4.62
15L	31.77	0.95	6.99	0.86	0.22	5.94	171.94	61.97	14.76	5.75	58.34	36.93	6.06
16L	31.77	1.00	6.75	0.93	0.23	6.24	172.82	62.08	14.82	5.75	59.34	36.30	6.03

Notation:
AMS --- Agricultural management system
RAIN --- Rainfall (in)
RO --- Runoff (in)
PERC. --- Water percolation (in)
SL --- Soil loss (tons/ac)
RON --- Nitrogen in runoff (lb/ac)
SEDN --- Nitrogen with sediment (lb/ac)
MIN. --- Mineralized nitrogen (lb/ac)
NO3 --- Soil nitrate (lb/ac)
POTM --- Potentially mineralizable nitrogen (lb/ac)
UPTAKE --- Nitrogen uptake by crop (lb/ac)
RAINN --- Rainfall nitrate (lb/ac)
LEACH --- Nitrate leached (lb/ac)
DENIT. --- Denitrification (lb/ac)

Table 3.3.1 The Average of Seasonal Outputs of CREAMS Simulation
(17 Crop Rotation Periods from 1951-1985)
(Continued)
(Soybean Season 7/1-11/30)

AMS	RAIN	RO	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
1	18.25	0.97	0.87	0.85	0.19	6.04	45.35	7.27	1.67	3.31	11.68	0.09	0.03
1L	18.25	0.97	0.87	0.85	0.19	6.04	115.22	28.12	4.56	3.31	36.92	0.30	0.21
2	18.25	0.92	0.90	0.61	0.18	4.65	45.28	7.27	1.67	3.31	13.46	0.09	0.03
2L	18.25	0.92	0.90	0.61	0.19	4.65	136.67	34.59	5.60	3.31	44.77	0.40	0.29
3	18.25	0.92	0.90	0.82	0.18	5.85	45.28	7.27	1.67	3.31	11.66	0.09	0.03
3L	18.25	0.92	0.90	0.82	0.18	5.85	105.55	25.28	4.14	3.31	33.44	0.27	0.18
4	18.25	0.97	0.87	0.85	0.19	6.04	45.31	7.26	1.68	3.31	15.24	0.11	0.07
5L	18.25	0.97	0.87	0.83	0.19	5.86	102.50	25.19	4.03	3.31	33.53	0.28	0.20
8	18.25	0.74	0.96	0.53	0.14	3.98	46.92	7.73	1.71	3.31	12.32	0.09	0.03
8L	18.25	0.74	0.96	0.53	0.15	3.98	120.83	30.32	4.78	3.31	39.73	0.36	0.23
11L	18.25	0.79	0.93	0.55	0.16	4.16	120.46	29.78	4.74	3.31	39.01	0.35	0.23
15	18.25	0.76	0.95	0.54	0.15	4.04	81.12	18.10	3.08	3.31	25.55	0.20	0.11
15L	18.25	0.76	0.95	0.54	0.15	4.04	154.17	40.03	6.49	3.31	51.25	0.57	0.39
16L	18.25	0.81	0.92	0.50	0.16	3.82	154.91	40.18	6.52	3.31	51.44	0.56	0.40

(Cover Crop Season 12/1-3/30)

AMS	RAIN	RO	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
1	11.72	0.26	4.39	0.28	0.06	2.01	41.15	4.19	31.43	2.12	0.00	2.80	0.54
1L	11.72	0.26	4.39	0.28	0.06	2.01	165.32	11.09	68.05	2.12	0.00	6.13	1.19
2	11.72	0.25	4.41	0.19	0.06	1.63	41.09	4.19	12.10	2.12	0.00	2.40	0.45
2L	11.72	0.25	4.41	0.19	0.07	1.63	194.35	13.15	39.30	2.12	0.00	6.30	1.20
3	11.72	0.25	4.41	0.23	0.05	1.86	41.09	4.19	30.91	2.12	0.00	2.80	0.54
3L	11.72	0.25	4.41	0.23	0.05	1.86	142.81	10.10	53.45	2.12	0.00	5.51	1.06
4	11.72	0.26	4.39	0.28	0.06	2.01	41.13	4.19	31.44	2.12	0.00	2.80	0.54
5L	11.72	0.26	4.18	0.21	0.06	1.98	149.97	9.90	67.14	2.12	0.00	5.41	1.07
8	11.72	0.14	2.20	0.02	0.03	0.23	42.92	4.00	0.33	2.12	6.73	0.68	0.10
8L	11.72	0.14	2.20	0.02	0.03	0.23	110.55	10.28	0.58	2.12	14.80	1.65	0.24
11L	11.72	0.16	2.08	0.02	0.03	0.24	110.27	10.19	0.00	2.12	15.49	1.45	0.20
15	11.72	0.15	2.20	0.02	0.03	0.24	74.22	6.90	0.00	2.12	10.84	1.14	0.16
15L	11.72	0.15	2.20	0.02	0.03	0.24	141.07	13.11	0.00	2.12	19.28	2.25	0.31
16L	11.72	0.16	2.07	0.02	0.03	0.24	141.81	13.10	0.00	2.12	19.46	2.11	0.29

Notation:
AMS --- Agricultural management system
RAIN --- Rainfall (in)
RO --- Runoff (in)
PERC. --- Water percolation (in)
SL --- Soil loss (tons/ac)
RON --- Nitrogen in runoff (lb/ac)
SEDN --- Nitrogen with sediment (lb/ac)
MIN. --- Mineralized nitrogen (lb/ac)
NO3 --- Soil nitrate (lb/ac)
POTM --- Potentially mineralizable nitrogen (lb/ac)
UPTAKE --- Nitrogen uptake by crop (lb/ac)
RAINN --- Rainfall nitrate (lb/ac)
LEACH --- Nitrate leached (lb/ac)
DENIT. --- Denitrification (lb/ac)

3.3.5 Regression results of Nitrate Leaching, Nitrogen uptake, and POTM Transition

In this study, the impacts of various AMSs on nitrate leaching, soil loss, and nitrogen uptake by crops are simulated individually in 17 crop rotation periods. These simulation outputs, thus, result from the employment of a particular AMS over the planning period, and they do not provide information on mixed employment of different AMSs over the planning period. For example, the inorganic AMSs usually have lower POTM in the soil. A continuous simulation does not provide the information on what could happen if a mixed employment of organic and inorganic AMSs over planning period takes place. Therefore, these simulation results have limits when they are directly coupled to dynamic programming models. A dynamic programming model compares all possible returns from various combinations of feasible AMSs to develops a optimal decision path over the planning horizon, which can include various mixtures of AMSs. Regression analysis was employed to extend these simulation results to a dynamic framework. It should be noted that although field experiments can be designed to capture the effects of various mixtures of AMSs, field experiments are costly and time consuming.

Ordinary least-squares estimation was used for the regression analysis. Regressions are based on individual AMSs. There was no effort to develop the general regression equations of nitrate leaching, nitrogen uptake, and POTM transition for all AMSs. Large variations in the mean values of nitrate leaching and nitrogen uptake by crops associated with the 14 AMSs could bias the regression results if general regression equations were developed. Data from 1951 to 1985, which consists of 17 crop rotation periods and includes 68 seasonal summaries of simulation outputs, were used for the regression. Since the nitrate leaching, nitrogen uptake, and POTM were simulated by CREAMS, determination of regressors was based on the simulation formula of CREAMS. Slight changes in these regressors made regression results more significant and interpretation of these regression equations easier.

3.3.5.1 Nitrate leaching

Estimation of nitrate leaching is necessary to predict the impacts of agricultural management systems on nitrate contamination of groundwater in the dynamic model. CREAMS estimates nitrate leaching by simulating water percolation and nitrates in the root zone. The amount of nitrates leached out of the root zone is the water percolated[21] times the nitrate content in the root zone. Nitrate content of the soil varies over large range due to random weather, and management practices. Since the regression analysis is based on individual AMS, fertilizer application rate for crops are constants. That is, a constant amount of fertilizer for a particular crop is repeated in each crop rotation period. Therefore, to a great degree, the variation in nitrate content of the soil depends on the POTM existing in the soil and random weather. The POTM was used as a regressor. In the multi-objective dynamic model discussed below, POTM is used as a state variable and the water percolated is used

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[21] The water percolated is a fraction of the water in root zone that percolates out of the root zone between storms. It is calculated by the hydrology submodel of CREAMS.

as a random variable. Regression of nitrate leaching on POTM and water percolation make the objective of groundwater protection a function of a state variable and a random variable. The general form of nitrate leaching regression equation is:

$$L^i_t = a^i_0 + a^i_1 P^i_t + a^i_2 PM^i_{t-1} + a^i_3 C_1 + a^i_4 C_2 + a^i_5 C_3 + a^i_6 C_4 \qquad (3.3.7)$$

Where: superscript i represents the i^{th} activity, $i = 1 \ldots 14$;

L^i_t is the accumulated nitrate leaching of the i^{th} AMS in stage t;

P^i_t is the accumulated water percolation of the i^{th} AMS in stage t;

PM^i_{t-1} is the POTM at the beginning of stage t;

C_j is the dummy variable, $j = 1 \ldots 4$; and

$a^i_0 \ldots a^i_6$ are the estimated coefficients.

The accumulated nitrate leaching varies with crop seasons in a crop rotation period. Use of dummy variables considers these seasonal changes. C_1 to C_4 represents the corn, wheat, soybean, and cover crop seasons, respectively. At most, three dummy variables were coupled to a regression equation. The base dummy variables vary with the AMSs. Dummy variables were used for nitrogen uptake and POTM regression equations below for the same reason. Regression results indicate that the accumulated nitrate leaching in a period is positively related to the POTM at the beginning of that period and the accumulated water percolated out of the root zone in that period. Regression results of nitrate leaching of the 14 AMSs are given in Table 3.3.2.

Table 3.3.2 Regression Results of the Nitrate Leaching

					Regressor				R-Squared
AMS		Constant	PER(t)	POTM(t)	C1	C2	C3	C4	
1	NL(t)	-31.147	0.751	0.9	-19.856				0.738
		(6.105)	(0.082)	(0.155)	(2.383)				
1L	NL(t)	-18.529	1.366	0.15				-9.196	0.807
		(6.849)	(0.109)	(0.043)				(2.656)	
2	NL(t)	-25.474	1.346	0.709		13.578		-22.977	0.847
		(8.532)	(0.131)	(0.216)		(2.877)		(3.336)	
2L	NL(t)	-23.631	1.843	0.154				-13.63	0.806
		(9.815)	(0.148)	(0.148)				(3.793)	
3	NL(t)	-27.09	0.643	0.802				-17.726	0.725
		(5.523)	(0.074)	(0.141)				(2.161)	
3L	NL(t)	-14.145	1.259	0.127				-8.914	0.789
		(6.931)	(0.103)	(0.049)				(2.453)	
4	NL(t)	-33.582	0.664	0.966				-19.928	0.713
		(6.123)	(0.083)	(0.156)				(2.393)	
5L	NL(t)	-8.016	1.345	0.088				-10.336	0.790
		(3.551)	(0.010)	(0.022)				(2.184)	
8	NL(t)	21.191	0.953	0.449			-7.065		0.671
		(8.216)	(0.116)	(0.164)			(3.099)		
8L	NL(t)	-14.676	1.363	0.119			-5.68		0.791
		(5.646)	(0.109)	(0.041)			(2.385)		
11L	NL(t)	-18.719	1.489	0.126	4.669				0.781
		(8.020)	(0.113)	(0.057)	(2.624)				
15	NL(t)	-28.476	1.478	0.284	5.815				0.750
		(10.82)	(0.134)	(0.118)	(2.960)				
15L	NL(t)	-30.062	1.746	0.151	9.908				0.815
		(8.389)	(0.130)	(0.044)	(3.123)				
16L	NL(t)	-28.972	1.792	0.144	9.261				0.816
		(8.251)	(0.132)	(0.043)	(3.071)				

Note:
(1) NL(t) is the nitrate leaching in stage t.
(2) POTM(t) is potentially mineralizable nitrogen in the soil at the beginning of stage t.
(3) C1 to C4 are dummy variables for corn, wheat, soybean, and cover crop season, respectively.
(4) OLS is used for regression.
(5) Numbers in parenthesis are standard deviations.

3.3.5.2 Nitrogen uptake

Option two for nitrogen uptake in CREAMS assumes nitrogen uptake by the crop follows a normal distribution. Therefore, once the maximum uptake, mean value, and standard deviation are selected, the uptake curve is determined. CREAMS uses an additional parameter to account for reduction of nitrogen uptake due to random weather (Smith et al., 1980). The general form of the nitrogen uptake regression equation is:

$$U^i_t = b^i_0 - b^i_1 P^i_t + b^i_2 PM^i_{t-1} + b^i_3 C_1 + b^i_4 C_2 + b^i_5 C_3 + b^i_6 C_4 \qquad (3.3.8)$$

where: superscript i represents the i^{th} AMS, $i = 1 \ldots 14$;

U^i_t is the accumulated nitrogen uptake of the i^{th} AMS in stage t;

P^i_t is the accumulated water percolation of the i^{th} AMS in stage t;

PM^i_{t-1} is the POTM at the beginning of stage t;

C_j is the dummy variable, $j = 1 \ldots 4$; and

$b^i_0 \ldots b^i_6$ are the estimated coefficients.

Regression results given in Table 3.3.3 indicate the accumulated nitrogen uptake by a crop is positively related to the POTM at the beginning of stage t and negatively related to the accumulated water percolated in stage t. The negative effect of water percolation on nitrogen uptake by crop indicates that nitrate losses caused by water percolation may play a dominant role in nitrogen uptake through their influence on nitrate available to crop. Nitrogen uptake by the crop is assumed to be equal to the total nitrogen in biomass. Crop yields are calculated by equation (3.3.3) in the dynamic analysis where the total

Table 3.3.3 Regression Results of Nitrogen Uptake

AMS		Constant	PER(t)	POTM(t)	C1	C2	C3	C4	R-Squared
1	NU(t)	-35.710	-0.817	3.470			-76.790	-145.500	0.95
		(23.26)	(0.215)	(0.518)			(6.965)	(5.697)	
1L	NU(t)	91.869	-0.747	0.155		-50.15	-69.85	-103.6	0.967
		(12.6)	(0.128)	(0.067)		(2.995)	(4.386)	(4.649)	
2	NU(t)	-32.22	-1.161	4.163			-91.51	-166.3	0.953
		(25.78)	(0.236)	(0.575)			(7.728)	(6.321)	
2L	NU(t)	111.4	-1.034	0.143		-52.39	-82.67	-121.7	0.962
		(14.96)	(0.161)	(0.067)		(3.654)	(5.002)	(5.566)	
3	NU(t)	19.969	-0.619	2.012			-73.84	-115.3	0.973
		(13.91)	(0.127)	(0.310)			(4.169)	(3.410)	
3L	NU(t)	76.589	-0.647	0.162		-38.92	-57.29	-88.52	0.964
		(11.14)	(0.113)	(0.068)		(2.598)	(3.675)	(3.785)	
4	NU(t)	-49.3	-0.596	3.968			-67.28	-145.9	0.932
		(26.67)	(0.246)	(0.595)			(7.995)	(6.530)	
5L	NU(t)	83.97	-0.747	0.191		-48.41	-67.96	-98.01	0.966
		(5.288)	(0.134)	(0.027)		(2.900)	(3.230)	(3.078)	
8	NU(t)	35.096	-0.81	2.119			-96.33	-134.6	0.918
		(19.68)	(0.253)	(0.424)			(6.735)	(6.411)	
8L	NU(t)	100.1	-0.857	0.151		-53.05	-75.52	-99.22	0.902
		(9.596)	(0.197)	(0.072)		(5.443)	(4.607)	(4.352)	
11L	NU(t)	110.9	-0.807	0.094		-56.31	-78.74	-102	0.966
		(7.265)	(0.120)	(0.057)		(3.481)	(2.817)	(2.612)	
15	NU(t)	122.36	-0.277	0.474		-64.55	-133.9	-151.8	0.951
		(19.33)	(0.227)	(0.227)		(7.668)	(5.042)	(5.208)	
15L	NU(t)	118.77	-0.815	0.161		-75.71	-90.36	-120.4	0.946
		(10.80)	(0.173)	(0.066)		(6.154)	(4.499)	(3.855)	
16L	NU(t)	117.62	-0.812	0.167		-75.64	-90.46	-120.6	0.946
		(10.80)	(0.178)	(0.065)		(6.174)	(4.447)	(3.861)	

Note:

(1) NU(t) is the nitrogen uptake in stage t.

(2) POTM(t) is potentially mineralizable nitrogen in the soil at the beginning of the stage t.

(3) C1 to C4 are dummy variables for corn, wheat, soybean, and cover crop season, respectively.

(4) OLS is used for regression.

(5) Numbers in parenthesis are standard deviations.

nitrogen in biomass in that equation is the nitrogen uptake predicted by these regression equations. Crop yield, thus, is a function of the POTM and water percolation. Note that since the regression equation of nitrogen uptake is based on an individual AMS, impacts of fertilizer practices of the AMSs on crop yield need to be compared through equations associated with these AMSs.

3.3.5.3 Transition of the POTM

As mentioned above, CREAMS treats the total volume of POTM in the soil as a pool. In this study, crop residues or poultry litter are the main sources of inputs to the pool, and the accumulated amount of mineralized nitrogen in a certain period is the output of the pool. The mineralized nitrogen in period t is affected by many factors including the POTM volume at the beginning of period t, average temperature, average water content during the period t (Frere et al., 1980). The general form of the POTM change regression equation is:

$$PM^i_t = c^i_0 - c^i_1 P^i_t + c^i_2 PM^i_{t-1} + c^i_3 C_1 + c^i_4 C_2 + c^i_5 C_3 + c^i_6 C_4 \tag{3.3.9}$$

Where: superscript i represents i^{th} AMS, $i = 1 \ldots 14$;

PM^i_t is the POTM at the *end* of stage t;

P^i_t is the accumulated water percolation of the i^{th} AMS in stage t;

PM^i_{t-1} is the POTM at the *beginning* of stage t;

C_j is the dummy variable, $j = 1 \ldots 4$; and

$c^i_0 \ldots c^i_6$ are the estimated coefficients.

Regression results given in Table 3.3.4 indicate that POTM at the beginning of period t has a positive effect on POTM at end of stage t, and water percolation has a negative effect. Higher water percolation may indicate higher water content in stage t, which could cause more POTM to be mineralized in stage t. Regression equations of POTM are the state transition equations in the multi-objective dynamic programming model.

3.4 A Multi-objective Dynamic Model for Evaluation of the 14 AMSs

3.4.1 General Description of Modeling

The objectives of modeling in this research were discussed in section 3.1. Model system that is developed for the problem on hand includes two main parts: an economic analysis model; and a physical simulation model. The former is a multi-objective dynamic programming model (MODP), while the later is the CREAMS simulation model discussed above. Figure 3.4.1 presents a flowchart of this model system. The arrows indicate the flow of input or output among various blocks of this model system. An RG near arrows indicates that regression analysis was employed to transform the output of the simulation into the input of the MODP model. Information on the AMSs from related disciplines, government policies, and market conditions are the decision environment. Historical weather data, including temperature; radiation; and precipitation constitute part of the inputs of the simulation model.

For analysis, the 14 existing or potentially employable AMSs listed in Table 3.2.1 are assumed to all be feasible AMSs in Richmond County. The 14 AMSs were simulated separately and continuously through 17 crop

Table 3.3.4 Regression Results of POTM Transition

					Regressor				
AMS		Constant	PER(t)	POTM(t)	C1	C2	C3	C4	R-Squared
1	POTM(t+1)	19.187	-0.094	0.463		-1.900	16.145	0.853	0.922
		(4.959)	(0.032)	(0.106)		(1.008)	(1.499)	(0.853)	
1L	POTM(t+1)	100.05	-0.262	0.227	35.137			59.114	0.763
		(14.56)	(0.209)	(0.097)	(5.243)			(4.964)	
2	POTM(t+1)	18.958	-0.092	0.467		-1.876	16.203	4.453	0.923
		(4.941)	(0.032)	(0.106)		(1.006)	(1.496)	(0.851)	
2L	POTM(t+1)	112.18	-0.239	0.265	47.457			68.041	0.731
		(18.31)	(0.264)	(0.099)	(6.148)			(6.638)	
3	POTM(t+1)	18.958	-0.092	0.467		-1.876	16.204	4.453	0.923
		(4.941)	(0.032)	(0.106)		(1.006)	(1.496)	(0.851)	
3L	POTM(t+1)	93.993	-0.277	0.209	30.634			44.662	0.722
		(7.226)	(0.180)	(0.097)	(4.236)			(4.213)	
4	POTM(t+1)	19.126	-0.093	0.464		-1.899	16.17	4.483	0.923
		(4.954)	(0.032)	(0.106)		(1.007)	(1.499)	(0.851)	
5L	POTM(t+1)	20.683	-0.783	0.753	19.041			69.326	0.752
		(10.84)	(0.301)	(0.071)	(7.010)			(6.834)	
8	POTM(t+1)	14.335	-0.141	0.648	-6.468		15.134		0.834
		(3.428)	(0.049)	(0.068)	(1.028)		(1.355)		
8L	POTM(t+1)	145.912	-0.662	0.108			-24.464	-32.784	0.309
		(15.72)	(0.307)	(0.110)			(7.068)	(6.649)	
11L	POTM(t+1)	87.45	-0.128	0.326	36.444				0.435
		(16.39)	(0.225)	(0.114)	(5.244)				
15	POTM(t+1)	59.652	-0.307	0.618		-34	-21.218	-30.883	0.904
		(5.229)	(0.061)	(0.062)		(2.074)	(1.364)	(1.409)	
15L	POTM(t+1)	182.39	-0.608	0.349		-58.526	-75.205	-81.037	0.779
		(16.44)	(0.263)	(0.101)		(9.366)	(6.772)	(5.867)	
16L	POTM(t+1)	182.28	-0.644	0.356		-58.968	-75.733	-81.418	0.781
		(16.44)	(0.270)	(0.100)		(9.379)	(5.755)	(5.865)	

Note:

(1) POTM(t) and POTM(t+1) are the mineralizable nitrogen in the soil at the beginning and end of the stage t.

(2) C1 to C4 are dummy variables for corn, wheat, soybean, and cover crop seasons, respectively.

(3) OLS is used for regression.

(4) Numbers in parenthesis are standard deviations.

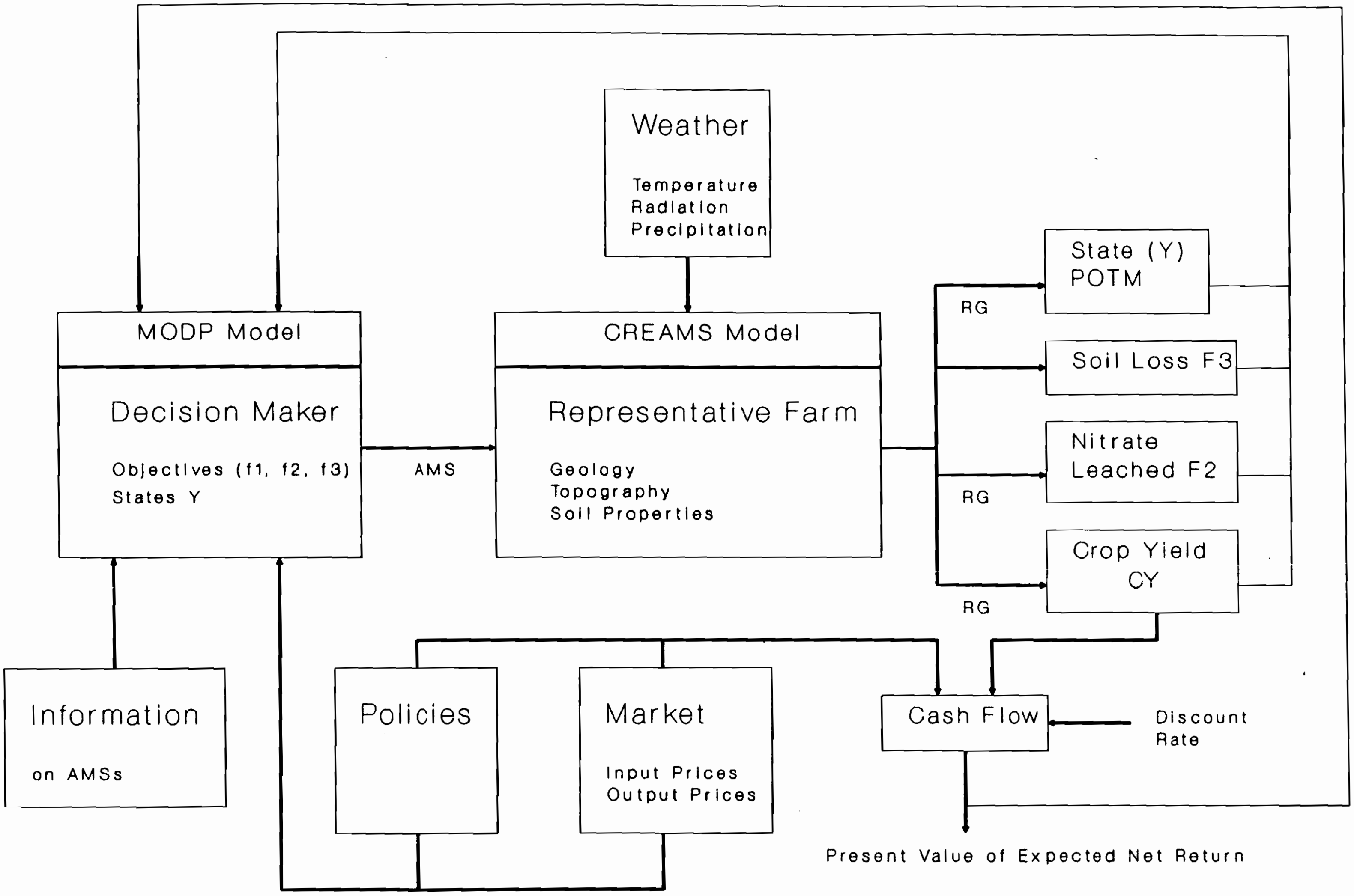

Figure 3.4.1 Flowchart for System of Models

rotation periods (1951-1985). The outputs of simulations, including the POTM; nitrate leaching; and nitrogen uptake by crop associated with the 14 AMSs were first used for regression analysis, and then coupled to the MODP as inputs. Given the: objectives; feasible AMSs; and possible economic and environmental impacts of these AMSs, the MODP model developed a non-inferior solution family under various decision environments. The non-inferior solution family depicts the trade-offs between the present value of the expected net revenue, soil conservation, and groundwater protection from nitrate contamination. A change in decision environment could lead to a change in the trade-offs. These trade-offs, thus, provide decision makers and policy analysts with comprehensive information on the effects of policies on the farm economy and the environment as measured by soil loss and nitrate leaching. This information provides quantitative trade-off data to permit the subjective choice of the *best* decision, which is the second step of the SWT method as described in section 3.1. The second step of the SWT method will not be covered in this research.

3.4.2 The General MODP Model

The general MODP model for trade-off analysis developed in this research is a three objective dynamic model. It is an extension and combination of Haimes et al.'s (1975) dynamic model and Haimes et al.'s (1980) statistical model. The basic model may be represented as:

Maximize $f^1(\underline{Y}_t)$ (3.4.1)

Subject to: $f_t^2(\underline{Y}_t) \leq E_2(t)$, (3.4.2)

$f_t^3(\underline{X}, w_t) \leq E_3(t)$, (3.4.3)

$\underline{Y}_{t+1} = h(\underline{X}_t, \underline{Y}_t, w_t)$, and (3.4.4)

$\underline{X} \geq 0$. (3.4.5)

Where:

$$f_t^1(\underline{Y}_t) = \underset{\underline{X}}{MAX} \sum_{w_t=1}^{W} P(w_t)\,[F_t^1(\underline{X}_t, \underline{Y}_t, w_t) + \alpha^{t-1} f_{t+1}^1(\underline{Y}_{t+1})]\,; \qquad (3.4.6)$$

$f_t^1(\underline{Y}_t)$ is the present value of expected net revenue per acre from stage t to stage T (\$/ac);

$F_t^1(\underline{X}_t, \underline{Y}_t, w_t)$ is the net return per acre from stage t (\$/ac);

$f^1_{t+1}(\underline{Y}_{t+1})$ is the net return per acre from stage t+1 to stage T (\$/ac);

t is the stage, a crop rotation period, which include two crop years, $t = 1, 2, \ldots, T$;

T is the total number of stages;

α is the discount factor;

$\underline{X}_t$ represents the 14 feasible AMSs, a decision variable vector (V x 1);

$w_t = 1, \ldots, W$ is the water percolation associated with the 14 AMSs, and is a random variable;

$P(w_t)$ is the probability matrix of water percolation associated with the 14 AMSs (V x W); and

$\underline{Y}_t$ is the potentially mineralizable nitrogen in the root zone at the beginning of stage t, a state variable, (lb/ac).

Where:

$$f_t^2(\underline{Y}_t) = \sum_{w_t=1}^{W} P(w_t)\,[F_t^2(\underline{X}_t, \underline{Y}_t, w_t) + f_{t+1}^2(\underline{Y}_{t+1})]\,; \qquad (3.4.7)$$

$f_t^2(\underline{Y}_t)$ is the expected nitrate leaching per acre from stage t to stage T (lb/ac);

$f^2_{t+1}(\underline{Y}_{t+1})$ is the nitrate leaching per acre from stage t+1 to stage T (lb/ac);

$F_t^2(\underline{X}_t, \underline{Y}_t, w_t)$ is the nitrate leaching per acre at stage t (lb/ac);

$\underline{Y}_{t+1}(s) = h(\underline{X}_t, \underline{Y}_t, w_t)$ is the state transition equation;

$\underline{Y} = (\ \underline{Y}_t\ ),\quad \underline{Y}_t = \{\ Y_t(s)\ \},\quad s = 1, \ldots, S;$

$Y_t(s)$ is the possible states at time t; and

$E_2(t)$ is the allowed nitrate leaching per acre from stage t to stage T (lb/ac).

Where:

$$f_t^3(X, w_t) = \underset{\underline{X}}{MIN}\ [\sum_{j=t}^{T} \sum_{w_j=1}^{W} P(w_j)\, F_j^3(\underline{X}_j, w_j)]\,; \qquad (3.4.8)$$

$f_t^3(\underline{X}, w_t)$ is the expected soil loss per acre from stage t to stage T (ton/ac);

$F_j^3(\underline{X},w_j)$ is the possible soil loss per acre at stage t (tons/ac);

$$F_j^3(\underline{X},w_j) = C_4(\underline{X}_j,w_j)\underline{X}; \qquad (3.4.9)$$

$C_4(\underline{X},w_j)$ is the probability matrix (W x V) of soil loss associated with the 14 AMSs; and

$E_3(t)$ is the allowed soil loss per acre from stage t to stage T (ton/ac).

The objectives, state variables, decision variables, and random variables of this general MODP model will be discussed in the following four sections.

3.4.3 Objectives of the MODP Model

The model has three objectives: maximizing the present value of the expected net returns; protection of groundwater from nitrate contamination; and soil conservation. The three objectives in this model are non-commensurable. Commensurable generally means equal in measure or extent. It is commonly thought that measurements with the same units are commensurable. In multi-objective modeling, however, interpretation of objectives in the model plays a crucial role in determining whether or not measurements are commensurable. Thus, objectives may be non-commensurable even though they have the same units. For example, consider the two objectives of minimizing nitrate contamination in surface and ground water. The levels of contamination in ground and surface water are measured in the same units so they are commensurable from this perspective, and the trade-off rate should be minus one based on Haimes et al. (1975). But they are not commensurable in terms of their environmental and social impacts. No matter whether these two objectives are in conflict or not, the trade-off rate between these two objectives is not necessary equal to minus one because the value of decreasing or increasing one unit of nitrate contamination in surface water may not be the same as that in groundwater. Decision makers may favor one objective over the another for many reasons. Furthermore, in terms of environmental impacts, nitrate contamination in surface water and in groundwater could have different impacts in different physical locations. The value that people in different locations place on these two objectives are likely to be different.

3.4.3.1 The first objective: maximizing the present value of the expected net return

In this research, net return was defined as the net return to land, management, and capital. The present value of the expected net return per acre from agricultural production in the planning period (PVENR) represents an economic criterion. A discount rate of 6 percent was used. A planning period of 10 years (5 crop rotation periods) was assumed[22]. Using the ε-constraint approach, the PVENR was selected as the reference objective and the second and third objectives are constraints. In the model, farmers maximize the PVENR with the constraints on nitrate contamination, $E_2(t)$, and soil loss, $E_3(t)$. The decrease in the PVENR from

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[22] Sensitivity analysis will be performed on discount rate and planning period in chapter 4.

more restrictive combinations of $E_2(t)$ and $E_3(t)$ represents the costs to farmers for improvements in environment quality. Equation 3.4.6 and equation 3.4.7 are the typical recursive equations, also called Bellman's functional equation, of stochastic dynamic programming. The first term of the right hand side of equation 3.4.6, $P(w_t)F_t^1(\underline{X}_t,\underline{Y}_t,w_t)$, is the expected net return in stage t. The second term of the right hand side, $P(w_t)\alpha^{t-1}f^1_{t+1}(\underline{Y}_{t+1})$, is the discounted net return from stage t+1 to T. The right hand side of equation (3.4.6) demonstrates the Bellman principle of optimality. That is, if a sequence of decisions ($\underline{x}_t$, $\underline{x}_{t+1}$, ... ,$\underline{x}_T$) is optimal from stage t to stage T, then the subsequent sequence ($\underline{x}_{t+1}$, ... ,$\underline{x}_T$) must be optimal from stage t+1 to stage T (Bellman, 1957).

The net return is equal to the gross income minus the total variable costs, without consideration of government policies. The gross income of cropping is equal to the crop yield times crop price. That is,

$$NR_i = CY_i * P_i^c - TVC_i \quad , \tag{3.4.10}$$

where:
NR_i is the net return from the i^{th} crop (\$/ac);
CY_i is the yield of the i^{th} crop (bu/ac);
P_i^c is the price of the i^{th} crop (\$/bu); and
TVC_i is the total variable cost of the i^{th} crop (\$/ac).

The net return NR in a crop rotation period is a sum of the net return of individual cropping in the rotation. That is,

$$NR = \sum_{i} [CY_i * p_i^c - TC_i] . \qquad (3.4.11)$$

Therefore, the net return is determined by the crop yields, crop prices, and the total variable cost of the AMS. These factors are discussed below.

3.4.3.1.1 The crop yields

Crop yields of the AMSs are different. Nutrients, especially nitrogen in the study area, available to the crop plays a crucial role in affecting crop yields. Baethgen and Alley's (1989) experiments showed that the wheat yields were strongly influenced by nitrogen available to the crop in the soil in the coastal plain of Virginia. The nitrogen available to the crop is influenced by not only the nitrogen application rate but also by many other factors, such as the POTM in the soil; timing and method of nitrogen application; tillage; and the method of incorporating crop residues and manures, which change the magnitudes and kinetics of the immobilization, nitrification, denitrification, and volatilization in the soil. Corn and wheat yield of a particular AMS varies mostly with the random weather. Crop yields of the 14 AMSs were simulated using the nitrogen uptake from CREAMS in equation (3.3.8). Therefor yield is a function of decision variables, state variables and random variables. That is, $CY_i = CY_i(\underline{X}_t, \underline{Y}_t, w_t)$.

3.4.3.1.2 The prices of inputs and outputs

It is recognized that prices are stochastic in a market economy. The random change of price can be roughly classified into three categories: time independent, time dependent, and other factors dependent.

A time independent change of price means price at time t+1, p_{t+1}, is considered "totally" independent of prices at time t, p_t, and/or prices before time t. A time dependent change in price means price at time t+1, p_{t+1}, is considered partly dependent on prices at time t, p_t, and/or prices before time t. Other factors dependent changes of price means a commodity price is correlated with other non-own-price variables or other commodity prices in either a time dependent or time independent fashion. As an example, corn price in the corn belt may be significantly related to corn yield or corn price may be significantly related to wheat price over a period of years in some areas. Three price patterns, which have been used in stochastic dynamic programming, are: (1) an average of adjusted price, (2) a pre-determined sequence of prices, and (3) a randomly generated price. When the evidence of a time dependent change in price does not exist and other factors related to the price change are not coupled to the stochastic dynamic programming model being analyzed as decision variables; state variables; or random variables, the average of adjusted price is an effective and appropriate price to use in the stochastic dynamic programming model. Note that the "deterministic" price pattern of the average of adjusted prices does not mean the price would not change in the planning period, rather that the *expected* gross return is a product of the *mean value* of the price and the yield. A more detailed examination of this issue has been completed by Zhu and Taylor (1991), and can be found in Appendix B.1.

There is no evidence that the change of cash prices of corn, wheat, and soybeans in Northern Virginia are time dependent, or related to the crop yields in this area (Kenyon, 1991). Results of a statistical analysis that support this conclusion are contained in Appendix B2. The average of adjusted prices of corn, wheat, and soybeans were used in this research. Nineteen year (1970-1988) cash prices of corn, wheat, and soybeans in the local market of Northern Virginia were adjusted by the USDA index of price received by farmers (Virginia Agricultural Statistics Service, 1990). The average of adjusted prices of corn, wheat, and soybeans (in 1988 dollars) are \$2.52, \$3.03, and \$6.13 per bushel, respectively.

All input prices are assumed constant and are based on 1991 Southeast Virginia crop budgets (Gallimore et al., 1991) except the price of poultry litter. These input prices are listed in Appendix B.3 and B.4.

Napit (1990) estimated that farmers in Richmond County would pay a price of \$27 per ton for poultry litter transferred from the Shenandoah Valley, Virginia. Let the equivalent commercial nitrogen content of one ton poultry litter be ECN and the price of ECN of poultry litter be PECN. According to equation 3.3.2,

$$ECN = 58 * (0.4 + 0.6 * 0.71) = 47.8 \text{ lb/ton, and}$$

$$PECN = 27/47.8 = \$0.57/\text{lb}.$$

The PECN of poultry litter is as about twice as high as the price of commercial nitrogen, which is \$0.28 per pound in Richmond County (Gallimore et al., 1991). But poultry litter has value other than just nitrogen. Accounting for 2 percent phosphorus and 1.5 percent potassium in poultry litter (Givens, 1987), the application rates of phosphorus and potassium are zero in all organic fertilizer AMSs in this research.

Actually, the poultry litter supplies more than the required phosphorus and potassium since the application rate of poultry litter is determined by *the equivalent nitrogen* rate. It also supplies organic matter, improves soil structure etc. the effect of which are not considered in this dissertation.

3.4.3.1.3 The total variable cost

The Southeast Virginia Crop Budget Guides[23] (Gallimore et al., 1991) and Diebel's budgets (1990) were used to estimate the total variable costs of the farm management systems in Richmond County. The variable costs of the AMSs in a crop rotation period are listed in Appendix B.3. For analysis, the total variable cost is classified into nine types, which are the costs of: (1) seeds; (2) lime; (3) pre-harvest machinery; (4) labor; (5) nitrogen; (6) phosphorus; (7) potassium; (8) chemicals; and (9) harvest. The first eight types of costs are assumed to be deterministic. That is, these costs are known before production and do not vary with the crop yields. The harvest cost consists of two parts: base harvest costs and variable harvest costs. The former include repairs; oil; and fuel costs; which are assumed deterministic, and the latter include hauling and drying costs, which vary with the crop yields. Since the cash price of corn in the local market of Northern Virginia is the dried corn price (Kenyon, 1991), a 0.30 dollar per bushel drying cost was added to variable

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[23] Richmond County has been in the Southeast district of Virginia as defined by the Virginia Cooperative Agriculture Extension Service since 1989.

harvest costs of corn. The hauling costs of corn, wheat, and soybeans are \$0.15 per bushel (Covey et al., 1991). The hauling and drying costs of corn, wheat, and soybeans in the Northern Virginia Crop Budget (Covey et al., 1991) were used due to the lack of this information in the Southeast Virginia crop production budgets. The classified variable costs of each AMS are listed in Table 3.4.1 except the variable harvest costs, which are determined by crop yields. Consideration of variable harvest costs leads the total variable cost of a AMS to be a function of decision variables, state variables, and a random variable. That is, $TVC_i = TVC_i(\underline{X}_t, \underline{Y}_t, w_t)$. The total variable costs, which exclude the variable harvest cost, of the 14 AMSs are from \$286.57 to \$429.72 per acre, in which nutrients costs range from 24 to 36 percent; nitrogen costs are from 14 to 36 percent; and labor costs from 4 to 7 percent. The chemical costs of management systems can be found in Appendix B.4 and other details on the variable costs are in Appendix B.3.

3.4.3.2 The second objective: protection of groundwater from nitrate contamination

The amount of nitrate leached in a crop rotation period, which was calculated by equation (3.4.7) in this study, is a function of: the state variable $\underline{Y}_t$, decision variables $\underline{X}_t$, and random variable w_t. Equation (3.4.7) contains the requirements of restricting nitrate leaching from stage t to T. Equation (3.4.6) searches for a expected optimal decision path from a more restrictive feasible decision paths.

Table 3.4.1 Total Variable Costs of AMSs in a Two-Year Crop Rotation Period

AMS	Seed	Lime	PHM	Harvest	-------Labor-----			-----Nitrogen----			-----Phosphorus--			-----Potassium--			Chemical	Total
	Cost	Cost	Cost	B. Cost	Required	Price	Cost	Rate	Price	Cost	Rate	Price	Cost	Rate	Price	Cost	Cost	Var.Cost
	----------($/ac)--------				(h/ac)	($/h)	($/ac)	(lb/ac)	($/lb)	($/ac)	(lb/ac)	($/lb)	($/ac)	(lb/ac)	($/lb)	($/ac)	($/ac)	($/ac)
1	48.00	29.70	56.77	34.63	4.04	4.50	18.18	210.00	0.28	58.80	76.15	0.26	19.80	132.27	0.14	18.52	56.17	340.57
1L	48.00	29.70	55.49	34.63	3.82	4.50	17.19	210.00	0.57	119.70	0.00	0.26	0.00	0.00	0.14	0.00	56.17	360.88
2	48.00	29.70	57.13	34.63	4.02	4.50	18.09	268.00	0.28	75.04	76.15	0.26	19.80	132.27	0.14	18.52	91.68	392.59
2L	48.00	29.70	55.85	34.63	3.80	4.50	17.10	268.00	0.57	152.76	0.00	0.26	0.00	0.00	0.14	0.00	91.68	429.72
3	48.00	29.70	46.75	34.63	4.01	4.50	18.04	177.00	0.28	49.56	76.15	0.26	19.80	132.27	0.14	18.52	21.57	286.57
3L	48.00	29.70	42.28	34.63	3.79	4.50	17.06	177.00	0.57	100.89	0.00	0.26	0.00	0.00	0.14	0.00	21.57	294.13
4	48.00	29.70	57.41	34.63	4.15	4.50	18.68	210.00	0.28	58.80	76.15	0.26	19.80	132.27	0.14	18.52	56.17	341.70
5L	48.00	29.70	43.12	34.63	4.84	4.50	21.78	207.00	0.57	117.99	0.00	0.26	0.00	0.00	0.14	0.00	0.00	295.22
8	72.57	29.70	78.16	34.63	4.33	4.50	19.49	210.00	0.28	58.80	76.15	0.26	19.80	132.27	0.14	18.52	78.25	409.91
8L	72.57	29.70	70.88	34.63	4.11	4.50	18.50	210.00	0.57	119.70	0.00	0.26	0.00	0.00	0.14	0.00	78.25	424.22
11L	72.57	29.70	50.82	34.63	4.88	4.50	21.96	210.00	0.57	119.70	0.00	0.26	0.00	0.00	0.14	0.00	0.00	329.38
15	79.59	29.70	63.46	34.63	4.13	4.50	18.59	210.00	0.28	58.80	76.15	0.26	19.80	132.27	0.14	18.52	78.25	401.33
15L	79.59	29.70	62.18	34.63	3.91	4.50	17.60	210.00	0.57	119.70	0.00	0.26	0.00	0.00	0.14	0.00	78.25	421.65
16L	79.59	29.70	49.13	34.63	4.84	4.50	21.78	210.00	0.57	119.70	0.00	0.26	0.00	0.00	0.14	0.00	0.00	334.53

Notes:
AMS --- Agricultural Management System
PHM Cost --- Pre-harvest Machnary Cost
* Variable harvest cost is not included in this table.

$E_2(t)$ is the allowed nitrate leaching from stage t to T. The value of $E_2(t)$ changes as t changes backward from T to 1. When the economic value and environmental quality are in conflict, discounted cash flow could lead to the model selecting a higher economic value decision resulting in more pollution in the beginning years of the planning period. Changing the value of E_2 at different stages, thus, reduces the tendency to discount the value of groundwater quality in latter stages of analysis.

3.4.3.3 The third objective: soil conservation

The CREAMS simulation results indicate that the average soil losses of the 14 AMSs in a crop rotation period range from about 2.16 to 4.82 tons per acre per crop rotation period. Choice of minimizing soil loss as an objective is based on: (1) the proximity of Richmond County to the Chesapeake Bay, (2) the effects of sediment on fishing and recreation quality, and (3) the implicit consideration of nitrogen in runoff and in sediment. From CREAMS results, Figure 3.4.2 shows that the nitrogen in sediment is approximately proportional to the soil loss. Nitrogen in runoff is determined by the amount of runoff and nitrogen content in the surface soil, and the amount of soil loss is determined by the runoff velocity and physical properties of the sediment (Mutchler and Murphree, 1980). Thus, a higher soil loss indicates a higher runoff and a higher nitrogen level in runoff in most cases. Soil loss is the function of decision variables $\underline{X}_t$ and random variable w_t, but it is independent of the state variable $\underline{Y}_t$. Like E_2, the allowed soil loss from stage t to T is restricted with E_3. These maximum and minimum values of E_2 and E_3 will be

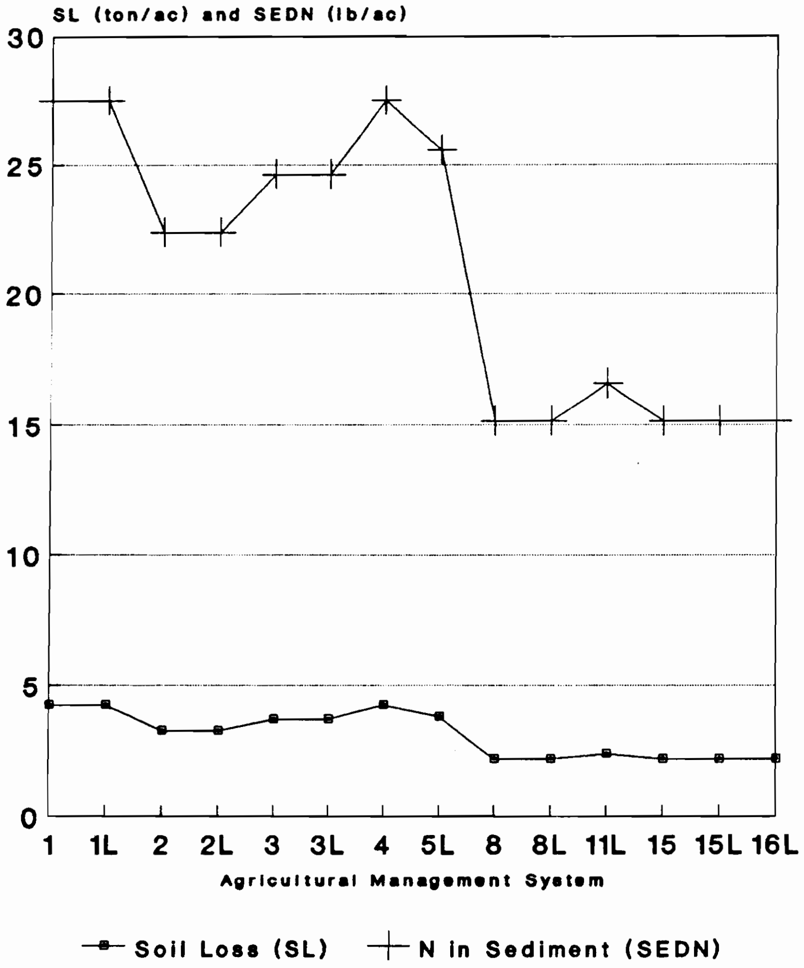

Figure 3.4.2 Soil Loss and Nitrogen in Sediment

(Average of 17 Crop Rotation Period)

discussed in section 3.4.7.

3.4.4 Decision Variables in the Model

In this research, decision variables are a certain number of predetermined AMSs, which are currently used AMSs or potentially employable AMSs in Richmond County. Since all the 14 AMSs being analyzed in this research consist of a two year crop rotation, decisions are only made at the beginning of every two years. That is, once an AMS has been selected by the model, all agricultural practices of that AMS in a crop rotation period are assumed to be executed sequentially. It is assumed that information from preceding agricultural practices, observed weather, or changes in decision environment within the two years has no effect on the practices in the following two years. Only the POTM value at the end of the crop rotation period will be transferred through the state transition equation. The MODP model in this study, thus, is a non-adaptive model.

The 14 AMSs in Table 3.2.1 are the decision variables in this research. Each AMS is a combinations of a sequence of agricultural management practices. The 14 AMSs represent different combinations of management strategies relating to: (1) applying low rates of nitrogen fertilizer versus high rates; (2) adopting organic fertilizer versus using commercial fertilizer; (3) employing a cover crop versus no cover crop; (4) selecting a legume cover crop versus a non-legume cover crop (5) using conventional tillage versus no-till; and (6) using chemicals versus no chemicals. Therefore, the differences between economic and environmental impacts from one AMS to another were caused by a sequence of management strategies rather than one specific management strategy.

3.4.5 State Variables in the Model

A state is a *summary* of prior history of the process that is in sufficient detail to enable evaluation of current alternatives (Denardo, 1982). State variables must reflect the transformation of states and their effects on the objective function value. At least, one of the explanatory variables of the objective functions must be a state variable in the multi-objective dynamic model. Otherwise, a dynamic problem conceptually can be expressed as a static problem.

However, the state variables can never really summarize the previous process, since models are abstractions of the real world and any model must be a misspecification of the system being evaluated. It is safer to judge the "sufficiency" of models rather than their "realism." In other words, the sufficiency of the constructed model to the study problem needs to be evaluated (Rausser and Hochman, 1979). In empirical applications, it is difficult to decide what and how many state variables are sufficient to represent that summary of the real world given the limits of knowledge on physical transition between states, data availability, and computational burden. Generally, state variables are selected to reflect the researcher's view of what the more important factors that affect the state transition in the study area.

The applications of dynamic programming models to agricultural production decisions were summarized by Kennedy (1986). The state variables in these applications have been crop growth or maturity, soilsalinity, soil moisture, nutrients, topsoil depth, weed/pest infestation, pest and predator populations, and water stocks. In all of these studies, the objective function is an explicit function of the state variable(s). The major reason for selecting these state variables was they had significant effects on the crop yields, which often had direct effects on the objective function value in these studies. For example, in Burt's (1981) study area, the tops of hills have shallow topsoil of less than 6 inches, with a lower percentage of organic matter than at the base of the hills. The topsoil depth and organic matter in the topsoil, thus, were chosen as the state variables to explicitly consider their impacts on soil productivity and crop yield.

All of these applications of dynamic programming models to fertilizer management issues summarized by Kennedy (1986) were concerned with nutrient carryover. The nutrient contents of soil in stage i, which are a function of fertilizer used in stage i and the nutrient carryover from a previous stage or stages, were selected as state variables. The objective function value was a function of state variables and control variables, such as the fertilizer used and the crop production systems selected. Single-period nutrient carryover or multi-period nutrient carryover were assumed in these studies. Single-period carryover is defined as nutrient carried to stage i as a proportion or a function of nutrient in stage i-1 only. Multi-period carryover is defined as nutrient carried to stage i as a function of nutrient levels in m previous stages. For an optimal solution, in a single carryover case, fertilizer used in stage i should be at a level such that the present value of the marginal value product of fertilizer from stage i and stage i+1 must equal the opportunity cost of the marginal unit of fertilizer, which equals the price of fertilizer in stage i less the present value of nutrient carried from stage i to stage i+1 (Kennedy, 1973; Fuller, 1965). For optimality to exist, in a multi-period carryover case, fertilizer used in stage i should be the level that the present value of marginal value product of fertilizer from stage i to stage i+m (assuming an m stage carryover case) must equal the opportunity cost of the marginal unit of fertilizer, which equals the price of fertilizer in stage i less the present value of nutrient carried from stage i to stage i+m (Kennedy, 1981; Bowden and Bennett, 1974; Godden and Helyar, 1980). Note that in all of these studies reviewed by Kennedy (1986) nutrient carryover only has a positive effect on the objective function since present value, or the expected present value in a stochastic case, of net revenue was the only objective in these studies.

Nitrogen carryover plays an important role in the evaluation of the AMSs in this study. When multiple objectives, including economic and environmental objectives, are considered, economic and environmental values of nitrogen carryover have to be considered simultaneously. The value of nitrogen carryover is no longer strictly positive since it can adversely impact environmental quality. Modification of the classic formulas for optimal nitrogen application rates presented in Kennedy (1986), thus, is necessary in order to include environmental impacts.

Nitrogen carryover has three effects on the economic value through influencing: (1) fertilizer costs; (2) crop yields; and (3) productivity of the soil in the long term. Since the nitrogen application rates of an AMS are assumed constant; and no effort has been made to evaluate the long term effects of soil productivity, in this study, only crop yields are considered to be influenced by nitrogen carryover. Nitrogen carryover has a negative effect on groundwater quality. The CREAMS' results showed that a large portion of nitrate leaching out of the root zone occurs in the winter and spring, which is the period following fall crop harvest and prior to spring crop growth. Nitrogen carryover, from surplus commercial fertilizer left from the previous season or the POTM of crop residuals and manures in the soil, can lead to a high soil nitrate content in the winter and spring, which represents a potential source of nitrate leaching during that time period.

The potential mineralizable nitrogen in the top soil at the beginning of the crop rotation period was selected as the state variable, $\underline{Y}$, in this study. Selecting the POTM as the state variable, to a great degree, is because in the CREAMS model, the POTM volume in the soil is used to simulate the dynamic interaction of nitrification; denitrification; immobilization; and volatilization in the soil as mentioned in the section 3.3. Equation 3.3.9 represents state transition equations of the 14 AMSs, which are independent of stage. The objective functions of PVENR, nitrate leaching and soil loss are also independent of stage. Therefore, the dynamic programming model used in this study is stationary. Nitrogen content in the top soil could affect the soil loss rate by influencing organic matter content and physical properties of soil in the long run, but this effect was not considered in this study.

3.4.6 Random Variable in the Model

"The types of random variables encountered in agricultural and natural resource management problems are: economic variables such as input and output prices, and the rate of interest; weather variables such as temperature and rainfall; and technical parameters particular to the resource system. Of the three types, there is probably greatest scope for revising technical parameters particular to the resource system, over the same period as decisions are being implemented (Kennedy, 1986, p.86)." It is known that only limited random variables can be coupled to a model. The number of random variables in a model could be limited by the lack of knowledge about these random events, data availability, and/or computer capacity. The selection of random variables usually is decided upon by the objectives of the research. Only random weather was considered in this study since focus of this study was the development of the multi-objective model.

In Richmond County, a only few farms have irrigation equipment. Those do generally use it on high value crops, such as vegetables (Giuranna et al., 1991). Rainfall is the only water source for row crops. Random weather affects all the three objective function as well as the state transition equation in this research. In general, weather can affect the gross incomes of an AMS through variations in crop yields and crop prices. But only the impacts on crop yield are considered[24] in this study. Weather mostly affects crop yields through water stress and nitrate availability to the crop. Weather affects the second and third objectives function because water is a direct carrier of nitrates and sediment. Weather affects the mineralization rate and the POTM in the soil through temperature and water content of the soil. Weather thus plays a crucial role in this study.

Rainfall is not the only random factor influencing the water balance in a weather-soil-crop system. Precipitation, temperature, radiation, percolation, topographical and geological factors, evapotranspiration, crop growth, AMS, and physical properties of the soil constitute a complex matrix of factors affecting the water balance of the soil. The water balance in a weather-soil-crop system, thus, includes components that are naturally uncontrollable such as weather and components that are controllable such as employing different agricultural practices. To reflect the interaction of these uncontrollable and controllable factors in the water balance, water percolation was selected as a random variable for several seasons. First, water percolated is the direct carrier of nitrates. That is, water percolation is the necessary condition for nitrate leaching. Second, water percolation is an indirect measure of water stress and nitrate availability to crops, which directly affects crop yields through nitrogen uptake by crops. Third, water percolation is

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[24] The crop prices in local market of the Northern Virginia are not related to the local crop production, but may be related to other factors such as national crop production. The impacts of local weather on crop price thus does not need to be considered in this study.

inversely related to runoff, *ceteris paribus*. Therefore, water percolation influences the amount of sediment and nitrogen in runoff. Higher water percolation will lead to less runoff. Fourth and finally, the amount of water percolation is partly affected by the management systems. CREAMS results indicate that the distributions of water percolation for the 14 AMSs were different. That is, these distributions are the conditional distribution of water percolation given the AMS and random rainfall. Appendix A3 shows that the seasonal water percolation of the 14 AMSs over 17 crop rotation period vary over a large range from 0 to 15.03 inches. To account for the seasonal distributions of water percolation associated with the 14 AMSs, this range was broken into to 18 increments from less than 0.394 inch to greater than 12.99 inch. The boundary value of the 18 increments, called the bin value, and their associated frequency are the value and probabilities of the random variable, which are listed in Table 3.4.2 are used for calculating the nitrogen uptake, nitrate leaching, and POTM transition as explained below.

3.4.7 Computer Program for the Multi-objective Dynamic Programming Model

There is no general computer programming algorithm for dynamic programming as there is for linear and non-linear programming. The major reason for this lack is that the development of dynamic programming is a process of half science and half art. In the past, the rule of thumb of evaluating the success of a computer program for dynamic programming was the amount of computing time and computer memory required (Kennedy, 1986). This criterion indicates that the applications of dynamic programming

Table 3.4.2 Probabilities and Values of Water Percolation of the 14 AMSs

Percolation (inch)	Probability of Percolation in Crop Seasons															
	AMS 1,1L,&4				AMS 2 & 2L				AMS 3 & 3L				AMS 5L			
	CORN	WHEAT	BEAN	COVER	CORN	WHEAT	BEAN	COVER	CORN	WHEAT	BEAN	COVER	CORN	WHEAT	BEAN	COVER
0.394	0.000	0.059	0.529	0.000	0.000	0.059	0.529	0.000	0.000	0.059	0.529	0.000	0.000	0.059	0.529	0.000
1.181	0.059	0.000	0.235	0.059	0.059	0.000	0.235	0.059	0.059	0.000	0.235	0.059	0.059	0.000	0.235	0.118
1.969	0.176	0.000	0.000	0.118	0.176	0.000	0.000	0.118	0.176	0.000	0.000	0.118	0.235	0.000	0.000	0.059
2.756	0.235	0.176	0.059	0.235	0.235	0.176	0.059	0.176	0.235	0.176	0.059	0.176	0.176	0.176	0.059	0.294
3.543	0.118	0.059	0.176	0.118	0.118	0.059	0.118	0.176	0.118	0.059	0.118	0.176	0.118	0.059	0.176	0.059
4.331	0.059	0.059	0.000	0.000	0.059	0.059	0.059	0.000	0.059	0.059	0.059	0.000	0.059	0.118	0.000	0.000
5.118	0.118	0.059	0.000	0.059	0.118	0.059	0.000	0.059	0.118	0.059	0.000	0.059	0.118	0.059	0.000	0.059
5.906	0.000	0.118	0.000	0.059	0.000	0.118	0.000	0.059	0.000	0.118	0.000	0.059	0.059	0.059	0.000	0.118
6.693	0.059	0.000	0.000	0.118	0.059	0.000	0.000	0.118	0.059	0.000	0.000	0.118	0.000	0.000	0.000	0.059
7.480	0.059	0.059	0.000	0.118	0.059	0.059	0.000	0.118	0.059	0.059	0.000	0.118	0.059	0.118	0.000	0.118
8.268	0.000	0.118	0.000	0.059	0.000	0.118	0.000	0.059	0.000	0.118	0.000	0.059	0.059	0.059	0.000	0.059
9.055	0.059	0.059	0.000	0.059	0.059	0.000	0.000	0.059	0.059	0.000	0.000	0.059	0.000	0.059	0.000	0.059
9.843	0.059	0.000	0.000	0.000	0.059	0.059	0.000	0.000	0.059	0.059	0.000	0.000	0.059	0.000	0.000	0.000
10.630	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000
11.417	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12.992	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000
>12.992	0.000	0.176	0.000	0.000	0.000	0.176	0.000	0.000	0.000	0.176	0.000	0.000	0.000	0.118	0.000	0.000

Percolation (inch)	AMS 8 & 8L				AMS 11L				AMS 15 & 15L				AMS 16L			
	CORN	WHEAT	BEAN	COVER	CORN	WHEAT	BEAN	COVER	CORN	WHEAT	BEAN	COVER	CORN	WHEAT	BEAN	COVER
0.394	0.294	0.059	0.412	0.235	0.294	0.059	0.529	0.294	0.294	0.059	0.412	0.235	0.294	0.059	0.529	0.294
1.181	0.235	0.000	0.353	0.294	0.235	0.000	0.235	0.235	0.235	0.000	0.353	0.294	0.235	0.000	0.235	0.235
1.969	0.118	0.000	0.059	0.059	0.118	0.000	0.059	0.059	0.118	0.000	0.059	0.059	0.118	0.000	0.059	0.059
2.756	0.059	0.118	0.000	0.000	0.059	0.176	0.000	0.000	0.059	0.118	0.000	0.000	0.059	0.176	0.000	0.000
3.543	0.000	0.059	0.059	0.059	0.000	0.059	0.118	0.118	0.000	0.118	0.059	0.059	0.000	0.059	0.118	0.118
4.331	0.059	0.118	0.118	0.118	0.059	0.059	0.059	0.118	0.059	0.059	0.118	0.118	0.059	0.059	0.059	0.118
5.118	0.000	0.059	0.000	0.176	0.000	0.059	0.000	0.118	0.000	0.059	0.000	0.176	0.000	0.059	0.000	0.118
5.906	0.118	0.118	0.000	0.000	0.118	0.118	0.000	0.000	0.118	0.118	0.000	0.000	0.118	0.118	0.000	0.000
6.693	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059
7.480	0.000	0.059	0.000	0.059	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.059	0.000	0.059	0.000	0.000
8.268	0.000	0.118	0.000	0.000	0.118	0.118	0.000	0.000	0.000	0.118	0.000	0.000	0.118	0.118	0.000	0.000
9.055	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.843	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000
10.630	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11.417	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059	0.000	0.000
12.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12.992	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
>12.992	0.000	0.176	0.000	0.000	0.000	0.176	0.000	0.000	0.000	0.176	0.000	0.000	0.000	0.176	0.000	0.000

techniques to agricultural and resource management problems were historically limited by the computational "curse of dimensionality." The rapid development of computer power, however, partly makes the "curse" fade and makes a numerical ε-constraint approach to the MODP model possible.

3.4.7.1 Algorithm of the Numerical ε-constraint Approach

Figure 3.4.3 represents a numerical ε-constraint approach algorithm. E_{2max} and E_{2min} are the maximum and minimum nitrate leaching allowed in the planning period, respectively. E_{3max} and E_{3min} are the maximum and minimum soil loss allowed in the planning period, respectively. The E_{2max} (or E_{2min}) was determined based on the assumption that E_{2max} (or E_{2min}) occurs when the AMS associated with the largest (or smallest) nitrogen leaching among the 14 AMSs is continuously employed in the planning period. The E_{3max} and E_{3min} were determined in the same way as E_{2max} and E_{2min}. From Table 3.3.1, AMS 2L has the maximum nitrate leaching of 73.55 pounds per acre in a crop rotation period; AMS 8 has the minimum nitrate leaching of 28.33 pounds per acre in a crop rotation period; AMSs 1 and 1L have the maximum soil loss of 4.26 tons per acre in a crop rotation period; and AMS 16 has the minimum soil loss of 2.16 tons per acre in a crop rotation period. Therefore, E_{2max}, E_{2min}, E_{3max}, and E_{3min} are 367.75 pounds per acre, 146.65 pounds per acre, 21.3 tons per acre, and 10.8 tons per acre, respectively.

The computer program for a numerical ε-constraint approach to the MODP model requires the subroutine of dynamic programming to run n times. The number n is determined by the combinations of the constraints on the nitrate leaching and soil loss, which are determined by the divided

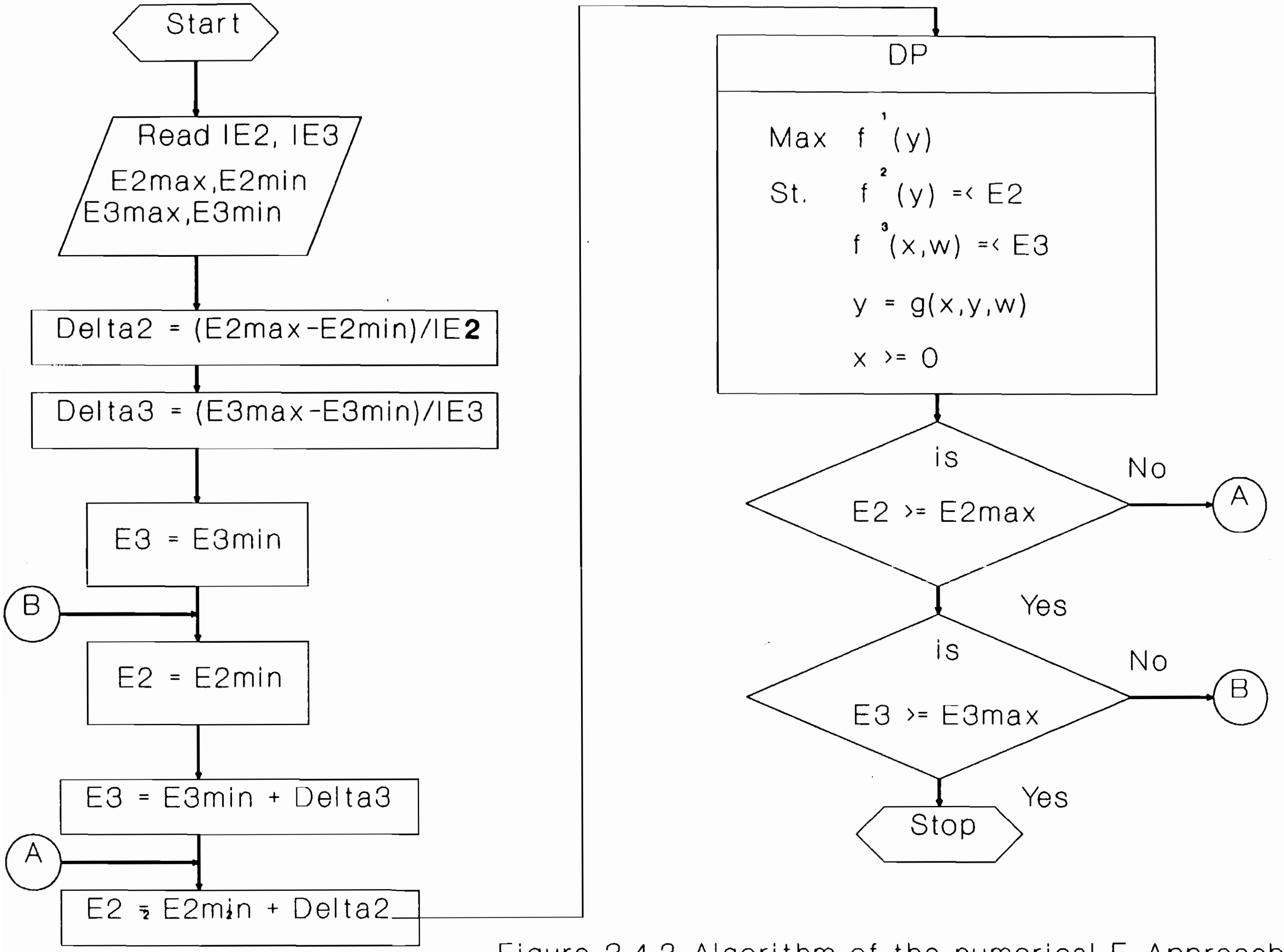

Figure 3.4.3 Algorithm of the numerical E-Approach

segments of E_2 and E_3, δ_2 and δ_3, where $\delta_2 = (E_{2max} - E_{2min})$ and $\delta_3 = (E_{3max} - E_{3min})$. Determination of δ_2 and δ_3 are based on the empirical problem being analyzed. A value of 10 is assigned for both δ_2 and δ_3 in this study[25]. Since the computer program starts from $\delta_2 = E_{2min}$ and $\delta_3 = E_{3min}$, the total number of $n = (\delta_2 + 1)(\delta_3 + 1) = 121$. That is, the computer program for numerical ε-constraint approach repeats the dynamic program subroutine 121 times under different combination of E_2 and E_3. The 121 solutions represent trade-offs among the PVENR, expected nitrate leaching, and expected soil loss.

3.4.7.2 Algorithm of the Stochastic Dynamic Programming Subroutine

The computer program of the dynamic programming model was developed in two independent parts: the computer program for solving the stochastic dynamic programming problem (CPSDPP) and the computer program for generating data (CPGD). The CPSDPP is written in FORTRAN 77 (Microsoft FORTRAN, Version 2.3) and the CPGD in GWBASIC (Epson GW-Basic, Version 3.20). The CPSDPP can be found in Appendix C1, and the CPGD in Appendix C2.

The algorithm of the CPSDPP is represented in Figure 3.4.4. A special feature of the CPSDPP is that the feasible sequence of decisions from stage t to stage T are always constrained by the allowed nitrate leaching and soil loss, $E_2(t)$ and $E_3(t)$. The optimal policy is selected

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[25] A sensitivity analysis will be performed on the grid size of δ_2 and δ_3.

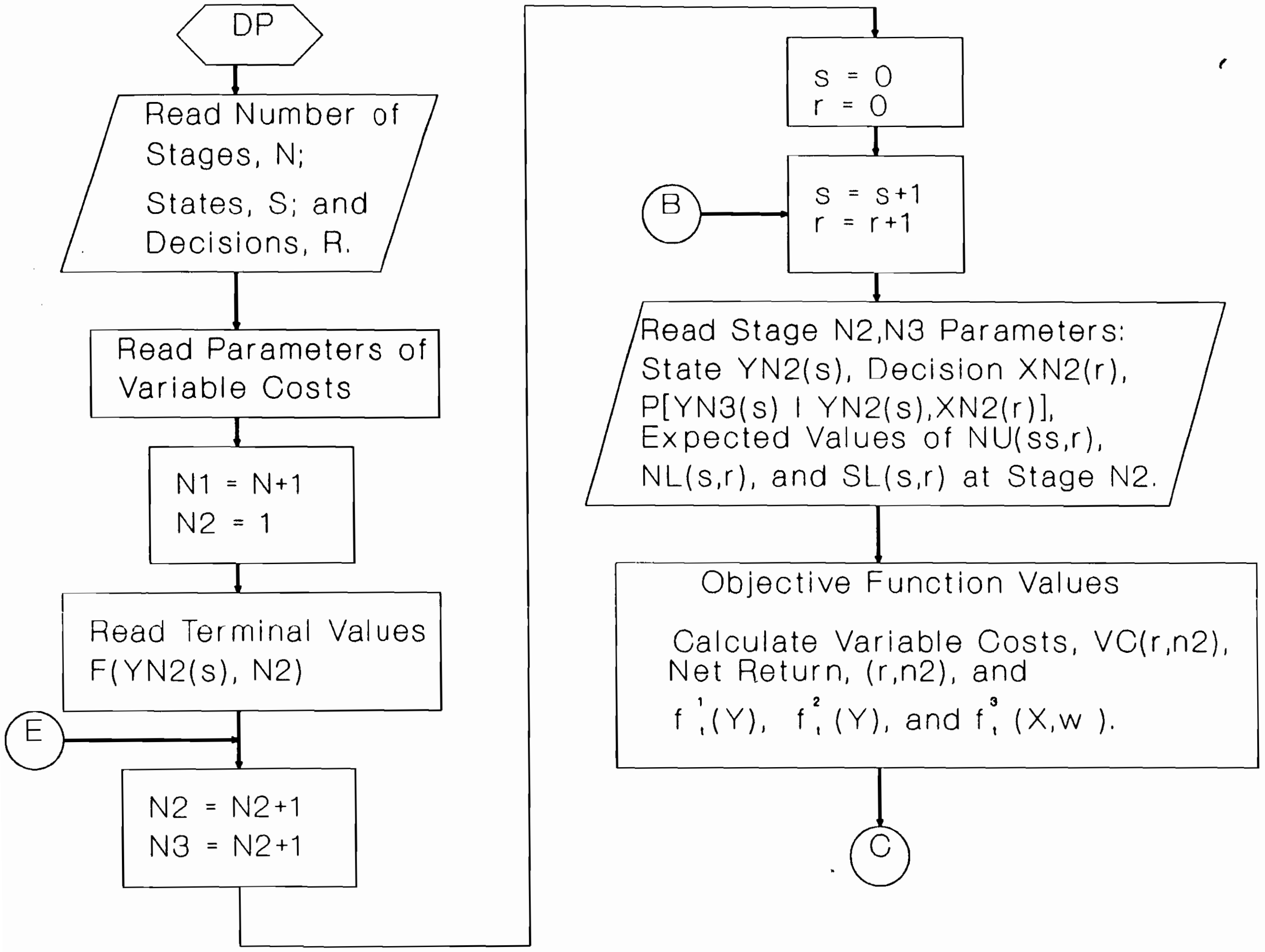

Figure 3.4.4 Algorithm of the Dynamic Programming Model

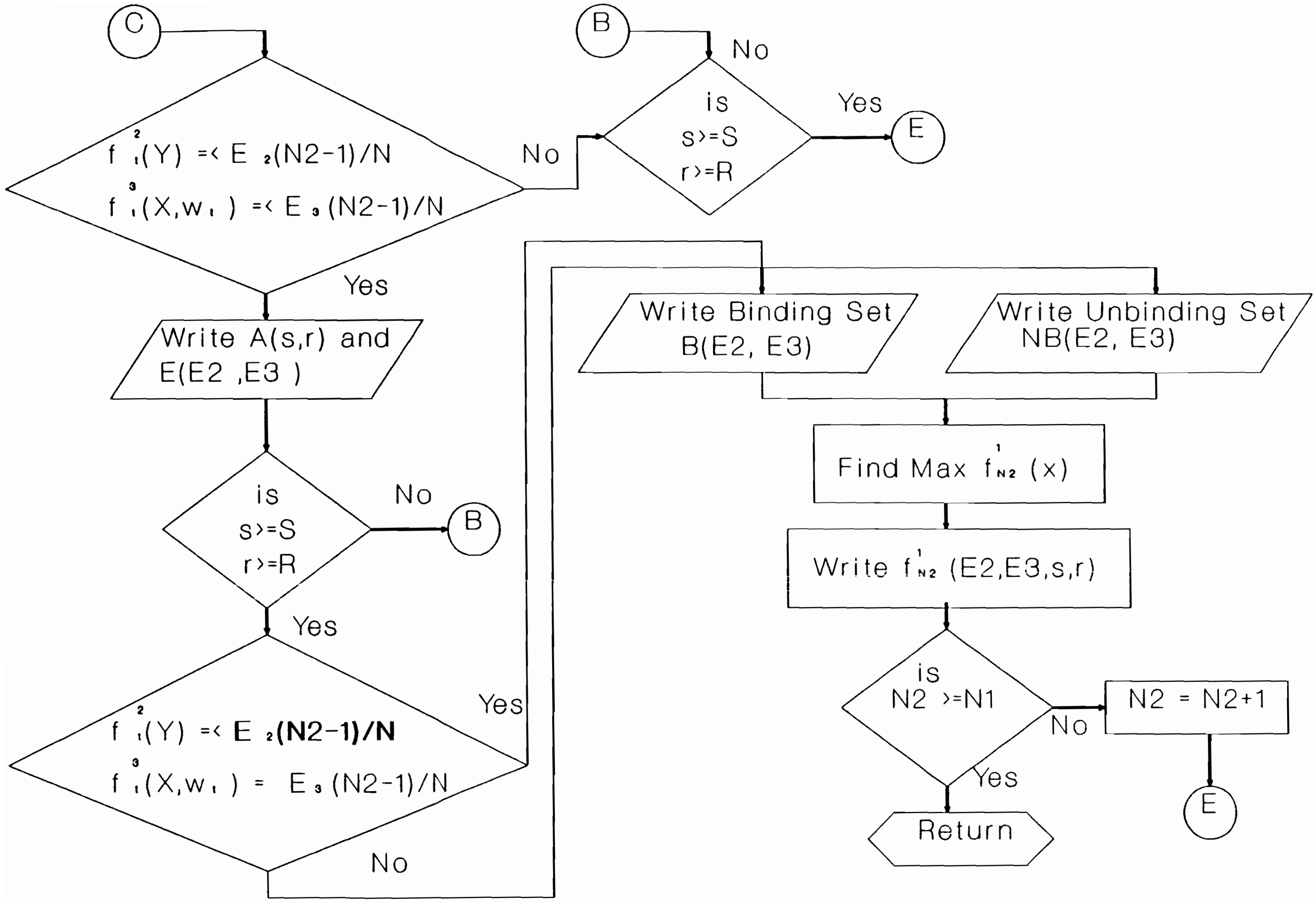

Figure 3.4.4 Algorithm of the Dynamic Programming(Continued)

from a restricted feasible policy set. Conceptually, the non-inferior solution is reached when all the constraints are binding. Since in most discrete problems, it will be impossible to have several constraints that are simultaneously binding (Haimes et al., 1975), the non-inferior solution from the CPSDPP in this study is only an approximation. With a sufficient number of decision variables and small grids of δ_2 and δ_3, the approximation is acceptable.

The algorithm of the CPGD is presented in Figure 3.4.5. The s; r; and i represent state; decision; and crop season, and capital S; R; and I represent the total states; decisions; and crop seasons in a stage, respectively. Since the 14 AMSs can be employed at any stage, R=14. Using r=1 represents AMS 1, and so on, using r=14 represents the AMS 16L. A stage, a crop rotation period, includes 4 crop seasons: corn; wheat; soybeans; and cover crop, so I=4. The corn season was represented as i=1; wheat season i=2; soybeans season i=3; and cover crop season i=4. Table 3.3.1 shows that the range of the average POTMs of AMSs at the end of cover crop seasons ranged from 20.04 pounds per acre to 205.09 pounds per acre. Like water percolation, the possible POTM in the soil was broken into 23 increments from less than 9 pounds per acre to greater than 196 pounds per acre, so S=23. Using s=1 represents a POTM is less than 9 pound per acre, and so on, using s=23 represents a POTM greater than 196 pounds per acre. The estimation of nitrate leaching, nitrogen uptake, and POTM transition are based on the regression analysis of CREAMS results, which was discussed in the section 3.3. Note that the regressions are based on individual AMSs so the estimated equations used in the computer

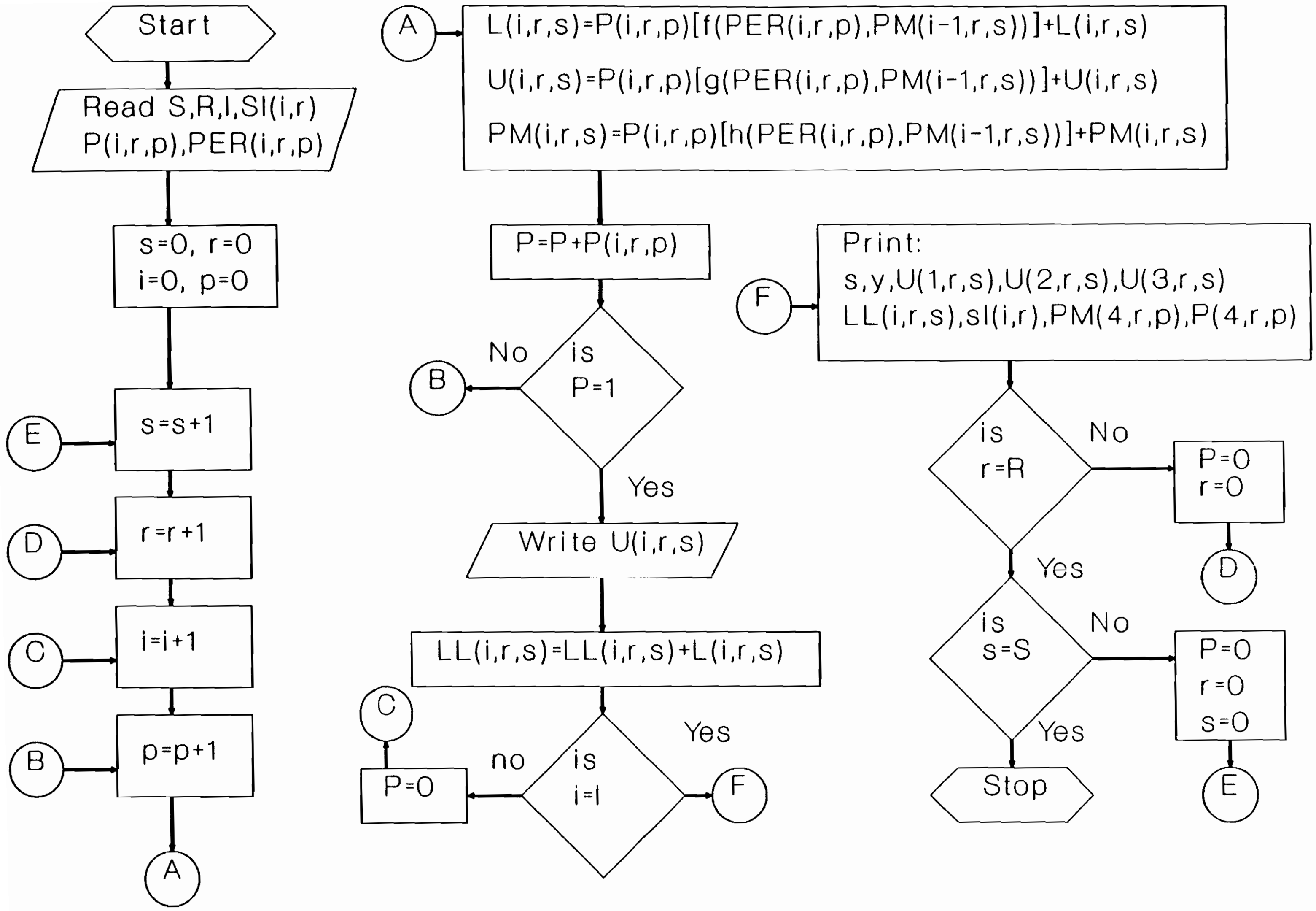

Figure 3.4.5 Algorithm of the CPGD

program consist of the 42 regression equations in Tables 3.3.2, 3.3.3, and 3.3.4.

Since the nitrate leaching; nitrogen uptake; and the POTM change in a current crop season is affected by the preceding crop season through effects on the POTM value; which is partly dependent on the random weather in the preceding season, the estimation of an expected value of nitrate leaching and nitrogen uptake in the current season needs to exhaust all the possible combinations of changes in POTM in that season as well as the possible value of the POTM at the beginning of the season. For example, assuming that each of four crop seasons has 10 possible POTM values at the end of season given a certain POTM value at the beginning of that season, then a certain POTM at the beginning of corn season leads to a $10^4 = 10,000$ possible POTM values at the end of the cover crop season. Fortunately, these possible POTM values are always in the range from 9 to 196 pounds per acre. The possible POTM values transferred from stage t to stage t+1 can be expressed by one of 23 bin values of increments associated with their probabilities. Therefore, given a certain POTM value at the beginning of the corn season, the CPGD generates the data, including the: (1) the expect nitrogen uptake by corn, wheat, and soybeans; (2) nitrate leaching in a crop rotation period; (3) soil loss in a crop rotation period; and (4) probability and value of the POTM at the end of the cover crop season. These data were transferred to the CPSDPP to find the non-inferior solutions.

3.5 Features of This Multiple Objective Analysis Related to Sustainable Development

A systematic analysis in section 2.2 found that from a stainable development perspective, absolute resource scarcity could result from "two sides" of the economic system. That is from the input side, absolute resource scarcity is represented by the limited quantity of resources; and from output side, absolute scarcity is represent by the limits of the assimilative capacity of the environment. The argument of limited quantity of resources is generally based on the concept of limits to economic growth stemming from the second law of thermodynamics. If this concept held, the best strategy of postponing the demise of human society would be simply to promote less economic development; and there would be no sustainable economic system at all. Thus, the second law of thermodynamics is not applicable to economic growth as discussed in section 2.3, which complicates the direction and measurement of sustainable development. Based on the conclusion of "inapplicability" in this research, low-input sustainable agriculture may or may not be necessary to have sustainable agricultural production. Note that the argument of "inapplicability" does not means the improvement of environmental quality ceases to be important, but it does mean that a wider range of alternative paths to sustainable development are available.

Consideration of the assimilative capacity of environment thus become more important in empirical environmental and natural resource issues. A direct, but not necessary correct, way of addressing this point is to diminish environmental disturbance of economic activity through the policy making processes. As demonstrated in section 2.4, to mitigate the contradictions between environmental and economic objectives, moving the net return curve to the left and flatting or lowering the adverse environmental impact curve in Figure 2.4.1 are necessary, which can be realized through technological progress.

As an innovative approach to explicitly couple environmental considerations to economic analysis, this multiple objective analysis has several features. First, the economic and environmental qualities, represented as net present value of income; soil conservation; and groundwater protection from nitrate contamination, are simultaneously considered as the objectives in this analysis. Second, development of non-inferior solution sets excludes less economical and environmentally benign AMSs, which moves the net return curve to the left and also changes its shape through selection of the better AMSs. Third, combining constraints on soil loss and nitrate leaching in each stage of the analysis avoids discounting of environmental quality at latter stages of the planning period when economic and environmental values are in conflict. Fourth and finally, the multiple objective approach avoids using a particular discount rate for both economic and environmental value. Various combinations of discount rates for economic and environmental value, thus, can be employed, which includes a zero discount rate for both economic and environmental values as suggested by some advocates of sustainable development.

Chapter 4

Results of the Multi-objective Dynamic Programming Model

This chapter discusses the results of the MODP model. The optimal decisions and objective function values of the general model. Included in this discussion will be unrestricted and restricted cases. The unrestricted case refers to a total relaxation of constraints on nitrate leaching and soil loss, while the restricted case refers to the situation in which a 40 percent reduction of nitrogen loading, required by the Chesapeake Bay Agreement, is imposed. Then, sensitivity analysis of these results, including changes of (1) the grid size of E_2 and E_3; (2) the interest rate; and (3) the planning horizon, will be employed. Finally, scenarios, including: (1) a 30 percent decrease of poultry litter price; (2) a 30 percent increase of commercial nitrogen price; (3) a 20 percent decrease of crop prices; (4) a 20 percent increase in crop prices, will be examined; and (5) an approximation of the price impacts of commodity program.

4.1 Results of the General MODP Model

The output of the general MODP model are the optimal decisions and objective function values. The optimal decisions at the beginning of the first stage, under different constraints on nitrate leaching and soil loss, represent the results of the general model in decision space. The present value of expected net returns and the expected nitrate leaching and soil loss associated with these optimal decisions represent the results of the general model in objective function space. These two types of results will be discussed below.

4.1.1 Optimal Decisions

The development of optimal decisions is influenced by many factors, including the expected net return, nitrate leaching, and soil loss of the AMSs; the POTM transition of the AMSs; constraints on nitrate leaching and soil loss; and the initial POTM in the soil. In a stochastic dynamic programming problem, outputs of the model in decision space are the optimal decision of the first stage and the expected optimal decision path.

4.1.1.1 Definitions of optimal decisions and expected optimal decision path

A decision for the first stage is optimal when a maximum present value of the expected net return (PVENR) associated with that decision, subject to certain constraints on nitrate leaching and soil loss, is obtained. A dynamic programming model is stochastic "when transition equations or observation equations for the state vector are not deterministic (Aoki, 1989 p.51)." A stochastic dynamic programming model can never find the optimal decision path over planning period by tracing forward from the initial state due to the absence of knowledge of random events over the planning period (Kennedy, 1986). Therefore, only the optimal decision of the first stage can be determined by the model.

The MODP model used in this research is stochastic since the transition of the POTM, a state variable, in the soil from one stage to another is dependent upon random weather. The optimal decision of the second stage, thus, can never be found until the random event in the first stage has been observed and so forth. That is, the optimal AMS for the second stage in this model will depend on the POTM in the soil after the first stage, which could be observed through either soil tests or information concerning the weather situation in the first stage. In this chapter, the optimal decision of the first stage is simply called the optimal decision. Therefore, the decisions listed in tables in this chapter are the optimal decisions of the first stage under different conditions of the initial POTM and constraints on nitrate leaching and soil loss.

An optimal decision subject to constraints on nitrate leaching and soil loss is only one of the non-inferior decisions in terms of the MODP model. As discussed in section 3.1, a multi-objective problem has a set of non-inferior solutions rather than an unique optimal solution when the objectives are in conflict. Since an optimal AMS is conditional to the constraints, when the constraints change, a previously optimal AMS may no longer be optimal. Different from the deterministic dynamic programming model, stochastic dynamic programming models provide "if-then" information. That is, if the random events in the previous stage have been observed then what the optimal decision for the following stage can be determined. Such information is not available in deterministic dynamic programming models. In a sense, the real return from employing a more complex stochastic dynamic programming model is the plentiful information on the system being analyzed.

An optimal decision path is a sequence of optimal decisions over the planning period in a deterministic dynamic problem. An optimal decision path does not exist for a stochastic dynamic programming problem since only the optimal decision for the first stage is available. When the expected values of random variables are coupled to a stochastic dynamic programming model an expected optimal decision path (EODP) is developed, and in fact, the stochastic dynamic programming becomes a deterministic one.

4.1.1.2 Optimal decisions and EODPs of the general model

The optimal decisions and EODPs of the general model in this study are listed in Table 4.1.1. The initial POTM in the table is the POTM in soil at the beginning of the first stage. The value of E_2 and E_3 in Table 4.1.1 represent the constraints on nitrate leaching and soil loss. Numbers in parentheses represent row and column numbers. Table 4.1.1 lists parts of the outputs of the general model, which are associated with the initial POTMs of 35.6; 44.5; 53.4; and 62.3 pounds per acre and 121 combinations of constraints on nitrate leaching and soil loss for each initial POTM. Reasons for selecting these four initial POTMs will discussed in section 4.1.2.2. Numbers and letters in a cell defined by a particular E_2 and E_3 present the optimal AMS and EODP subject to E_2 and E_3. For example, in Table 4.1.1, when E_2 is 210.6 pounds per acre and E_3 is 22 tons per acre, the number 15 and letter A in the cell of row 11 crossing

Table 4.1.1 Optimal Decisions and Expected Optimal Paths of the General Model

			IPOTM = 35.6 (lb/ac)										
			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	G	F	F	F	F	F	F	F	F	F
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	G	F	F	F	F	F	F	F	F	F
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	G	F	E	E	E	E	E	E	E	E
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	D	D	D	D	D	D	D	D	D
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	C	C	C	C	C	C	C	C
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	C	C	C	C	C	C	C	C
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	C	C	C	C	C	C	C	C
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	C	C	C	B	B	B	B	B
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	C	C	C	B	B	B	B	B
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	C	C	C	B	B	B	B	B
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		EODP	H	D	C	A	A	A	A	A	A	A	A

Notation:
Numbers in parenthesis represent row or column numbers.
AMS -- Agricultural Management System
EODP --- Expected Optimal Decision Path over planning period
IPOTM --- Initial potentially mineralizable nitrogen
A - H represent the expected optimal decision paths:

A --- AMS 15- AMS 8 - AMS 15 - AMS 8 - AMS 15;
B --- AMS 15 - AMS 8 - AMS 15 - AMS 8 - AMS 3;
C --- AMS 15 - AMS 8 - AMS 4 - AMS 15 - AMS 8
D --- AMS 15 - AMS 8 - AMS 3 - AMS 15 - AMS 8;
E --- AMS 15 - AMS 8 - AMS 2 - AMS 15 - AMS 8;
F --- AMS 15 - AMS 8 - AMS 15 - AMS 15 - AMS 15;
G --- AMS 15 - AMS 15 - AMS 15 - AMS 8 - AMS 15; and
H --- AMS 15 - AMS 8 - AMS 8 - AMS 8 - AMS 8.

Table 4.1.1 Optimal Decisions and Expected Optimal Path of the General Model (Continued)

			IPOTM = 44.5 (lb/ac)										
			E2 (lb/ac)										
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E3 (ton/ac)			142.5	165.2	187.9	210.6	233.4	256.1	278.8	301.5	324.2	346.9	369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	C	C	C	C	C
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	C	C	C	C	C
(3)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4
		EODP	E	B	B	B	B	B	B	B	B	B	B
(4)	14.3	AMS	8	4	4	4	4	4	4	4	4	4	4
		EODP	E	B	B	B	B	B	B	B	B	B	B
(5)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A
(6)	16.5	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A
(7)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A
(8)	18.7	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A
(9)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A
(10)	20.9	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A
(11)	22.0	AMS	8	4	15	15	15	15	15	15	15	15	15
		EODP	E	B	A	A	A	A	A	A	A	A	A

Notation:
Numbers in parenthesis represent row or column numbers.
AMS -- Agricultural Management System
EODP --- Expected Optimal Decision Path over planning period
IPOTM --- Initial potentially mineralizable nitrogen
A - E represent the expected optimal decision paths:

- A --- AMS 15 - AMS 8 - AMS 15 - AMS 8 AMS 15;
- B --- AMS 4 - AMS 15 - AMS 8 - AMS 15 - AMS 8;
- C --- AMS 15 - AMS 8 - AMS 15 - AMS 15 - AMS 8;
- D --- AMS 4 - AMS - 15 - AMS 8 - AMS 15 - AMS 8; and
- E --- AMS 8 - AMS 8 - AMS 8 - AMS 8 - AMS 8.

Table 4.1.1 Optimal Decisions and Expected Optimal Paths of the General Model
(Continued)

			IPOTM = 53.4 (lb/ac)										
			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		EODP	F	E	C	C	C	C	C	C	C	C	C
(2)	12.1	AMS	8	15	15	2	2	2	2	2	2	2	2
		EODP	F	E	C	B	B	B	B	B	B	B	B
(3)	13.2	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	E	A	A	A	A	A	A	A	A	A
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(5)	15.4	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(6)	16.5	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(7)	17.6	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(8)	18.7	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(9)	19.8	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(10)	20.9	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A
(11)	22.0	AMS	8	15	4	4	4	4	4	4	4	4	4
		EODP	F	D	A	A	A	A	A	A	A	A	A

Notation:
Numbers in parenthesis represent row or column numbers.
AMS -- Agricultural Management System
EODP --- Expected Optimal Decision Path
IPOTM --- Initial potentially mineralizable nitrogen
A - F represent the expected optimal decision paths:
A --- AMS 4 - AMS 15 - AMS 8 - AMS 15 - AMS 8;
B --- AMS 2 - AMS 15 - AMS 8 - AMS 15 - AMS 8;
C --- AMS 15 - AMS 8 - AMS 15 - AMS 15 - AMS 8;
D --- AMS 15 - AMS 8 - AMS 3 - AMS 15 - AMS 8;
E --- AMS 15 - AMS 15 - AMS 8 - AMS 15 - AMS 8; and
F --- AMS 8 - AMS 8 - 8 AMS 8 - AMS 8 - AMS 8.

Table 4.1.1 Optimal Decisions and Expected Optimal Paths of the General Model
(Continued)

			IPOTM = 62.3 (lb/ac)										
			E2 (lb/ac)										
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E3 (ton/ac)			142.5	165.2	187.9	210.6	233.4	256.1	278.8	301.5	324.2	346.9	369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		EODP	E	D	D	D	D	D	D	D	D	D	D
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		EODP	E	D	D	D	D	D	D	D	D	D	D
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		EODP	E	D	D	D	D	D	D	D	D	D	D
(4)	14.3	AMS	8	8	8	8	8	8	8	8	8	8	8
		EODP	E	D	D	D	D	D	D	D	D	D	D
(5)	15.4	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	C	C	C	C	C
(6)	16.5	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	C	C	C	C	C
(7)	17.6	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	C	C	C	C	C
(8)	18.7	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	B	B	B	B	B
(9)	19.8	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	B	B	B	B	B
(10)	20.9	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	C	C	C	B	B	B	B	B
(11)	22.0	AMS	8	8	15	15	15	15	15	15	15	15	15
		EODP	E	D	C	A	A	A	A	A	A	A	A

Notation:
Numbers in parenthesis represent row or column numbers.
AMS -- Agricultural Management System
EODP --- Expected Optimal Decision Path
IPOTM --- Initial potentially mineralizable nitrogen
A - F represent the expected optimal decision paths:

A --- AMS 15 - AMS 8 - AMS 15 - AMS 8 - AMS 4;
B --- AMS 15 - AMS 8 - AMS 15 - AMS 8 - AMS 15;
C --- AMS 15 - AMS 8 - AMS 4 - AMS 15 - AMS 8;
D --- AMS 8 - AMS 15 - AMS 8 - AMS 15 - AMS 8; and
E --- AMS 8 - AMS 8 - 8 AMS 8 - AMS 8 - AMS 8.

column 4, case (11 x 4)[26], indicate that the optimal decision is AMS 15 and the expected optimal decision path is A. The EODP is AMS 15 in first stage followed by AMS 8 in the second stage and then with AMS 15 and AMS 8 alternating through the rest of the stages.

The EODPs are represented by letters A to H, and explained in the notation at the bottom of the tables. Only AMSs 2, 4, 8, and 15 are included in the optimal AMSs; and AMSs 2, 3, 4, 8, and 15 are included in the EODPs in all cases in Table 4.1.1. AMSs 1, 1L, 2L, 3L, 5L, 8L, 11L, 15L, and 16L are not included in the optimal decisions or EODPs.

4.1.1.3 Analysis of the Optimal Decisions and EODPs

Four general points from the optimal decisions and EODPs of the general model in Table 4.1.1 are: (1) AMS 8 and AMS 15 are the dominant AMSs in the EODPs; (2) AMSs 2, 3, and 4 occasionally enter the EODP; (3) when the constraint on nitrate leaching is restrictive, AMS 8 will be the major AMS in the EODP; and (4) totally relaxing the E_2 and E_3 will lead to the alternating use of AMS 15 and AMS 8.

These four general points are supported by the following: (1) at least, four out of five AMSs in a EODP are AMS 8 or AMS 15; (2) at most, one of AMSs 2, 3, or 4 enters the EODP; (3) in the cases in the first column, in which the nitrate leaching constraint is restrictive, at least, four out five AMSs are AMS 8 in the EODP; (4) in case (11 x 11), which represents a total relaxation of constraints on nitrate leaching and soil

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[26] A case represents a combination of constraints on nitrate leaching and soil loss. The number of case is presented by the number of E_2 times the number of E_3. For example, case (1 x 2) indicates E_3=11 and E_2=165.2.

loss, an alternating use of the AMS 8 and AMS 15 is employed when the initial POTM is 35.6 or 44.5 pounds per acre, and employed after first stage when the initial POTM is 53.4 pounds per acre.

4.1.2 Objective Function Values

The three objective function values are the PVENR, expected nitrate leaching, and expected soil loss. The PVENR is the reference objective, while the expected nitrate leaching and soil loss are the constraints in the general model. The PVENR is first maximized subject to the constrains on nitrate leaching and soil loss in a ε-constrained approach, and then the expected total nitrate leaching and soil loss over the planning period associated with the optimal AMS are calculated. The PVENR and expected total nitrate leaching and soil loss over the planning period in different cases are listed in Table 4.1.2, assuming four different initial POTMs. As in Table 4.1.1, the values in a cell are refereed to a particular E_2 and E_3 in Table 4.1.2.

4.1.2.1 Analysis of the objective function values

Several general points from Table 4.1.2 are: (1) the PVENR is the highest in case (11 x 11) and the lowest in case (1 x 1), and decreases from the bottom right to the upper left of the table; (2) from the case (11 x 11) to the case (1 x 2), the PVENR decreases by 3.5, 4.3, 14.7, and 0.6 percent associated with four different initial POTMs; and (3) from case (1 x 2) to the case (1 x 1), the PVENR decreases by 26.7, 51, 45.4, and 38 percent associated with four different initial POTMs.

The four points above indicate: (1) PVENR increases with relaxation

Table 4.1.2 Present Value of Expected Net Return and Expected Nitrate Leaching and Soil Loss over the Planning Period of the General Model

IPOTM = 35.6 (lb/ac)

			E2 (lb/ac)										
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E3 (ton/ac)			142.5	165.2	187.9	210.6	233.4	256.1	278.8	301.5	324.2	346.9	369.6
(1)	11.0	PVENR	368.3	502.8	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(2)	12.1	PVENR	368.3	502.8	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(3)	13.2	PVENR	368.3	502.8	509.4	511.8	512.0	512.0	512.0	512.0	512.0	512.0	512.0
		ESL	10.9	10.9	10.9	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
		ENL	140.4	155.4	154.9	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5
(4)	14.3	PVENR	368.3	518.0	518.1	518.1	518.2	518.2	518.2	518.2	518.2	518.2	518.2
		ESL	10.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
		ENL	140.4	152.7	152.8	152.8	152.8	152.8	152.9	152.9	152.9	152.9	152.9
(5)	15.4	PVENR	368.3	518.0	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0
(6)	16.5	PVENR	368.3	518.0	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	154.0	154.0	154.0	154.0	154.0	153.9	154.1
(7)	17.6	PVENR	368.3	518.0	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.1
(8)	18.7	PVENR	369.4	518.0	519.9	520.0	520.0	520.0	520.1	520.1	520.1	520.1	520.1
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	153.9	154.0	154.0	152.9	153.0	153.0	153.0	153.0
(9)	19.8	PVENR	369.4	518.0	519.9	520.0	520.0	520.0	520.1	520.1	520.1	520.1	520.1
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	153.9	154.0	154.0	152.9	153.0	153.0	153.0	153.0
(10)	20.9	PVENR	369.4	518.0	519.9	520.0	520.0	520.1	520.1	520.1	520.1	520.1	520.1
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	153.9	154.0	154.0	152.9	152.9	152.9	152.9	152.9
(11)	22.0	PVENR	369.4	518.0	519.9	520.9	520.9	521.0	521.1	521.1	521.1	521.1	521.1
		ESL	10.9	11.9	12.3	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	140.5	152.7	153.9	153.8	153.8	153.9	153.9	153.9	153.9	153.9	153.9

Notation:
Numbers in parenthesis represent row or column numbers.
PVENR --- Present Value of Expected Net Retruen ($/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
ESL --- Expected Soil Loss over the planning period (ton/ac)
IPOTM --- Initial potentially mineralizable nitrogen in the soil (lb/ac)

Table 4.1.2 Present Value of Expected Net Return and Expected Nitrate Leaching and Soil Loss over the Planning Period of the General Model
(Continued)
IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E3 (ton/ac)			142.5	165.2	187.9	210.6	233.4	256.1	278.8	301.5	324.2	346.9	369.6
(1)	11.0	PVENR	253.0	516.0	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(2)	12.1	PVENR	253.0	516.0	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(3)	13.2	PVENR	253.0	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(4)	14.3	PVENR	253.0	536.3	536.3	536.3	536.3	536.3	536.4	536.4	536.4	536.4	536.4
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.7	157.7	157.7	157.7	157.7
(5)	15.4	PVENR	253.0	536.3	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.1	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2
(6)	16.5	PVENR	253.0	536.3	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.1	157.2
(7)	17.6	PVENR	253.0	536.3	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	157.2
(8)	18.7	PVENR	254.1	536.3	537.9	538.0	538.0	538.0	538.1	538.1	538.1	538.1	538.1
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.1	157.1	157.2	157.2	155.8	155.9	155.9	155.9	155.9
(9)	19.8	PVENR	254.1	536.3	537.9	538.0	538.0	538.0	538.1	538.1	538.1	538.1	538.1
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.1	157.1	157.2	157.2	155.8	155.9	155.9	155.9	155.9
(10)	20.9	PVENR	254.1	536.3	537.9	538.0	538.0	538.1	538.2	538.2	538.2	538.2	538.2
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.1	157.1	157.2	157.2	155.8	155.8	155.8	155.8	155.8
(11)	22.0	PVENR	254.1	536.3	537.9	539.2	539.2	539.3	539.4	539.5	539.5	539.5	539.5
		ESL	10.9	13.0	12.6	12.3	12.3	12.3	12.4	12.4	12.4	12.4	12.4
		ENL	142.0	157.5	157.1	156.9	156.9	157.0	157.0	157.0	157.0	157.0	157.0

Notation:
Numbers in parenthesis represent row or column numbers.
PVENR --- Present Value of Expected Net Retruen ($/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
ESL --- Expected Soil Loss over the planning period (ton/ac)
IPOTM --- Initial potentially mineralizable nitrogen in the soil (lb/ac)

Table 4.1.2 Present Value of Expected Net Return and Expected Nitrate Leaching and Soil Loss over the Planning Period of the General Model
(Continued)
IPOTM = 53.4 (lb/ac)

			E2 (lb/ac)										
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E3 (ton/ac)			142.5	165.2	187.9	210.6	233.4	256.1	278.8	301.5	324.2	346.9	369.6
(1)	11.0	PVENR	300.4	528.3	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	162.8	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
(2)	12.1	PVENR	300.4	528.3	538.0	607.7	607.7	607.7	607.7	607.7	607.7	607.7	607.7
		ESL	10.9	10.9	10.9	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	139.4	162.8	162.0	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5
(3)	13.2	PVENR	300.4	528.3	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	162.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(4)	14.3	PVENR	300.4	550.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9
(5)	15.4	PVENR	300.4	550.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9
(6)	16.5	PVENR	300.4	550.4	618.8	618.8	618.9	618.9	618.9	618.9	618.9	618.8	618.9
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.7	173.0
(7)	17.6	PVENR	300.4	550.4	618.8	618.8	618.9	618.9	618.9	618.9	618.9	618.9	618.9
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.9	173.0
(8)	18.7	PVENR	301.6	550.4	618.8	618.8	618.9	618.9	618.9	619.0	619.0	619.0	619.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	172.7	172.8	172.8	172.8	172.9	172.9	172.9	172.9
(9)	19.8	PVENR	301.6	550.4	618.8	618.8	618.9	618.9	618.9	619.0	619.0	619.0	619.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	172.7	172.8	172.8	172.8	172.9	172.9	172.9	172.9
(10)	20.9	PVENR	301.6	550.4	618.8	618.8	618.9	619.0	619.0	619.0	619.0	619.0	619.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	172.7	172.8	172.9	172.9	172.9	172.9	172.9	172.9
(11)	22.0	PVENR	301.6	550.4	618.8	619.0	619.0	619.2	619.2	619.3	619.3	619.3	619.3
		ESL	10.9	12.3	13.0	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
		ENL	139.5	158.8	172.7	176.6	176.6	176.7	176.7	176.7	176.7	176.7	176.7

Notation:
Numbers in parenthesis represent row or column numbers.
PVENR --- Present Value of Expected Net Retruen ($/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
ESL --- Expected Soil Loss over the planning period (ton/ac)
IPOTM --- Initial potentially mineralizable nitrogen in the soil (lb/ac)

Table 4.1.2 Present Value of Expected Net Return and Expected Nitrate Leaching and Soil Loss over the Planning Period of the General Model
(Continued)
IPOTM = 62.3 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(2)	12.1	PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(3)	13.2	PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(4)	14.3	PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.3	142.3	142.3	142.3	142.3
(5)	15.4	PVENR	350.2	565.1	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(6)	16.5	PVENR	350.2	565.1	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(7)	17.6	PVENR	350.2	565.1	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(8)	18.7	PVENR	351.3	565.1	566.3	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8
(9)	19.8	PVENR	351.3	565.1	566.3	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8
(10)	20.9	PVENR	351.3	565.1	566.3	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8
(11)	22.0	PVENR	351.3	565.1	566.3	568.0	568.0	568.0	568.1	568.2	568.2	568.2	568.2
		ESL	10.9	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	139.5	142.1	164.4	164.1	164.1	164.1	164.2	164.2	164.2	164.2	164.2

Notation:
Numbers in parenthesis represent row or column numbers.
PVENR --- Present Value of Expected Net Retruen ($/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
ESL --- Expected Soil Loss over the planning period (ton/ac)
IPOTM --- Initial potentially mineralizable nitrogen in the soil (lb/ac)

of constraints on nitrate leaching and/or soil loss; (2) except for the cases in the first column, the impacts of tightening constraints on nitrate leaching and soil loss on the PVENR are small in the general model; and (3) the PVENR will be highly affected when a 142.5 pounds per acre restriction of nitrate leaching is imposed.

4.1.2.2 Implications of the results

As demonstrated in Table 4.1.1 and Table 4.1.2, initial POTM does influence the selection of optimal AMSs and EODPs as well as the objective function values. That is, the results of the general model are sensitive to the initial POTM. The initial POTM should be explicitly considered in evaluating the transfer of agricultural management systems. The influence of the initial POTM on the outputs of general model indicates that information on the POTM in the soil is valuable to decision makers. A higher initial POTM could increase the PVENR, but also may cause a narrowing of the feasible decision set when constraints on nitrate leaching and soil loss are imposed. Conceptually, all of the bin values, which represent the values of the 23 increments of POTM in the soil as discussed in section 3.4.7.2, can be used as the initial POTM. Only four POTMs of 35.6; 44.5; 53.4; and 62.3 pounds per acre were selected here because the POTM in the soil, associated with the optimal decisions developed by the MODP model, are mostly in that range; and the current POTM in the soil in Richmond County are within that range. The most popular AMS used by farmers in Richmond County is the AMS 1 (Giuranna et al., 1991). Thus AMS 1 can be considered the conventional production practice in Richmond County. The CREAMS simulation results show that the

AMS 1 has an average POTM of 41.2 pounds per acre in a range from maximum 45.5 to minimum 38.6 pounds per acre at the beginning of the corn season. An initial POTM of 44.5 pounds per acre is thus employed to facilitate the analysis in the rest of this chapter. Results associated with the other initial POTM values are presented in Appendices D1 to D9.

4.1.2.2.1 Unrestricted case

Over the planning period, CREAMS simulation results indicate that the maximum expected nitrate leaching is 367.8 pounds per acre if AMS 2L is employed, and the maximum expected soil loss is 21.3 tons per acre if AMSs 1, 1L, or 4 are employed. In case (11 x 11), the total nitrate leaching allowed, E_2, is 369.6 pounds per acre, and the total soil loss allowed, E_3, is 22 tons per acre. Therefore, only case (11 x 11) can represent an unrestricted situation, where all potential combinations of the 14 AMSs are available. From Table 4.1.1, it can be seen AMS 15, followed by the alternating use of AMS 8 and AMS 15, is optimal in case (11 x 11). The PVENR and expected total nitrate leaching and soil loss over the planning period associated with AMS 15 and AMS 8 are \$539.5 per acre, 157.1 pounds per acre, and 12.35 tons per acre, respectively.

Three implications of the unrestricted results are: (1) priority is given to the use of commercial fertilizer; (2) winter cover crops are employed; and (3) there is an alternating use of legume and non-legume cover crops. Simulation results in Table 3.3.1 show that AMSs 1L, 2L, 3L, 8L, and 15L have an average of 62, 27, 51.5, 60.3, and 34.9 percent more nitrate leaching in a crop rotation period; an average of 19.2, 17.1, 14.1, 20.6, and 12.7 percent less nitrogen uptake by the corn; and an average of 36.7, 29.5, 38.6, 37.2, and 36.8 percent less nitrogen uptake by wheat, respectively; than their corresponding inorganic AMSs, 1, 2, 3, 8, and 15. In addition to these disadvantages of the organic fertilizer AMS, the total variable costs of AMSs 1L, 2L, 3L, 8L, and 15L are 6, 9.5, 2.6, 3.5, and 5.1 percent more, respectively, than AMSs 1, 2, 3, 8, and 15 (see Table 3.4.1). The combination of these economic and environmental disadvantages excludes all the organic fertilizer AMSs from the optimal decisions and EODPs.

Winter cover crops are essential in the model. In Table 4.1.2, most of the optimal decisions are AMS 8 and 15, and at least four out of five AMSs in the EODP of any case are the AMS 8 and 15, which employ rye and rye mixed with crimson clover as cover crops, respectively.

The environmental impacts of cover crops combined with their economic value, ultimately, result in AMS 8 and AMS 15 being the dominant optimal decisions in the general model. Two major attributes of evaluating the usefulness of legume or non-legume cover crops in an AMS are the ability to significantly reduce nitrate leaching and the ability to supply nitrogen to the next crop. In general, a non-legume cover crop can significantly reduce nitrate leaching, but make little nitrogen contribution to the next crop. Quickly establishing and exhibiting fall growth allows non-legume cover crops to compete with nitrate leaching in a timely manner. On the other hand, legumes have repeatly demonstrated their value as nitrogen source, but their impact on nitrate leaching is uncertain (Meisinger et al., 1991, Hoderbaum et al., 1990). In this study, AMSs 8, 8L, and 11L employ rye, a non-legume cover crop, and AMS

15, 15L, and 16L employ rye mixed with crimson clover, a legume cover crop. Simulation results in Table 3.3.1 show that AMS 8 has the lowest average nitrate leaching of 129.6 pounds per acre of the 14 AMSs, which is 63.9 pound per acre less than that of AMS 15, but AMS 15 has an average of 4.1 percent higher nitrogen uptake than AMS 8 in the corn season and 9.4 percent higher in the wheat season. Furthermore, AMS 15 generates a higher POTM in the soil, which can benefit to next crop in terms of nitrogen available in the soil. Alternating the use of AMS 8 and AMS 15 in the EODPs could be caused by different attributes of the legume and non-legume cover crops regarding nitrate leaching and uptake.

4.1.2.2.2 Restricted Case

The analysis of the restricted case below is based on imposing the requirements of soil conservation and water quality from the Chesapeake Bay Agreement. The Chesapeake Bay Commission (1987, p.5-6) agreed "to develop, adopt, and begin implementation of a basin-wide strategy to equitably achieve by the year 2000 at least a 40 percent reduction of nitrogen and phosphorus entering the main stem of the Chesapeake Bay" as one of its water quality goals. In terms of a living resources goal, the agreement required conserving soil resources and reducing erosion and sedimentation to protect the Bay habitat. However, no specific percentage of a reduction in soil erosion was identified.

Given that AMS 1 is the conventional AMS in Richmond County, the estimated average nitrogen loading and soil loss per acre are 178.4 pounds per acre and 21.3 tons per acre over 10 years. A 40 percent reduction of the nitrate loading requires that nitrate leaching be lower than 107 pounds per acre. From Table 4.1.1 and Table 4.1.2, a continuous use of AMS 8 in case (1 x 1) results the lowest nitrate leaching of about 142 pounds per acre, which is still 33 percent higher than the required level of nitrate loading. That is, except through idling land or employing new AMSs, none of the 14 AMSs being analyzed can be used to achieve the goal of a 40 percent reduction of nitrogen loading. However, a decrease in nitrate leaching and soil loss is possible by adopting two different sequences of AMSs, instead of conventional AMS 1. The results of adopting the unrestricted optimal decision, an alternating use of AMS 15 and AMS 8, from the general model will lead to about a 12 percent and 42 percent reduction in nitrate leaching and soil loss, respectively. Continuously using AMS 8 will lead to about 20 percent and 49 percent of reduction in nitrate leaching and soil loss, respectively. In the former case, an improvement of economic profit is expected since the unrestricted optimal decision has the maximum PVENR compared to all potential combinations of AMSs over planning period. The expected economic and environmental values are consistent in the unrestricted case. In the latter case, restricted cases in column 1, the option of continuous employment of AMS 1 is excluded from the feasible solution set due to constraints on nitrate leaching and soil loss, it is quite possible that a trade-off between economic and environmental benefits exists.

4.2 Sensitivity Analysis of the Results

Sensitivity is a system feature relating the changes in the system output due to variations in decision variables, uncontrolled parameters, constraint levels or the model's coefficients (Haimes et al., 1975). Sensitivity analysis of the general model includes variations in the grid size of the constraints on nitrate leaching and soil loss, interest rates, and planning horizon in this study. In section 4.2.1, the numbers in cells of tables represent AMSs and their associated PVENR, expected nitrate leaching, and expected soil loss. In section 4.2.2 and 4.2.3, the numbers in cells of tables represent changes in optimal AMSs and percentage changes in PVENR, expected soil loss and nitrate leaching from the results of the general model. A blank indicates that there is no change from the results of the general model. Results of the sensitivity analysis associated with four initial POTMs are given in Appendices D1 to D5.

4.2.1 Variation in the Grid Size of E_2 and E_3

The E_2 and E_3 in the tables represent not only the total limits of nitrate leaching and soil loss over planning period, but also the stage constraints on nitrate leaching and soil loss. For example, case (11 x 4) in the Table 4.1.1 generates a constraint that the soil loss and nitrate leaching from any stage, t, to the end of the planning period are equal to or less than (T-t+1)*22/T; and (T-t+1)*210.65/T, respectively. The total stages, T, are equal to 5 in the general model. The diverse EODPs associated with a particular optimal decision are partly caused by these stage constraints because, sometimes, an EODP can be employed in several different cases in terms of total soil loss and nitrate leaching over the planing period, but may not employable in terms of stage constraints.

In the general model, the intervals of constraints on nitrate leaching and soil loss were 10. Table 4.2.1 lists the optimal decisions and their associated objective function values when the intervals of E_2 and E_3 are 15. Table 4.2.1 suggests that a quite few new AMSs enter the solution and their associated objective function values seem only to represent interpolated values relative to the results in Table 4.1.2. The results of the general model are, thus, not sensitive to the grid size of the E_2 and E_3. A grid size of 10 will be used in the rest of this dissertation. Results of other initial POTM associated with an interval of 15 for the E_2 and E_3 are given in Appendix D1.

4.2.2 Variations in the Interest Rate

The discount rate used in the general model is 6 percent. Historically, estimated real interest rates have fluctuated widely in a range from negative to 10 percent in brief periods (Randall, 1987). The interest rates of 2, 10, and 0 percent were be used for the sensitivity analysis.

Table 4.2.2 shows changes in the optimal decisions and objective function values associated with an interest rate of 2 percent. The optimal decisions are unchanged, and decreases in the expected total nitrogen leaching and soil loss with an interest rate of 2 percent are than 5.5 percent less than that of the general model in Table 4.1.1 and Table 4.1.2. The lower discount rate leads to higher PVENRs in all cases. These results suggest that a lower interest rate would not significantly result in an improvement in controlling nitrate leaching and soil loss if

Table 4.2.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3

IPOTM = 44.5 (lb/ac)

E2 (lb/ac)

E3 (ton/ac)			(1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	502.6	516.0	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5
(2)	11.7	AMS	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	502.6	516.0	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5
(3)	12.5	AMS	8	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		PVENR	253.0	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9	532.9
(4)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	253.0	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3
(5)	13.9	AMS	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	253.0	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.3	536.4	536.4	536.4	536.4	536.4	536.4	536.4
(6)	14.7	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(7)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(8)	16.1	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(9)	16.9	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(10)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(11)	18.3	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	253.0	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(12)	19.1	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	254.1	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.1	538.1	538.1	538.1	538.1	538.1	538.1	538.1
(13)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	254.1	536.3	537.7	537.9	538.0	538.0	538.0	538.0	538.1	538.1	538.1	538.1	538.1	538.1	538.1	538.1
(14)	20.5	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	254.1	536.3	537.7	537.9	538.0	538.0	538.0	538.1	538.2	538.2	538.2	538.2	538.2	538.2	538.2	538.2
(15)	21.3	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	254.1	536.3	537.7	537.9	538.0	538.0	538.0	538.1	538.2	538.2	538.2	538.2	538.2	538.2	538.2	538.2
(16)	22.0	AMS	8	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	254.1	536.3	537.7	537.9	538.0	539.2	539.2	539.3	539.4	539.4	539.5	539.5	539.5	539.5	539.5	539.5

Notation:
AMS --- Optimal Agricultural Mangement System
PVENR --- Present Value of Expected Net Retruen ($/ac)
Numbers in parenthesis represent row or column numbers.

IPOTM --- Initial potentially mineralizable nitrogen

Table 4.2.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3
(continued)
IPOTM = 44.5 (lb/ac)
E2 (lb/ac)

E3 (ton/ac)			(1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	146.4	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	142.1
(2)	11.7	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	146.4	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	142.1
(3)	12.5	ESL	10.9	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
		ENL	141.9	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	142.1
(4)	13.2	ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	142.1
(5)	13.9	ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.7	157.7	157.7	157.7	157.7	157.7	142.3
(6)	14.7	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.0	157.1	157.1	157.1	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	164.4
(7)	15.4	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.0	157.1	157.1	157.1	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	164.4
(8)	16.1	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.0	157.1	157.1	157.1	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	164.4
(9)	16.9	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.0	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.1	157.1	164.4
(10)	17.6	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.0	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.2	164.4
(11)	18.3	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.0	157.1	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.2	157.2	164.4
(12)	19.1	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.0	157.1	157.1	157.1	157.2	157.2	155.8	155.8	155.8	155.9	155.9	155.9	155.9	162.8
(13)	19.8	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.0	157.1	157.1	157.1	157.2	157.2	155.8	155.8	155.8	155.9	155.9	155.9	155.9	162.8
(14)	20.5	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.0	157.1	157.1	157.1	157.2	157.2	155.8	155.8	155.8	155.8	155.8	155.8	155.8	162.8
(15)	21.3	ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.0	157.1	157.1	157.1	157.2	157.2	155.8	155.8	155.8	155.8	155.8	155.8	155.8	162.8
(16)	22.0	ESL	10.9	13.0	12.6	12.6	12.6	12.3	12.3	12.3	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
		ENL	142.0	157.5	157.0	157.1	157.1	156.9	156.9	157.0	157.0	157.0	157.0	157.0	157.0	157.0	157.0	164.2

Notation:
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
ESL --- Expected Soil Loss over the planning period (ton/ac)
Numbers in parenthesis represent row or column numbers.

Table 4.2.2 Chnages in Optimal Decision (AMS) and Percentage Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model With an Interest of 2 Percent

IPOTM = 44.5 lb/ac

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	16.6	19.8	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
		ESL											
		ENL											
(2)	12.1	AMS											
		PVENR	16.6	19.8	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
		ESL											
		ENL											
(3)	13.2	AMS											
		PVENR	16.6	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
		ESL											
		ENL											
(4)	14.3	AMS											
		PVENR	16.6	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
		ESL											
		ENL											
(5)	15.4	AMS											
		PVENR	16.6	18.3	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4
		ESL											
		ENL											
(6)	16.5	AMS											
		PVENR	16.6	18.3	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4
		ESL											
		ENL											
(7)	17.6	AMS											
		PVENR	16.6	18.3	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4
		ESL											
		ENL											
(8)	18.7	AMS											
		PVENR	16.7	18.3	18.4	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
		ESL				-5.5	-5.4	-5.4					
		ENL				-0.9	-0.9	-0.9					
(9)	19.8	AMS											
		PVENR	16.7	18.3	18.4	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
		ESL				-5.5	-5.4	-5.4					
		ENL				-0.9	-0.9	-0.9					
(10)	20.9	AMS											
		PVENR	16.7	18.3	18.4	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
		ESL				-5.5	-5.4	-5.4					
		ENL				-0.9	-0.9	-0.9					
(11)	22.0	AMS											
		PVENR	16.7	18.3	18.4	18.5	18.5	18.5	18.6	18.6	18.6	18.6	18.6
		ESL											
		ENL											

the optimal AMSs in the general model are employed in Richmond County.

Table 4.2.3 shows changes in the optimal decisions and objective function values associated with an interest rate of 10 percent. The optimal decisions are unchanged in all cases. The increases in the expected nitrate leaching are less than or equal to 1.1 percent, and the increases in the expected soil loss are less than or equal to 8.7 percent in all cases. These changes in nitrate leaching and soil loss indicate a changes in the EODPs. However, these slight changes do not necessarily suggest the results of the general model are very sensitive to a high interest rate.

Table 4.2.4 shows changes in the optimal decision and objective function values associated with an interest rate of 0 percent. The optimal decisions in all cases are unchanged, and decreases in nitrate leaching and soil loss are less than 0.9 and 5.5 percent in all cases compared to that of the general model in table 4.1.1. Zero discount rate leads to an increase in the present value of the expected net return in all cases, which ranges from 26.50 to 30.18 percent compared to the corresponding cases in general model. Detailed results associated with the interest rates of 2, 10, and 0 percent are given in Appendices D2 and D4.

4.2.3 Variation in Planning Horizon

The planning horizon can affect the optimal decisions and the EODPs as well as the objective values (Burt and Allison, 1963). The planning horizon of the general model is 10 years, which includes 5 crop rotation

Table 4.2.3 Chnages in Optimal Decision (AMS) and Percentage Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model With an Interest Rate of 10 Percent

IPOTM = 44.5 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	-13.7	-14.8	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5
		ESL											
		ENL		-5.4									
(2)	12.1	AMS											
		PVENR	-13.7	-14.8	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5	-15.5
		ESL											
		ENL		-5.4									
(3)	13.2	AMS											
		PVENR	-13.7	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9
		ESL											
		ENL											
(4)	14.3	AMS											
		PVENR	-13.7	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9	-14.9
		ESL											
		ENL											
(5)	15.4	AMS											
		PVENR	-13.7	-14.9	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
		ESL											
		ENL											
(6)	16.5	AMS											
		PVENR	-13.7	-14.9	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
		ESL			2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
		ENL											
(7)	17.6	AMS											
		PVENR	-13.7	-14.9	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
		ESL			2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
		ENL											
(8)	18.7	AMS											
		PVENR	-13.8	-14.9	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
		ESL			2.8	2.8	2.8	2.8	8.7	5.7	5.7	5.7	5.7
		ENL							1.1	0.9	0.9	0.9	0.9
(9)	19.8	AMS											
		PVENR	-13.8	-14.9	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
		ESL			2.8	2.8	2.8	2.8	8.7	5.7	5.7	5.7	5.7
		ENL							1.1	0.9	0.9	0.9	0.9
(10)	20.9	AMS											
		PVENR	-13.8	-14.9	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1	-15.1
		ESL			2.8	2.8	2.8		5.7	5.7	5.7	5.7	5.7
		ENL							0.9	0.9	0.9	0.9	0.9
(11)	22.0	AMS											
		PVENR	-13.8	-14.9	-15.1	-15.3	-15.3	-15.3	-15.3	-15.3	-15.3	-15.3	-15.3
		ESL			2.8	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
		ENL											

Table 4.2.4 Changes in Optimal Decision (AMS) and Percent Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model with an Interest of 0 percent

IPOTM = 44.5 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	26.33	31.41	30.18	30.18	30.18	30.18	30.18	30.18	30.18	30.18	30.18
		ESL											
		ENL											
(2)	12.1	AMS											
		PVENR	26.33	31.41	30.18	30.18	30.18	30.18	30.18	30.18	30.18	30.18	30.18
		ESL											
		ENL											
(3)	13.2	AMS											
		PVENR	26.33	29.05	29.05	29.05	29.05	29.05	29.05	29.05	29.05	29.05	29.05
		ESL											
		ENL											
(4)	14.3	AMS											
		PVENR	26.33	29.05	29.05	29.05	29.05	29.05	29.05	29.05	29.05	29.05	29.05
		ESL											
		ENL							-0.11	-0.11	-0.11	-0.11	-0.11
(5)	15.4	AMS											
		PVENR	26.33	29.05	29.18	29.17	29.17	29.17	29.17	29.17	29.17	29.17	29.17
		ESL											
		ENL							-0.03	-0.03	-0.03	-0.03	-0.03
(6)	16.5	AMS											
		PVENR	26.33	29.05	29.18	29.17	29.17	29.17	29.17	29.17	29.17	29.17	29.17
		ESL											
		ENL					-0.02	-0.02	-0.02	-0.02	-0.02	0.00	0.00
(7)	17.6	AMS											
		PVENR	26.33	29.05	29.18	29.17	29.17	29.17	29.17	29.17	29.17	29.17	29.17
		ESL											
		ENL					-0.02	-0.02	-0.02	-0.02	-0.02	-0.04	
(8)	18.7	AMS											
		PVENR	26.50	29.05	29.18	29.29	29.29	29.29	29.30	29.30	29.30	29.30	29.30
		ESL				-5.46	-5.38	-5.38					
		ENL				-0.90	-0.90	-0.90					
(9)	19.8	AMS											
		PVENR	26.50	29.05	29.18	29.29	29.29	29.29	29.30	29.30	29.30	29.30	29.30
		ESL				-5.46	-5.38	-5.38					
		ENL				-0.90	-0.90	-0.90					
(10)	20.9	AMS											
		PVENR	26.50	29.05	29.18	29.29	29.29	29.29	29.30	29.30	29.30	29.30	29.30
		ESL				-5.46	-5.38	-5.38					
		ENL				-0.90	-0.90	-0.90					
(11)	22.0	AMS											
		PVENR	26.50	29.05	29.18	29.37	29.37	29.37	29.38	29.39	29.39	29.39	29.39
		ESL											
		ENL											

periods. A 20 year planning horizon is used for this sensitivity analysis. Table 4.2.5 shows the changes from the results of the general model: (1) the PVENRs only increase from 55.4 to 60.9 percent due to discounting even though the planning horizon is now twice as long as that of the general model, (2) the expected total nitrate leaching increases from 82.6 to 100 percent, (3) the expected soil loss increase from 72.3 to 100.2 percent, and (4) the optimal decisions change in some cases.

Apart from these changes, the optimal decision, AMS 15 is unchanged in the unrestricted case (11 x 11) and the optimal decision, AMS 8, is unchanged in the restricted cases in the first column. However, the expected nitrate leaching, soil loss and optimal decision path of the general model vary with the planning horizon. Detailed results associated with a 20 year planning period are given in Appendix D5.

4.3 Scenarios

Stability is a measure of the resistance of the model output to expected variation in exogenous variables (Haimes et al., 1975), including changes in the decision environment such as market prices; government policy; and information on agricultural management systems. The variation of prices, including input and output prices, are considered in this section to test the stability of the results of the general model. Variations in prices could be caused by changes in market prices or changes in government policies. As in sensitivity analysis, the tables in this section represent changes in the optimal AMSs and percentage changes in the objective function values associated with four scenarios from the

Table 4.2.5 Chnages in Optimal Decision (AMS) and Percentage Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model With a 20 Year Planning Period

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	55.4	60.9	58.3	58.3	58.3	58.3	58.3	58.3	58.3	58.3	58.3
		ESL	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		ENL	100.0	82.6	83.4	83.4	83.4	83.4	83.4	83.4	83.4	83.4	83.4
(2)	12.1	AMS											
		PVENR	55.4	60.9	58.3	58.3	58.3	58.3	58.3	58.3	58.3	58.3	58.3
		ESL	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		ENL	100.0	82.6	83.4	83.5	83.5	83.5	83.5	83.5	83.5	83.5	83.5
(3)	13.2	AMS		15	15	15	15	15	15	15	15	15	15
		PVENR	55.4	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9
		ESL	100.2	72.3	72.4	72.3	72.3	72.3	72.3	72.3	72.3	72.3	72.3
		ENL	100.0	89.0	89.1	89.0	89.0	89.0	89.0	89.0	89.0	89.0	89.0
(4)	14.3	AMS		15	15	15	15	15	15	15	15	15	15
		PVENR	55.4	54.9	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0
		ESL	100.2	72.3	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5
		ENL	100.0	89.0	89.1	89.2	89.2	89.3	89.1	89.1	89.1	89.1	89.1
(5)	15.4	AMS		15	15	15	15	15	15	15	15	15	15
		PVENR	55.4	55.0	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6
		ESL	100.2	73.4	78.5	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.6
		ENL	100.0	90.5	91.1	91.2	91.2	91.2	91.2	91.2	91.2	91.2	91.2
(6)	16.5	AMS		15	15	15	15	15	15	15	15	15	15
		PVENR	55.4	55.0	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6
		ESL	100.2	73.4	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.6
		ENL	100.0	90.5	91.2	91.2	91.1	91.1	91.1	91.1	91.1	91.3	91.2
(7)	17.6	AMS		15									
		PVENR	55.4	55.0	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6	54.6
		ESL	100.2	73.4	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.6	78.6
		ENL	100.0	90.5	91.2	91.2	91.1	91.1	91.1	91.1	91.2	91.2	91.2
(8)	18.7	AMS		15									
		PVENR	55.0	55.0	54.6	54.6	54.6	54.6	54.5	54.5	54.5	54.5	54.5
		ESL	99.7	73.4	78.6	78.6	78.6	76.3	86.4	86.4	86.4	86.4	86.4
		ENL	100.0	90.5	91.2	91.1	91.1	90.8	92.5	92.4	92.4	92.4	92.4
(9)	19.8	AMS		15									
		PVENR	55.0	55.0	54.6	54.6	54.6	54.6	54.5	54.5	54.5	54.5	54.5
		ESL	99.7	73.4	78.6	78.6	78.6	76.3	86.4	86.4	86.4	86.4	86.4
		ENL	100.0	90.5	91.2	91.1	91.1	90.8	92.5	92.4	92.4	92.4	92.4
(10)	20.9	AMS		15									
		PVENR	55.0	55.0	54.6	54.6	54.6	54.6	54.5	54.5	54.5	54.5	54.5
		ESL	99.7	73.4	78.6	78.6	78.6	76.3	86.4	86.4	86.4	86.4	86.4
		ENL	100.0	90.5	91.2	91.1	91.1	90.8	92.4	92.4	92.4	92.4	92.4
(11)	22.0	AMS		15									
		PVENR	55.0	55.0	54.6	54.3	54.3	54.3	54.3	54.2	54.2	54.2	54.2
		ESL	99.7	73.4	78.6	83.5	83.6	83.7	83.6	83.6	83.6	83.6	83.6
		ENL	100.0	90.5	91.2	92.8	92.9	92.8	92.7	92.7	92.7	92.7	92.7

results of the general model. Detailed results associated with four different initial POTMs are given in Appendices D6 to D9.

4.3.1 A 30 Percent Decrease in Poultry Litter Prices

The general model totally excludes the organic fertilizer AMSs from the optimal decisions. Higher nitrate leaching and lower nitrogen uptake of these organic fertilizer AMSs lead to lower fertilizer use efficiency[27]. In addition to their environmental disadvantages, the cost, which include the costs of nitrogen; phosphorus; and potassium, of these organic fertilizer AMSs is about 14.8 to 34.8 percent higher than that of the corresponding inorganic fertilizer AMSs. Savings in the application cost is only $1.28 per acre for the organic fertilizer AMSs. The total variable costs of organic fertilizer AMSs are about 2.6 to 9.5 percent higher than that of the corresponding inorganic fertilizer AMSs. However, the price of poultry litter could be lower than the price used in this study if: (1) a more competitive market for poultry litter is developed, (2) the poultry operators are required to dispose of their waste in an environmentally sound manner (Diebel, 1990), or (3) government subsidies for the use of poultry litter are available.

This scenario assumes a 30 percent decrease of the poultry litter price from $27 per ton to $18.9 per ton, which makes the nutrient costs of the organic fertilizer AMSs about 5.4 to 19.4 lower than that of their corresponding inorganic fertilizer AMSs. Results associated with a 30

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[27] Fertilizer use efficiency is defined by Parr (1973) as the percentage recovery of fertilizer nitrogen by the crop.

percent decrease in the price of poultry litter show that there is not any change in either the optimal decisions or the objective values. That is, all organic fertilizer AMSs are still excluded from the optimal decisions and EODPs. Lower crop yields, as mentioned in section 4.1.2.2, make organic fertilizer AMSs inferior to their corresponding inorganic fertilizer AMSs.

4.3.2 A 30 Percent Increase in Commercial Nitrogen Price

A higher commercial fertilizer price, through taxing commercial fertilizer, has been proposed as a strategy to lower the use of commercial fertilizer in agriculture (Diebel, 1990; Halstead, 1988). The consequence of a 30 percent increase in the price of commercial nitrogen in the study area was examined. The results of this price increase in Table 4.3.1 show that: (1) the optimal decisions are unchanged in most cases, (2) the expected nitrate leaching and soil loss are slightly changed in some cases, (3) the PVENRs are less than that of the general model in Table 4.1.2. The first two points are due to slight changes in EODPs. Inorganic fertilizer AMSs are still preferred to organic fertilizer AMSs in the study area.

The nitrogen costs of the 6 inorganic fertilizer AMSs range from 56.4 to 66.2 percent of their nutrient costs, and are about 14.3 to 19.1 percent of their total variable costs. A 30 percent increase of commercial nitrogen price, from $0.28 per pound to $0.36 per pound, results in only an 4.3 to 5.7 percent increase in the total variable costs of these inorganic fertilizer AMSs. Detailed results of this scenario

Table 4.3.1 Chnages in Optimal Decision and Percentage Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model With a 30 Percent Increasing Commercial Nitrogen Price

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	-26.3	-12.9	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7
		ESL											
		ENL											
(2)	12.1	AMS											
		PVENR	-26.3	-12.9	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7	-12.7
		ESL											
		ENL											
(3)	13.2	AMS											
		PVENR	-26.3	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4
		ESL											
		ENL											
(4)	14.3	AMS		15	15	15	15	15	15	15	15	15	15
		PVENR	-26.3	-12.3	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2
		ESL		-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4
		ENL		-1.2	-1.1	-1.1	-1.1	-1.1	-1.2	-1.2	-1.2	-1.2	-1.2
(5)	15.4	AMS		15									
		PVENR	-26.3	-12.3	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4
		ESL		-6.4									
		ENL		-1.2									
(6)	16.5	AMS		15									
		PVENR	-26.3	-12.3	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4
		ESL		-6.4									
		ENL		-1.2									
(7)	17.6	AMS		15									
		PVENR	-26.3	-12.3	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4
		ESL		-6.4									
		ENL		-1.2									
(8)	18.7	AMS		15									
		PVENR	-26.2	-12.3	-12.4	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2
		ESL		-6.4		-5.4	-5.4	-5.4					
		ENL		-1.2		-0.9	-0.9	-0.9					
(9)	19.8	AMS		15									
		PVENR	-26.2	-12.3	-12.4	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2
		ESL		-6.4		-5.4	-5.4	-5.4					
		ENL		-1.2		-0.9	-0.9	-0.9					
(10)	20.9	AMS		15									
		PVENR	-26.2	-12.3	-12.4	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2
		ESL		-6.4		-5.4	-5.4	-5.4					
		ENL		-1.2		-0.9	-0.9	-0.9					
(11)	22.0	AMS		15									
		PVENR	-26.2	-12.3	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4	-12.4
		ESL		-6.4									
		ENL		-1.2									

associated with four different initial POTMs are given in Appendix D6.

4.3.3 A 20 Percent Reduction in Crop Prices

To eliminate the effects of inflation when historical prices are used, price indexes are commonly used, which include the U.S. Department of Labor Consumer Price Index (CPI) and Producer Price Index (PPI), and Department of Agriculture Index of Prices Received by Farmer (PRF) and Index of Prices Paid by Farmer (PPF). The PRF index was used to adjust the nineteen year crop prices in Northern Virginia, then the average of the adjusted prices was used in the general model. McSweeny et al. (1987) argued that different price indexes will lead to different solutions in a risk programming model. When different indices are used for adjusting historical price data, the mean values as well as variances are different. The average of adjusted prices, thus, vary when different price indices are employed. For example, in this study, the average of the adjusted prices (in 1988 dollars) of corn; wheat; and soybeans are $2.52; $3.03; and $6.13 per bushel when the PRF is employed, but are $4.02; $4.82; and $9.59 per bushel when the CPI is employed.

With a 20 percent decrease in crop prices, Table 4.3.2 shows that outputs of the general model, including optimal decision; PVENR; and expected total nitrate leaching and soil loss are changed. Several points are apparent: (1) AMS 15 is replaced by AMS 3, (2) the PVENRs decrease from 72.7 to 89.6 percent, (3) changes in the expected nitrate leaching vary from -12 to +24.7 percent, (4) changes in soil loss vary from -32.4 to +50.6 percent. These changes are because AMS 15 has a higher yield,

Table 4.3.2 Chnages in Optimal Decision (AMS) and Percentage Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model With a 20 Percent Decreasing Crop Prices

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	-89.6	-89.0	-89.1	-89.1	-89.1	-89.1	-89.1	-89.1	-89.1	-89.1	-89.1
		ESL	-32.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4
		ENL	-12.0	-9.7	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2
(2)	12.1	AMS											
		PVENR	-89.6	-88.7	-88.9	-88.9	-88.9	-88.9	-88.9	-88.9	-88.9	-88.9	-88.9
		ESL	-32.4	-6.9	-6.9	-6.9	-6.9	-6.9	-6.9	-6.9	-6.9	-6.9	-6.9
		ENL	-12.0	-9.2	-8.8	-8.8	-8.8	-8.8	-8.8	-8.8	-8.8	-8.8	-8.8
(3)	13.2	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.9	-81.9	-81.9	-81.9	-81.9	-81.9	-81.9	-81.9	-81.9	-81.9
		ESL	-32.4										
		ENL	-12.0	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
(4)	14.3	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-81.7	-81.7	-81.7	-81.7	-81.7	-81.7	-81.7	-81.7	-81.7
		ESL	-32.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
		ENL	-12.0	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1
(5)	15.4	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-81.8	-81.8	-81.8	-81.8	-81.8	-81.8	-81.8	-81.8	-81.8
		ESL	-32.4	1.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
		ENL	-12.0	3.2	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4
(6)	16.5	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6
		ESL	-32.4	1.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
		ENL	-12.0	3.2	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
(7)	17.6	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6	-76.6
		ESL	-32.4	1.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
		ENL	-12.0	3.2	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
(8)	18.7	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-76.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6
		ESL	-32.7	1.5	26.8	47.2	47.2	47.2	55.5	55.5	55.5	55.5	55.5
		ENL	-12.0	3.3	13.9	23.7	23.6	23.6	24.7	24.7	24.7	24.7	24.7
(9)	19.8	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-76.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6
		ESL	-32.7	1.5	26.8	47.2	47.2	47.2	55.5	55.5	55.5	55.5	55.5
		ENL	-12.0	3.3	13.9	23.7	23.6	23.6	24.7	24.7	24.7	24.7	24.7
(10)	20.9	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-76.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6	-72.6
		ESL	-32.7	1.5	26.8	47.2	47.2	47.2	55.5	55.5	55.5	55.5	55.5
		ENL	-12.0	3.3	13.9	23.7	23.6	23.6	24.7	24.7	24.7	24.7	24.7
(11)	22.0	AMS		3	3	3	3	3	3	3	3	3	3
		PVENR	-89.6	-81.7	-76.6	-72.7	-72.7	-72.7	-72.7	-72.7	-72.7	-72.7	-72.7
		ESL	-32.7	1.5	26.8	50.7	50.7	50.7	50.6	50.6	50.6	50.6	50.6
		ENL	-12.0	3.3	13.9	23.8	23.8	23.8	23.7	23.7	23.7	23.7	23.7

higher variable cost, and lower soil loss than AMS 3, while AMS 3 has a lower fertilizer application rate, total variable cost, yield, and a higher soil loss. A lower crop price makes AMS 15 less profitable than AMS 3. For example, in case (11 x 11), optimal decision, AMS 15, is replaced by AMS 3. As a result, the PVENR declines 72.7 percent, the expected total nitrate leaching increases 23.7 percent, and the expected total soil loss increases 50.6 percent. Detailed results of this scenario associated with four different initial POTMs are given in Appendix D7.

4.3.4 A 20 Percent Increase in Crop Prices

Table 4.3.3 shows the changes in the optimal decisions, expected nitrate leaching, and expected soil loss when the crop prices by increase 20 percent. The optimal decisions are unchanged in most cases, especially in the unrestricted case (11 x 11) and restricted cases in column 1. With a 20 percent increase in crop prices, the PVENRs increase from 86.7 to 163.4 percent per acre. Changes in the expected nitrate leaching vary from 0 to 13.3 percent, and changes in the expected soil loss vary from -9.5 to 5.7 percent. It is interesting to note that the PVENR of the restricted case is now $666.17 per acre, which is quit a bit higher than the PVENR of $253.00 per acre in the restricted case of the general model. The expected nitrate leaching and soil loss associated in the restricted cases are unchanged. Detailed results of this scenario associated with four different initial POTMs are given in Appendix D8.

Table 4.3.3 Chnages in Optimal Decision (AMS) and Percentage Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model With a 20 Percent Increasing Crop Prices

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	163.4	91.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1
		ESL											
		ENL											
(2)	12.1	AMS											
		PVENR	163.4	91.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1
		ESL											
		ENL											
(3)	13.2	AMS				15	15	15	15	15	15	15	15
		PVENR	163.4	86.0	86.0	86.4	86.4	86.4	86.4	86.4	86.4	86.4	86.4
		ESL				-9.5	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4
		ENL				13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
(4)	14.3	AMS				15	15	15	15	15	15	15	15
		PVENR	163.4	86.0	86.0	86.4	86.4	86.4	86.4	86.4	86.4	86.4	86.4
		ESL				-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4
		ENL				13.3	13.3	13.3	13.2	13.2	13.2	13.2	13.2
(5)	15.4	AMS											
		PVENR	163.4	86.0	86.7	86.7	86.7	86.7	86.7	86.7	86.7	86.7	86.7
		ESL											
		ENL											
(6)	16.5	AMS											
		PVENR	163.4	86.0	86.7	86.7	86.7	86.7	86.7	86.7	86.7	87.1	87.1
		ESL										-8.0	-8.0
		ENL										11.0	11.0
(7)	17.6	AMS											
		PVENR	163.4	86.0	86.7	86.7	86.7	86.7	86.7	86.7	86.7	87.1	87.1
		ESL										-8.0	-8.0
		ENL										11.0	11.0
(8)	18.7	AMS											
		PVENR	163.0	86.0	86.7	86.7	86.7	86.7	86.7	86.7	86.7	87.0	87.0
		ESL							5.7	5.7	5.7	-2.8	-2.8
		ENL							0.8	0.9	0.9	12.0	12.0
(9)	19.8	AMS											
		PVENR	163.0	86.0	86.7	86.7	86.7	86.7	86.7	86.7	86.7	87.0	87.0
		ESL							5.7	5.7	5.7	-2.7	-2.7
		ENL							0.8	0.9	0.9	12.0	12.0
(10)	20.9	AMS											
		PVENR	163.0	86.0	86.7	86.7	86.7	86.7	86.7	86.7	86.7	87.0	87.0
		ESL							5.7	5.7	5.7	-2.7	-2.7
		ENL							0.9	0.9	0.9	12.0	12.0
(11)	22.0	AMS											
		PVENR	163.0	86.0	86.7	87.2	87.2	87.2	87.2	87.1	87.1	87.1	87.1
		ESL											
		ENL											

4.3.5 An Approximation of the Price Impacts of Commodity Programs

As described in section 3.2, to precisely examine the impacts of commodity program on the optimal decision and objective function values in this model, the patterns of target prices and market prices, acreage reduction percentage in the planning period, and alternative crops in the required and optional flex acres have to be considered. Due to a lacks of data such as relationship between market prices and target prices in Richmond County, an approximation of the price impacts of commodity programs is examined in this research through changing the average of adjusted prices in the model. Tirupattur (1990) employed a target MOTAD model to find that farmers join government commodity program could significantly increase the net return. An approximate examination of the price impacts of commodity program assumes a 20 percent increases in the prices of corn and wheat, crops in this model which are eligible to join the government commodity programs, and unchanged soybean prices.

Table 4.3.4 shows the changes in the optimal decision and objective functions associated with this approximate examination. The optimal decisions are unchanged in most cases. The present value of expected net return increase from 65.2 to 119.4 percent compared to the results of the general model. Nitrate leaching increases from 0.8 to 13.3; and soil loss changes from -9.5 to 5.7 percent in some cases. However, there is no changes in optimal decision and expected soil loss and nitrate leaching in either restricted case in column 1 or unrestricted case (11 X 11). Detailed results of this scenario associated with four different initial POTMs are given in Appendix D9.

Table 4.3.4 Changes in Optimal Decision (AMS) and Percent Changes in Present Value of Expected Net Return (PVENR) and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) from the General Model with Impacts of Commodity Programs

IPOTM = 44.5 (lb/ac)

E2 (lb/ac)

E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS											
		PVENR	119.39	69.51	68.78	68.78	68.78	68.78	68.78	68.78	68.78	68.78	68.78
		ESL											
		ENL											
(2)	12.1	AMS											
		PVENR	119.39	69.51	68.78	68.78	68.78	68.78	68.78	68.78	68.78	68.78	68.78
		ESL											
		ENL											
(3)	13.2	AMS				15	15	15	15	15	15	15	15
		PVENR	119.39	65.19	65.19	65.55	65.60	65.60	65.60	65.60	65.60	65.60	65.60
		ESL				-9.46	-9.38	-9.38	-9.38	-9.38	-9.38	-9.38	-9.38
		ENL				13.25	13.33	13.33	13.33	13.33	13.33	13.33	13.33
(4)	14.3	AMS				15	15	15	15	15	15	15	15
		PVENR	119.39	65.19	65.19	65.56	65.60	65.60	65.60	65.60	65.60	65.60	65.60
		ESL				-9.38	-9.38	-9.38	-9.38	-9.38	-9.38	-9.38	-9.38
		ENL				13.27	13.33	13.33	13.20	13.20	13.20	13.20	13.20
(5)	15.4	AMS											
		PVENR	119.39	65.19	65.99	65.99	65.99	65.99	65.99	65.99	65.99	65.99	65.99
		ESL											
		ENL							-0.03	-0.03	-0.03	-0.03	-0.03
(6)	16.5	AMS											
		PVENR	119.39	65.19	65.99	65.99	65.99	65.99	65.99	65.99	65.99	66.33	66.33
		ESL										-7.99	-7.99
		ENL					-0.02	-0.02	-0.02	-0.02	-0.02	11.00	10.99
(7)	17.6	AMS											
		PVENR	119.39	65.19	65.99	65.99	65.99	65.99	65.99	65.99	65.99	66.33	66.33
		ESL											
		ENL					-0.02	-0.02	-0.02	-0.02	-0.02	10.95	10.99
(8)	18.7	AMS											
		PVENR	119.12	65.19	65.99	65.99	65.98	65.98	65.95	65.95	65.95	66.31	66.31
		ESL							5.69	5.69	5.69	-2.76	-2.76
		ENL					-0.02	-0.02	0.83	0.86	0.86	11.95	12.02
(9)	19.8	AMS											
		PVENR	119.12	65.19	65.99	65.99	65.98	65.98	65.95	65.95	65.95	66.31	66.31
		ESL							5.69	5.69	5.69	-2.68	-2.68
		ENL					-0.02	-0.02	0.83	0.86	0.86	12.00	12.00
(10)	20.9	AMS											
		PVENR	119.12	65.19	65.99	65.99	65.98	65.98	65.95	65.95	65.95	66.31	66.31
		ESL							5.69	5.69	5.69	-2.68	-2.68
		ENL							0.86	0.86	0.86	12.02	12.02
(11)	22.0	AMS											
		PVENR	119.12	65.19	65.99	66.49	66.49	66.48	66.46	66.46	66.46	66.46	66.46
		ESL				-0.08	-0.08	0.00	-0.08	-0.08	-0.08	-0.08	-0.08
		ENL				-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03

Chapter 5 Summary and Conclusions

This chapter starts with a summary of this dissertation through reviewing the completion of the objectives through the theoretical development and its empirical application. Then, some conclusions are presented. Finally, limitations and suggestions for further research are given.

5.1 Summary

In the theoretical part of this dissertations, the interpretation, foundations, and framework of the concept of sustainable development were addressed. Four specific objectives were completed in this part.

5.1.1 Objective 1--Review of Various Consideration of Sustainable Development

The formation of the concept of sustainable development could be thought as being due to public concerns with respect to the global challenge of environmental decline and a new understanding of the environment. Various aspects of sustainable development are based on the six "E" considerations: *Economics*, *Energy*, *Environment*, *Ecology*, *Equity*, *and Ethics*. These different considerations complement each other and widen the alternative ways of inquiry into sustainable development. However, sometimes, these considerations are in conflict, explicitly or implicitly. The metabelief of relative or absolute scarcity is one of the basic differences between the concept of sustainable development and neoclassical economics.

5.1.2 Objective 2--A Systems Theory Perspective of the Concept of Sustainable Development and Neoclassical Economics

The definition and classification of systems were explained as the basis for systematic analysis. Several carelessly defined systems were discussed, and their associated incorrect conclusions were identified.

An economic system, from the neoclassical point of view, could be abstracted as a closed-loop system in terms of marketing and policy feedback, but an open system in terms of its relation to the environment of the economic system. The economic system has two "open ends" to its environment, represented by resource inputs and waste output. Resource scarcity is only an economic concept, not physical one. Scarcity could be mitigated by technical innovation and substitution through price changes such that there is only relative scarcity, rather than absolute scarcity. The neoclassical economics perspective is a one dimensional approach, a pure economic approach.

The concept of sustainable development challenges these two "open ends" of the neoclassical paradigm. This concept connects these two "open ends" to ecosystems and social systems. Advocates of sustainable development view the economic approach a process that "pumps" resources from the environment and discharges wastes into the environment. The gradually increasing dimensions of the economic system accelerate natural resource use and environmental decline, which leads to absolute resource scarcity. From the input side, absolute scarcity is represented by the limited quantity of resources. From the output side, absolute scarcity is represented by the limits of the assimilative capacity of the environment.

Sustainable economic development, thus, requires an explicit consideration of economic systems, social systems, and ecosystems, a three dimensional approach.

5.1.3 Objective 3--Examination of the Applicability of the Second Law of Thermodynamics to the Conclusion of the Absolute Quantity Limit to Growth

Advocates of the absolute quantity limit of resources generally employ the second law of thermodynamics to argue the absolute quantity limit to economic growth is imposed by the irreversible trends of entropy. This conclusion is incorrect because of: (1) their careless definition of the global system, (2) their use of an inappropriate form of the second law of thermodynamics, and (3) conceptual contradictions in their argument. In fact: (1) the global system is an open system rather than a closed system; (2) irreversible tendency of entropy changes can be applied only to closed and non-living systems; and (3) if absolute entropy throughput limits exist, then no system can be sustained on the earth, including sustainable development systems. If absolute entropy limits do not exist, the second law of thermodynamics should not provide the foundation for sustainable development concepts.

5.1.4 Objective 4-- Analysis of Sustainable Low-input Agricultural Production Systems

Low-input agriculture is often thought as a step to sustainable agriculture, which has multiple goals of economic vitality; environmental soundness; and social justice. However, low-input production systems do not necessarily achieve all these goals automatically. A three range relationship between economic and environmental goals was suggested. The viability of low-input agricultural production systems depends on the natural and marketing conditions being analyzed. When inconsistent relationships among these goals exists, trade-offs are an important feature to be considered. In addition to the multiple objective, dynamic and stochastic features of agricultural production systems have to be considered when either low-input or conventional production systems are evaluated.

The second part of this dissertation employs multiple criteria to evaluate the agricultural management systems (AMSs), including conventional and low-input systems, in Richmond County, Virginia. Economic impacts and environmental impacts, measured as soil loss and nitrate leaching, of these systems are simultaneously evaluated. The second part of the dissertation completes the final three specific objectives.

5.1.5 Objective 5--Development of An Empirical Technique to Evaluate the Economic and Environmental Impacts of Agricultural Management Systems

Models are generally constructed to provide information about systems of interest. An appropriate model for evaluation of the AMSs needs to consider multi-objective, dynamic, and stochastic features of the AMSs. Basically, three types of approaches can be used as solution methods for multi-objective problems. The first finds the preferred solution directly; the second weighs objectives and transforms the multi-objective problem to single objective problem; and the third starts from objectively generating a non-inferior solution and then subjectively finds a preferred solution from the non-inferior set. The third approach has advantages of separating objective analysis from subjective choices and avoiding the need to initialize the analysis with exploration of decision makers' preferences. As one of the third approaches, the surrogate worth trade-off (SWT) method can: (1) handle quantitatively multidimensional and multidirectional objectives in both commensurable and non-commensurable cases; (2) provide decision makers additional quantitative information on the non-inferior frontiers; and (3) incorporate operational methods, such as stochastic and dynamic analysis techniques, with multi-objectives. The SWT method was used as the solution method in this study.

5.1.6 Objective 6--Development of Parameters for CREAMS Simulation Model in Order to Predict and Compare Non-point Source Pollution and Crop Yield Response of the AMSs

Estimation of soil loss and nitrate leaching caused by various AMSs is necessary to conduct the multiple objective evaluation of the AMSs. The CREAMS simulation model predicts surface runoff, sediment, and nitrate leaching, but does not completely simulate the nitrogen cycle. CREAMS does not consider nitrogen fixation and immobilization and incompletely considers mineralization; denitrification; and volatilization. These deficiencies are ameliorated through adjusting parameters of nutrient components. One of the obstacles to coupling the CREAMS simulation model to a multi-objective dynamic programming model is that the simulation results only represent a continuous employment of a particular AMS over the simulation period. To provide the information on the environmental impacts of mixed employment of the different AMSs, regression analysis was employed to extend these simulation results to a dynamic framework.

5.1.7 Objective 7--Employment of a Multi-objective Dynamic Model to Quantitatively Determine Consistent and Inconsistent Relationships between Economic and Non-point Source Pollution Impacts of Conventional and Low-input Agriculture

A three objective dynamic programming model was developed for evaluating the AMSs in Richmond County, Virginia. This model has three objectives: maximizing the present value of the expected net return per acre over a 10 year planning horizon; protection of groundwater from nitrate contamination; and soil conservation. The present value of net returns per acre is an economic criterion and is the reference objective, while the two environmental objectives are imposed as constraints. The state variable of the multi-objective dynamic programming (MODP) model is potentially mineralizable nitrogen (POTM), and the random variable is water percolation. Fourteen existing or potentially employable AMSs are the decision variables. A computer program in FORTRAN 77 was developed to solve the MODP model.

Results from the general MODP model include the optimal decisions, expected optimal decision paths, present value of the expected net return (PVENR), expected nitrate leaching and soil loss over the planning horizon under various constraints on nitrate leaching and soil loss. Analysis of these results were based on unrestricted and restricted cases. In the former case, constraints on the soil loss and nitrate leaching are totally relaxed. In that case, results of the general model are that: (1) priority is given to the use of commercial fertilizer, (2) winter cover crops are employed, and (3) there is an alternating use of legume and non-legume cover crops. The results of adoption of unrestricted optimal decision, an alternating use of AMS 15 and AMS 8, lead to about 12 percent and 42 percent of reduction in nitrate leaching and soil loss, respectively, from the conventional AMS, AMS 1. In the latter case, a 40 percent decrease in nitrate loading as required by the Chesapeake Bay Agreement is considered. The restricted results show that a continuous use of AMS 8 will only lead to 20 percent reduction in nitrate loading, a 49 percent reduction in soil loss from the conventional AMS 1, and a 75 percent reduction in PVENR from the unrestricted case. None of the 14 AMSs being analyzed can be used to achieve the goal of a 40 percent reduction in nitrogen leaching except through idling land.

Sensitivity analysis includes variation of the grid size of constraints on nitrate leaching and soil loss, interest rates, and planning horizon. The results of the sensitivity analysis indicate that the general MODP model results are not sensitive to grid size and lower interest rate, and that they are not very sensitive to the higher interest rates and planning horizon.

Scenarios being employed include: (1) a 30 percent decrease in poultry litter prices, (2) a 30 percent increase in commercial nitrogen price, (3) a 20 percent reduction in crop prices, (4) a 20 percent increase in crop prices, and (5) an approximation of the price impacts of commodity program. A brief summary of results from these scenarios are follows.

The scenario of a 30 percent decrease in poultry litter price changes neither optimal decisions nor the objective function values associated with these optimal decisions when compared to the general model. A 30 percent decrease in poultry litter price, from $27 per ton to $18.9 per ton, makes the nutrient costs of the organic fertilizer AMSs about 5.4 to 19.4 lower than that of their corresponding inorganic fertilizer AMSs. However, results from this scenario show all organic fertilizer AMSs are still excluded from the optimal decisions.

The scenario of a 30 percent increase in commercial nitrogen price results in a decrease in PVENR and slightly changes the optimal decisions. The expected soil loss and nitrate leaching associated with these optimal decisions decreases approximately 1 percent and 6 percent, respectively.

The scenario of a 20 percent decrease in crop prices results in large changes in optimal decisions and PVENR as well as the expected nitrate leaching and soil loss. Compared to the general model, AMS 15 is replaced by AMS 3 in the unrestricted case (11 X 11). As a result, the PVENR decreases 73 percent, the expected nitrate leaching increases 24 percent, and the expected total soil loss increases 51 percent. These changes are because AMS 15 has a higher yield, higher variable cost, and lower soil loss than AMS 3, while AMS 3 has a lower fertilizer application rate, total variable cost, yield, and a higher soil loss.

The scenario of a 20 percent increase in crop prices results in no change in optimal decisions and the expected nitrate leaching and soil loss in unrestricted and restricted cases of the general model, but the PVENR increases 87 and 163 percent in these cases, respectively.

The scenario of an approximation of the price impacts of commodity program results in no change in optimal decisions and the expected nitrate leaching and soil loss in unrestricted and restricted cases of the general model, but the PVENR increases 66 and 119 percent in these cases, respectively.

5.2 Conclusions

5.2.1 Conclusions of the Theoretical Part

Formation and development of the concept of sustainable development is the product of the evolution of the global system, including human societies, biosystems, and physical systems. The spread of this concept is a process of criss-cross effects of "scholarly knowledge" and "folk knowledge." Maturitation of this concept depends on the communication among disciplines and among disciplines and the public. Applicability of the concept of sustainable development requires that it be compatible with social ideology, the social environment, and harmonious social relations, which change with time; human knowledge; ethics; and economic conditions at different stages of socioeconomic development.

As a concept and a way of thinking, sustainable development is easily acceptable. As a guide to the decision and policy making process related to environmental and natural resources management, further theoretical study is necessary. Not all decisions related to resource and environmental management can be made based on the beliefs, morals, and ethics of sustainable development.

Exploration of the scientific foundations of the concept of sustainable development is important. In fact, whether the tendency for entropy change can be applied to a large system such as the universe, the solar system, or the global system is not yet known. Building the foundation of sustainable development on the assumption that economic growth is ultimately constrained by the second law of thermodynamics is conceptually self-contradictory. If absolute entropy throughput limits exist, then no system can be sustained on the earth, including sustainable development systems. If absolute entropy limits do not exist, such an assumption should not provide the foundation for sustainable development concepts. The conclusion that the second law of thermodynamics is not appropriately applied to the global system implies that sustainable development advocates can not rely on an immutable scientific principle to claim that there are severe near-term limits to economic growth. Nor are there obvious near-term limits to population growth. Nor can the possibility of continually rising standards of living be ruled a scientific impossibility. However neither does the inapplicability of the second law imply that there are no limits to growth posed by the assimilative capacity of the biosphere or by a catastrophe collapse due to factors such as deforestation or species extinction. Instead, the inapplicability of the second law would widen the range of alternative choices that can be included in the design of a sustainable development path.

Development of applicable technologies is also necessary in order to apply the concept of sustainable development to empirical resource and environmental problems. The concept of sustainable development can inspire new evaluation techniques as well as stimulate modification of traditional techniques of economic analysis. Appropriate technologies can, quantitatively or qualitatively, explore the interdependencies and relationships among the factors of interest in complex resource and environmental issues including the perceptions of analysts and decision makers.

5.2.2 Conclusions of the Empirical Application Part

Results of the general MODP model indicate that the conventional AMS, AMS 1, in Richmond County is not preferred from the perspective of either economic benefits or environmental objectives. Improvement in these objectives can not be achieved by simply decreasing fertilizer rate or using poultry litter as nitrogen source in the study area. Results of the general MODP model in this study suggest that an alternating use of legume and non-legume cover crops, AMS 15 and AMS 8, over the planning horizon lead to an increase in economic profit and decrease in nitrate leaching and soil loss.

Results of scenarios with adjustment in commercial and poultry litter prices indicate that fertilizer prices have little impact on the optimal decisions as well as the objective function values. Benefits from higher nitrogen uptake of inorganic fertilizer AMSs and their low environmental impacts rules out the employment of organic fertilizer AMSs even when commercial fertilizer price increases 30 percent or poultry litter price decreases 30 percent. These results also indicate that the lower fertilizer use efficiency, which leads to a lower economic return and higher environmental impacts, is a major barrier to adoption of the organic fertilizer AMSs in the study area, but that the price of poultry litter is itself, not a barrier.

Results of scenarios with adjustments to crop prices indicate that lower crop prices lead to a decrease in the economic and environmental objective function values; and lead to employment of less environmental benign AMSs. However, higher crop prices stimulate the employment of cover crops in the study area, which is helpful in protecting the environment. Therefore, policy implications of this study are that maintaining a higher crop price will be an incentive to adopt the more environmentally sound AMSs, and is more effective than subsidizing the use of poultry litter or penalizing the price of commercial fertilizer.

Multiple criteria evaluation of the AMSs is complex. Both estimation of the environmental impacts of the AMSs and the decision environment such as market prices play a crucial role in these results. Low-input agricultural production systems are generally thought to be a step to sustainable agriculture. However, to be economically viable and environmentally sound, the most important consideration for selection of the best AMSs in different areas is the suitability of these management systems to local natural conditions and marketing conditions, rather than simply advocating practices with the "low-input" label.

5.3 The Limitations of this Research

There are several limitations to this research. First, information on economic and environmental impacts of the AMSs for multiple criteria evaluation is inadequate. This limitation arises due to two deficiencies in this study. They are a deficiency in simulating the nitrogen cycle in CREAMS and the deficiency of an appropriate algorithm to directly combine the physical simulation model with the economic analysis model. The first deficiency is ameliorated through adjusting parameters of nutrient components as described in section 3.3.2. The second deficiency is Overcame by regressing the simulation results as described in section 3.3.5. However, these adjustments need to be carried further.

Second, due to a lack of appropriate patterns for target prices and percent of required acreage reduction, the general MODP model and analysis scenarios did not include the government programs. Tirupattur (1990) argued that government commodity programs could significantly increase the expected net return and decrease the associated risk level, even if there is a relatively low rate of enrollment in government commodity programs in Virginia's Northern Neck. Explicitly adding government policy to the MODP model could make the decision model more realistic.

Third, more AMSs for study area need to be evaluated in the MODP model. The results of the general MODP model in Table 4.1.2 indicate that trade-offs exist among the PVENR, expected nitrate leaching, and expected soil loss. Conceptually, these trade-offs could be represented by a "smooth" trade-off surface. However, insufficient decision variables make the trade-off surface kinked.

5.4 Implications for Further Research

The subjective choice of the best decision from the non-inferior solution set, developed by this study, is the natural extension of this research, and it is the second step of the SWT method; while the MODP model in this study is the first step. The best decisions chosen by farmers and non-farmer groups are likely to different. Their reactions to these quantitative results reflect their social desirability in different social groups.

Risk analysis could be added to the MODP model. As mentioned in section 3.1.3, the uncertainty/sensitivity index method can treat risk and sensitivity as separate objectives rather than as an over all index of model performance. This technique has been used by previous researchers. Adding risk analysis to the MODP model will provide more information for the subjective choice of the best decision.

In this study, decisions are only made at the beginning of every crop rotation period, an inter-crop rotation period decision approach. All agricultural practices of a particular AMS in a crop rotation period, thus, are unchanged. Such a decision making approach could be improved through treating fertilizer rate as an independent variable. That is, inter- and intra-crop rotation period decision making approaches could be combined. Variation in fertilizer rates can determine the optimal fertilizer rates of crops under circumstances of multiple criteria evaluation.

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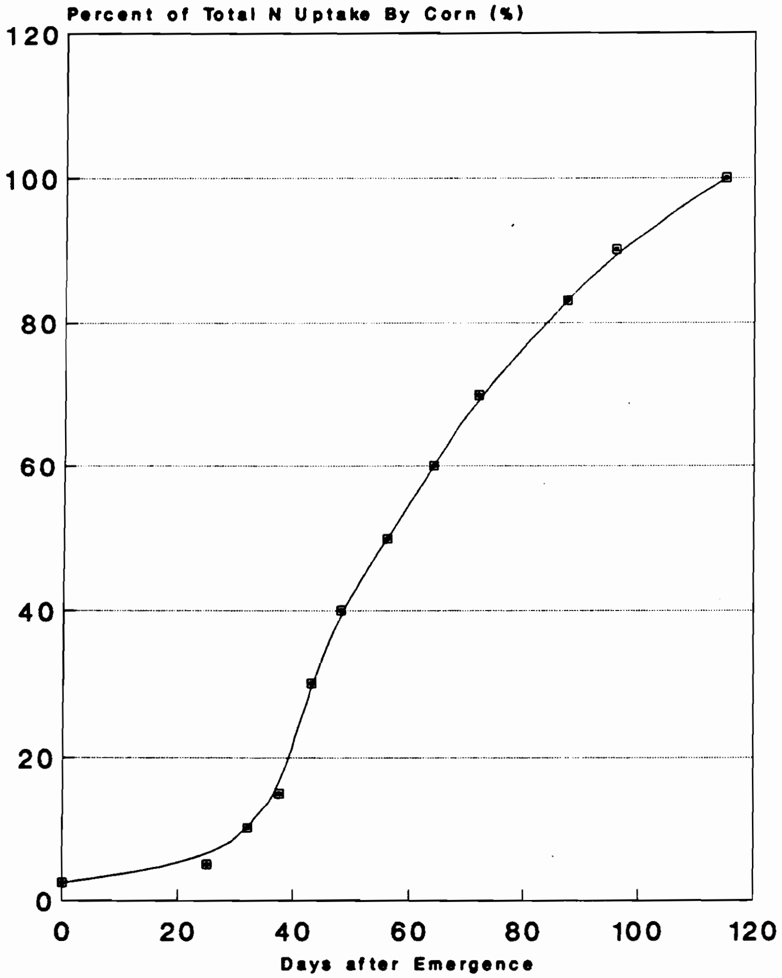
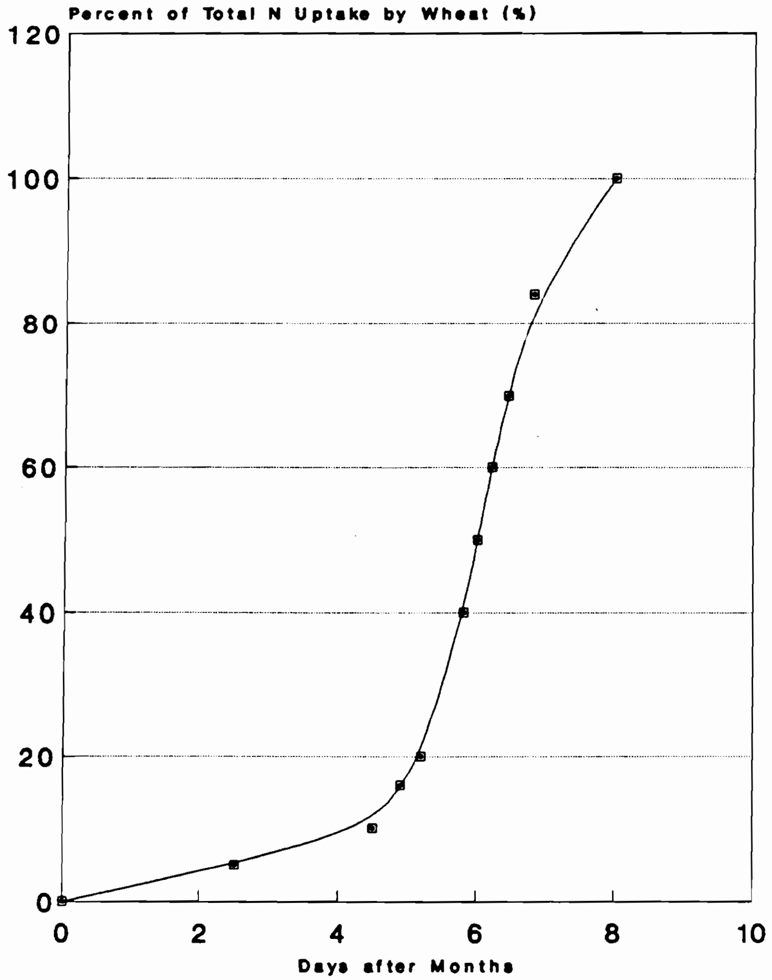
Appendix A.1 Distributions of Nitrogen Uptake by Crops



Source: Martin et al. (1976)

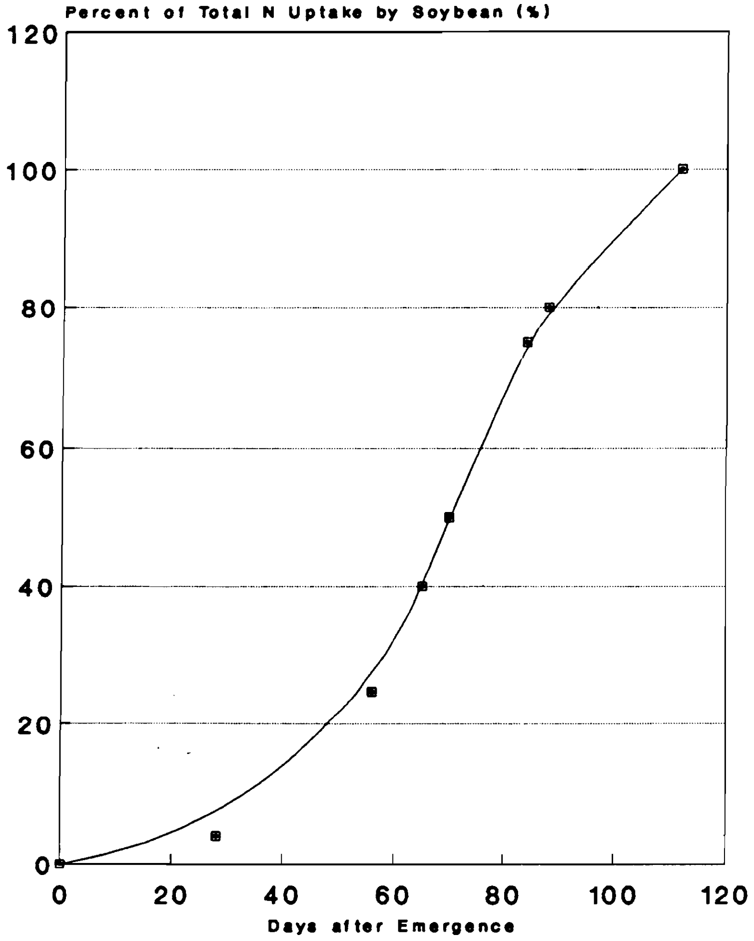
Appendix A.1 Distributions of Nitrogen Uptake By Crops

(Continued)



Source: Alley et al. (1987)

Appendix A.1 Distributions of Nitrogen Uptake by Crops (Continued)



Source: Hanway and Weber (1971)

Appendix A.2 Parameter File of CREAMS' Nutrient Component

Agricultural Management System: 1
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001       1       0       0       1        0
  0.40    0.22    0.50
     2
   0.2     0.2    20.0  0.0018  0.0007    0.075    0.075       7.4     -0.2      7.4
  -0.2     0.8
 51001   51263
     2     110     263
 762.0  9400.0     2.5    42.0    60.0     27.0    225.0         1
 51084
  34.0    44.8    0.07
 51130
 112.0       0     1.0
 51288   52166
     2     298     166
 762.0  2000.0     3.7   10.13   152.0     20.0    130.0         1
 51270
  17.0    40.4    0.07
 52051
  73.0       0     1.0
 52166   52319
     0     176     319
 762.0    3020     4.2    4.31    60.0     20.0    180.0         1
 52319   53083
     0     010     070
 762.0    3000     3.7    25.0    50.0     20.0      1.0         1
```

Agricultural Management System: 1L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001       1       0       0       1        0
  0.40    0.22    0.50
     2
   0.2     0.2    20.0  0.0018  0.0007    0.075    0.075       7.4     -0.2      7.4
  -0.2     0.8
 51001   51263
     1     110     263
 762.0  9400.0     2.5   144.0    60.0     27.0    225.0         1
 51084
  73.0    44.8    0.07
 51288   52166
     1     298     166
 762.0  2000.0     3.7    55.1   152.0     20.0    130.0         1
 51270
  45.0    40.4    0.07
 52166   52319
     0     176     319
 762.0    3020     4.2     4.3    60.0     20.0    180.0         1
 52319   53083
     0     010     070
 762.0    3000     3.7    25.0    50.0     20.0      1.0         1
```

Appendix A.2 Parameter File of CREAMS' Nutrient Component (Continued)

Agricultural Management System: 2
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001       1        0       0        1         0
  0.40    0.22     0.50
     2
   0.2     0.2     20.0  0.0018   0.0007     0.075     0.075       7.4      -0.2       7.4
  -0.2     0.8
 51001   51263
     2     110      263
 762.0  9400.0      2.5    42.0     60.0      27.0     225.0         1
 51084
  23.0       0      1.0
 51130
 146.0       0      1.0
 51288   52166
     2     298      166
 762.0  2000.0      3.7    10.1    152.0      20.0     130.0         1
 51270
  64.0    40.4     0.07
 52051
  68.0       0      1.0
 52166   52319
     0     176      319
 762.0    3020      4.2     4.3     60.0      20.0     180.0         1
 52319   53083
     0     010      070
 762.0    3000      3.7    25.0     50.0      20.0       1.0         1
```

Agricultural Management System: 2L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001       1        0       0        1         0
  0.40    0.22     0.50
     2
   0.2     0.2     20.0  0.0018   0.0007     0.075     0.075       7.4      -0.2       7.4
  -0.2     0.8
 51001   51263
     1     110      263
 762.0  9400.0      2.5   174.0     60.0      27.0     225.0         1
 51084
  84.5    44.8      1.0
 51288   52166
     1     298      166
 762.0  2000.0      3.7    76.1    152.0      20.0     130.0         1
 51270
  66.0    40.4     0.07
 52166   52319
     0     176      319
 762.0    3020      4.2     4.3     60.0      20.0     180.0         1
 52319   53083
     0     010      070
 762.0    3000      3.7    25.0     50.0      20.0       1.0         1
```

Appendix A.2 Parameter File of CREAMS' Nutrient Component (Continued)

Agricultural Management System: 3
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001       1       0       0       1       0
  0.40    0.22    0.50
  2
   0.2     0.2    20.0  0.0018  0.0007   0.075   0.075     7.4    -0.2     7.4
  -0.2     0.8
 51001   51263
     2     110     263
 762.0  9400.0     2.5    42.0    60.0    27.0   225.0       1
 51084
  34.0    44.8     0.1
 51130
  79.0       0     0.1
 51288   52166
     2     298     166
 762.0  2000.0     3.7    10.1   152.0    20.0   130.0       1
 51270
  18.0    44.8    0.07
 52051
  68.0       0     1.0
 52166   52319
     0     176     319
 762.0    3020     4.2     4.3    60.0    20.0   180.0       1
 52319   53083
     0     010     070
 762.0    3000     3.7    25.0    50.0    20.0     1.0       1
```

Agricultural Management System: 3L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001       1       0       0       1       0
  0.40    0.22    0.50
  2
   0.2     0.2    20.0  0.0018  0.0007   0.075   0.075     7.4    -0.2     7.4
  -0.2     0.8
 51001   51263
     1     110     263
 762.0  9400.0     2.5   130.0    60.0    27.0   225.0       1
 51084
  56.5    44.8     0.1
 51288   52166
     1     298     166
 762.0  2000.0     3.7    53.1   152.0    20.0   130.0       1
 51270
  43.0    40.4    0.07
 52166   52319
     0     176     319
 762.0    3020     4.2     4.3    60.0    20.0   180.0       1
 52319   53083
     0     010     070
 762.0    3000     3.7    25.0    50.0    20.0     1.0       1
```

Appendix A.2 Parameter File of CREAMS' Nutrient Component
(Continued)

Agricultural Management System: 4
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001        1       0        0        1        0
  0.40     0.22    0.50
     2
   0.2      0.2    20.0   0.0018   0.0007    0.075    0.075      7.4     -0.2      7.4
  -0.2      0.8
 51001    51263
     2      110     263
 762.0   9400.0     2.5     42.0     60.0     27.0    225.0        1
 51084
  34.0     44.8    0.07
 51130
 112.0        0     1.0
 51288    52166
     3      298     166
 762.0   2000.0     3.7     10.1    152.0     20.0    130.0        1
 51270
  17.0     40.4    0.07
 52051
  39.0        0     1.0
 52079
  34.0        0     1.0
 52166    52319
     0      176     319
 762.0     3020     4.2      4.3     60.0     20.0    180.0        1
 52319    53083
     0      010     070
 762.0     3000     3.7     25.0     50.0     20.0      1.0        1
```

Agricultural Management System: 5L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans
Simulation Period: 1951-1985

```
 51001        1       0        0        1        0
  0.40     0.22    0.50
     2
   0.2      0.2    20.0   0.0018   0.0007    0.075    0.075      7.4     -0.2      7.4
  -0.2      0.8
 51001    51263
     1      110     263
 762.0   9400.0     2.5    130.0     60.0     27.0    225.0        1
 51084
  73.0     44.8    0.07
 51288    52166
     1      298     166
 762.0   2000.0     3.7     53.1    152.0     20.0    130.0        1
 51270
  43.0     44.8    0.07
 52166    52319
     0      176     319
 762.0     3020     4.2      4.3     60.0     20.0    180.0        1
 52319    53083
     0      010     070
 762.0     3000     3.7     25.0     50.0     20.0      1.0        1
```

Appendix A.2 Parameter File of CREAMS' Nutrient Component (Continued)

Agricultural Management System: 8
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans/rye cover crop
Simulation Period: 1951-1985

```
    51001         1         0         0         1         0
     0.40      0.22      0.50
        2
      0.2       0.2      20.0    0.0018    0.0007     0.075     0.075       7.4      -0.2       7.4
     -0.2       0.8
    51001     51270
        2       125       270
    762.0    9400.0       2.5      60.0      60.0      27.0     225.0         1
    51105
     34.0      44.8      0.07
    51166
    112.0         0       1.0
    51288     52166
        2       298       166
    762.0    2000.0       3.7      10.1     152.0      20.0     130.0         1
    51273
     17.0      40.4      0.07
    52051
     73.0         0       1.0
    52166     52319
        0       176       319
    762.0      3020       4.2       4.3      60.0      20.0     180.0         1
    52258     53095
        0       270       095
    600.0      2000       3.7      25.0     165.0      20.0      90.0         1
```

Agricultural Management System: 8L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans/rye cover crop
Simulation Period: 1951-1985

```
    51001         1         0         0         1         0
     0.40      0.22      0.50
        2
      0.2       0.2      20.0    0.0018    0.0007     0.075     0.075       7.4      -0.2       7.4
     -0.2       0.8
    51001     51270
        1       125       270
    762.0    9400.0       2.5     167.0      60.0      27.0     225.0         1
    51105
     73.0      44.8      0.07
    51288     52166
        1       298       166
    762.0    2000.0       3.7      55.1     152.0      20.0     130.0         1
    51273
     45.0      40.4      0.07
    52166     52319
        0       176       319
    762.0      3020       4.2       4.3      60.0      20.0     180.0         1
    52258     53095
        0       270       095
    600.0      2000       3.7      25.0     165.0      20.0      90.0         1
```

Appendix A.2 Parameter File of CREAMS' Nutrient Component (Continued)

Agricultural Management System: 11L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans/rye cover crop
Simulation Period: 1951-1985

```
 51001       1      0       0       1        0
  0.40    0.22   0.50
  2
  0.2      0.2   20.0  0.0018  0.0007    0.075    0.075      7.4     -0.2      7.4
 -0.2      0.8
 51001   51270
  1        125    270
 762.0  9400.0    2.5   165.0    60.0     27.0    225.0      1
 51105
  73.0    44.8    0.1
 51288   52166
  1        298    166
 762.0  2000.0    3.7    55.1   152.0     20.0    130.0      1
 51273
  45.0    40.4   0.07
 52166   52319
  0        176    319
 762.0    3020    4.2     4.3    60.0     20.0    180.0      1
 52258   53095
  0        270    095
 600.0    2000    3.7    25.0   165.0     20.0     90.0      1
```

Agricultural Management System: 16L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans/rye mixed with crimson clover
Simulation Period: 1951-1985

```
 51001       1      0       0       1        0
  0.40    0.22   0.50
  2
  0.2      0.2   20.0  0.0018  0.0007    0.075    0.075      7.4     -0.2      7.4
 -0.2      0.8
 51001   51270
  1        135    270
 762.0  9400.0    2.5   200.0    60.0     27.0    225.0      1
 51105
  73.0    44.8    0.1
 51288   52166
  1        298    166
 762.0  2000.0    3.7    55.1   152.0     20.0    130.0      1
 51273
  45.0    40.4   0.07
 52166   52319
  0        176    319
 762.0    3020    4.2     4.3    60.0     20.0    180.0      1
 52258   53095
  0        280    095
 600.0    2000    3.7    25.0   165.0     20.0    135.0      1
```

Appendix A.2 Parameter File of CREAMS' Nutrient Component
(Continued)

Agricultural Management System: 15
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans/rye mixed with crimson clover
Simulation Period: 1951-1985

```
 51001       1       0       0       1       0
  0.40    0.22    0.50
  2
   0.2     0.2    20.0  0.0018  0.0007   0.075   0.075      7.4     -0.2      7.4
  -0.2     0.8
 51001   51270
     2     135     270
 762.0  9400.0     2.5    96.0    60.0    27.0   225.0      1
 51105
  34.0    44.8    0.07
 51166
 112.0       0     1.0
 51288   52166
     2     298     166
 762.0  2000.0     3.7    10.1   152.0    20.0   130.0      1
 51273
  17.0    40.4    0.07
 52051
  73.0       0     1.0
 52166   52319
     0     176     319
 762.0    3020     4.2     4.3    60.0    20.0   180.0      1
 52258   53095
     0     280     095
 600.0    2000     3.7    25.0   165.0    20.0   135.0      1
```

Agricultural Management System: 15L
Allocation: Richmond County, Virginia
Size: 1 acre field
Soil: Suffolk sandy loam
Rotation: Corn/winter wheat double cropped with soybeans/rye mixed with crimson clover
Simulation Period: 1951-1985

```
 51001       1       0       0       1       0
  0.40    0.22    0.50
  2
   0.2     0.2    20.0  0.0018  0.0007   0.075   0.075      7.4     -0.2      7.4
  -0.2     0.8
 51001   51270
     1     135     270
 762.0  9400.0     2.5   200.0    60.0    27.0   225.0      1
 51105
  73.0    44.8    0.07
 51288   52166
     1     298     166
 762.0  2000.0     3.7    55.1   152.0    20.0   130.0      1
 51273
  45.0    40.4    0.07
 52166   52319
     0     176     319
 762.0    3020     4.2     4.3    60.0    20.0   180.0      1
 52258   53095
     0     280     095
 600.0    2000     3.7    25.0   165.0    20.0   135.0      1
```

Appendix A.3 Seasonal Reports of CREAMS Simulation Results

Agricultural Managment System: 1
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.39	2.29	0.79	0.11	5.72	34.99	12.27	1.63	3.90	127.10	23.58	13.49
53	16.52	0.28	1.78	0.54	0.07	4.14	37.94	12.85	15.28	2.97	137.40	8.23	2.37
55	33.41	3.90	6.99	5.12	1.08	28.89	37.28	17.19	16.39	6.04	126.74	22.04	6.40
57	19.86	0.69	2.00	1.05	0.57	7.57	35.70	13.69	16.41	3.60	125.98	14.71	8.33
59	22.16	2.00	3.16	3.73	0.45	20.24	34.57	13.08	16.01	4.01	139.07	7.61	2.45
61	22.85	0.84	4.59	1.12	1.02	8.14	26.64	12.68	1.06	4.14	117.60	23.97	6.27
63	14.37	1.71	2.23	3.96	0.45	17.20	36.62	11.94	19.17	2.60	117.65	22.01	4.44
65	21.82	0.17	1.26	0.21	0.11	2.12	36.40	14.80	1.72	3.95	137.09	8.17	4.98
67	20.67	0.32	0.93	0.29	0.13	2.73	37.61	13.73	15.53	3.74	147.87	3.54	0.56
69	30.64	3.50	2.90	4.35	1.41	20.71	36.57	14.95	1.79	5.55	134.54	13.77	4.40
71	22.40	0.73	5.06	1.08	0.93	7.70	37.60	13.71	15.43	4.05	105.13	37.61	8.67
73	19.48	0.09	2.15	0.03	0.04	0.43	36.59	12.26	1.31	3.53	138.13	9.00	3.14
75	35.24	1.26	8.28	2.12	0.48	15.94	36.02	15.06	2.09	6.39	121.98	18.42	9.71
77	16.21	0.56	1.62	0.63	0.12	4.02	37.28	12.65	20.10	2.94	120.42	6.77	2.57
79	40.20	4.35	9.35	6.21	1.25	35.96	34.22	14.95	16.17	7.29	106.44	38.45	8.77
81	25.21	1.07	3.84	1.62	0.86	11.25	27.91	13.11	1.55	4.56	113.59	28.64	9.53
83	23.88	0.62	5.92	0.33	0.49	3.03	36.90	13.22	17.53	4.33	112.25	26.28	9.39
AVE.	23.91	1.32	3.78	1.95	0.56	11.52	35.34	13.65	10.54	4.33	125.23	18.40	6.20

Agricultural Managment System: 1
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.68	7.74	0.85	0.16	6.48	29.43	9.40	2.44	6.24	76.18	16.02	2.48
54	21.23	0.35	2.14	0.55	0.08	4.20	33.37	8.40	2.11	3.83	82.33	7.19	1.56
56	22.13	0.10	2.22	0.04	0.03	0.53	31.04	10.07	2.36	4.01	86.16	6.11	2.06
58	43.91	2.07	13.36	1.25	0.56	10.16	28.79	10.74	2.90	7.94	66.55	26.41	4.59
60	35.39	2.10	7.52	1.74	0.52	11.20	28.89	9.49	2.30	6.41	78.26	14.95	1.88
62	40.23	3.88	10.44	4.72	1.00	25.14	28.93	10.57	3.30	7.29	68.02	22.75	4.00
64	28.56	0.54	5.21	0.38	0.12	3.41	31.27	9.19	2.40	5.17	81.21	12.83	2.30
66	19.74	0.03	0.00	0.03	0.01	0.35	32.45	7.79	2.90	3.57	90.32	0.00	0.00
68	29.18	0.47	3.46	0.62	0.23	5.05	32.25	9.20	4.46	5.27	75.17	13.45	2.35
70	25.94	0.34	2.68	0.54	0.07	3.87	30.84	9.56	3.20	4.69	85.03	6.73	1.18
72	44.13	3.32	8.96	2.57	0.72	15.37	29.94	11.50	3.85	7.97	79.65	14.18	2.57
74	27.73	0.71	4.37	0.43	0.18	3.92	30.97	9.47	1.88	5.02	81.69	10.30	1.66
76	27.89	1.55	6.87	2.01	0.34	12.51	30.27	9.58	3.67	5.06	77.42	12.77	2.26
78	44.11	1.33	15.16	1.15	0.40	10.13	28.94	12.17	3.66	7.98	76.49	35.74	5.15
80	25.52	0.32	5.65	0.13	0.08	1.33	28.91	9.15	1.58	4.62	80.59	10.52	2.28
82	24.73	0.13	3.68	0.09	0.12	1.09	30.43	10.33	3.24	4.47	79.42	11.43	2.00
84	45.25	2.44	15.40	2.99	0.62	20.27	29.14	11.60	3.57	8.20	70.55	23.89	3.73
AVE.	31.77	1.20	6.76	1.18	0.31	7.94	30.35	9.90	2.93	5.75	78.53	14.43	2.47

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 1
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.46	0.00	0.65	0.09	4.32	45.96	5.74	1.34	2.85	9.76	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	49.61	6.03	1.75	2.07	8.51	0.00	0.00
56	28.33	2.39	3.31	1.84	0.45	13.06	45.05	8.25	2.14	5.14	12.71	0.49	0.08
58	23.08	1.18	0.54	1.14	0.22	8.62	42.76	8.29	1.82	4.19	13.42	0.00	0.00
60	23.93	2.07	0.40	2.02	0.39	12.78	43.48	7.68	1.59	4.33	12.33	0.00	0.00
62	20.42	0.93	0.73	0.95	0.19	7.39	43.94	7.28	1.93	3.69	11.98	0.20	0.04
64	18.02	0.35	0.00	0.34	0.07	2.40	46.11	7.44	1.55	3.27	11.59	0.00	0.00
66	22.35	3.22	3.42	2.31	0.61	14.46	46.78	7.94	1.83	4.04	12.51	0.01	0.01
68	13.17	0.08	0.32	0.10	0.01	1.03	46.48	8.04	1.31	2.38	13.66	0.00	0.00
70	8.91	0.53	0.00	0.32	0.11	2.28	46.26	6.85	1.00	1.62	10.55	0.00	0.00
72	20.81	0.47	2.01	0.55	0.10	4.65	44.16	8.06	2.18	3.78	12.41	0.75	0.37
74	18.92	1.37	0.13	1.42	0.27	9.91	46.31	6.93	0.76	3.42	11.37	0.00	0.00
76	24.16	1.91	3.21	1.33	0.37	9.38	44.77	7.76	2.04	4.37	13.75	0.04	0.01
78	11.20	0.11	0.00	0.14	0.03	1.26	44.34	6.88	1.43	2.03	11.37	0.00	0.00
80	16.41	0.71	0.00	0.56	0.14	4.13	45.26	5.93	2.00	2.97	8.83	0.00	0.00
82	19.17	0.65	0.57	0.64	0.13	5.17	45.46	7.23	2.08	3.47	12.04	0.00	0.00
84	14.24	0.12	0.08	0.20	0.03	1.90	44.17	7.24	1.66	2.59	11.73	0.01	0.03
AVE.	18.25	0.97	0.87	0.85	0.19	6.04	45.35	7.27	1.67	3.31	11.68	0.09	0.03

Agricultural Managment System: 1
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.17	7.42	0.14	0.04	1.18	41.76	4.19	32.29	2.73	0.00	3.95	1.10
54	11.03	0.06	2.81	0.54	0.02	0.29	45.45	4.16	33.16	2.00	0.00	2.03	0.37
56	13.28	0.14	7.35	0.12	0.04	1.26	40.37	4.69	32.63	2.40	0.00	3.87	0.77
58	9.95	0.56	2.71	0.72	0.11	4.37	38.63	4.13	33.14	1.81	0.00	2.55	0.69
60	16.31	0.65	7.82	0.72	0.14	5.99	39.33	4.16	32.33	2.95	0.00	4.58	0.92
62	12.57	0.42	6.18	0.38	0.09	3.22	39.53	4.41	32.78	2.28	0.00	3.56	0.55
64	10.71	0.06	2.38	0.03	0.02	0.35	42.18	3.93	32.39	1.94	0.00	3.19	0.94
66	9.82	0.01	3.28	0.01	0.00	0.14	42.33	4.45	33.67	1.77	0.00	1.86	0.43
68	11.30	0.30	2.65	0.24	0.06	2.02	42.49	3.99	34.80	2.04	0.00	1.67	0.29
70	10.53	0.06	1.30	0.03	0.02	0.35	42.30	3.96	33.53	1.90	0.00	0.75	0.17
72	11.43	0.34	5.34	0.35	0.07	2.80	39.84	4.31	33.75	2.08	0.00	2.34	0.37
74	16.92	0.51	6.45	0.48	0.12	4.11	42.08	4.23	31.00	3.06	0.00	6.10	0.69
76	6.99	0.00	2.16	0.00	0.00	0.00	40.90	3.87	5.60	1.26	0.00	1.24	0.29
78	17.63	0.71	8.85	0.68	0.14	5.29	40.14	4.19	32.25	3.20	0.00	3.87	0.53
80	5.24	0.00	0.90	0.00	0.00	0.00	41.03	4.22	35.32	0.94	0.00	0.61	0.15
82	12.34	0.46	5.06	0.36	0.10	2.60	41.11	4.36	32.40	2.24	0.00	4.39	0.88
84	8.14	0.04	1.88	0.01	0.01	0.14	40.16	4.01	33.29	1.47	0.00	1.03	0.09
AVE.	11.72	0.26	4.39	0.28	0.06	2.01	41.15	4.19	31.43	2.12	0.00	2.80	0.54

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 1L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.39	2.29	0.79	0.09	5.72	137.83	42.35	5.68	3.90	105.76	15.16	9.71
53	16.52	0.28	1.78	0.54	0.08	4.14	161.54	50.13	43.24	2.97	98.21	15.74	4.29
55	33.41	3.90	6.99	5.12	0.80	28.89	162.87	69.72	51.67	6.04	106.34	24.83	6.69
57	19.86	0.69	2.00	1.05	0.19	7.57	158.72	56.65	51.78	3.60	103.17	11.33	5.54
59	22.16	2.00	3.16	3.73	0.41	20.24	153.98	54.34	46.04	4.01	101.98	16.58	5.36
61	22.85	0.84	4.59	1.12	0.25	8.14	110.13	52.44	7.68	4.14	85.96	27.74	5.98
63	14.37	1.71	2.23	3.96	0.37	17.20	163.33	49.66	51.51	2.60	99.79	11.43	2.42
65	21.82	0.17	1.26	0.21	0.04	2.12	162.53	61.55	6.72	3.95	123.83	3.99	2.99
67	20.67	0.32	0.93	0.29	0.14	2.73	167.65	57.18	45.91	3.74	120.76	9.33	1.49
69	30.64	3.50	2.90	4.35	0.69	20.71	162.72	61.83	10.80	5.55	105.63	22.06	5.58
71	22.40	0.73	5.06	1.08	0.28	7.70	166.41	56.62	44.77	4.05	95.39	28.39	7.75
73	19.48	0.09	2.15	0.03	0.06	0.43	162.85	50.88	8.18	3.53	96.86	19.96	6.94
75	35.24	1.26	8.28	2.12	0.29	15.94	160.05	62.28	6.67	6.39	103.64	17.19	8.27
77	16.21	0.56	1.62	0.63	0.13	4.02	165.80	52.40	11.47	2.94	98.95	16.41	6.35
79	40.20	4.35	9.35	6.21	0.93	35.96	152.45	62.07	45.82	7.29	96.43	31.15	7.38
81	25.21	1.07	3.84	1.62	0.32	11.25	115.17	54.12	5.42	4.56	99.90	25.31	8.92
83	23.88	0.62	5.92	0.33	0.23	3.03	164.04	54.88	49.31	4.33	77.59	37.36	7.02
AVE.	23.91	1.32	3.78	1.95	0.31	11.52	154.59	55.83	28.98	4.33	101.19	19.64	6.04

Agricultural Managment System: 1L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.68	7.74	0.85	0.20	6.48	105.00	36.66	7.63	6.24	37.55	38.24	4.60
54	21.23	0.35	2.14	0.55	0.11	4.20	129.92	35.44	7.63	3.83	59.36	15.52	2.02
56	22.13	0.10	2.22	0.04	0.04	0.53	123.18	43.52	8.84	4.01	70.28	17.88	5.71
58	43.91	2.07	13.36	1.25	0.47	10.16	115.15	47.39	10.86	7.94	36.89	51.19	10.34
60	35.39	2.10	7.52	1.74	0.49	11.20	115.82	42.00	9.73	6.41	41.75	39.73	5.13
62	40.23	3.88	10.44	4.72	0.80	25.14	116.48	46.56	11.48	7.29	38.09	44.77	6.69
64	28.56	0.54	5.21	0.38	0.13	3.41	126.61	40.55	8.72	5.17	48.85	34.18	6.07
66	19.74	0.03	0.00	0.03	0.02	0.35	131.95	34.42	9.97	3.57	74.78	0.00	0.00
68	29.18	0.47	3.46	0.62	0.14	5.05	131.12	40.35	14.73	5.27	59.20	16.57	2.90
70	25.94	0.34	2.68	0.54	0.08	3.87	124.42	42.11	9.92	4.69	62.98	21.20	3.74
72	44.13	3.32	8.96	2.57	0.72	15.37	120.09	50.13	12.72	7.97	46.24	39.07	7.13
74	27.73	0.71	4.37	0.43	0.18	3.92	124.96	41.72	6.98	5.02	57.02	26.52	3.46
76	27.89	1.55	6.87	2.01	0.38	12.51	121.75	42.13	7.99	5.06	41.09	37.18	6.45
78	44.11	1.33	15.16	1.15	0.35	10.13	116.07	53.55	15.10	7.98	31.54	57.97	7.51
80	25.52	0.32	5.65	0.13	0.11	1.33	115.86	40.42	6.32	4.62	46.60	31.11	6.65
82	24.73	0.13	3.68	0.09	0.06	1.09	122.56	45.51	11.03	4.47	53.79	24.96	4.93
84	45.25	2.44	15.40	2.99	0.53	20.27	117.28	50.59	14.06	8.20	38.95	45.67	8.93
AVE.	31.77	1.20	6.76	1.18	0.28	7.94	121.07	43.12	10.22	5.75	49.70	31.87	5.43

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 1L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.46	0.00	0.65	0.09	4.32	107.54	19.73	3.48	2.85	27.17	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	129.69	22.50	6.10	2.07	26.25	0.00	0.00
56	28.33	2.39	3.31	1.84	0.48	13.06	113.71	31.74	4.61	5.14	39.84	1.16	0.19
58	23.08	1.18	0.54	1.14	0.23	8.62	105.09	32.32	4.44	4.19	43.15	0.00	0.00
60	23.93	2.07	0.40	2.02	0.40	12.78	108.48	29.62	4.53	4.33	39.18	0.00	0.00
62	20.42	0.93	0.73	0.95	0.20	7.39	110.51	28.23	4.02	3.69	39.06	0.42	0.09
64	18.02	0.35	0.00	0.34	0.07	2.40	120.47	28.41	3.65	3.27	37.07	0.00	0.00
66	22.35	3.22	3.42	2.31	0.61	14.46	122.92	31.28	5.91	4.04	38.92	0.01	0.01
68	13.17	0.08	0.32	0.10	0.02	1.03	121.33	32.06	4.38	2.38	44.29	0.35	0.51
70	8.91	0.53	0.00	0.32	0.12	2.28	119.66	27.04	3.61	1.62	34.85	0.00	0.00
72	20.81	0.47	2.01	0.55	0.10	4.65	111.19	31.17	4.85	3.78	38.92	2.66	1.56
74	18.92	1.37	0.13	1.42	0.28	9.91	119.62	27.61	2.31	3.42	36.13	0.00	0.00
76	24.16	1.91	3.21	1.33	0.37	9.38	113.96	30.05	6.25	4.37	36.20	0.34	0.06
78	11.20	0.11	0.00	0.14	0.03	1.26	111.34	27.01	4.35	2.03	40.92	0.00	0.00
80	16.41	0.71	0.00	0.56	0.14	4.13	115.58	22.54	5.84	2.97	27.50	0.00	0.00
82	19.17	0.65	0.57	0.64	0.14	5.17	116.53	28.30	5.40	3.47	38.03	0.00	0.00
84	14.24	0.12	0.08	0.20	0.04	1.90	111.12	28.42	3.78	2.59	40.13	0.20	1.13
AVE.	18.25	0.97	0.87	0.85	0.19	6.04	115.22	28.12	4.56	3.31	36.92	0.30	0.21

Agricultural Managment System: 1L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.17	7.42	0.14	0.04	1.18	162.60	9.97	68.41	2.73	0.00	8.00	2.24
54	11.03	0.06	2.81	0.54	0.02	0.29	183.52	11.20	72.77	2.00	0.00	5.07	0.94
56	13.28	0.14	7.35	0.12	0.04	1.26	166.29	12.44	70.07	2.40	0.00	8.02	1.59
58	9.95	0.56	2.71	0.72	0.12	4.37	159.26	10.87	71.64	1.81	0.00	5.56	1.49
60	16.31	0.65	7.82	0.72	0.14	5.99	162.59	10.91	69.25	2.95	0.00	9.87	1.97
62	12.57	0.42	6.18	0.38	0.10	3.22	163.92	11.61	70.16	2.28	0.00	7.37	1.16
64	10.71	0.06	2.38	0.03	0.02	0.35	174.99	10.49	69.67	1.94	0.00	6.87	2.01
66	9.82	0.01	3.28	0.01	0.00	0.14	175.77	12.18	73.96	1.77	0.00	4.72	1.05
68	11.30	0.30	2.65	0.24	0.06	2.02	175.48	10.87	75.88	2.04	0.00	3.95	0.66
70	10.53	0.06	1.30	0.03	0.02	0.35	173.95	10.72	73.31	1.90	0.00	1.78	0.40
72	11.43	0.34	5.34	0.35	0.07	2.80	164.64	11.57	72.83	2.08	0.00	4.97	0.80
74	16.92	0.51	6.45	0.48	0.14	4.11	173.24	11.39	66.42	3.06	0.00	12.95	1.48
76	6.99	0.00	2.16	0.00	0.00	0.00	104.10	9.86	13.34	1.26	0.00	3.15	0.75
78	17.63	0.71	8.85	0.68	0.15	5.29	165.43	10.92	69.00	3.20	0.00	8.31	1.12
80	5.24	0.00	0.90	0.00	0.00	0.00	169.28	11.33	78.22	0.94	0.00	1.54	0.38
82	12.34	0.46	5.06	0.36	0.11	2.60	169.84	11.70	69.95	2.24	0.00	9.81	2.00
84	8.14	0.04	1.88	0.01	0.01	0.14	165.61	10.54	72.03	1.47	0.00	2.21	0.19
AVE.	11.72	0.26	4.39	0.28	0.06	2.01	165.32	11.09	68.05	2.12	0.00	6.13	1.19

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 2
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.35	2.30	0.61	0.10	4.66	34.96	12.28	1.63	3.90	141.77	27.52	15.34
53	16.52	0.25	1.79	0.41	0.07	3.19	37.88	12.85	62.57	2.97	151.70	6.53	1.95
55	33.41	3.74	7.14	3.8	1.13	22.87	37.22	17.17	54.88	6.04	142.27	25.67	7.65
57	19.86	0.64	2.01	0.83	0.59	6.31	35.62	13.69	55.91	3.60	142.59	16.82	9.81
59	22.16	1.90	3.23	2.33	0.45	14.09	34.49	13.06	54.95	4.01	160.67	7.37	2.49
61	22.85	0.77	4.64	0.86	1.14	6.64	26.57	12.67	1.07	4.14	134.10	26.87	8.33
63	14.37	1.66	2.28	2.11	0.44	10.33	36.49	11.92	60.89	2.60	131.23	27.26	5.34
65	21.82	0.15	1.28	0.19	0.07	1.91	36.30	14.78	1.72	3.95	153.39	11.94	6.89
67	20.67	0.29	0.94	0.29	0.15	2.73	37.53	13.72	55.30	3.74	170.38	1.75	0.28
69	30.64	3.39	2.99	3.24	1.52	16.39	36.49	14.92	1.81	5.55	155.80	12.84	4.40
71	22.40	0.68	5.10	0.89	1.09	6.64	37.52	13.69	54.36	4.05	117.11	44.13	10.47
73	19.48	0.08	2.16	0.03	0.05	0.43	36.52	12.26	1.31	3.53	162.93	5.79	1.99
75	35.24	1.16	8.40	1.81	0.52	14.01	35.96	15.05	2.09	6.39	138.92	22.68	12.02
77	16.21	0.53	1.63	0.46	0.12	3.14	37.21	12.62	29.95	2.94	133.82	4.24	1.67
79	40.20	4.13	9.53	4.5	1.26	27.72	34.16	14.94	53.00	7.29	119.82	47.22	10.66
81	25.21	1.00	3.88	1.25	0.93	9.25	27.87	13.10	1.54	4.56	128.41	33.08	10.68
83	23.88	0.59	5.98	0.32	0.60	2.92	36.83	13.20	59.17	4.33	131.91	26.17	11.45
AVE.	23.91	1.25	3.84	1.41	0.60	9.01	35.27	13.64	32.48	4.33	142.17	20.46	7.14

Agricultural Managment System: 2
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.61	7.80	0.77	0.18	5.96	29.39	9.40	2.44	6.24	84.06	42.27	5.74
54	21.23	0.32	2.18	0.50	0.11	3.89	33.32	8.39	6.85	3.83	108.46	20.23	3.23
56	22.13	0.08	2.22	0.04	0.03	0.53	30.99	10.07	2.48	4.01	109.14	16.73	5.71
58	43.91	1.95	13.50	1.11	0.56	9.22	28.72	10.72	2.90	7.94	69.00	55.53	10.68
60	35.39	2.01	7.61	1.65	0.52	10.63	28.80	9.51	2.31	6.41	86.86	40.68	4.96
62	40.23	3.74	10.57	4.39	0.99	23.32	28.84	10.56	3.30	7.29	72.80	51.25	8.12
64	28.56	0.48	5.23	0.32	0.12	2.95	31.17	9.16	2.40	5.17	94.40	33.97	6.06
66	19.74	0.02	0.00	0.02	0.01	0.25	32.36	7.75	26.03	3.57	103.76	0.00	0.00
68	29.18	0.42	3.48	0.54	0.23	4.45	32.19	9.17	4.85	5.27	95.07	28.06	4.84
70	25.94	0.32	2.71	0.51	0.08	3.71	30.76	9.57	3.30	4.69	107.05	19.75	3.45
72	44.13	3.16	9.09	1.83	0.72	11.94	29.86	11.49	3.84	7.97	90.06	37.53	6.23
74	27.73	0.66	4.42	0.38	0.20	3.52	30.90	9.46	1.89	5.02	98.35	28.56	4.11
76	27.89	1.46	6.93	1.79	0.35	11.34	30.20	9.58	3.83	5.06	86.41	36.56	6.68
78	44.11	1.22	15.29	0.95	0.40	8.61	28.88	12.16	3.65	7.98	78.92	76.01	10.35
80	25.52	0.30	5.65	0.12	0.10	1.26	28.86	9.13	1.59	4.62	90.74	29.82	6.62
82	24.73	0.10	3.71	0.07	0.10	0.89	30.35	10.34	3.30	4.47	97.52	27.62	5.10
84	45.25	2.28	15.52	2.54	0.60	17.77	29.07	11.58	3.58	8.20	72.14	53.82	9.64
AVE.	31.77	1.13	6.82	1.03	0.31	7.07	30.27	9.89	4.62	5.75	90.87	35.20	5.97

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 2
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.43	0.00	0.40	0.09	2.99	45.92	5.74	1.34	2.85	9.76	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	49.57	6.02	1.77	2.07	13.81	0.00	0.00
56	28.33	2.29	3.39	1.34	0.45	10.13	44.99	8.27	2.14	5.14	12.87	0.50	0.08
58	23.08	1.08	0.59	0.78	0.22	6.29	42.68	8.30	1.83	4.19	13.44	0.00	0.00
60	23.93	1.97	0.45	1.44	0.37	9.75	43.39	7.69	1.59	4.33	12.36	0.00	0.00
62	20.42	0.87	0.74	0.70	0.17	5.84	43.83	7.28	1.91	3.69	12.01	0.20	0.06
64	18.02	0.34	0.00	0.23	0.06	1.75	46.00	7.44	1.56	3.27	11.60	0.00	0.00
66	22.35	3.10	3.55	1.66	0.60	11.13	46.71	7.93	1.83	4.04	36.44	0.01	0.01
68	13.17	0.08	0.35	0.08	0.01	0.86	46.40	8.05	1.30	2.38	14.06	0.00	0.00
70	8.91	0.50	0.00	0.19	0.10	1.51	46.17	6.85	1.00	1.62	10.65	0.00	0.00
72	20.81	0.43	2.04	0.42	0.09	3.74	44.09	8.05	2.18	3.78	12.39	0.75	0.37
74	18.92	1.30	0.19	1.07	0.25	7.90	46.24	6.91	0.75	3.42	11.39	0.00	0.00
76	24.16	1.83	3.28	1.00	0.36	7.45	44.72	7.76	2.05	4.37	13.94	0.04	0.01
78	11.20	0.09	0.00	0.10	0.02	0.97	44.29	6.86	1.43	2.03	11.36	0.00	0.00
80	16.41	0.67	0.00	0.41	0.12	3.15	45.20	5.93	2.01	2.97	8.82	0.00	0.00
82	19.17	0.58	0.62	0.49	0.12	4.20	45.38	7.23	2.08	3.47	12.10	0.00	0.00
84	14.24	0.10	0.11	0.13	0.02	1.37	44.10	7.24	1.66	2.59	11.74	0.01	0.03
AVE.	18.25	0.92	0.90	0.61	0.18	4.65	45.28	7.27	1.67	3.31	13.46	0.09	0.03

Agricultural Managment System: 2
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.16	7.45	0.13	0.04	1.11	41.73	4.19	16.91	2.73	0.00	3.63	0.91
54	11.03	0.06	2.83	0.02	0.02	0.29	45.41	4.16	5.30	2.00	0.00	2.05	0.38
56	13.28	0.12	7.36	0.09	0.03	0.95	40.30	4.69	4.45	2.40	0.00	3.86	0.77
58	9.95	0.53	2.77	0.41	0.11	2.79	38.55	4.13	20.30	1.81	0.00	1.83	0.47
60	16.31	0.59	7.89	0.54	0.12	4.79	39.23	4.16	16.07	2.95	0.00	3.83	0.58
62	12.57	0.38	6.21	0.30	0.08	2.56	39.42	4.41	6.33	2.28	0.00	3.57	0.54
64	10.71	0.05	2.39	0.02	0.01	0.25	42.09	3.93	16.97	1.94	0.00	1.97	0.69
66	9.82	0.00	3.30	0.00	0.00	0.00	42.25	4.44	5.50	1.77	0.00	1.86	0.43
68	11.30	0.29	2.67	0.20	0.06	1.76	42.43	3.98	21.19	2.04	0.00	1.67	0.29
70	10.53	0.05	1.31	0.02	0.01	0.25	42.22	3.95	10.81	1.90	0.00	0.76	0.17
72	11.43	0.32	5.35	0.27	0.06	2.26	39.78	4.31	12.74	2.08	0.00	2.35	0.37
74	16.92	0.48	6.50	0.42	0.18	3.76	42.01	4.23	21.24	3.06	0.00	3.29	0.37
76	6.99	0.00	2.16	0.00	0.00	0.00	40.86	3.87	5.59	1.26	0.00	1.24	0.29
78	17.63	0.66	8.89	0.56	0.13	4.52	40.10	4.19	5.81	3.20	0.00	3.89	0.53
80	5.24	0.00	0.93	0.00	0.00	0.00	40.96	4.23	14.70	0.94	0.00	0.62	0.15
82	12.34	0.43	5.10	0.30	0.09	2.25	41.03	4.35	16.22	2.24	0.00	3.39	0.61
84	8.14	0.03	1.90	0.01	0.01	0.14	40.09	4.01	5.53	1.47	0.00	1.04	0.12
AVE.	11.72	0.25	4.41	0.19	0.06	1.63	41.09	4.19	12.10	2.12	0.00	2.40	0.45

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 2L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.35	2.30	0.61	0.08	4.66	174.88	51.33	7.05	3.90	119.86	18.60	11.57
53	16.52	0.25	1.79	0.41	0.10	3.19	201.09	59.62	62.43	2.97	115.66	17.70	4.79
55	33.41	3.74	7.14	3.8	0.82	22.87	202.19	82.77	72.33	6.04	121.92	30.00	8.08
57	19.86	0.64	2.01	0.83	0.21	6.31	196.44	66.90	72.49	3.60	118.77	13.08	6.89
59	22.16	1.90	3.23	2.33	0.39	14.09	190.28	64.00	65.53	4.01	120.82	17.99	6.11
61	22.85	0.77	4.64	0.86	0.26	6.64	128.92	61.46	9.27	4.14	101.57	32.61	6.89
63	14.37	1.66	2.28	2.11	0.38	10.33	201.39	58.43	72.56	2.60	113.12	15.09	3.01
65	21.82	0.15	1.28	0.19	0.04	1.91	200.85	72.46	8.29	3.95	143.66	6.61	4.39
67	20.67	0.29	0.94	0.29	0.29	2.73	207.17	67.46	65.48	3.74	142.80	8.55	1.35
69	30.64	3.39	2.99	3.24	0.69	16.39	201.26	72.89	13.09	5.55	121.90	26.09	6.42
71	22.40	0.68	5.10	0.89	0.40	6.64	205.51	66.75	63.79	4.05	110.56	32.63	9.25
73	19.48	0.08	2.16	0.03	0.16	0.43	201.06	59.79	9.93	3.53	116.11	20.05	6.89
75	35.24	1.16	8.40	1.81	0.29	14.01	197.95	73.32	7.89	6.39	123.12	22.72	11.24
77	16.21	0.53	1.63	0.46	0.14	3.14	204.73	61.68	14.14	2.94	117.10	16.97	6.90
79	40.20	4.13	9.53	4.5	0.90	27.72	188.51	73.22	64.49	7.29	110.58	38.03	8.43
81	25.21	1.00	3.88	1.25	0.33	9.25	135.25	63.58	6.53	4.56	116.36	29.38	10.12
83	23.88	0.59	5.98	0.32	0.29	2.92	202.56	64.67	70.18	4.33	90.45	44.61	8.67
AVE.	23.91	1.25	3.84	1.41	0.34	9.01	190.59	65.90	40.32	4.33	117.90	22.98	7.12

Agricultural Managment System: 2L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.61	7.80	0.77	0.18	5.96	132.20	46.50	9.68	6.24	48.23	53.43	6.47
54	21.23	0.32	2.18	0.50	0.12	3.89	160.82	44.12	9.57	3.83	79.04	21.97	2.84
56	22.13	0.08	2.22	0.04	0.03	0.53	152.01	54.01	11.04	4.01	91.83	24.63	7.95
58	43.91	1.95	13.50	1.11	0.45	9.22	141.58	58.70	13.66	7.94	45.00	69.80	13.98
60	35.39	2.01	7.61	1.65	0.50	10.63	142.14	51.96	12.18	6.41	52.76	55.03	6.99
62	40.23	3.74	10.57	4.39	0.78	23.32	142.98	57.55	14.05	7.29	46.47	62.60	9.24
64	28.56	0.48	5.23	0.32	0.13	2.95	155.24	49.99	10.87	5.17	62.54	46.95	8.31
66	19.74	0.02	0.00	0.02	0.01	0.25	162.17	42.50	12.35	3.57	100.75	0.00	0.00
68	29.18	0.42	3.48	0.54	0.16	4.45	161.14	49.86	18.11	5.27	75.15	25.67	4.44
70	25.94	0.32	2.71	0.51	0.09	3.71	152.91	52.18	12.13	4.69	82.56	29.14	5.09
72	44.13	3.16	9.09	1.83	0.71	11.94	147.39	61.93	15.41	7.97	58.68	53.65	9.57
74	27.73	0.66	4.42	0.38	0.20	3.52	153.32	51.57	8.67	5.02	73.95	36.61	4.86
76	27.89	1.46	6.93	1.79	0.37	11.34	149.67	52.10	10.30	5.06	52.16	51.05	8.87
78	44.11	1.22	15.29	0.95	0.32	8.61	142.41	66.16	18.73	7.98	38.55	78.50	10.11
80	25.52	0.30	5.65	0.12	0.11	1.26	142.38	49.96	7.78	4.62	59.86	42.48	9.12
82	24.73	0.10	3.71	0.07	0.04	0.89	150.52	56.34	13.56	4.47	69.79	35.03	6.81
84	45.25	2.28	15.52	2.54	0.52	17.77	143.90	62.50	17.50	8.20	47.75	62.93	12.28
AVE.	31.77	1.13	6.82	1.03	0.28	7.07	148.99	53.41	12.68	5.75	63.83	44.09	7.47

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 2L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.43	0.00	0.40	0.09	2.99	129.68	24.79	4.31	2.85	33.61	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	155.31	27.79	7.56	2.07	32.04	0.00	0.00
56	28.33	2.29	3.39	1.34	0.47	10.13	135.06	39.23	5.37	5.14	48.66	1.39	0.22
58	23.08	1.08	0.59	0.78	0.23	6.29	124.05	39.80	5.26	4.19	52.77	0.00	0.00
60	23.93	1.97	0.45	1.44	0.38	9.75	128.02	36.38	5.72	4.33	47.33	0.02	0.03
62	20.42	0.87	0.74	0.70	0.19	5.84	130.49	34.77	4.66	3.69	47.45	0.49	0.15
64	18.02	0.34	0.00	0.23	0.06	1.75	142.68	34.83	4.35	3.27	45.04	0.00	0.00
66	22.35	3.10	3.55	1.66	0.60	11.13	146.05	38.39	7.52	4.04	46.80	0.08	0.03
68	13.17	0.08	0.35	0.08	0.02	0.86	144.00	39.41	5.40	2.38	53.24	0.74	0.98
70	8.91	0.50	0.00	0.19	0.11	1.51	141.90	33.28	4.40	1.62	42.50	0.00	0.00
72	20.81	0.43	2.04	0.42	0.10	3.74	131.46	38.21	5.71	3.78	46.93	3.27	1.91
74	18.92	1.30	0.19	1.07	0.27	7.90	141.72	33.87	2.83	3.42	43.74	0.00	0.00
76	24.16	1.83	3.28	1.00	0.36	7.45	135.05	36.89	7.76	4.37	43.90	0.50	0.10
78	11.20	0.09	0.00	0.10	0.02	0.97	131.59	33.08	5.29	2.03	49.99	0.00	0.00
80	16.41	0.67	0.00	0.41	0.13	3.15	137.01	27.64	7.30	2.97	32.96	0.00	0.00
82	19.17	0.58	0.62	0.49	0.12	4.20	138.05	34.75	6.43	3.47	46.16	0.00	0.00
84	14.24	0.10	0.11	0.13	0.02	1.37	131.30	34.86	5.40	2.59	47.93	0.36	1.49
AVE.	18.25	0.92	0.90	0.61	0.19	4.65	136.67	34.59	5.60	3.31	44.77	0.40	0.29

Agricultural Managment System: 2L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.16	7.45	0.13	0.04	1.11	192.92	12.01	56.43	2.73	0.00	8.95	2.33
54	11.03	0.06	2.83	0.02	0.02	0.29	217.18	13.40	15.34	2.00	0.00	6.09	1.12
56	13.28	0.12	7.36	0.09	0.04	0.95	195.57	14.76	11.11	2.40	0.00	9.31	1.85
58	9.95	0.53	2.77	0.41	0.11	2.79	186.49	12.82	68.39	1.81	0.00	5.23	1.34
60	16.31	0.59	7.89	0.54	0.12	4.79	190.38	12.91	53.82	2.95	0.00	9.74	1.47
62	12.57	0.38	6.21	0.30	0.08	2.56	192.03	13.72	17.76	2.28	0.00	8.55	1.34
64	10.71	0.05	2.39	0.02	0.01	0.25	205.52	12.43	56.50	1.94	0.00	5.43	1.82
66	9.82	0.00	3.30	0.00	0.00	0.00	206.86	14.45	16.04	1.77	0.00	5.74	1.28
68	11.30	0.29	2.67	0.20	0.06	1.76	206.36	12.90	73.09	2.04	0.00	4.70	0.78
70	10.53	0.05	1.31	0.02	0.02	0.25	204.47	12.70	34.83	1.90	0.00	2.11	0.47
72	11.43	0.32	5.35	0.27	0.07	2.26	193.07	13.66	40.93	2.08	0.00	5.78	0.92
74	16.92	0.48	6.50	0.42	0.42	3.76	203.48	13.49	72.70	3.06	0.00	8.02	0.91
76	6.99	0.00	2.16	0.00	0.00	0.00	123.36	11.69	15.85	1.26	0.00	3.79	0.90
78	17.63	0.66	8.89	0.56	0.14	4.52	193.94	12.91	16.05	3.20	0.00	9.74	1.31
80	5.24	0.00	0.93	0.00	0.00	0.00	198.84	13.43	49.83	0.94	0.00	1.92	0.46
82	12.34	0.43	5.10	0.30	0.09	2.25	199.45	13.86	54.32	2.24	0.00	9.22	1.73
84	8.14	0.03	1.90	0.01	0.01	0.14	194.11	12.45	15.12	1.47	0.00	2.81	0.31
AVE.	11.72	0.25	4.41	0.19	0.07	1.63	194.35	13.15	39.30	2.12	0.00	6.30	1.20

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 3
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.35	2.30	0.62	0.08	4.66	34.96	12.28	1.63	3.90	105.33	18.20	11.25
53	16.52	0.25	1.79	0.46	0.06	3.49	37.88	12.85	16.11	2.97	105.20	10.26	3.17
55	33.41	3.74	7.14	4.3	0.77	24.65	37.22	17.17	17.21	6.04	103.50	17.72	4.83
57	19.86	0.64	2.01	0.84	0.20	6.17	35.62	13.69	17.10	3.60	103.38	10.75	6.02
59	22.16	1.90	3.23	3.08	0.37	17.45	34.49	13.06	16.84	4.01	109.73	7.62	2.45
61	22.85	0.77	4.64	0.75	0.26	5.56	26.57	12.67	1.06	4.14	86.29	26.83	6.09
63	14.37	1.66	2.28	2.48	0.37	11.76	36.49	11.92	19.03	2.60	97.05	15.54	3.22
65	21.82	0.15	1.28	0.14	0.04	1.43	36.30	14.78	1.72	3.95	112.65	4.71	3.58
67	20.67	0.29	0.94	0.26	0.10	2.51	37.53	13.72	16.38	3.74	118.51	3.54	0.56
69	30.64	3.39	2.99	3.68	0.70	17.78	36.49	14.92	1.81	5.55	99.54	19.67	4.76
71	22.40	0.68	5.10	0.64	0.29	5.06	37.52	13.69	16.26	4.05	85.02	31.41	6.20
73	19.48	0.08	2.16	0.03	0.04	0.43	36.52	12.26	1.31	3.53	108.75	9.00	3.13
75	35.24	1.16	8.40	1.88	0.28	14.20	35.96	15.05	2.09	6.39	98.57	15.20	7.19
77	16.21	0.53	1.63	0.56	0.12	3.67	37.21	12.62	2.77	2.94	109.53	6.77	2.57
79	40.20	4.13	9.53	4.89	0.90	29.62	34.16	14.94	16.96	7.29	87.11	30.92	6.67
81	25.21	1.00	3.88	1.19	0.33	8.47	27.87	13.10	1.54	4.56	87.95	26.69	8.26
83	23.88	0.59	5.98	0.33	0.20	2.95	36.83	13.20	18.40	4.33	84.03	27.01	7.78
AVE.	23.91	1.25	3.84	1.54	0.30	9.40	35.27	13.64	9.90	4.33	100.13	16.58	5.16

Agricultural Managment System: 3
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.61	7.80	0.77	0.14	5.96	29.39	9.40	2.44	6.24	72.36	16.34	2.44
54	21.23	0.32	2.18	0.51	0.08	3.95	33.32	8.39	2.10	3.83	78.64	7.35	1.52
56	22.13	0.08	2.22	0.03	0.02	0.43	30.99	10.07	2.36	4.01	82.40	6.24	2.10
58	43.91	1.95	13.50	1.09	0.51	9.07	28.72	10.72	2.90	7.94	63.61	25.76	4.48
60	35.39	2.01	7.61	1.66	0.45	10.75	28.80	9.51	2.31	6.41	74.23	15.44	1.91
62	40.23	3.74	10.57	4.57	0.94	24.35	28.84	10.56	3.30	7.29	64.60	22.73	3.91
64	28.56	0.48	5.23	0.31	0.11	2.87	31.17	9.16	2.40	5.17	76.79	12.67	2.25
66	19.74	0.02	0.00	0.02	0.01	0.25	32.36	7.75	2.89	3.57	86.74	0.00	0.00
68	29.18	0.42	3.48	0.56	0.20	4.61	32.19	9.17	4.43	5.27	72.29	12.91	2.24
70	25.94	0.32	2.71	0.51	0.07	3.66	30.76	9.57	3.18	4.69	81.11	7.06	1.24
72	44.13	3.16	9.09	2.49	0.68	14.87	29.86	11.49	3.84	7.97	75.66	14.63	2.60
74	27.73	0.66	4.42	0.37	0.16	3.46	30.90	9.46	1.88	5.02	78.06	10.41	1.63
76	27.89	1.46	6.93	1.95	0.32	12.19	30.20	9.58	3.46	5.06	73.46	13.34	2.33
78	44.11	1.22	15.29	1.05	0.35	9.32	28.88	12.16	3.65	7.98	70.10	22.07	3.22
80	25.52	0.30	5.65	0.12	0.07	1.26	28.86	9.13	1.57	4.62	76.44	10.95	2.37
82	24.73	0.10	3.71	0.06	0.08	0.78	30.35	10.34	3.22	4.47	75.78	11.55	2.02
84	45.25	2.28	15.52	2.88	0.56	19.62	29.07	11.58	3.58	8.20	68.25	22.69	3.70
AVE.	31.77	1.13	6.82	1.11	0.28	7.49	30.27	9.89	2.91	5.75	74.74	13.66	2.35

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 3
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.43	0.00	0.64	0.09	4.28	45.92	5.74	1.34	2.85	9.76	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	49.57	6.02	1.75	2.07	8.48	0.00	0.00
56	28.33	2.29	3.39	1.78	0.45	12.70	44.99	8.27	2.14	5.14	12.74	0.50	0.08
58	23.08	1.08	0.59	1.08	0.22	8.14	42.68	8.30	1.83	4.19	13.44	0.00	0.00
60	23.93	1.97	0.45	1.98	0.37	12.55	43.39	7.69	1.59	4.33	12.36	0.00	0.00
62	20.42	0.87	0.74	0.91	0.17	7.13	43.83	7.28	1.91	3.69	12.01	0.20	0.06
64	18.02	0.34	0.00	0.33	0.06	2.34	46.00	7.44	1.56	3.27	11.59	0.00	0.00
66	22.35	3.10	3.55	2.27	0.59	14.27	46.71	7.93	1.83	4.04	12.48	0.01	0.01
68	13.17	0.08	0.35	0.09	0.01	0.94	46.40	8.05	1.30	2.38	13.62	0.00	0.00
70	8.91	0.50	0.00	0.31	0.10	2.23	46.17	6.85	1.00	1.62	10.53	0.00	0.00
72	20.81	0.43	2.04	0.53	0.09	4.51	44.09	8.05	2.18	3.78	12.39	0.75	0.37
74	18.92	1.30	0.19	1.37	0.25	9.61	46.24	6.91	0.75	3.42	11.37	0.00	0.00
76	24.16	1.83	3.28	1.30	0.36	9.17	44.72	7.76	2.05	4.37	13.51	0.04	0.01
78	11.20	0.09	0.00	0.13	0.02	1.18	44.29	6.86	1.43	2.03	11.36	0.00	0.00
80	16.41	0.67	0.00	0.55	0.12	4.08	45.20	5.93	2.01	2.97	8.81	0.00	0.00
82	19.17	0.58	0.62	0.58	0.12	4.74	45.38	7.23	2.08	3.47	12.02	0.00	0.00
84	14.24	0.10	0.11	0.17	0.02	1.59	44.10	7.24	1.66	2.59	11.74	0.01	0.03
AVE.	18.25	0.92	0.90	0.82	0.18	5.85	45.28	7.27	1.67	3.31	11.66	0.09	0.03

Agricultural Managment System: 3
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.16	7.45	0.13	0.04	1.11	41.73	4.19	31.98	2.73	0.00	3.95	1.10
54	11.03	0.06	2.83	0.02	0.02	0.29	45.41	4.16	32.25	2.00	0.00	2.04	0.37
56	13.28	0.12	7.36	0.10	0.03	1.03	40.30	4.69	31.71	2.40	0.00	3.86	0.77
58	9.95	0.53	2.77	0.70	0.11	4.28	38.55	4.13	32.95	1.81	0.00	2.55	0.69
60	16.31	0.59	7.89	0.67	0.12	5.64	39.23	4.16	31.98	2.95	0.00	4.60	0.91
62	12.57	0.38	6.21	0.33	0.08	2.74	39.42	4.41	31.94	2.28	0.00	3.57	0.54
64	10.71	0.05	2.39	0.02	0.01	0.25	42.09	3.93	32.06	1.94	0.00	3.16	0.93
66	9.82	0.00	3.30	0.00	0.00	0.00	42.25	4.44	32.75	1.77	0.00	1.86	0.43
68	11.30	0.29	2.67	0.23	0.06	1.96	42.43	3.98	34.60	2.04	0.00	1.67	0.29
70	10.53	0.05	1.31	0.02	0.01	0.25	42.22	3.95	32.88	1.90	0.00	0.76	0.17
72	11.43	0.32	5.35	0.33	0.06	2.66	39.78	4.31	33.18	2.08	0.00	2.35	0.37
74	16.92	0.48	6.50	0.45	0.12	3.87	42.01	4.23	30.91	3.06	0.00	6.07	0.69
76	6.99	0.00	2.16	0.00	0.00	0.00	40.86	3.87	5.59	1.26	0.00	1.24	0.29
78	17.63	0.66	8.89	0.63	0.13	4.92	40.10	4.19	31.41	3.20	0.00	3.88	0.53
80	5.24	0.00	0.93	0.00	0.00	0.00	40.96	4.23	34.79	0.94	0.00	0.62	0.15
82	12.34	0.43	5.10	0.34	0.09	2.49	41.03	4.35	32.05	2.24	0.00	4.38	0.87
84	8.14	0.03	1.90	0.01	0.01	0.14	40.09	4.01	32.38	1.47	0.00	1.04	0.12
AVE.	11.72	0.25	4.41	0.23	0.05	1.86	41.09	4.19	30.91	2.12	0.00	2.80	0.54

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 3L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.35	2.30	0.62	0.07	4.66	127.36	38.29	5.16	3.90	93.54	10.88	7.22
53	16.52	0.25	1.79	0.46	0.07	3.49	145.57	43.93	40.86	2.97	82.26	12.50	3.37
55	33.41	3.74	7.14	4.3	0.76	24.65	146.01	60.69	47.86	6.04	91.48	18.86	5.07
57	19.86	0.64	2.01	0.84	0.15	6.17	141.67	49.01	48.03	3.60	88.39	7.25	3.50
59	22.16	1.90	3.23	3.08	0.37	17.45	137.23	46.85	43.11	4.01	85.17	13.32	4.30
61	22.85	0.77	4.64	0.75	0.20	5.56	94.53	45.07	6.41	4.14	72.49	21.74	4.64
63	14.37	1.66	2.28	2.48	0.34	11.76	145.25	42.79	47.68	2.60	84.83	7.14	1.52
65	21.82	0.15	1.28	0.14	0.04	1.43	144.81	53.05	5.61	3.95	105.48	1.87	1.54
67	20.67	0.29	0.94	0.26	0.11	2.51	149.40	49.38	42.98	3.74	100.67	7.38	1.17
69	30.64	3.39	2.99	3.68	0.67	17.78	145.14	53.38	9.24	5.55	89.24	17.14	4.29
71	22.40	0.68	5.10	0.64	0.22	5.06	148.31	48.87	42.06	4.05	82.34	20.90	5.84
73	19.48	0.08	2.16	0.03	0.04	0.43	145.04	43.80	6.92	3.53	80.75	15.97	5.52
75	35.24	1.16	8.40	1.88	0.25	14.20	142.77	53.72	5.82	6.39	88.65	12.97	6.01
77	16.21	0.53	1.63	0.56	0.12	3.67	147.69	45.18	9.57	2.94	82.56	13.08	5.05
79	40.20	4.13	9.53	4.89	0.86	29.62	135.94	53.61	42.96	7.29	83.97	22.94	5.44
81	25.21	1.00	3.88	1.19	0.29	8.47	99.14	46.62	4.60	4.56	84.66	19.76	6.97
83	23.88	0.59	5.98	0.33	0.20	2.95	146.14	47.35	46.20	4.33	66.36	29.46	5.24
AVE.	23.91	1.25	3.84	1.54	0.28	9.40	137.76	48.33	26.77	4.33	86.05	14.89	4.51

Agricultural Managment System: 3L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.61	7.80	0.77	0.16	5.96	97.28	33.92	7.08	6.24	35.37	36.27	4.31
54	21.23	0.32	2.18	0.51	0.11	3.95	117.45	31.94	6.90	3.83	55.08	14.72	1.87
56	22.13	0.08	2.22	0.03	0.03	0.43	110.80	39.05	7.96	4.01	64.61	16.40	5.23
58	43.91	1.95	13.50	1.09	0.43	9.07	103.15	42.34	9.64	7.94	33.96	47.30	9.46
60	35.39	2.01	7.61	1.66	0.46	10.75	103.55	37.52	8.67	6.41	38.44	37.03	4.72
62	40.23	3.74	10.57	4.57	0.77	24.35	104.11	41.55	10.37	7.29	35.07	41.42	6.08
64	28.56	0.48	5.23	0.31	0.12	2.87	113.00	36.10	7.70	5.17	44.82	31.38	5.55
66	19.74	0.02	0.00	0.02	0.01	0.25	117.96	30.68	8.87	3.57	69.25	0.00	0.00
68	29.18	0.42	3.48	0.56	0.13	4.61	117.23	35.99	13.24	5.27	55.35	14.81	2.59
70	25.94	0.32	2.71	0.51	0.08	3.66	111.30	37.66	8.95	4.69	57.79	19.79	3.46
72	44.13	3.16	9.09	2.49	0.69	14.87	107.37	44.76	11.40	7.97	42.66	36.33	6.54
74	27.73	0.66	4.42	0.37	0.18	3.46	111.64	37.23	6.23	5.02	52.34	24.81	3.19
76	27.89	1.46	6.93	1.95	0.33	12.19	108.98	37.61	7.01	5.06	37.90	34.78	6.01
78	44.11	1.22	15.29	1.05	0.29	9.32	103.76	47.78	13.40	7.98	28.97	53.45	6.86
80	25.52	0.30	5.65	0.12	0.10	1.26	103.71	36.06	5.66	4.62	42.77	28.95	6.19
82	24.73	0.10	3.71	0.06	0.04	0.78	109.59	40.68	9.92	4.47	49.72	23.16	4.55
84	45.25	2.28	15.52	2.88	0.50	19.62	104.80	45.15	12.61	8.20	35.75	42.48	8.27
AVE.	31.77	1.13	6.82	1.11	0.26	7.49	108.57	38.59	9.15	5.75	45.87	29.59	4.99

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 3L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.43	0.00	0.64	0.09	4.28	101.24	18.31	3.25	2.85	25.38	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	119.34	20.38	5.52	2.07	23.94	0.00	0.00
56	28.33	2.29	3.39	1.78	0.45	12.70	104.39	28.68	4.28	5.14	36.30	1.09	0.18
58	23.08	1.08	0.59	1.08	0.23	8.14	96.34	29.09	4.10	4.19	38.99	0.00	0.00
60	23.93	1.97	0.45	1.98	0.38	12.55	99.20	26.60	4.06	4.33	35.57	0.00	0.00
62	20.42	0.87	0.74	0.91	0.19	7.13	100.98	25.40	3.65	3.69	35.44	0.38	0.12
64	18.02	0.34	0.00	0.33	0.06	2.34	109.77	25.50	3.36	3.27	33.39	0.00	0.00
66	22.35	3.10	3.55	2.27	0.59	14.27	112.21	28.01	5.34	4.04	35.13	0.01	0.01
68	13.17	0.08	0.35	0.09	0.02	0.94	110.77	28.73	3.91	2.38	40.22	0.22	0.29
70	8.91	0.50	0.00	0.31	0.11	2.23	109.30	24.28	3.23	1.62	31.49	0.00	0.00
72	20.81	0.43	2.04	0.53	0.09	4.51	101.71	27.93	4.47	3.78	35.15	2.40	1.39
74	18.92	1.30	0.19	1.37	0.27	9.61	109.21	24.70	2.08	3.42	32.62	0.00	0.00
76	24.16	1.83	3.28	1.30	0.36	9.17	104.28	26.97	5.62	4.37	32.74	0.29	0.05
78	11.20	0.09	0.00	0.13	0.02	1.18	101.87	24.16	3.90	2.03	36.70	0.00	0.00
80	16.41	0.67	0.00	0.55	0.12	4.08	105.74	20.24	5.32	2.97	24.91	0.00	0.00
82	19.17	0.58	0.62	0.58	0.12	4.74	106.49	25.37	4.94	3.47	34.42	0.00	0.00
84	14.24	0.10	0.11	0.17	0.02	1.59	101.61	25.46	3.41	2.59	36.17	0.23	0.98
AVE.	18.25	0.92	0.90	0.82	0.18	5.85	105.55	25.28	4.14	3.31	33.44	0.27	0.18

Agricultural Managment System: 3L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.16	7.45	0.13	0.04	1.11	142.20	9.36	53.78	2.73	0.00	7.38	2.00
54	11.03	0.06	2.83	0.02	0.02	0.29	159.41	10.25	56.70	2.00	0.00	4.69	0.87
56	13.28	0.12	7.36	0.10	0.04	1.03	143.38	11.33	54.14	2.40	0.00	7.46	1.48
58	9.95	0.53	2.77	0.70	0.11	4.28	136.79	9.87	56.97	1.81	0.00	4.76	1.26
60	16.31	0.59	7.89	0.67	0.12	5.64	139.60	9.94	54.31	2.95	0.00	8.82	1.68
62	12.57	0.38	6.21	0.33	0.08	2.74	140.75	10.55	54.27	2.28	0.00	6.82	1.05
64	10.71	0.05	2.39	0.02	0.01	0.25	150.56	9.52	55.03	1.94	0.00	5.79	1.75
66	9.82	0.00	3.30	0.00	0.00	0.00	151.49	11.04	57.62	1.77	0.00	4.33	0.97
68	11.30	0.29	2.67	0.23	0.06	1.96	151.22	9.87	60.16	2.04	0.00	3.65	0.61
70	10.53	0.05	1.31	0.02	0.02	0.25	149.89	9.73	57.52	1.90	0.00	1.65	0.37
72	11.43	0.32	5.35	0.33	0.07	2.66	141.55	10.48	57.13	2.08	0.00	4.60	0.74
74	16.92	0.48	6.50	0.45	0.12	3.87	149.19	10.34	52.58	3.06	0.00	11.01	1.26
76	6.99	0.00	2.16	0.00	0.00	0.00	95.26	9.02	12.23	1.26	0.00	2.87	0.68
78	17.63	0.66	8.89	0.63	0.13	4.92	142.24	9.95	53.32	3.20	0.00	7.69	1.03
80	5.24	0.00	0.93	0.00	0.00	0.00	145.75	10.31	61.85	0.94	0.00	1.46	0.35
82	12.34	0.43	5.10	0.34	0.09	2.49	146.19	10.63	55.09	2.24	0.00	8.64	1.74
84	8.14	0.03	1.90	0.01	0.01	0.14	142.35	9.58	55.98	1.47	0.00	2.04	0.22
AVE.	11.72	0.25	4.41	0.23	0.05	1.86	142.81	10.10	53.45	2.12	0.00	5.51	1.06

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 4
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.39	2.29	0.79	0.11	5.72	34.96	12.27	1.63	3.90	127.10	23.58	13.49
53	16.52	0.28	1.78	0.54	0.07	4.14	37.90	12.85	15.28	2.97	137.39	8.23	2.37
55	33.41	3.90	6.99	5.12	1.08	28.89	37.24	17.17	16.38	6.04	126.81	22.10	6.42
57	19.86	0.69	2.00	1.05	0.57	7.57	35.65	13.68	16.40	3.60	125.98	14.71	8.33
59	22.16	2.00	3.16	3.73	0.45	20.24	34.52	13.07	16.01	4.01	139.06	7.61	2.45
61	22.85	0.84	4.59	1.12	1.02	8.14	26.62	12.68	1.06	4.14	117.59	23.97	6.27
63	14.37	1.71	2.23	3.96	0.45	17.20	36.57	11.94	19.17	2.60	117.63	22.00	4.44
65	21.82	0.17	1.26	0.21	0.11	2.12	36.36	14.79	1.72	3.95	137.09	8.17	4.98
67	20.67	0.32	0.93	0.29	0.13	2.73	37.56	13.72	15.53	3.74	147.86	3.54	0.56
69	30.64	3.50	2.90	4.35	1.41	20.71	36.53	14.94	1.79	5.55	134.53	13.77	4.40
71	22.40	0.73	5.06	1.08	0.93	7.70	37.56	13.69	15.43	4.05	105.11	37.60	8.67
73	19.48	0.09	2.15	0.03	0.04	0.43	36.54	12.26	1.31	3.53	138.13	9.00	3.14
75	35.24	1.26	8.28	2.12	0.48	15.94	35.97	15.05	2.09	6.39	121.97	18.42	9.71
77	16.21	0.56	1.62	0.63	0.12	4.02	37.24	12.64	20.09	2.94	120.41	6.77	2.57
79	40.20	4.35	9.35	6.21	1.25	35.96	34.18	14.95	16.17	7.29	106.44	38.45	8.77
81	25.21	1.07	3.84	1.62	0.86	11.25	27.89	13.10	1.55	4.56	113.59	28.64	9.52
83	23.88	0.62	5.92	0.33	0.49	3.03	36.86	13.22	17.53	4.33	112.24	26.28	9.39
AVE.	23.91	1.32	3.78	1.95	0.56	11.52	35.30	13.65	10.54	4.33	125.23	18.40	6.20

Agricultural Managment System: 4
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.68	7.74	0.85	0.16	6.48	29.40	9.39	2.44	6.24	77.73	14.91	2.03
54	21.23	0.35	2.14	0.55	0.08	4.20	33.34	8.38	19.12	3.83	64.57	6.20	1.10
56	22.13	0.10	2.22	0.04	0.04	0.53	31.00	10.07	3.29	4.01	85.91	5.54	1.80
58	43.91	2.07	13.36	1.25	0.86	10.16	28.75	10.72	2.89	7.94	74.10	19.22	3.93
60	35.39	2.10	7.52	1.74	0.53	11.20	28.85	9.49	2.56	6.41	78.27	14.54	1.97
62	40.23	3.88	10.44	4.72	0.88	25.14	28.89	10.56	3.35	7.29	74.30	17.58	2.91
64	28.56	0.54	5.21	0.38	0.13	3.41	31.23	9.18	2.44	5.17	81.99	12.10	2.16
66	19.74	0.03	0.00	0.03	0.01	0.35	32.40	7.78	12.58	3.57	80.30	0.00	0.00
68	29.18	0.47	3.46	0.62	0.21	5.05	32.21	9.17	26.83	5.27	59.06	7.21	1.30
70	25.94	0.34	2.68	0.54	0.07	3.87	30.80	9.56	3.33	4.69	84.88	6.72	1.18
72	44.13	3.32	8.96	2.57	0.71	15.37	29.90	11.48	3.96	7.97	80.59	13.26	2.40
74	27.73	0.71	4.37	0.43	0.21	3.92	30.92	9.46	1.89	5.02	82.15	10.05	1.40
76	27.89	1.55	6.87	2.01	0.36	12.51	30.23	9.57	9.76	5.06	70.50	12.77	2.26
78	44.11	1.33	15.16	1.15	0.45	10.13	28.90	12.15	3.66	7.98	77.55	34.91	4.84
80	25.52	0.32	5.65	0.13	0.08	1.33	28.88	9.14	1.64	4.62	80.50	10.52	2.28
82	24.73	0.13	3.68	0.09	0.09	1.09	30.38	10.33	3.87	4.47	81.12	9.32	1.75
84	45.25	2.44	15.40	2.99	0.72	20.27	29.11	11.57	3.56	8.20	73.68	20.92	3.47
AVE.	31.77	1.20	6.76	1.18	0.33	7.94	30.31	9.88	6.30	5.75	76.89	12.69	2.16

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 4
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.46	0.00	0.65	0.09	4.32	45.93	5.74	1.34	2.85	9.76	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	49.58	6.02	2.00	2.07	27.43	0.00	0.00
56	28.33	2.39	3.31	1.84	0.45	13.06	45.02	8.24	2.14	5.14	13.72	0.49	0.08
58	23.08	1.18	0.54	1.14	0.22	8.62	42.74	8.29	1.82	4.19	13.42	0.00	0.00
60	23.93	2.07	0.40	2.02	0.39	12.78	43.46	7.65	1.59	4.33	12.62	0.00	0.00
62	20.42	0.93	0.73	0.95	0.19	7.39	43.90	7.25	1.93	3.69	12.02	0.20	0.04
64	18.02	0.35	0.00	0.34	0.07	2.40	46.08	7.43	1.55	3.27	11.63	0.00	0.00
66	22.35	3.22	3.42	2.31	0.61	14.46	46.74	7.94	1.83	4.04	22.50	0.01	0.01
68	13.17	0.08	0.32	0.10	0.02	1.03	46.44	8.04	1.32	2.38	36.11	0.38	0.56
70	8.91	0.53	0.00	0.32	0.11	2.28	46.23	6.84	1.00	1.62	10.66	0.00	0.00
72	20.81	0.47	2.01	0.55	0.10	4.65	44.12	8.03	2.17	3.78	12.50	0.77	0.38
74	18.92	1.37	0.13	1.42	0.27	9.91	46.27	6.92	0.76	3.42	11.37	0.00	0.00
76	24.16	1.91	3.21	1.33	0.37	9.38	44.75	7.76	2.04	4.37	20.63	0.04	0.01
78	11.20	0.11	0.00	0.14	0.03	1.26	44.30	6.88	1.43	2.03	11.36	0.00	0.00
80	16.41	0.71	0.00	0.56	0.14	4.13	45.22	5.92	2.00	2.97	8.92	0.00	0.00
82	19.17	0.65	0.57	0.64	0.13	5.17	45.43	7.22	2.08	3.47	12.75	0.00	0.00
84	14.24	0.12	0.08	0.20	0.03	1.90	44.13	7.24	1.66	2.59	11.72	0.01	0.03
AVE.	18.25	0.97	0.87	0.85	0.19	6.04	45.31	7.26	1.68	3.31	15.24	0.11	0.07

Agricultural Managment System: 4
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.17	7.42	0.14	0.04	1.18	41.75	4.19	32.29	2.73	0.00	3.95	1.10
54	11.03	0.06	2.81	0.54	0.02	0.29	45.42	4.16	33.32	2.00	0.00	2.11	0.38
56	13.28	0.14	7.35	0.12	0.04	1.26	40.34	4.69	32.62	2.40	0.00	3.86	0.77
58	9.95	0.56	2.71	0.72	0.11	4.37	38.60	4.12	33.14	1.81	0.00	2.55	0.69
60	16.31	0.65	7.82	0.72	0.14	5.99	39.31	4.14	32.32	2.95	0.00	4.58	0.92
62	12.57	0.42	6.18	0.38	0.09	3.22	39.50	4.41	32.77	2.28	0.00	3.56	0.55
64	10.71	0.06	2.38	0.03	0.02	0.35	42.15	3.93	32.38	1.94	0.00	3.19	0.94
66	9.82	0.01	3.28	0.01	0.00	0.14	42.29	4.44	33.66	1.77	0.00	1.86	0.43
68	11.30	0.30	2.65	0.24	0.06	2.02	42.47	3.97	34.81	2.04	0.00	1.67	0.29
70	10.53	0.06	1.30	0.03	0.02	0.35	42.26	3.95	33.53	1.90	0.00	0.75	0.17
72	11.43	0.34	5.34	0.35	0.07	2.80	39.80	4.31	33.75	2.08	0.00	2.34	0.37
74	16.92	0.51	6.45	0.48	0.12	4.11	42.05	4.23	31.00	3.06	0.00	6.10	0.69
76	6.99	0.00	2.16	0.00	0.00	0.00	40.87	3.87	5.59	1.26	0.00	1.24	0.29
78	17.63	0.71	8.85	0.68	0.14	5.29	40.12	4.19	32.25	3.20	0.00	3.87	0.53
80	5.24	0.00	0.90	0.00	0.00	0.00	41.00	4.22	35.32	0.94	0.00	0.61	0.15
82	12.34	0.46	5.06	0.36	0.10	2.60	41.07	4.35	32.40	2.24	0.00	4.39	0.88
84	8.14	0.04	1.88	0.01	0.01	0.14	40.13	4.01	33.29	1.47	0.00	1.03	0.09
AVE.	11.72	0.26	4.39	0.28	0.06	2.01	41.13	4.19	31.44	2.12	0.00	2.80	0.54

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 5L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.39	2.17	0.67	0.09	4.95	127.35	38.31	5.16	3.90	103.52	13.72	9.61
53	16.52	0.28	1.76	0.51	0.08	3.88	155.84	48.40	41.31	2.97	96.88	15.46	4.27
55	33.41	3.89	6.83	4.44	0.80	25.45	159.17	68.35	49.68	6.04	105.90	24.24	6.65
57	19.86	0.70	1.95	0.89	0.20	6.51	155.81	56.02	49.73	3.60	103.21	10.98	5.56
59	22.16	2.00	3.08	3.18	0.42	17.97	151.36	53.89	44.21	4.01	102.75	15.98	5.41
61	22.85	0.84	4.44	0.79	0.26	5.88	109.38	51.95	7.60	4.14	86.39	27.12	6.02
63	14.37	1.71	2.19	2.55	0.37	12.02	160.77	49.28	49.66	2.60	99.84	11.20	2.42
65	21.82	0.17	1.21	0.19	0.04	1.88	159.74	61.23	6.57	3.95	124.22	3.76	3.03
67	20.67	0.32	0.92	0.32	0.14	2.95	165.15	56.50	44.03	3.74	120.34	9.25	1.49
69	30.64	3.50	2.82	3.79	0.70	18.44	160.19	61.35	10.66	5.55	105.93	21.43	5.60
71	22.40	0.72	4.97	0.72	0.28	5.55	163.82	56.26	42.98	4.05	95.54	27.99	7.76
73	19.48	0.08	1.98	0.03	0.06	0.43	160.37	50.48	8.09	3.53	98.61	18.73	6.18
75	35.24	1.26	8.02	1.98	0.28	14.95	46.51	20.96	2.53	6.39	72.03	11.45	5.34
77	16.21	0.55	1.55	0.57	0.12	3.71	107.53	27.32	5.50	2.94	74.60	13.06	5.25
79	40.20	4.34	9.19	5.09	0.93	30.88	133.24	52.02	43.07	7.29	89.67	27.65	6.82
81	25.21	1.07	3.71	1.25	0.33	8.93	108.20	50.77	5.01	4.56	97.14	23.87	8.75
83	23.88	0.62	5.80	0.33	0.23	2.95	159.34	53.49	47.22	4.33	77.13	36.91	7.04
AVE.	23.91	1.32	3.68	1.61	0.31	9.84	140.22	50.39	27.24	4.33	97.28	18.40	5.72

Agricultural Managment System: 5L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.68	7.50	0.85	0.20	6.48	97.38	33.80	7.09	6.24	36.02	35.37	4.42
54	21.23	0.34	2.06	0.53	0.11	4.06	125.54	34.13	7.37	3.83	57.54	14.38	1.94
56	22.13	0.10	2.09	0.04	0.04	0.53	120.53	42.48	8.65	4.01	69.68	16.56	4.67
58	43.91	2.05	12.97	1.24	0.47	10.11	113.14	46.51	10.65	7.94	36.94	48.72	10.03
60	35.39	2.10	7.35	1.73	0.49	11.15	113.95	41.25	9.56	6.41	41.25	37.79	5.03
62	40.23	3.85	10.29	4.67	0.79	24.86	114.73	45.77	11.32	7.29	37.83	43.17	6.07
64	28.56	0.54	5.06	0.38	0.13	3.41	124.76	39.85	8.58	5.17	48.28	32.40	5.99
66	19.74	0.03	0.00	0.03	0.02	0.35	129.85	33.70	9.80	3.57	72.33	0.00	0.00
68	29.18	0.47	3.33	0.62	0.14	5.05	129.27	39.69	14.53	5.27	58.46	15.03	2.83
70	25.94	0.34	2.51	0.54	0.08	3.87	122.73	41.29	9.80	4.69	62.30	19.34	3.67
72	44.13	3.31	8.69	2.57	0.72	15.37	118.41	49.26	12.55	7.97	46.00	36.79	7.00
74	27.73	0.70	4.26	0.41	0.18	3.76	123.20	41.02	6.89	5.02	56.40	25.26	2.89
76	27.89	1.53	6.71	1.99	0.35	12.39	3.69	10.97	1.45	5.06	23.90	26.58	4.40
78	44.11	1.33	14.88	1.15	0.33	10.13	76.61	34.75	9.77	7.98	24.18	45.66	6.07
80	25.52	0.32	5.35	0.13	0.11	1.33	101.78	35.29	5.55	4.62	43.33	27.83	6.26
82	24.73	0.13	3.56	0.09	0.06	1.09	116.35	42.98	10.49	4.47	51.86	22.94	4.75
84	45.25	2.43	15.06	2.99	0.53	20.27	114.08	49.08	13.67	8.20	38.48	43.09	8.78
AVE.	31.77	1.19	6.57	1.17	0.28	7.89	108.59	38.93	9.28	5.75	47.34	28.88	4.99

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 5L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.46	0.00	0.65	0.09	4.32	101.32	18.31	3.25	2.85	25.40	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	126.05	21.76	5.91	2.07	25.44	0.00	0.00
56	28.33	2.39	3.31	1.84	0.48	13.06	111.74	31.06	4.54	5.14	39.07	1.14	0.19
58	23.08	1.18	0.54	1.14	0.23	8.62	103.64	31.76	4.38	4.19	42.44	0.00	0.00
60	23.93	2.07	0.40	2.04	0.40	12.75	107.09	29.13	4.45	4.33	38.61	0.00	0.00
62	20.42	0.93	0.73	0.88	0.20	6.89	109.18	27.82	3.97	3.69	38.52	0.41	0.09
64	18.02	0.35	0.00	0.34	0.07	2.40	119.02	28.01	3.61	3.27	36.57	0.00	0.00
66	22.35	3.22	3.42	2.31	0.61	14.46	121.32	30.80	5.83	4.04	38.35	0.01	0.01
68	13.17	0.08	0.32	0.07	0.02	0.78	119.93	31.62	4.32	2.38	43.74	0.32	0.48
70	8.91	0.53	0.00	0.32	0.12	2.28	118.33	26.68	3.55	1.62	34.41	0.00	0.00
72	20.81	0.47	2.01	0.55	0.10	4.65	109.94	30.74	4.80	3.78	38.43	2.62	1.54
74	18.92	1.37	0.13	1.20	0.28	8.63	64.67	26.94	2.00	3.42	35.66	0.00	0.00
76	24.16	1.91	3.21	1.33	0.37	9.38	24.67	1.27	0.98	4.37	5.91	0.01	0.00
78	11.20	0.11	0.00	0.14	0.03	1.26	80.99	17.88	2.95	2.03	27.45	0.00	0.00
80	16.41	0.71	0.00	0.56	0.14	4.13	104.20	19.85	5.20	2.97	24.49	0.00	0.00
82	19.17	0.65	0.57	0.52	0.14	4.44	111.74	26.87	5.17	3.47	36.28	0.00	0.00
84	14.24	0.12	0.08	0.17	0.04	1.60	108.69	27.65	3.62	2.59	39.17	0.19	1.10
AVE.	18.25	0.97	0.87	0.83	0.19	5.86	102.50	25.19	4.03	3.31	33.53	0.28	0.20

Agricultural Managment System: 5L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.17	7.14	0.14	0.04	1.18	156.95	9.40	68.21	2.73	0.00	7.49	2.08
54	11.03	0.06	2.65	0.02	0.02	0.29	180.23	10.83	72.73	2.00	0.00	4.73	0.72
56	13.28	0.13	7.14	0.11	0.04	1.18	164.53	12.23	70.13	2.40	0.00	7.78	1.49
58	9.95	0.56	2.51	0.00	0.12	4.37	157.96	10.69	71.94	1.81	0.00	5.00	1.33
60	16.31	0.64	7.55	0.70	0.14	5.84	161.34	10.77	69.46	2.95	0.00	9.39	1.96
62	12.57	0.42	5.89	0.38	0.10	3.22	162.74	11.46	70.28	2.28	0.00	7.03	1.15
64	10.71	0.05	2.11	0.02	0.01	0.25	173.68	10.36	69.93	1.94	0.00	6.56	1.82
66	9.82	0.01	3.08	0.00	0.00	0.14	174.34	12.00	74.03	1.77	0.00	4.43	1.00
68	11.30	0.30	2.45	0.24	0.06	2.02	174.25	10.72	76.03	2.04	0.00	3.68	0.66
70	10.53	0.06	1.13	0.03	0.02	0.35	172.78	10.56	73.32	1.90	0.00	1.56	0.40
72	11.43	0.34	5.15	0.35	0.07	2.80	163.55	11.41	72.72	2.08	0.00	4.75	0.74
74	16.92	0.51	6.19	0.48	0.13	4.11	58.79	5.90	63.28	3.06	0.00	10.52	1.25
76	6.99	0.00	2.08	0.00	0.00	0.00	22.54	2.13	3.48	1.26	0.00	0.69	0.17
78	17.63	0.71	8.56	0.68	0.15	5.29	137.97	8.05	67.23	3.20	0.00	6.09	0.86
80	5.24	0.00	0.83	0.00	0.00	0.00	158.97	10.24	76.81	0.94	0.00	1.29	0.35
82	12.34	0.44	4.81	0.35	0.09	2.54	165.53	11.23	70.10	2.24	0.00	8.93	1.97
84	8.14	0.04	1.79	0.01	0.01	0.14	163.41	10.30	71.71	1.47	0.00	2.06	0.19
AVE.	11.72	0.26	4.18	0.21	0.06	1.98	149.97	9.90	67.14	2.12	0.00	5.41	1.07

Appendix A.3 Seasonal Reports of CREAMS Simulation Results

Agricultural Managment System: 8
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.23	0.00	0.21	0.06	1.87	40.82	14.06	7.36	3.90	162.10	0.00	0.00
53	16.52	0.15	0.91	0.22	0.08	1.94	34.67	15.25	30.40	2.97	108.90	3.48	1.17
55	33.41	3.07	5.85	2.93	0.82	16.83	40.21	18.10	15.52	6.04	141.29	7.99	2.59
57	19.86	0.42	0.59	0.54	0.11	4.03	37.19	13.61	36.47	3.60	122.02	0.73	1.01
59	22.16	1.57	1.36	1.15	0.39	7.95	36.38	12.43	15.37	4.01	134.58	7.53	2.69
61	22.85	0.56	4.13	0.47	0.21	3.29	27.26	12.98	0.12	4.14	117.81	19.44	9.52
63	14.37	1.31	1.10	0.53	0.26	3.42	37.70	11.02	37.99	2.60	105.34	3.06	0.58
65	21.82	0.04	0.00	0.03	0.04	0.35	30.09	13.13	1.13	3.95	145.95	0.00	0.00
67	20.67	0.12	0.00	0.06	0.07	0.69	40.86	12.34	0.63	3.74	145.44	0.00	0.00
69	30.64	3.05	1.72	2.63	0.59	12.95	29.29	15.25	0.69	5.55	144.16	4.17	1.23
71	22.40	0.42	2.71	0.15	0.21	1.59	39.34	13.15	14.39	4.05	136.28	8.08	2.33
73	19.48	0.00	0.00	0	0.00	0.00	29.31	11.61	0.63	3.53	144.62	0.00	0.00
75	35.24	0.82	8.37	0.75	0.50	6.63	27.84	15.27	1.26	6.39	128.92	12.79	8.20
77	16.21	0.41	0.00	0.42	0.10	2.84	31.01	10.73	65.91	2.94	73.40	0.00	0.00
79	40.20	3.39	8.53	2.72	0.69	18.06	35.79	14.79	16.16	7.29	140.70	7.40	1.80
81	25.21	0.68	0.70	0.6	0.24	4.57	30.16	12.50	1.02	4.56	137.10	6.58	2.14
83	23.88	0.39	5.50	0.15	0.10	1.41	37.85	13.48	17.00	4.33	128.08	13.75	3.95
AVE.	23.91	0.98	2.44	0.80	0.26	5.20	34.46	13.51	15.42	4.33	130.39	5.59	2.19

Agricultural Managment System: 8
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.42	7.99	0.54	0.10	4.41	40.29	13.36	3.11	6.24	79.69	21.19	3.07
54	21.23	0.23	2.26	0.37	0.07	2.89	37.84	9.66	2.46	3.83	106.32	16.54	2.72
56	22.13	0.03	2.24	0.01	0.01	0.14	33.16	10.90	2.53	4.01	85.92	5.94	2.00
58	43.91	1.68	13.89	0.87	0.48	7.47	29.83	11.19	2.98	7.94	69.48	42.08	7.49
60	35.39	1.69	7.97	1.36	0.37	8.93	30.15	10.07	2.43	6.41	77.99	14.92	2.05
62	40.23	3.34	11.01	3.74	0.82	20.03	29.29	10.80	3.38	7.29	67.60	22.65	3.82
64	28.56	0.35	5.31	0.23	0.10	2.29	32.06	9.46	2.49	5.17	95.70	30.99	5.41
66	19.74	0.02	0.00	0.02	0.01	0.25	34.56	8.35	3.05	3.57	90.14	0.00	0.00
68	29.18	0.31	3.55	0.39	0.16	3.33	34.70	10.00	4.74	5.27	75.01	13.66	2.32
70	25.94	0.23	2.78	0.35	0.05	2.67	32.08	10.03	3.30	4.69	84.44	6.62	1.13
72	44.13	2.70	9.52	1.86	0.56	11.64	31.11	12.05	3.95	7.97	79.37	14.08	2.48
74	27.73	0.51	4.56	0.24	0.12	2.37	32.18	9.94	1.94	5.02	81.36	10.47	1.62
76	27.89	1.20	7.12	1.41	0.26	9.21	30.84	9.82	3.72	5.06	77.11	12.60	2.16
78	44.11	0.92	15.65	0.61	0.29	6.00	30.74	13.11	3.88	7.98	82.52	74.48	9.97
80	25.52	0.20	5.75	0.07	0.04	0.77	30.05	9.55	1.64	4.62	80.71	10.65	2.26
82	24.73	0.04	3.84	0.02	0.04	0.29	31.94	11.04	3.39	4.47	79.25	11.73	1.95
84	45.25	1.88	15.83	2.07	0.47	14.89	29.72	11.96	3.74	8.20	70.45	23.90	3.63
AVE.	31.77	0.93	7.02	0.83	0.23	5.74	32.38	10.66	3.10	5.75	81.36	19.56	3.18

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 8
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.31	0.00	0.10	0.05	1.01	54.80	7.74	1.64	2.85	12.21	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	53.33	6.79	1.88	2.07	9.48	0.00	0.00
56	28.33	1.87	3.26	1.05	0.37	8.00	46.54	8.89	2.21	5.14	13.53	0.53	0.09
58	23.08	0.88	0.68	0.76	0.17	6.05	43.49	8.60	1.84	4.19	13.84	0.00	0.00
60	23.93	1.65	0.59	1.48	0.31	9.80	44.33	8.09	1.64	4.33	12.91	0.00	0.00
62	20.42	0.66	0.64	0.63	0.13	5.12	44.04	7.51	1.95	3.69	12.39	0.17	0.04
64	18.02	0.26	0.00	0.25	0.05	1.88	46.67	7.65	1.53	3.27	11.93	0.00	0.00
66	22.35	2.62	3.92	1.58	0.50	10.66	48.47	8.35	1.86	4.04	13.14	0.01	0.01
68	13.17	0.04	0.41	0.04	0.01	0.44	48.29	8.68	1.32	2.38	14.56	0.00	0.00
70	8.91	0.42	0.00	0.24	0.08	1.82	47.14	7.21	0.96	1.62	11.08	0.00	0.00
72	20.81	0.28	1.87	0.24	0.06	2.16	44.99	8.39	2.21	3.78	12.78	0.79	0.38
74	18.92	1.03	0.42	1.02	0.20	7.54	47.22	7.24	0.74	3.42	11.80	0.00	0.00
76	24.16	1.55	3.58	0.87	0.29	6.48	45.22	7.90	2.03	4.37	14.02	0.05	0.01
78	11.20	0.08	0.00	0.10	0.02	1.03	45.74	7.28	1.46	2.03	12.00	0.00	0.00
80	16.41	0.54	0.00	0.30	0.11	2.43	46.17	6.15	2.05	2.97	9.11	0.00	0.00
82	19.17	0.41	0.79	0.38	0.08	3.14	46.60	7.61	2.08	3.47	12.61	0.00	0.00
84	14.24	0.04	0.22	0.02	0.01	0.14	44.59	7.41	1.67	2.59	12.04	0.03	0.04
AVE.	18.25	0.74	0.96	0.53	0.14	3.98	46.92	7.73	1.71	3.31	12.32	0.09	0.03

Agricultural Managment System: 8
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.11	4.46	0.01	0.03	0.14	49.92	4.87	0.00	2.73	7.62	1.39	0.28
54	11.03	0.01	0.72	0.00	0.00	0.00	49.32	4.00	0.00	2.00	7.99	0.00	0.00
56	13.28	0.04	4.65	0.00	0.01	0.00	41.80	4.74	0.00	2.40	7.74	1.43	0.18
58	9.95	0.39	1.18	0.10	0.08	0.90	39.82	3.67	0.00	1.81	6.56	0.63	0.09
60	16.31	0.33	4.73	0.04	0.06	0.53	40.25	4.08	0.00	2.95	7.57	1.02	0.18
62	12.57	0.21	3.62	0.02	0.04	0.29	39.72	4.31	5.58	2.28	0.00	2.57	0.37
64	10.71	0.00	0.00	0.00	0.00	0.00	43.23	3.44	0.00	1.94	6.96	0.00	0.00
66	9.82	0.00	0.62	0.00	0.00	0.00	44.21	4.25	0.00	1.77	7.75	0.09	0.03
68	11.30	0.13	0.30	0.01	0.03	0.14	44.53	3.76	0.00	2.04	7.21	0.00	0.00
70	10.53	0.01	0.00	0.00	0.00	0.00	43.48	3.65	0.00	1.90	6.56	0.00	0.00
72	11.43	0.22	4.05	0.02	0.04	0.25	40.93	4.07	0.00	2.08	6.51	1.54	0.18
74	16.92	0.23	3.20	0.03	0.04	0.43	43.11	4.10	0.00	3.06	7.31	0.57	0.07
76	6.99	0.00	0.40	0.00	0.00	0.00	41.76	3.47	0.00	1.26	6.42	0.29	0.08
78	17.63	0.49	6.84	0.08	0.09	0.82	41.59	4.16	0.00	3.20	6.64	1.91	0.19
80	5.24	0.00	0.00	0.00	0.00	0.00	42.65	3.53	0.00	0.94	6.56	0.00	0.00
82	12.34	0.27	1.91	0.04	0.05	0.44	42.33	4.28	0.00	2.24	8.51	0.06	0.00
84	8.14	0.00	0.77	0.00	0.00	0.00	41.02	3.56	0.00	1.47	6.52	0.12	0.02
AVE.	11.72	0.14	2.20	0.02	0.03	0.23	42.92	4.00	0.33	2.12	6.73	0.68	0.10

Appendix A.3 Seasonal Reports of CREAMS Simulation Results

Agricultural Managment System: 8L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTN	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.23	0.00	0.21	0.06	1.87	113.62	39.13	4.32	3.90	130.31	0.00	0.00
53	16.52	0.15	0.91	0.22	0.03	1.94	123.04	53.42	3.47	2.97	106.78	8.14	2.75
55	33.41	3.07	5.85	2.93	0.64	16.83	170.01	70.36	44.84	6.04	112.49	15.53	4.83
57	19.86	0.42	0.59	0.54	0.11	4.03	163.88	55.45	46.09	3.60	106.39	4.52	4.76
59	22.16	1.57	1.36	1.15	0.30	7.95	161.33	51.27	44.05	4.01	113.09	0.00	0.00
61	22.85	0.56	4.13	0.47	0.12	3.29	55.35	26.37	0.20	4.14	28.68	7.93	3.52
63	14.37	1.31	1.10	0.53	0.28	3.42	183.24	51.11	12.66	2.60	94.95	8.72	1.65
65	21.82	0.04	0.00	0.03	0.02	0.35	130.56	56.54	5.47	3.95	119.88	0.00	0.00
67	20.67	0.12	0.00	0.06	0.04	0.69	183.89	51.94	3.86	3.74	116.70	0.00	0.00
69	30.64	3.05	1.72	2.63	0.60	12.95	122.16	63.19	5.18	5.55	114.01	10.65	3.14
71	22.40	0.42	2.71	0.15	0.17	1.59	174.50	54.15	41.11	4.05	95.64	17.96	5.39
73	19.48	0.00	0.00	0.00	0.00	0.00	121.74	48.03	3.58	3.53	113.05	0.00	0.00
75	35.24	0.82	8.37	0.75	0.18	6.63	115.26	62.87	4.03	6.39	101.75	17.64	10.64
77	16.21	0.41	0.00	0.42	0.08	2.84	128.56	43.81	7.86	2.94	103.44	0.00	0.00
79	40.20	3.39	8.53	2.72	0.70	18.06	159.94	60.91	45.92	7.29	94.58	24.70	5.99
81	25.21	0.68	0.70	0.60	0.20	4.57	124.53	51.30	4.50	4.56	111.77	3.30	1.07
83	23.88	0.39	5.50	0.15	0.13	1.41	168.77	55.55	47.26	4.33	81.59	28.56	7.18
AVE.	23.91	0.98	2.44	0.80	0.22	5.20	141.20	52.67	19.08	4.33	102.65	8.68	2.99

Agricultural Managment System: 8L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTN	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.42	7.99	0.54	0.11	4.41	123.17	43.36	9.01	6.24	39.81	39.81	4.64
54	21.23	0.23	2.26	0.37	0.07	2.89	138.15	37.80	8.11	3.83	58.79	15.96	1.96
56	22.13	0.03	2.24	0.01	0.01	0.14	128.34	45.51	9.27	4.01	66.35	16.22	5.07
58	43.91	1.68	13.89	0.87	0.35	7.47	118.76	48.95	11.22	7.94	35.96	48.02	9.17
60	35.39	1.69	7.97	1.36	0.37	8.93	120.90	44.27	10.32	6.41	41.03	39.53	5.65
62	40.23	3.34	11.01	3.74	0.66	20.03	147.53	48.01	14.62	7.29	43.71	31.53	4.54
64	28.56	0.35	5.31	0.23	0.10	2.29	141.49	45.59	9.88	5.17	51.22	35.98	6.23
66	19.74	0.02	0.00	0.02	0.01	0.25	145.44	38.02	11.02	3.57	76.04	0.00	0.00
68	29.18	0.31	3.55	0.39	0.10	3.33	143.40	44.31	16.16	5.27	58.34	15.79	2.72
70	25.94	0.23	2.78	0.35	0.06	2.67	130.66	44.41	10.44	4.69	60.12	20.24	3.45
72	44.13	2.70	9.52	1.86	0.58	11.64	125.60	52.74	13.08	7.97	45.37	38.58	6.80
74	27.73	0.51	4.56	0.24	0.12	2.37	130.63	44.03	7.31	5.02	55.06	26.05	3.21
76	27.89	1.20	7.12	1.41	0.29	9.21	124.85	43.32	8.28	5.06	40.21	36.67	6.15
78	44.11	0.92	15.65	0.61	0.22	6.00	123.91	57.56	16.19	7.98	32.04	56.93	7.13
80	25.52	0.20	5.75	0.07	0.06	0.77	121.37	42.41	6.62	4.62	47.40	31.72	6.68
82	24.73	0.04	3.84	0.02	0.02	0.29	128.96	48.47	11.65	4.47	54.06	26.11	4.90
84	45.25	1.88	15.83	2.07	0.39	14.89	120.25	52.35	14.78	8.20	38.84	45.22	8.59
AVE.	31.77	0.93	7.02	0.83	0.21	5.74	130.20	45.95	11.06	5.75	49.67	30.85	5.11

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 8L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.31	0.00	0.10	0.05	1.01	122.33	23.10	4.02	2.85	31.50	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	136.52	23.88	6.37	2.07	27.77	0.00	0.00
56	28.33	1.87	3.26	1.05	0.37	8.00	117.15	33.45	4.71	5.14	41.92	1.23	0.20
58	23.08	0.88	0.68	0.76	0.18	6.05	107.60	33.43	4.51	4.19	44.62	0.00	0.00
60	23.93	1.65	0.59	1.48	0.32	9.80	90.00	30.91	4.50	4.33	41.25	0.00	0.00
62	20.42	0.66	0.64	0.63	0.15	5.12	133.30	36.51	4.71	3.69	49.74	0.54	0.11
64	18.02	0.26	0.00	0.25	0.05	1.88	131.81	31.95	3.90	3.27	41.56	0.00	0.00
66	22.35	2.62	3.92	1.58	0.50	10.66	133.46	34.24	6.37	4.04	42.58	0.04	0.02
68	13.17	0.04	0.41	0.04	0.01	0.44	130.48	35.19	4.70	2.38	48.03	0.62	0.70
70	8.91	0.42	0.00	0.24	0.09	1.82	124.17	28.76	3.79	1.62	37.00	0.00	0.00
72	20.81	0.28	1.87	0.24	0.06	2.16	115.15	32.72	5.02	3.78	40.50	2.81	1.61
74	18.92	1.03	0.42	1.02	0.20	7.54	123.88	29.02	2.34	3.42	37.90	0.00	0.00
76	24.16	1.55	3.58	0.87	0.29	6.48	116.26	30.84	6.26	4.37	37.31	0.37	0.07
78	11.20	0.08	0.00	0.10	0.02	1.03	117.43	28.76	4.54	2.03	43.64	0.00	0.00
80	16.41	0.54	0.00	0.30	0.11	2.43	119.98	23.65	6.09	2.97	28.77	0.00	0.00
82	19.17	0.41	0.79	0.38	0.08	3.14	121.37	29.86	5.54	3.47	40.16	0.00	0.00
84	14.24	0.04	0.22	0.02	0.01	0.14	113.28	29.24	3.92	2.59	41.10	0.57	1.19
AVE.	18.25	0.74	0.96	0.53	0.15	3.98	120.83	30.32	4.78	3.31	39.73	0.36	0.23

Agricultural Managment System: 8L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.11	4.46	0.01	0.03	0.14	111.44	10.89	0.00	2.73	13.92	3.19	0.61
54	11.03	0.01	0.72	0.00	0.00	0.00	126.26	10.27	0.00	2.00	19.04	0.00	0.00
56	13.28	0.04	4.65	0.00	0.01	0.00	105.23	11.92	0.00	2.40	14.92	3.68	0.47
58	9.95	0.39	1.18	0.10	0.08	0.90	98.52	9.09	0.00	1.81	13.76	1.43	0.20
60	16.31	0.33	4.73	0.04	0.07	0.53	81.72	8.27	9.94	2.95	0.00	5.02	0.87
62	12.57	0.21	3.62	0.02	0.04	0.29	120.25	13.05	0.00	2.28	18.40	1.42	0.33
64	10.71	0.00	0.00	0.00	0.00	0.00	122.08	9.73	0.00	1.94	15.69	0.00	0.00
66	9.82	0.00	0.62	0.00	0.00	0.00	121.74	11.73	0.00	1.77	19.24	0.51	0.12
68	11.30	0.13	0.30	0.01	0.04	0.14	120.32	10.15	0.00	2.04	17.13	0.00	0.00
70	10.53	0.01	0.00	0.00	0.00	0.00	114.55	9.62	0.00	1.90	15.43	0.00	0.00
72	11.43	0.22	4.05	0.02	0.04	0.25	104.74	10.41	0.00	2.08	12.98	4.00	0.44
74	16.92	0.23	3.20	0.03	0.05	0.43	113.11	10.77	0.00	3.06	14.42	1.75	0.23
76	6.99	0.00	0.40	0.00	0.00	0.00	107.35	8.91	0.00	1.26	15.55	0.75	0.22
78	17.63	0.49	6.84	0.08	0.09	0.82	106.76	10.66	0.00	3.20	13.31	4.67	0.46
80	5.24	0.00	0.00	0.00	0.00	0.00	110.82	9.17	0.00	0.94	16.31	0.00	0.00
82	12.34	0.27	1.91	0.04	0.05	0.44	110.23	11.14	0.00	2.24	18.01	0.87	0.06
84	8.14	0.00	0.77	0.00	0.00	0.00	104.22	9.06	0.00	1.47	13.49	0.81	0.09
AVE.	11.72	0.14	2.20	0.02	0.03	0.23	110.55	10.28	0.58	2.12	14.80	1.65	0.24

Appendix A.3 Seasonal Reports of CREAMS Simulation Results

Agricultural Managment System: 11L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.25	0.00	0.33	0.07	2.73	113.04	37.74	4.31	3.90	128.62	0.00	0.00
53	16.52	0.17	0.87	0.28	0.04	2.36	123.03	53.24	3.49	2.97	106.74	7.96	2.73
55	33.41	3.20	5.49	3.16	0.68	18.46	170.30	70.16	44.85	6.04	113.57	14.17	4.87
57	19.86	0.46	0.51	0.58	0.12	4.33	164.30	55.33	46.03	3.60	108.31	3.98	3.29
59	22.16	1.65	1.27	1.35	0.33	9.12	162.32	50.65	44.11	4.01	112.42	0.00	0.00
61	22.85	0.60	3.96	0.52	0.19	3.93	113.52	53.81	3.14	4.14	89.84	24.30	5.22
63	14.37	1.33	1.02	0.92	0.29	5.32	169.14	45.75	11.24	2.60	91.87	7.94	1.60
65	21.82	0.07	0.00	0.07	0.02	0.74	127.09	52.64	5.27	3.95	116.15	0.00	0.00
67	20.67	0.13	0.00	0.12	0.05	1.32	182.79	51.27	3.78	3.74	116.08	0.00	0.00
69	30.64	3.13	1.57	2.77	0.61	13.87	122.00	62.93	5.13	5.55	114.57	9.85	3.14
71	22.40	0.45	2.45	0.25	0.19	2.36	175.04	53.88	41.14	4.05	96.85	16.30	5.50
73	19.48	0.00	0.00	0.00	0.00	0.00	122.52	47.62	3.63	3.53	112.59	0.00	0.00
75	35.24	0.89	8.03	0.98	0.20	8.42	115.64	63.03	4.06	6.39	103.71	16.74	9.71
77	16.21	0.43	0.00	0.43	0.08	2.89	129.09	43.60	7.87	2.94	103.21	0.00	0.00
79	40.20	3.51	8.23	3.10	0.74	20.52	160.23	60.98	46.00	7.29	95.29	23.94	6.02
81	25.21	0.74	0.54	0.71	0.23	5.37	125.13	51.04	4.52	4.56	112.19	2.57	1.06
83	23.88	0.40	5.34	0.18	0.14	1.69	169.12	55.75	47.26	4.33	82.28	27.99	7.24
AVE.	23.91	1.02	2.31	0.93	0.23	6.08	143.78	53.49	19.17	4.33	106.14	9.16	2.96

Agricultural Managment System: 11L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.45	7.71	0.57	0.12	4.62	122.86	43.08	8.99	6.24	40.40	38.89	4.73
54	21.23	0.25	2.15	0.40	0.08	3.06	138.21	37.73	8.12	3.83	59.40	15.30	1.98
56	22.13	0.06	2.10	0.02	0.02	0.29	128.63	45.51	9.30	4.01	67.76	15.52	4.34
58	43.91	1.78	13.36	1.00	0.38	8.46	119.09	49.03	11.25	7.94	36.80	47.06	9.22
60	35.39	1.74	7.69	1.41	0.38	9.23	121.74	44.41	10.36	6.41	42.02	39.31	5.01
62	40.23	3.40	10.73	3.81	0.69	20.41	118.74	47.70	11.83	7.29	37.27	42.52	5.68
64	28.56	0.38	5.16	0.28	0.10	2.68	130.99	41.99	9.08	5.17	49.40	33.74	6.07
66	19.74	0.03	0.00	0.03	0.02	0.35	142.83	37.17	10.81	3.57	75.19	0.00	0.00
68	29.18	0.33	3.39	0.43	0.12	3.71	142.66	43.96	16.06	5.27	58.87	14.86	2.76
70	25.94	0.24	2.60	0.37	0.06	2.79	130.77	44.15	10.44	4.69	60.99	19.01	3.49
72	44.13	2.81	9.13	1.92	0.61	12.02	126.11	52.76	13.17	7.97	46.34	37.40	6.94
74	27.73	0.55	4.41	0.26	0.13	2.54	131.31	44.12	7.36	5.02	55.83	25.34	3.27
76	27.89	1.26	6.90	1.44	0.29	9.36	125.25	43.31	8.27	5.06	41.13	36.28	5.63
78	44.11	1.02	15.29	0.73	0.25	6.99	124.38	57.60	16.26	7.98	32.48	56.34	7.29
80	25.52	0.22	5.45	0.08	0.07	0.86	121.64	42.41	6.64	4.62	48.51	30.60	6.74
82	24.73	0.06	3.69	0.03	0.03	0.43	129.60	48.44	11.70	4.47	54.84	25.17	4.98
84	45.25	2.02	15.39	2.22	0.44	15.86	120.63	52.35	14.76	8.20	39.52	44.31	8.78
AVE.	31.77	0.98	6.77	0.88	0.22	6.10	127.97	45.63	10.85	5.75	49.81	30.69	5.11

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 11L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.33	0.00	0.10	0.06	1.01	122.09	23.04	4.00	2.85	31.42	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	136.58	23.91	6.37	2.07	27.78	0.00	0.00
56	28.33	1.95	3.19	1.07	0.39	8.23	117.46	33.45	4.73	5.14	41.93	1.21	0.20
58	23.08	0.96	0.64	0.78	0.20	6.21	107.88	33.47	4.50	4.19	44.69	0.00	0.00
60	23.93	1.73	0.56	1.51	0.34	9.99	112.63	31.39	4.85	4.33	41.38	0.00	0.00
62	20.42	0.73	0.62	0.68	0.17	5.50	111.70	29.30	3.97	3.69	40.51	0.45	0.09
64	18.02	0.28	0.00	0.26	0.05	1.93	123.69	29.57	3.64	3.27	38.58	0.00	0.00
66	22.35	2.73	3.80	1.61	0.52	10.82	131.47	33.62	6.23	4.04	41.89	0.03	0.02
68	13.17	0.05	0.39	0.05	0.01	0.52	129.94	35.00	4.68	2.38	47.81	0.59	0.69
70	8.91	0.44	0.00	0.25	0.10	1.88	124.29	28.74	3.79	1.62	36.99	0.00	0.00
72	20.81	0.33	1.84	0.28	0.07	2.62	115.55	32.82	5.04	3.78	40.69	2.80	1.62
74	18.92	1.09	0.37	1.06	0.22	7.81	124.45	29.13	2.36	3.42	38.04	0.00	0.00
76	24.16	1.62	3.50	0.89	0.31	6.67	116.59	30.92	6.28	4.37	37.35	0.37	0.07
78	11.20	0.10	0.00	0.14	0.03	1.35	117.79	28.86	4.58	2.03	43.78	0.00	0.00
80	16.41	0.56	0.00	0.30	0.11	2.43	120.23	23.68	6.07	2.97	28.81	0.00	0.00
82	19.17	0.45	0.75	0.41	0.09	3.45	121.90	29.97	5.53	3.47	40.30	0.00	0.00
84	14.24	0.06	0.19	0.03	0.02	0.25	113.60	29.29	3.95	2.59	41.19	0.49	1.19
AVE.	18.25	0.79	0.93	0.55	0.16	4.16	120.46	29.78	4.74	3.31	39.01	0.35	0.23

Agricultural Managment System: 11L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.12	4.29	0.01	0.03	0.14	111.25	10.84	0.00	2.73	13.97	3.07	0.60
54	11.03	0.03	0.61	0.00	0.01	0.00	126.38	10.21	0.00	2.00	18.99	0.00	0.00
56	13.28	0.04	4.50	0.00	0.01	0.00	105.53	11.92	0.00	2.40	15.05	3.55	0.47
58	9.95	0.41	1.13	0.10	0.08	0.90	98.89	8.99	0.00	1.81	13.71	1.36	0.20
60	16.31	0.36	4.48	0.04	0.07	0.53	102.30	10.32	0.00	2.95	14.52	3.30	0.51
62	12.57	0.22	3.43	0.02	0.04	0.29	100.80	10.90	0.00	2.28	16.08	1.01	0.17
64	10.71	0.00	0.00	0.00	0.00	0.00	114.71	8.98	0.00	1.94	14.67	0.00	0.00
66	9.82	0.00	0.42	0.00	0.00	0.00	119.96	11.53	0.00	1.77	19.19	0.23	0.12
68	11.30	0.14	0.17	0.01	0.04	0.14	119.90	10.04	0.00	2.04	16.97	0.00	0.00
70	10.53	0.01	0.00	0.00	0.00	0.00	114.82	9.47	0.00	1.90	15.28	0.00	0.00
72	11.43	0.24	3.88	0.03	0.05	0.35	105.12	10.42	0.00	2.08	13.08	3.94	0.44
74	16.92	0.26	3.01	0.03	0.05	0.43	113.65	10.80	0.00	3.06	14.61	1.61	0.20
76	6.99	0.00	0.34	0.00	0.00	0.00	107.68	8.92	0.00	1.26	15.75	0.64	0.15
78	17.63	0.52	6.65	0.08	0.11	0.82	107.11	10.67	0.00	3.20	13.39	4.62	0.46
80	5.24	0.00	0.00	0.00	0.00	0.00	111.15	9.09	0.00	0.94	16.21	0.00	0.00
82	12.34	0.28	1.72	0.04	0.05	0.44	110.77	11.14	0.00	2.24	18.21	0.66	0.06
84	8.14	0.00	0.67	0.00	0.00	0.00	104.53	9.07	0.00	1.47	13.61	0.71	0.09
AVE.	11.72	0.16	2.08	0.02	0.03	0.24	110.27	10.19	0.00	2.12	15.49	1.45	0.20

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 15
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.24	0.00	0.25	0.09	2.15	65.94	22.61	30.43	3.90	148.41	0.00	0.00
53	16.52	0.15	0.91	0.20	0.08	1.79	86.40	37.35	35.31	2.97	124.44	4.22	1.44
55	33.41	3.14	5.81	2.79	0.86	16.09	98.09	51.33	17.64	6.04	154.22	21.83	6.80
57	19.86	0.44	0.59	0.35	0.12	2.89	97.48	41.74	53.71	3.60	128.82	2.36	2.49
59	22.16	1.60	1.34	1.43	0.42	9.36	97.79	39.08	17.47	4.01	153.14	11.83	4.31
61	22.85	0.57	4.13	0.32	0.21	2.67	88.50	42.09	0.81	4.14	138.97	23.92	12.21
63	14.37	1.32	1.09	1.11	0.27	6.18	102.98	35.39	58.44	2.60	101.04	4.46	0.85
65	21.82	0.07	0.00	0.05	0.07	0.58	96.92	41.82	3.87	3.95	171.75	0.00	0.00
67	20.67	0.12	0.00	0.06	0.08	0.72	111.21	38.99	8.19	3.74	163.66	0.00	0.00
69	30.64	3.08	1.69	2.52	0.59	12.50	93.59	48.36	1.67	5.55	173.96	5.93	1.76
71	22.40	0.42	2.70	0.18	0.23	1.82	105.52	41.45	24.68	4.05	145.19	13.64	4.48
73	19.48	0.00	0.00	0.00	0.00	0.00	94.89	37.40	28.62	3.53	141.82	0.00	0.00
75	35.24	0.84	8.34	0.62	0.53	5.83	89.26	48.65	2.14	6.39	143.74	24.76	13.89
77	16.21	0.42	0.00	0.26	0.11	1.93	99.64	33.86	71.53	2.94	90.57	0.00	0.00
79	40.20	3.44	8.47	2.03	0.70	14.52	95.97	47.25	17.80	7.29	164.28	13.12	3.26
81	25.21	0.70	0.69	0.46	0.27	3.85	96.24	39.60	2.84	4.56	159.00	9.09	2.99
83	23.88	0.39	5.48	0.11	0.11	1.10	102.07	42.77	40.17	4.33	127.61	17.64	6.51
AVE.	23.91	1.00	2.43	0.75	0.28	4.94	95.44	40.57	24.43	4.33	142.98	8.99	3.59

Agricultural Managment System: 15
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.44	7.98	0.56	0.12	4.56	58.74	20.02	4.38	6.24	89.60	38.31	5.22
54	21.23	0.24	2.25	0.38	0.08	2.94	78.23	20.98	12.98	3.83	108.46	19.23	3.07
56	22.13	0.03	2.24	0.01	0.01	0.14	75.60	26.32	5.58	4.01	97.67	8.02	2.56
58	43.91	1.72	13.84	0.95	0.51	8.09	72.15	29.16	6.38	7.94	78.94	61.53	11.17
60	35.39	1.71	7.94	1.38	0.38	9.03	74.77	26.85	6.14	6.41	86.99	20.02	2.84
62	40.23	3.37	10.96	3.80	0.85	20.36	72.60	28.72	7.49	7.29	75.10	28.64	4.73
64	28.56	0.36	5.31	0.26	0.12	2.53	81.15	25.66	5.70	5.17	113.30	45.10	7.86
66	19.74	0.02	0.00	0.02	0.01	0.25	87.28	22.47	6.59	3.57	103.44	0.00	0.00
68	29.18	0.33	3.53	0.42	0.18	3.64	88.17	26.88	10.54	5.27	87.67	19.33	3.29
70	25.94	0.23	2.77	0.36	0.05	2.73	79.76	26.66	6.77	4.69	95.73	8.98	1.53
72	44.13	2.76	9.48	1.89	0.61	11.87	77.37	31.97	8.36	7.97	92.65	25.69	4.57
74	27.73	0.52	4.54	0.24	0.14	2.37	80.92	26.80	4.59	5.02	105.30	26.77	3.82
76	27.89	1.22	7.10	1.43	0.27	9.34	76.14	25.96	7.40	5.06	85.01	16.99	2.78
78	44.11	1.00	15.63	0.71	0.34	6.80	77.22	35.24	9.85	7.98	90.95	86.08	11.53
80	25.52	0.21	5.74	0.07	0.05	0.77	74.32	25.46	4.07	4.62	91.09	14.14	2.91
82	24.73	0.06	3.81	0.03	0.04	0.43	79.65	29.41	7.54	4.47	89.89	16.06	2.78
84	45.25	1.94	15.77	2.12	0.51	15.18	74.14	31.75	9.11	8.20	78.46	49.19	7.94
AVE.	31.77	0.95	6.99	0.86	0.25	5.94	76.95	27.08	7.26	5.75	92.37	28.47	4.62

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 15
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.32	0.00	0.10	0.06	1.01	69.84	11.17	2.16	2.85	16.47	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	86.82	13.66	3.80	2.07	25.99	0.00	0.00
56	28.33	1.89	3.22	1.05	0.37	8.00	78.04	19.82	3.33	5.14	26.21	0.84	0.13
58	23.08	0.91	0.67	0.77	0.18	6.13	74.01	20.41	3.11	4.19	27.91	0.00	0.00
60	23.93	1.69	0.58	1.49	0.32	9.85	77.59	19.45	3.11	4.33	26.74	0.00	0.00
62	20.42	0.68	0.63	0.64	0.14	5.18	76.77	18.10	2.88	3.69	26.09	0.32	0.06
64	18.02	0.27	0.00	0.25	0.05	1.88	84.87	18.55	2.55	3.27	25.15	0.00	0.00
66	22.35	2.66	3.86	1.59	0.51	10.71	88.88	20.66	3.94	4.04	26.94	0.01	0.01
68	13.17	0.04	0.40	0.04	0.01	0.44	88.72	21.72	2.87	2.38	31.98	0.00	0.00
70	8.91	0.43	0.00	0.24	0.09	1.82	84.40	17.64	2.32	1.62	23.64	0.00	0.00
72	20.81	0.30	1.87	0.27	0.06	2.55	79.34	20.30	3.59	3.78	26.31	1.77	0.98
74	18.92	1.06	0.40	1.04	0.21	7.70	85.18	18.02	1.53	3.42	24.72	0.00	0.00
76	24.16	1.56	3.56	0.88	0.29	6.56	79.46	18.95	3.88	4.37	27.17	0.14	0.03
78	11.20	0.09	0.00	0.12	0.02	1.18	81.50	17.99	2.89	2.03	27.69	0.00	0.00
80	16.41	0.55	0.00	0.30	0.11	2.43	81.96	14.63	3.95	2.97	18.70	0.00	0.00
82	19.17	0.41	0.77	0.38	0.08	3.14	83.39	18.54	3.75	3.47	26.28	0.00	0.00
84	14.24	0.04	0.21	0.02	0.01	0.14	78.30	18.11	2.66	2.59	26.36	0.29	0.61
AVE.	18.25	0.76	0.95	0.54	0.15	4.04	81.12	18.10	3.08	3.31	25.55	0.20	0.11

Agricultural Managment System: 15
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.12	4.46	0.01	0.03	0.14	63.62	6.20	0.00	2.73	8.68	2.07	0.38
54	11.03	0.02	0.71	0.00	0.00	0.00	80.30	6.53	0.00	2.00	12.56	0.00	0.00
56	13.28	0.05	4.64	0.00	0.01	0.00	70.11	7.94	0.00	2.40	10.58	2.75	0.35
58	9.95	0.39	1.17	0.10	0.08	0.90	67.76	6.25	0.00	1.81	9.98	1.01	0.14
60	16.31	0.35	4.69	0.04	0.07	0.53	70.45	7.13	0.00	2.95	10.33	2.61	0.37
62	12.57	0.21	3.62	0.02	0.04	0.29	69.26	7.51	0.00	2.28	11.64	0.87	0.21
64	10.71	0.00	0.00	0.00	0.00	0.00	78.61	6.26	0.00	1.94	10.82	0.00	0.00
66	9.82	0.00	0.62	0.00	0.00	0.00	81.08	7.81	0.00	1.77	13.03	0.39	0.09
68	11.30	0.14	0.30	0.01	0.04	0.14	81.82	6.89	0.00	2.04	11.96	0.00	0.00
70	10.53	0.01	0.00	0.00	0.00	0.00	77.86	6.54	0.00	1.90	10.82	0.00	0.00
72	11.43	0.24	4.05	0.03	0.05	0.35	72.17	7.18	0.00	2.08	9.30	3.09	0.33
74	16.92	0.24	3.19	0.03	0.04	0.43	77.77	7.40	0.00	3.06	10.55	1.38	0.20
76	6.99	0.00	0.40	0.00	0.00	0.00	73.37	6.09	0.00	1.26	10.63	0.50	0.15
78	17.63	0.50	6.82	0.08	0.10	0.82	74.11	7.41	0.00	3.20	9.80	3.35	0.33
80	5.24	0.00	0.00	0.00	0.00	0.00	75.71	6.25	0.00	0.94	11.21	0.00	0.00
82	12.34	0.27	1.90	0.04	0.05	0.44	75.74	7.64	0.00	2.24	12.87	0.72	0.05
84	8.14	0.00	0.77	0.00	0.00	0.00	72.04	6.27	0.00	1.47	9.57	0.69	0.08
AVE.	11.72	0.15	2.20	0.02	0.03	0.24	74.22	6.90	0.00	2.12	10.84	1.14	0.16

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 15L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.24	0.00	0.25	0.08	2.15	137.36	47.10	2.97	3.90	141.21	0.00	0.00
53	16.52	0.15	0.91	0.20	0.04	1.79	174.25	75.31	5.76	2.97	125.07	8.87	3.02
55	33.41	3.14	5.81	2.79	0.69	16.09	227.69	103.47	46.04	6.04	132.39	24.54	7.78
57	19.86	0.44	0.59	0.35	0.12	2.89	224.15	83.52	48.30	3.60	129.19	6.07	6.21
59	22.16	1.60	1.34	1.43	0.33	9.36	222.73	77.94	45.40	4.01	132.41	4.43	1.59
61	22.85	0.57	4.13	0.32	0.18	2.67	174.19	82.83	3.07	4.14	107.46	31.88	9.16
63	14.37	1.32	1.09	1.11	0.29	6.18	234.09	70.01	22.25	2.60	101.48	10.67	2.03
65	21.82	0.07	0.00	0.05	0.03	0.58	192.01	82.79	6.76	3.95	144.80	0.00	0.00
67	20.67	0.12	0.00	0.06	0.05	0.72	252.12	77.75	4.41	3.74	141.98	0.00	0.00
69	30.64	3.08	1.69	2.52	0.61	12.50	185.73	95.90	5.88	5.55	143.79	12.35	3.67
71	22.40	0.42	2.70	0.18	0.18	1.82	240.41	82.33	41.08	4.05	114.25	24.60	8.47
73	19.48	0.00	0.00	0.00	0.00	0.00	187.24	73.77	4.03	3.53	138.39	0.00	0.00
75	35.24	0.84	8.34	0.62	0.20	5.83	176.67	96.23	4.23	6.39	124.04	24.57	14.58
77	16.21	0.42	0.00	0.26	0.09	1.93	197.20	66.91	40.21	2.94	92.13	0.00	0.00
79	40.20	3.44	8.47	2.03	0.72	14.52	220.16	93.36	47.36	7.29	118.72	30.11	7.40
81	25.21	0.70	0.69	0.46	0.21	3.85	190.66	78.41	5.75	4.56	133.49	6.47	2.13
83	23.88	0.39	5.48	0.11	0.13	1.10	233.03	84.88	49.72	4.33	101.62	32.63	9.95
AVE.	23.91	1.00	2.43	0.75	0.23	4.94	204.10	80.74	22.54	4.33	124.85	12.78	4.47

Agricultural Managment System: 15L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.44	7.98	0.56	0.12	4.56	140.63	49.64	10.35	6.24	42.44	40.54	4.74
54	21.23	0.24	2.25	0.38	0.08	2.94	178.15	49.02	10.66	3.83	67.73	17.84	2.22
56	22.13	0.03	2.24	0.01	0.01	0.14	170.64	60.89	12.50	4.01	77.21	18.05	5.55
58	43.91	1.72	13.84	0.95	0.37	8.09	161.07	66.91	15.64	7.94	43.92	54.46	10.32
60	35.39	1.71	7.94	1.38	0.38	9.03	165.57	60.99	14.36	6.41	49.42	44.10	6.38
62	40.23	3.37	10.96	3.80	0.69	20.36	161.55	65.55	15.96	7.29	44.02	48.11	6.80
64	28.56	0.36	5.31	0.26	0.10	2.53	179.74	58.17	12.74	5.17	61.84	43.61	7.56
66	19.74	0.02	0.00	0.02	0.01	0.25	193.91	51.02	14.81	3.57	86.45	0.00	0.00
68	29.18	0.33	3.53	0.42	0.12	3.64	195.26	60.70	21.82	5.27	66.29	18.43	3.16
70	25.94	0.23	2.77	0.36	0.06	2.73	177.79	60.84	14.03	4.69	70.99	22.45	3.84
72	44.13	2.76	9.48	1.89	0.60	11.87	171.68	72.56	17.67	7.97	54.32	43.46	7.91
74	27.73	0.52	4.54	0.24	0.12	2.37	179.32	60.82	10.22	5.02	65.62	28.97	3.68
76	27.89	1.22	7.10	1.43	0.29	9.34	170.13	59.44	11.87	5.06	48.03	40.63	6.70
78	44.11	1.00	15.63	0.71	0.27	6.80	170.42	79.68	22.60	7.98	43.76	90.45	11.42
80	25.52	0.21	5.74	0.07	0.07	0.77	165.66	58.33	9.05	4.62	57.75	35.07	7.29
82	24.73	0.06	3.81	0.03	0.03	0.43	176.74	66.83	16.11	4.47	64.08	30.12	5.70
84	45.25	1.94	15.77	2.12	0.42	15.18	164.71	72.14	20.50	8.20	47.89	51.50	9.67
AVE.	31.77	0.95	6.99	0.86	0.22	5.94	171.94	61.97	14.76	5.75	58.34	36.93	6.06

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 15L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.32	0.00	0.10	0.06	1.01	136.55	26.35	4.54	2.85	35.65	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	169.70	30.71	8.25	2.07	35.30	0.00	0.00
56	28.33	1.89	3.22	1.05	0.37	8.00	148.58	44.34	5.91	5.14	54.64	1.57	0.25
58	23.08	0.91	0.67	0.77	0.18	6.13	138.12	45.23	5.76	4.19	59.77	0.00	0.00
60	23.93	1.69	0.58	1.49	0.33	9.85	145.21	42.63	6.80	4.33	54.36	0.27	0.29
62	20.42	0.68	0.63	0.64	0.16	5.18	143.97	39.85	5.08	3.69	54.06	0.58	0.11
64	18.02	0.27	0.00	0.25	0.05	1.88	161.59	40.42	5.05	3.27	51.85	0.00	0.00
66	22.35	2.66	3.86	1.59	0.51	10.71	170.63	45.54	8.92	4.04	55.00	0.19	0.07
68	13.17	0.04	0.40	0.04	0.01	0.44	169.69	47.84	6.52	2.38	63.19	1.30	1.51
70	8.91	0.43	0.00	0.24	0.10	1.82	161.00	39.07	5.15	1.62	49.55	0.00	0.00
72	20.81	0.30	1.87	0.27	0.06	2.55	149.36	44.59	6.56	3.78	53.92	3.85	2.23
74	18.92	1.06	0.40	1.04	0.21	7.70	161.81	39.78	3.46	3.42	50.72	0.00	0.00
76	24.16	1.56	3.56	0.88	0.29	6.56	150.51	41.89	8.76	4.37	49.44	0.68	0.12
78	11.20	0.09	0.00	0.12	0.03	1.18	153.22	39.48	6.22	2.03	59.58	0.00	0.00
80	16.41	0.55	0.00	0.30	0.11	2.43	155.81	32.12	9.55	2.97	36.74	0.00	0.00
82	19.17	0.41	0.77	0.38	0.09	3.14	158.20	40.80	7.26	3.47	53.37	0.45	0.32
84	14.24	0.04	0.21	0.02	0.01	0.14	147.03	39.96	6.63	2.59	54.09	0.81	1.78
AVE.	18.25	0.76	0.95	0.54	0.15	4.04	154.17	40.03	6.49	3.31	51.25	0.57	0.39

Agricultural Managment System: 15L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.12	4.46	0.01	0.03	0.14	124.40	12.15	0.00	2.73	14.34	4.42	0.75
54	11.03	0.02	0.71	0.00	0.01	0.00	156.95	12.76	0.00	2.00	23.55	0.00	0.00
56	13.28	0.05	4.64	0.00	0.02	0.00	133.46	15.11	0.00	2.40	17.80	5.01	0.64
58	9.95	0.39	1.17	0.10	0.08	0.90	126.46	11.66	0.00	1.81	17.18	1.78	0.26
60	16.31	0.35	4.69	0.04	0.07	0.53	131.88	13.33	0.00	2.95	17.16	5.43	0.77
62	12.57	0.21	3.62	0.02	0.04	0.29	129.87	14.09	0.00	2.28	19.61	1.58	0.38
64	10.71	0.00	0.00	0.00	0.00	0.00	149.66	11.94	0.00	1.94	19.08	0.00	0.00
66	9.82	0.00	0.62	0.00	0.00	0.00	155.65	14.98	0.00	1.77	24.00	1.38	0.29
68	11.30	0.14	0.30	0.01	0.04	0.14	156.49	13.21	0.00	2.04	22.05	0.00	0.00
70	10.53	0.01	0.00	0.00	0.00	0.00	148.53	12.48	0.00	1.90	19.64	0.00	0.00
72	11.43	0.24	4.05	0.03	0.05	0.35	135.86	13.49	0.00	2.08	15.68	5.72	0.62
74	16.92	0.24	3.19	0.03	0.05	0.43	147.75	14.06	0.00	3.06	17.91	2.64	0.37
76	6.99	0.00	0.40	0.00	0.00	0.00	138.97	11.53	0.00	1.26	20.34	1.02	0.29
78	17.63	0.50	6.82	0.08	0.10	0.82	139.30	13.91	0.00	3.20	16.58	6.22	0.61
80	5.24	0.00	0.00	0.00	0.00	0.00	143.93	11.87	0.00	0.94	22.42	0.00	0.00
82	12.34	0.27	1.90	0.04	0.05	0.44	143.69	14.52	0.00	2.24	22.47	1.51	0.11
84	8.14	0.00	0.77	0.00	0.00	0.00	135.28	11.76	0.00	1.47	17.98	1.59	0.18
AVE.	11.72	0.15	2.20	0.02	0.03	0.24	141.07	13.11	0.00	2.12	19.28	2.25	0.31

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 16L
Crop Season: Corn

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
51	21.59	0.27	0.00	0.29	0.08	2.43	138.27	45.98	3.12	3.90	139.64	0.00	0.00
53	16.52	0.17	0.87	0.23	0.04	2.00	174.85	75.30	6.34	2.97	124.57	8.68	3.00
55	33.41	3.26	5.42	2.78	0.70	15.86	228.36	103.30	46.05	6.04	134.30	22.35	7.84
57	19.86	0.47	0.51	0.36	0.14	2.93	224.84	83.40	50.51	3.60	129.22	5.36	4.33
59	22.16	1.66	1.25	1.45	0.36	9.48	224.25	77.00	45.46	4.01	131.25	4.44	1.71
61	22.85	0.63	3.96	0.33	0.21	2.73	175.07	82.93	3.07	4.14	108.39	30.92	9.25
63	14.37	1.35	1.01	0.68	0.29	4.18	234.61	70.20	22.92	2.60	101.63	9.98	2.03
65	21.82	0.07	0.00	0.05	0.04	0.58	194.89	80.54	6.86	3.95	142.44	0.00	0.00
67	20.67	0.14	0.00	0.06	0.07	0.72	253.67	77.94	4.40	3.74	142.18	0.00	0.00
69	30.64	3.16	1.54	2.58	0.62	12.83	186.60	96.09	5.90	5.55	144.84	11.44	3.68
71	22.40	0.45	2.43	0.13	0.21	1.40	241.65	82.10	41.16	4.05	115.98	22.37	8.60
73	19.48	0.00	0.00	0.00	0.00	0.00	188.58	73.21	4.03	3.53	137.82	0.00	0.00
75	35.24	0.92	8.01	0.63	0.23	5.88	177.28	96.50	4.27	6.39	125.58	24.06	13.73
77	16.21	0.44	0.00	0.26	0.10	1.93	197.99	66.61	41.03	2.94	90.82	0.00	0.00
79	40.20	3.56	8.17	2.04	0.77	14.53	220.54	93.48	47.45	7.29	119.64	29.14	7.45
81	25.21	0.75	0.53	0.07	0.25	3.99	191.53	77.98	5.78	4.56	134.46	5.02	2.11
83	23.88	0.45	5.32	0.12	0.18	1.19	233.49	85.13	49.73	4.33	102.47	31.90	10.01
AVE.	23.91	1.04	2.30	0.71	0.25	4.86	205.09	80.45	22.83	4.33	125.01	12.10	4.34

Agricultural Managment System: 16L
Crop Season: Wheat

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	34.46	0.46	7.70	0.60	0.12	4.79	141.41	49.76	10.41	6.24	43.27	39.80	4.85
54	21.23	0.25	2.15	0.41	0.08	3.14	178.70	49.06	10.71	3.83	68.87	17.35	2.26
56	22.13	0.06	2.09	0.02	0.02	0.29	171.24	60.96	12.54	4.01	78.85	17.20	4.78
58	43.91	1.81	13.32	1.03	0.40	8.66	161.61	67.07	15.69	7.94	45.29	55.11	10.73
60	35.39	1.78	7.66	1.43	0.40	9.33	166.80	61.29	14.46	6.41	50.56	43.85	5.71
62	40.23	3.46	10.68	3.88	0.70	20.83	162.33	65.65	15.97	7.29	44.72	47.84	6.46
64	28.56	0.41	5.14	0.29	0.11	2.75	180.26	58.20	12.77	5.17	62.97	42.96	7.74
66	19.74	0.03	0.00	0.03	0.02	0.35	196.36	51.44	15.00	3.57	86.79	0.00	0.00
68	29.18	0.36	3.38	0.47	0.12	3.97	196.58	60.91	21.93	5.27	67.17	17.57	3.24
70	25.94	0.25	2.59	0.37	0.06	2.79	178.75	60.76	14.10	4.69	72.13	21.12	3.89
72	44.13	2.85	9.08	1.95	0.61	12.22	172.77	72.72	17.84	7.97	55.50	42.17	8.07
74	27.73	0.57	4.39	0.29	0.14	2.78	180.49	60.99	10.28	5.02	66.53	28.10	3.73
76	27.89	1.28	6.86	1.46	0.29	9.49	170.74	59.44	11.89	5.06	49.10	40.11	6.15
78	44.11	1.07	15.24	0.76	0.30	7.23	171.08	79.83	22.69	7.98	44.61	90.28	11.77
80	25.52	0.22	5.45	0.08	0.07	0.86	166.02	58.35	9.07	4.62	58.95	33.86	7.38
82	24.73	0.06	3.67	0.44	0.03	0.43	177.59	66.85	16.19	4.47	64.90	29.19	5.79
84	45.25	2.06	15.34	2.26	0.45	16.12	165.22	72.09	20.47	8.20	48.58	50.57	9.91
AVE.	31.77	1.00	6.75	0.93	0.23	6.24	172.82	62.08	14.82	5.75	59.34	36.30	6.03

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Agricultural Managment System: 16L
Crop Season: Soybeans

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.78	0.34	0.00	0.10	0.06	1.01	137.20	26.47	4.55	2.85	35.83	0.00	0.00
54	11.40	0.00	0.00	0.00	0.00	0.00	170.17	30.81	8.27	2.07	35.42	0.00	0.00
56	28.33	1.99	3.17	1.14	0.40	8.62	149.15	44.37	5.92	5.14	54.70	1.56	0.25
58	23.08	0.99	0.63	0.86	0.20	6.69	138.59	45.28	5.76	4.19	59.89	0.00	0.00
60	23.93	1.78	0.54	1.24	0.35	8.55	146.26	42.81	6.80	4.33	54.63	0.25	0.29
62	20.42	0.76	0.62	0.59	0.17	4.76	144.71	39.89	5.10	3.69	54.06	0.57	0.12
64	18.02	0.29	0.00	0.29	0.05	2.11	162.06	40.46	5.04	3.27	51.94	0.00	0.00
66	22.35	2.78	3.76	1.70	0.53	11.26	172.52	46.10	9.04	4.04	55.60	0.19	0.07
68	13.17	0.06	0.39	0.02	0.02	0.29	170.72	48.14	6.57	2.38	63.54	1.28	1.52
70	8.91	0.45	0.00	0.25	0.10	1.88	161.87	39.15	5.18	1.62	49.68	0.00	0.00
72	20.81	0.33	1.84	0.30	0.07	2.78	150.20	44.83	6.60	3.78	54.28	3.83	2.24
74	18.92	1.11	0.35	0.55	0.22	4.68	162.76	40.00	3.50	3.42	50.95	0.00	0.00
76	24.16	1.64	3.48	0.90	0.31	6.72	151.01	42.01	8.80	4.37	49.51	0.67	0.12
78	11.20	0.10	0.00	0.09	0.04	0.90	153.72	39.64	6.25	2.03	59.79	0.00	0.00
80	16.41	0.58	0.00	0.34	0.12	2.72	156.13	32.16	9.55	2.97	36.79	0.00	0.00
82	19.17	0.46	0.73	0.20	0.10	1.97	158.92	40.94	7.26	3.47	53.58	0.44	0.33
84	14.24	0.06	0.18	0.01	0.03	0.00	147.46	40.03	6.65	2.59	54.21	0.69	1.78
AVE.	18.25	0.81	0.92	0.50	0.16	3.82	154.91	40.18	6.52	3.31	51.44	0.56	0.40

Agricultural Managment System: 16L
Crop Season: Cover crop

Yr.	RAIN	RUNOFF	PERC.	SL	RON	SEDN	POTM	MIN.	NO3	RAINN	UPTAKE	LEACH	DENIT.
52	15.06	0.12	4.28	0.01	0.03	0.14	125.02	12.18	0.00	2.73	14.55	4.28	0.71
54	11.03	0.03	0.61	0.00	0.01	0.00	157.46	12.72	0.00	2.00	23.53	0.00	0.00
56	13.28	0.06	4.50	0.00	0.03	0.00	134.00	15.14	0.00	2.40	17.98	4.87	0.64
58	9.95	0.41	1.11	0.10	0.08	0.90	127.04	11.55	0.00	1.81	17.14	1.70	0.26
60	16.31	0.37	4.45	0.04	0.08	0.53	132.86	13.40	0.00	2.95	17.42	5.25	0.77
62	12.57	0.23	3.43	0.02	0.04	0.29	130.57	14.13	0.00	2.28	20.09	1.32	0.22
64	10.71	0.00	0.00	0.00	0.00	0.00	150.29	11.77	0.00	1.94	18.91	0.00	0.00
66	9.82	0.00	0.42	0.00	0.00	0.00	157.40	15.12	0.00	1.77	24.69	0.94	0.30
68	11.30	0.15	0.15	0.01	0.04	0.14	157.55	13.16	0.00	2.04	22.07	0.00	0.00
70	10.53	0.01	0.00	0.00	0.00	0.00	149.54	12.34	0.00	1.90	19.52	0.00	0.00
72	11.43	0.25	3.87	0.03	0.05	0.35	136.64	13.57	0.00	2.08	15.92	5.55	0.62
74	16.92	0.26	3.00	0.03	0.05	0.43	148.64	14.11	0.00	3.06	18.27	2.44	0.31
76	6.99	0.00	0.34	0.00	0.00	0.00	139.46	11.55	0.00	1.26	20.64	0.87	0.20
78	17.63	0.55	6.62	0.08	0.12	0.82	139.80	13.92	0.00	3.20	16.69	6.14	0.61
80	5.24	0.00	0.00	0.00	0.00	0.00	144.36	11.77	0.00	0.94	22.30	0.00	0.00
82	12.34	0.29	1.71	0.05	0.05	0.52	144.41	14.52	0.00	2.24	22.83	1.13	0.11
84	8.14	0.00	0.67	0.00	0.00	0.00	135.70	11.77	0.00	1.47	18.21	1.40	0.18
AVE.	11.72	0.16	2.07	0.02	0.03	0.24	141.81	13.10	0.00	2.12	19.46	2.11	0.29

Appendix A.3 Seasonal Reports of CREAMS Simulation Results
(Continued)

Notation:
AMS --- Agricultural management system
RAIN --- Rainfall (in)
RO --- Runoff (in)
PERC. --- Water percolation (in)
SL --- Soil loss (tons/ac)
RON --- Nitrogen in runoff (lb/ac)
SEDN --- Nitrogen with sediment (lb/ac)

MIN. --- Mineralized nitrogen (lb/ac)
NO3 --- Soil nitrate (lb/ac)
POTM --- Potentially mineralizable nitrogen (lb/ac)
UPTAKE --- Nitrogen uptake by crop (lb/ac)
RAINN --- Rainfall nitrate (lb/ac)
LEACH --- Nitrate leached (lb/ac)
DENIT. --- Denitrification (lb/ac)

Appendix B.1 An Examination of Appropriate Price Patterns to Employ in Stochastic Dynamic Programming Models

Applications of dynamic programming to agricultural and resource management issues are gaining popularity since these issues are often problems of a dynamic nature. Most of these applications have monetary objective functions, which are generally the present value of net returns in deterministic models and the present value of the expected net returns in stochastic models (Kennedy, 1986). Price patterns including both input price patterns and output price patterns, thus, play an important role in influencing these objective function values. Furthermore, the selection of the price patterns to employ in dynamic programming may influence the selection of optimal decision path over the planning period. In this paper, after a brief review of the random features of prices, several price patterns used for stochastic dynamic programming will be compared focusing on output price patterns. The objective of this paper is to point out when it is appropriate to use a particular output price pattern. A similar analysis could be conducted for input prices.

Random Changes in Prices

It is recognized that prices are stochastic in a market economy. The stochastic variation of prices through time can be caused by short term shocks, seasonal changes, annual changes, trends in supply and demand, and cyclical behavior (Tomek and Robinson). Marketing economists, in general, accept the stochastic nature of prices. A "totally" random change in price indicates an "efficient" market; that is, the expected value of the difference between the observed price p^o_{t+1} at time t+1 and the predicted price p^p_t at time t is zero. Three tests: a weak form, a semi-strong form, and a strong form[28] were employed to prove that with a few exceptions the efficient market model stands up well (Fama, 1970). After Fama's work, many researchers have supported the conclusion of random price change. Washburn et al. (1990) used the weak form of Fama's test to confirm information efficiency in the market for pine saw-timber stumpage in the Southern United States. Colling and Irwin (1990) used market survey data to directly test the efficiency of live hog future prices and their results supported the efficient market hypothesis. Gordon (1985) reached a similar conclusion stating that no strong evidence of serial dependence or trends existed in his analysis of many agricultural future prices including: corn, cotton, wheat, live-cattle, rice, and soybeans. He pointed out, however, that not all price changes follow a normal distribution and have a constant variance. Gordon's research indicated a "non-totally" random change of price in some cases. On the other hand, some economists question the "efficient" market. Leuthold and Hartmann (1979) used a semi-strong form of Fama's test to

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[28] The three tests use three information subsets to assess the efficiency of market. The weak form uses historical prices; the semi-strong form uses price information that is publicly available; and the strong form assesses whether investors or groups have special information relevant for price formation (Fama).

prove that on occasion the live-hog future market had not performed efficiently.

To analyze the impacts of these stochastic features of price on the selection of price patterns for dynamic decision making models, the random changes of price are classified into three categories. First, price at time t+1, p_{t+1}, is considered "totally" independent of prices at time t, p_t and/or prices before time t. That is, prices are time independent. The adjusted values of historical prices constitute the price distributions, in which each past price shares an equal weight in the distributions, making the sequence of the historical price irrelevant. These distributions are used for predicting possible prices at all planning stages. Fama (1970) classified time independent changes of price as a random walk. He stated that if price follows a random walk, the price change is independently and identically distributed.

Second, price at time t+1, p_{t+1}, is considered partly or totally dependent on prices at time t, p_t, and/or prices before time t. That is, prices are time dependent. Both the level and the sequence of prices at current and past price stages are relevant to predict prices after the current stage. Prices in p_{t+1} are assumed to be an "extension" of current and past prices, p_t, p_{t-1}, . . . ,p_{t-n}. The length of the relevant past is the order of time lags, n, in the price forecast models. Fama (1970) categorized time dependent changes of price as a random walk with drift. He pointed out that in this case, the expected price changes can be non-zero, and that the distribution of price changes could be identical.

Third, the random change of price of one commodity is correlated with other non-price variables or other commodity prices in either a time dependent or time independent fashion. As an example, corn price in the corn belt may be significantly related to corn yield or corn inventory, and corn price may be significantly related to wheat price over a period of years in some areas. In this third category, when any one of these price related variables is employed as a decision or state variable or a function of decision or state variables in dynamic programming, these correlations should be considered explicitly in the context of a stochastic dynamic programming model. Note that the classification of the stochastic price changes above is not exhaustive.

Output Price Patterns Used in Dynamic Programming

Several price patterns that have been coupled to dynamic programming are: (1) an average of adjusted prices;[29] (2) a pre-determined sequence of prices; (3) random price as state variable; and (4) a random generated price.

The average of adjusted price (AAP) is simply an average of the adjusted prices over a certain period. The AAP may be considered as "the least efficient" method of using historical price information since it only uses the first moment of the data; however, it is the most common price pattern used in the dynamic programming analysis of agricultural and

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[29] Adjusted prices are a price series that is generated by deflating original time series prices with a certain price index. Adjusted prices can be thought of as a set of real observations on price at equal intervals over time.

resource management issues. As a complement, a post-optimization analysis, consisting of a sensitivity or parametric analysis of price is usually employed as a test of the stability of the optimal decision path over the planning horizon obtained (Burt, 1981; Burt and Allison, 1963; Fisher and Lee, 1981; Stauber et al., 1975).

There are several forms of the predetermined sequence of price (PSP) that have been implicitly employed. The PSP will be discussed in more detail later.

Taylor and Burt (1984) derived a conceptual formula to treat random price as a state variable (RPSV). Taylor (1983) and Kennedy (1986) also used price as a state variable in their stochastic dynamic programming models of fertilizer management. Prices are treated as endogenous random variables in the RPSV method as opposed to the AAP and the PSP, in which prices are exogenous random variables.

Random generated prices (RGP) have rarely been used. When insufficient time series data including prices and yields are available and the correlations between these time series data have to be explicitly considered, random prices and yields with assumed distributions, such as a triangular distribution, have been used to generate a "corrected" random variable for building a multivariate distribution of net returns in stochastic dynamic models (Walker et al., 1986). Using RGP is an alternative to RPSV when the formulation of state transition equations is not possible.

Appropriate Output Price Patterns to Employ in Stochastic Dynamic Programming Models

Dynamic programming models seek the dynamic optimum of systems with the emphasis on changes across time and the inter-connections among the system's states. Based on the feature of state change, dynamic programming can be roughly divided into two categories: deterministic dynamic programming and stochastic dynamic programming. Dynamic programming that has one or more undetermined state transition equations or observation equations is considered stochastic dynamic programming (Aoki, 1989).

Depending on the nature of the empirical problem, the output price in stochastic dynamic programming models has been considered either as a known or unknown parameter of a monetary objective function if output price change is "autonomous,"[30] or a state variable if the output price changes with changes in the system being modeled. However, in the former case, the estimation of the unknown output price may be separated from control aspects (Aoki, 1989). In the latter case, the randomness of output price is involved in control aspects of stochastic dynamic programming as a state variable.

All four of the price patterns discussed above can be used in dynamic programming as the output price pattern. However, previous research on applications of dynamic programming to agricultural and

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[30] Here autonomous means random change of a specific price is totally independent of other variables except its own past prices (Burt and Taylor, 1989).

resource management problems has generally used the AAP as the output price (Kennedy, 1986). To extend the applications of dynamic programming to agricultural and resource management issues, a more detailed analysis of the impacts of these price patterns on dynamic programming models is called for. In the following, three different output price patterns, the RPSV, AAP, and PSP in the stochastic dynamic models are analyzed and their implications are discussed.

A typically discrete stochastic dynamic programming model with the objective function consisting of the present value of expected net return can be expressed as follows:

$$f_t^*(\underline{Y}_t) = \underset{\underline{X}}{\mathrm{MAX}} \; \underset{\mu}{\mathrm{E}} \; [F_t(\underline{X}_t, \underline{Y}_t, \mu) + \alpha f_{t+1}^*(\underline{Y}_{t+1})], \qquad (5)$$

$$\text{subject to:} \quad \underline{Y}_{t+1} = h(\underline{X}_t, \underline{Y}_t, \mu), \qquad (2)$$

$$\sum_{\mu} P_{\mu}(\mu) = 1, \qquad (7)$$

$$f_T^*(\underline{Y}_T) = h(\underline{Y}_T), \qquad (8)$$

where: $\underline{X}_t$ is a vector of decision variables;

$\underline{Y}_t$ is a vector of state variables;

$f^*_t(\underline{Y}_t)$ is the maximum present value of expected net returns from stage t to stage T;

T is the total number of stages;

$F_t(\underline{X}_t, \underline{Y}_t, \mu)$ is the net return from stage t;

$\underset{\mu}{E}[F_t(\underline{X}_t, \underline{Y}_t, \mu)]$ is the expected net return from stage t;

$\underset{\mu}{E}[F_t(\underline{X}_t, \underline{Y}_t, \mu)] = \sum_{\mu} P_{\mu}(\mu) F_t(\underline{X}_t, \underline{Y}_t, \mu)$;

μ is a vector of random variables;

$P_{\mu}(\mu)$ is the probability associated with random variable vector μ;

$\underset{\mu}{E}[\alpha f^*_{t+1}(\underline{Y}_{t+1})]$ is the maximum present value of expected net returns from stage t+1 to stage T;

$\underset{\mu}{E}[\alpha f^*_{t+1}(\underline{Y}_{t+1})] = \sum_{\mu} P_{\mu}(\mu) \alpha f^*_{t+1}(\underline{Y}_{t+1})$;

α is the discount factor;

$\underline{Y}_{t+1} = h(\underline{X}_t, \underline{Y}_t, \mu)$ is the state transition equation; and

$h(\underline{Y}_T)$ is the terminal value at stage T.

Since equation (1) is a recursive equation,

$$f^*_{t+1}(\underline{Y}_{t+1}) = \underset{X}{\text{MAX}} \; \underset{\mu}{E} \; [F_{t+1}(\underline{X}_{t+1}, \underline{Y}_{t+1}, \mu) + \alpha f^*_{t+2}(\underline{Y}_{t+2})];$$

$$f^*_{t+2}(\underline{Y}_{t+2}) = \underset{\underline{X}}{\text{MAX}} \underset{\mu}{E} \left[F_{t+2}(\underline{X}_{t+2},\underline{Y}_{t+2},\mu) + \alpha f^*_{t+3}(\underline{Y}_{t+3})\right];$$ and so on until,

$$f^*_t(\underline{Y}_t) = \underset{\underline{X}}{\text{MAX}} \left\{ \underset{\mu}{E} \left[F_t(\underline{X}_t,\underline{Y}_t,\mu) + \alpha \underset{\mu}{E}[F_{t+1}(\underline{X}_{t+1},\underline{Y}_{t+1},\mu) + \alpha \underset{\mu}{E}[F_{t+2}(\underline{X}_{t+2},\underline{Y}_{t+2},\mu)\right.\right.$$

$$\left.\left. + \ldots + \alpha \underset{\mu}{E}[F_{T+1}(\underline{X}_{T-1},\underline{Y}_{T-1},\mu) + \alpha h(\underline{Y}_T)] \ldots \right]\right\} \qquad (5)$$

The impacts of price patterns on dynamic programming, thus, can be determined through examining the impacts of price pattern on the expected stage net return function, $E[F_t(\underline{X}_t,\underline{Y}_t,\mu)]$, where $t = 1, \ldots, T-1$.

For illustration, a stochastic dynamic program for an agricultural management problem is developed. Let the stage return function, $F_t(\underline{X}_t,\underline{Y}_t,\mu)$, be gross income minus variable cost, where gross income is a product of price and crop yield; variable cost is a deterministic function of decision variable $\underline{X}_t$; and crop yield is a stochastic function of the decision variable $\underline{X}_t$, state variables $\underline{Y}_t$, and random variables μ. The general form of the net return function for stage t can be expressed as following:

$$F_t(\underline{X}_t,\underline{Y}_t,\mu) = p_t(\mu) g_t(\underline{X}_t,\underline{Y}_t,\mu) - C_t(\underline{X}_t); \qquad (6)$$

where, $p_t(\mu)$ is the crop price at stage t; $g_t(\underline{X}_t,\underline{Y}_t,\mu)$ is the crop yield at stage t; and $C_t(\underline{X}_t)$ is the variable cost at stage t. $\underline{Y}_t$ is a state variable vector, *which does not include the crop price*. This general form of the stage net return function is reformulated below with different price patterns.

Random Price as a State Variable

When crop price is affected by yield and/or any decision or state variables and it is considered as a state variable; and crop yield is not affected by crop price, equation (6) can be rewritten as:

$$F_t(\underline{X}_t,\underline{Y}_t,p_t,\mu) = p_t(\underline{X}_t,\underline{Y}_t,\xi,\theta)g_t(\underline{X}_t,\underline{Y}_t,\xi) - C_t(\underline{X}_t) \qquad (7)$$

where: $\xi \subset \mu$, random variables affecting yield;

$\theta \subset \mu$, random variables affecting price; and

$\mu = \theta \cap \xi$.

A new vector of state variables is, thus, represented by $\underline{Y}$ and p_t . Then the expected net return function for stage t is:

$$\underset{\mu}{E}[F_t(\underline{X}_t,\underline{Y}_t,p_t,\mu)] = \underset{\mu}{E}[p_t(\underline{X}_t,\underline{Y}_t,\xi,\theta)g_t(\underline{X}_t,\underline{Y}_t,\xi)] - E[C_t(\underline{X}_t)]$$

$$= \sum_{\mu} [P_\mu(\mu)p_t(\underline{X}_t,\underline{Y}_t,\xi,\theta)g_t(\underline{X}_t,\underline{Y}_t,\xi)] - C(\underline{X}_t) \qquad (8)$$

where, $P_\mu(\mu)$ is the probability associated with the multivariate distribution of θ and ξ.

The price transition equation can be established in several ways, such as ordinary least squares, the Kalman filter, Wiener filters, and

Bayesian estimation (Aoki, 1989). Furthermore, when the price change is time dependent the price transition equation in the model will include time lags. The selection of the appropriate time series model and the order of time lags depend on the real problem being analyzed and the data used. Here, for illustration, it is assumed that the price follows a second order auto-regressive model:

$$p_t = a_0 + a_1 P_{t-1} + a_2 p_{t-2} + \theta \qquad (9)$$

where, a_0, a_1, and a_2 are the estimators; p_{t-1} and p_{t-2} are the prices at time t-1 and t-2. Therefore, the basic assumption of Makovian processes in dynamic programming no longer holds. Bertsekas (1987) suggested reformulating the problem into the framework of dynamic programming by using additional state variables. Here, the p_{t-2} is defined as an additional state variable.[31] The reformulated state variable vector would include $\underline{Y}_t$, p_t, p_{t-1}, and p_{t-2}. Equation (8) becomes:

$$\underset{\mu}{E}[F_t(\underline{X}_t, \underline{Y}_t, p_t, p_{t-2}, \mu)] = \sum_{\mu}[P_\mu(\mu) p_t(\underline{X}_t, \underline{Y}_t, p_{t-2}, \xi, \theta) g_{t'}(\underline{X}_t, \underline{Y}_t, \xi)] - C(\underline{X}_t) \qquad (10)$$

where, $\theta = \theta_1 \cap \theta_2$; θ_1 is the random disturbance of p_{t-1}; and θ_2 is the random disturbance of p_{t-2}. Little research has been done with equation (10). The main difficulty in employing this formulation in empirical

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[31] Since p_{t-1} has been included in the price transition equation, $p_t = p_t(p_{t-1}, \theta)$, only p_{t-2} needs to be defined.

problems is related to developing a meaningful multivariate distribution with limited data.

When crop price is not correlated with crop yield and/or other decision and state variables; but is still a time dependent state variable, equation (10) becomes:

$$\underset{\mu}{E}[F_t(X_t,Y_t,p_t,p_{t-2},\mu)] = \underset{\mu}{E}[p_t(p_{t-1},p_{t-2},\theta_1,\theta_2)g_t(X_t,Y_t,\xi) - C_t(X_t)]$$

$$= \underset{\theta}{E}[p_t(p_{t-1},p_{t-2},\theta_1,\theta_2,)]\underset{\xi}{E}[g_t(X_t,Y_t,\xi)] - C_t(X_t) \qquad (11)$$

where $\underset{\theta}{E}[p_t(p_{t-1},p_{t-2},\theta_1,\theta_2)]$ is the mean value of p_t. In a discrete dynamic programming model, the mean value of price p_t is calculated numerically by a summation of the product of probability $P_\theta(\theta)$ and associated random value of p_t, which is determined by the price transition equation.

$$\underset{\mu}{E}[F_t(X_t,Y_t,p_t,p_{t-2},\mu)] = \sum_{\theta}[P_\theta(\theta)p_t(p_{t-1},p_{t-2},\theta)] \sum_{\xi}[P_\xi(\xi)g_t(X_t,Y_t,\xi)] - C(X_t) \qquad (12)$$

Since the prices are random and the distributions of prices are identical, then

$\theta_1 = \theta_2 = \theta$ and $E(\theta) = \sum_{\theta}[P_{\theta}(\theta)\theta] = 0$. Assuming price is time dependent and price transition follows the equation (9) again, then:

$$\begin{aligned}\sum_{\theta}[P_{\theta}(\theta)p_t(p_{t-1},p_{t-2},\xi,\theta)] &= \sum_{\theta}[P_{\theta}(\theta)(a_0 + a_1p_{t-1} + a_2p_{t-2} + \theta)] \\ &= \sum_{\theta}(P_{\theta}(\theta)a_0) + \sum_{\theta}(P_{\theta}(\theta)a_1p_{t-1}) + \sum_{\theta}(P_{\theta}(\theta)a_2p_{t-2}) + \sum_{\theta}(P_{\theta}(\theta)\theta) \\ &= a_0 + a_1\overline{p}_{t-1} + a_2\overline{p}_{t-2} \qquad (13) \\ &= \overline{p}_t\end{aligned}$$

where: $\overline{p}_t$, $\overline{p}_{t-1}$, and $\overline{p}_{t-2}$ are the average prices of stage t, t-1, and t-2 over the specific period.

Substituting equation (13) to (12), the expected net return from stage t is:

$$\underset{\mu}{E}[F_t(X_t,Y_t,p_{t-1},\mu)] = \overline{p}_t \sum_{\xi}[P_{\xi}(\xi)g_t(X_t,Y_t,\xi)] - C(X_t) \qquad (14)$$

This result suggests that the average price $\overline{p}_t$, based on the average prices at time t-1 and t-2, $\overline{p}_{t-1}$ and $\overline{p}_{t-2}$, was used as expected price at time t. Obviously, this is not a satisfactory result. As an alternative, if the state transition equation is first estimated separately and then the estimated prices at each stage are directly used in the dynamic program, the prices at t, t-1, and t-2 should be $\hat{p}_t$, $\hat{p}_{t-1}$, and $\hat{p}_{t-2}$. Assuming the estimation is the best as judged by the specific statistic inference employed, treating the price as a state variable causes bias and inefficiency under the conditions of equation (11). Furthermore, a large number of state variables cause the "curse of dimensionality," a serious problem associated with dynamic programming, especially when using numerical solution algorithm.

Generally in empirical applications, under conditions of equation (11), the time series variable price, p_t, is only a random variable that has not been related to other variables such as yields.[32] Price as predicted by these time series models is only an unknown parameter rather than an autonomous state variable as asserted by Burt and Taylor. No matter how complex these time series models are, the sequence of prices over the planning period can be determined separately from the control of the dynamic model. The separation principle in optimal control theory reveals that the problems of obtaining the best estimate of unknown parameters and of formulating the best control of a system can be attacked separately under some conditions (Aoki, 1989). When the separation principle holds, the RPSV is a analogous to the PSP.

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[32] In some studies, the time series models have been used as state transition equations.

The RPSV is conceptually an ideal price pattern for stochastic dynamic programming models when conditions of equation (6) hold. The main obstacle to its use may be determining a relationship to explain the random behavior of price in a way that is meaningful in the real world and is acceptable to most marketing economists, although other obstacles, such as data availability and computer limits, also exist.

Average of Adjusted Price

When price is independent of yield in some production area of a crop such as corn production in Virginia (Tirupattur, 1990); and is not correlated with decision and state variables, the crop price is a function of independent random variable θ, and equation (6) can be rewritten as:

$$F_t(X_t,Y_t,\mu) = p_t(\theta)g_t(X_t,Y_t,\xi) - C_t(X_t); \tag{15}$$

where, θ and ξ are as defined above, but $\theta \cup \xi = \emptyset$. Then, the expected stage net return function is:

$$\begin{aligned} \underset{\mu}{E}[F_t(X_t,Y_t,\mu)] &= \underset{\theta}{E}[p_t(\theta)]\underset{\xi}{E}[g_t(X_t,Y_t,\xi)] - \underset{\mu}{E}[C_t(X_t)] \\ &= \sum_{\theta}[P_\theta(\theta)p_t(\theta)]\sum_{\xi}[P_\xi(\xi)g(X_t,Y_t,\xi)] - C_t(X_t) \end{aligned} \tag{16}$$

When the adjusted prices are used as samples of observation over a certain historical period, $\sum_{\theta}[P_\theta(\theta)p_t(\theta)]$ is the sample mean or the average of adjusted prices, AAP. That is, the expected stage return function becomes:

$$\underset{\mu}{E}[F_t(X_t,Y_t,\mu)] = AAP \sum_{\xi}[P_{\xi}(\xi)g(X_t,Y_t,\xi)] - C_t(X_t) \tag{17}$$

Note that conceptually, equation (15) can be used in cases of either time independent prices or time dependent prices, but if the time dependency of price does exist, equation (16) will lose information on the *drift* of prices' random walk, which is actually the trends in price change over time and will bias the results. An improvement can be made by using the PSP below.

Predetermined Sequence of Prices:

When the PSP is coupled to the stochastic dynamic programming model, prices at each stage can be different but are pre-determined by separable estimations. The expected price, $E[p_t(\theta)]$, is approximated by an estimated $\hat{p}_t$, so the expected stage net return function becomes:

$$\begin{aligned}\underset{\mu}{E}[F_t(X_t,Y_t,\mu)] &= \underset{\theta}{E}[p_t]\underset{\xi}{E}[g_t(X_t,Y_t,\xi)] - \underset{\mu}{E}[C_t(X_t)] \\ &= \hat{p}_t\sum_{\xi}[P_{\xi}(\xi)g(X_t,Y_t,\xi)] - C_t(X_t)\end{aligned} \tag{18}$$

The PSP is the simplest approach to coupling random price changes to dynamic programming models when the crop price is not correlated with any decision or state variables in the model being analyzed, but when it is time dependent. The PSP can couple some price sequences suggested by other research such as the FAPRI price (Food and Agricultural Policy Research Institute, 1991), or price sequences estimated by other researchers.

Conclusions

The selection of the output price pattern to employ in stochastic dynamic programming models typically depends on: (1) the type of objective function; (2) the correlation between price and yield and other variables; and (3) the time dependency of price. If the following three conditions, that are the: (1) stochastic dynamic programming model has an objective function in terms of the present value of expected net returns; (2) output price is not correlated with yields or any decision or state variables; and (3) output price is time independent, are satisfied, the AAP is "the most efficient" price pattern to employ although AAP uses historical data in "the least efficient" way. If conditions one and two are satisfied, but the price change is time dependent, then PSP is the choice where the price at each stage is estimated by a separate time series model; then the estimated prices are used as the price at each stage in the dynamic programming model. Remember that the AAP and PSP incorporate output prices into dynamic programming in a "deterministic" manner even though the price is random in nature. The "deterministic" price of the AAP does not mean the price will never change in the planning period, rather that the expected gross return is a product of the mean value of the prices and the yields. Like the AAP, the "pre-determined" prices of the PSP do not mean that price in the planning period will exactly follow the deterministic sequence without random change. Rather, the predetermined price implies that the best approximation of expected price, $E[p_t]$, will be the estimated value that has been determined, p_t, by a specific statistical inference such as ordinary least squares or maximum likelihood. In other words, if the objective function of a stochastic dynamic programming model is not the present value of *expected* net return, AAP and PSP should not be used. Finally, when a correlation among price and yield or other variables does exist, then RPSV or RGP is the method of choice. When such correlation exists and the AAP or PSP is used, the results can only be considered as a biassed approximation.

An approach to select the output price pattern for stochastic dynamic programming with expected net return as the objective function is suggested as follows:

(1) Check the correlation between prices and other variables in the model being analyzed. If there is evidence correlation exists, then RPSV is the choice. Any other price patterns will produce biased results.

(2) Check time dependency of price. If time dependency exists, then PSP is the choice.

If time dependency does not exist, then AAP is the choice.

Appendix B.2 Correlations of Historical Yields and Prices of Crops in Richmond County, Virginia

Detrended Yields and Adjusted Prices
(1970-1988)

Year	YCA	YWA	YSA	PCA	PWA	PSA
	-----(bu/ac)------			-----($/bu)-----		
70	80.49	55.94	18.00	2.70	1.26	2.63
71	76.50	52.31	27.00	2.64	2.74	5.53
72	89.51	42.69	23.00	2.54	2.56	6.46
73	93.52	36.56	28.00	2.46	3.62	7.46
74	94.53	37.94	24.00	2.43	2.95	5.02
75	110.54	31.81	25.00	2.40	2.70	4.67
76	83.55	31.19	23.00	2.37	2.93	5.15
77	35.56	31.56	15.00	2.53	2.34	8.04
78	81.58	31.44	32.00	2.60	3.40	7.20
79	84.59	35.32	30.00	2.66	4.01	6.99
80	49.10	34.69	13.00	2.62	3.37	5.89
81	84.61	42.07	26.50	2.47	2.62	5.60
82	98.62	35.44	28.50	2.37	2.96	5.81
83	31.63	39.32	14.00	2.64	3.41	5.58
84	90.14	30.19	25.00	2.59	3.01	5.50
85	80.65	22.57	23.50	2.45	2.75	5.31
86	29.16	41.94	20.00	2.56	2.95	6.19
87	65.18	37.82	17.00	2.41	3.60	7.47
88	59.69	46.69	23.00	2.52	3.25	7.44

Descriptive Statistics
Based on 19 observations.

Variable	Mean	Std. Dev.	Skewness	Kurtosis	Minimum	Maximum
YCA	74.692	23.437	-.73597	2.3866	29.16	110.5
YWA	37.762	7.9999	.55201	3.0452	22.57	55.94
YSA	22.921	5.4652	-.33839	2.0716	13.00	32.00
PCA	2.5232	.10403	.02940	1.6497	2.370	2.700
PWA	3.0337	.44218	.45620	2.3252	2.340	4.010
PSA	6.1300	1.0086	.44569	1.7805	4.670	8.040

Covariance Matrix

	1-YCA	2-YWA	3-YSA	4-PCA	5-PWA	6-PSA
1-YCA	549.294					
2-YWA	-24.7058	63.9990				
3-YSA	91.4181	-5.07857	29.8684			
4-PCA	-.976744	.383136	-.104737	.108228E-01		
5-PWA	-.693139	-.589632	.415863	.620439E-02	.195525	
6-PSA	-8.35925	-.202846	-.386112E-01	.111667E-01	.174089	1.01733

Correlation Matrix

	1-YCA	2-YWA	3-YSA	4-PCA	5-PWA	6-PSA
1-YCA	1.000000					
2-YWA	-.131768	1.000000				
3-YSA	.713713	-.116158	1.000000			
4-PCA	-.400598	.460359	-.184214	1.000000		
5-PWA	-.066883	-.166684	.172085	.134874	1.000000	
6-PSA	-.353617	-.025139	-.007004	.106420	.390336	1.000000

Notation:
(1) YCA, YWA, and YSA are the detrended yields of corn, wheat, and soybean in Richmond County, respectively.
(2) PCA, PWA, and PSA are the adjusted prices of corn, wheat, and soybean in Northern Neck, Virginia, respectively.
(3) Std. Dev. is standard deviation.
(4) The crop prices were adjusted to 1988 dollars using the USDA index of price received by farmers.

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)

Agricultural Management System: 1

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	6.56	6.56
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	2	0.64	1.28
		Wheat	acre	2	0.64	1.28
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.28	36.40
		Wheat	lb	80.00	0.28	22.40
		Soybean	lb			
	Phosphorus	Corn	lb	40.08	0.26	10.42
		Wheat	lb	36.07	0.26	9.38
		Soybean	lb			
	Potassium	Corn	lb	60.12	0.14	8.42
		Wheat	lb	72.15	0.14	10.10
		Soybean	lb			
Chemical Costs		Corn				4.06
		Wheat				5.74
		Soybean				46.37
Labor Cost		Corn	hour	1.62	4.50	7.29
		Wheat	hour	1.33	4.50	5.99
		Soybean	hour	1.09	4.50	4.91
					Total :	340.6

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 1L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	6.56	6.56
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.57	74.10
		Wheat	lb	80.00	0.57	45.60
		Soybean	lb			
	Phosphorus	Corn	lb	0.00	0.26	0.00
		Wheat	lb	0.00	0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb	0.00	0.14	0.00
		Wheat	lb	0.00	0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				4.06
		Wheat				5.74
		Soybean				46.37
Labor Cost		Corn	hour	1.51	4.50	6.80
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.09	4.50	4.91
					Total :	360.8

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems (Per Acre in a Crop Rotation Period) (Continued)

Agricultural Management System: 2

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre			
		Wheat	acre	1	6.56	6.56
		Soybean	acre	1	3.62	3.62
	Plant	Corn	acre	1	7.70	7.70
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	2	0.64	1.28
		Wheat	acre	2	0.64	1.28
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	150.00	0.28	42.00
		Wheat	lb	118.00	0.28	33.04
		Soybean	lb			
	Phosphorus	Corn	lb	40.08	0.26	10.42
		Wheat	lb	36.07	0.26	9.38
		Soybean	lb			
	Potassium	Corn	lb	60.12	0.14	8.42
		Wheat	lb	72.15	0.14	10.10
		Soybean	lb			
Chemical Costs		Corn				22.24
		Wheat				10.78
		Soybean				58.66
Labor Cost		Corn	hour	1.31	4.50	5.90
		Wheat	hour	1.33	4.50	5.99
		Soybean	hour	1.38	4.50	6.21
					Total :	392.5

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 2L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre			
		Wheat	acre	1	6.56	6.56
		Soybean	acre	1	3.62	3.62
	Plant	Corn	acre	1	7.70	7.70
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	150.00	0.57	85.50
		Wheat	lb	118.00	0.57	67.26
		Soybean	lb			
	Phosphorus	Corn	lb		0.26	0.00
		Wheat	lb		0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb		0.14	0.00
		Wheat	lb		0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				22.24
		Wheat				10.78
		Soybean				58.66
Labor Cost		Corn	hour	1.20	4.50	5.40
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.38	4.50	6.21
					Total :	429.7

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 3

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	6.56	6.56
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	2	0.64	1.28
		Wheat	acre	2	0.64	1.28
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre		5.01	0.00
		Soybean	acre	2	5.01	10.02
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	100.00	0.28	28.00
		Wheat	lb	77.00	0.28	21.56
		Soybean	lb			
	Phosphorus	Corn	lb	40.08	0.26	10.42
		Wheat	lb	36.07	0.26	9.38
		Soybean	lb			
	Potassium	Corn	lb	60.12	0.14	8.42
		Wheat	lb	72.15	0.14	10.10
		Soybean	lb			
Chemical Costs		Corn				4.06
		Wheat				0.00
		Soybean				17.51
Labor Cost		Corn	hour	1.59	4.50	7.16
		Wheat	hour	1.33	4.50	5.99
		Soybean	hour	1.09	4.50	4.91
					Total :	286.5

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 3L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	3.37	3.37
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre		5.01	0.00
		Soybean	acre	2	5.01	10.02
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	100.00	0.57	57.00
		Wheat	lb	77.00	0.57	43.89
		Soybean	lb			
	Phosphorus	Corn	lb		0.26	0.00
		Wheat	lb		0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb		0.14	0.00
		Wheat	lb		0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				4.06
		Wheat				0.00
		Soybean				17.51
Labor Cost		Corn	hour	1.48	4.50	6.66
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.09	4.50	4.91
					Total :	294.1

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 4

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	6.56	6.56
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Nitrogen Appl.	Corn	acre	2	0.64	1.28
		Wheat	acre	3	0.64	1.92
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.28	36.40
		Wheat	lb	80.00	0.28	22.40
		Soybean	lb			
	Phosphorus	Corn	lb	40.08	0.26	10.42
		Wheat	lb	36.07	0.26	9.38
		Soybean	lb			
	Potassium	Corn	lb	60.12	0.14	8.42
		Wheat	lb	72.15	0.14	10.10
		Soybean	lb			
Chemical Costs		Corn				4.06
		Wheat				5.74
		Soybean				46.37
Labor Cost		Corn	hour	1.62	4.50	7.29
		Wheat	hour	1.44	4.50	6.48
		Soybean	hour	1.09	4.50	4.91
					Total :	341.7

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 5L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	2	3.62	7.24
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
	Cultivation	Corn	acre	3	2.00	6.00
		Wheat	acre		2.00	0.00
		Soybean	acre	3	2.00	6.00
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre		5.01	0.00
		Wheat	acre		5.01	0.00
		Soybean	acre		5.01	0.00
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.57	74.10
		Wheat	lb	77.00	0.57	43.89
		Soybean	lb			
	Phosphorus	Corn	lb	0.00	0.26	0.00
		Wheat	lb	0.00	0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb	0.00	0.14	0.00
		Wheat	lb	0.00	0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				
		Wheat				
		Soybean				
Labor Cost		Corn	hour	2.06	4.50	9.27
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.55	4.50	6.98
					Total :	295.1

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 8

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
		Rye	bu	3.09	7.95	24.57
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre			0.00
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	7.70	7.70
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
		Rye	acre	1	8.02	8.02
	Cultivation	Corn	acre	1	2.00	2.00
		Wheat	acre	3	2.00	6.00
		Soybean	acre			0.00
	Mow	Rye	acre	1	3.62	3.62
	Nitrogen Appl.	Corn	acre	2	0.64	1.28
		Wheat	acre	2	0.64	1.28
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	4	5.01	20.04
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.28	36.40
		Wheat	lb	80.00	0.28	22.40
		Soybean	lb			
	Phosphorus	Corn	lb	40.08	0.26	10.42
		Wheat	lb	36.07	0.26	9.38
		Soybean	lb			
	Potassium	Corn	lb	60.12	0.14	8.42
		Wheat	lb	72.15	0.14	10.10
		Soybean	lb			
Chemical Costs		Corn				15.97
		Wheat				5.74
		Soybean				56.54
Labor Cost		Corn	hour	1.46	4.50	6.57
		Wheat	hour	1.33	4.50	5.99
		Soybean	hour	1.09	4.50	4.91
		Rye	hour	0.45	4.50	2.03
					Total :	409.9

* Hauling and drying costs are not included in harvest costs.
** See Appendix B.4 for chemical costs.
Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 8L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
		Rye	bu	3.09	7.95	24.57
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre			0.00
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	7.70	7.70
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
		Rye	acre	1	8.02	8.02
	Cultivation	Corn	acre	1	2.00	2.00
		Wheat	acre		2.00	0.00
		Soybean	acre			0.00
	Mow	Rye	acre	1	3.62	3.62
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	4	5.01	20.04
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.57	74.10
		Wheat	lb	80.00	0.57	45.60
		Soybean	lb			
	Phosphorus	Corn	lb		0.26	0.00
		Wheat	lb		0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb		0.14	0.00
		Wheat	lb		0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				15.97
		Wheat				5.74
		Soybean				56.54
Labor Cost		Corn	hour	1.35	4.50	6.08
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.09	4.50	4.91
		Rye	hour	0.45	4.50	2.03
					Total :	424.2

* Hauling and drying costs are not included in harvest costs.
** See Appendix B.4 for chemical costs.
Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 11L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
		Rye	bu	3.09	7.95	24.57
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre			0.00
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	7.70	7.70
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
		Rye	acre	1	8.02	8.02
	Cultivation	Corn	acre	3	2.00	6.00
		Wheat	acre		2.00	0.00
		Soybean	acre	3	2.00	6.00
	Mow	Rye	acre	1	3.62	3.62
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre		5.01	0.00
		Wheat	acre		5.01	0.00
		Soybean	acre		5.01	0.00
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.57	74.10
		Wheat	lb	80.00	0.57	45.60
		Soybean	lb			
	Phosphorus	Corn	lb		0.26	0.00
		Wheat	lb		0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb		0.14	0.00
		Wheat	lb		0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				
		Wheat				
		Soybean				
Labor Cost		Corn	hour	2.10	4.50	9.45
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.09	4.50	4.91
		Rye	hour	0.45	4.50	2.03
					Total :	329.2

* Hauling and drying costs are not included in harvest costs.
** See Appendix B.4 for chemical costs.
Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 15

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
		Mix	unit	0.58	54.46	31.59
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	3.62	3.62
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
		Mix	acre	1	6.01	6.01
	Cultivation	Corn	acre		2.00	0.00
		Wheat	acre		2.00	0.00
		Soybean	acre			0.00
	Plough in	Mix	acre	1	3.62	3.62
	Nitrogen Appl.	Corn	acre	2	0.64	1.28
		Wheat	acre	2	0.64	1.28
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.28	36.40
		Wheat	lb	80.00	0.28	22.40
		Soybean	lb			
	Phosphorus	Corn	lb	40.08	0.26	10.42
		Wheat	lb	36.07	0.26	9.38
		Soybean	lb			
	Potassium	Corn	lb	60.12	0.14	8.42
		Wheat	lb	72.15	0.14	10.10
		Soybean	lb			
Chemical Costs		Corn				15.97
		Wheat				5.74
		Soybean				56.54
Labor Cost		Corn	hour	1.43	4.50	6.44
		Wheat	hour	1.33	4.50	5.99
		Soybean	hour	1.09	4.50	4.91
		Mix	hour	0.29	4.50	1.31
					Total :	401.3

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 15L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
		Mix	unit	0.58	54.46	31.59
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	3.62	3.62
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
		Mix	acre	1	6.01	6.01
	Cultivation	Corn	acre		2.00	0.00
		Wheat	acre		2.00	0.00
		Soybean	acre			0.00
	Plough in	Mix	acre	1	3.62	3.62
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre	1	5.01	5.01
		Wheat	acre	1	5.01	5.01
		Soybean	acre	3	5.01	15.03
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.57	74.10
		Wheat	lb	80.00	0.57	45.60
		Soybean	lb			
	Phosphorus	Corn	lb		0.26	0.00
		Wheat	lb		0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb		0.14	0.00
		Wheat	lb		0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				15.97
		Wheat				5.74
		Soybean				56.54
Labor Cost		Corn	hour	1.32	4.50	5.94
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.09	4.50	4.91
		Mix	hour	0.29	4.50	1.31
					Total :	421.6

* Hauling and drying costs are not included in harvest costs.
** See Appendix B.4 for chemical costs.
Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.3 Variable Costs of Agricultural Management Systems
(Per Acre in a Crop Rotation Period)
(Continued)

Agricultural Management System: 16L

Item		Crop	Unit	Quantity	Unit Price ($)	Total ($)
	Seed	Corn	unit	0.30	70.00	21.00
		Wheat	bu	2.00	9.00	18.00
		Soybean	bu	1.00	9.00	9.00
		Mix	unit	0.58	54.46	31.59
	Lime	Corn	ton	0.60	27.00	16.20
		Wheat	ton	0.30	27.00	8.10
		Soybean	ton	0.20	27.00	5.40
Pre-harvest Machinery Costs	Tillage	Corn	acre	1	3.62	3.62
		Wheat	acre	1	6.56	6.56
		Soybean	acre			
	Plant	Corn	acre	1	4.40	4.40
		Wheat	acre	1	3.94	3.94
		Soybean	acre	1	7.70	7.70
		Mix	acre	1	6.01	6.01
	Cultivation	Corn	acre	3	2.00	6.00
		Wheat	acre		2.00	0.00
		Soybean	acre	3	2.00	6.00
	Plough in	Mix	acre	1	3.62	3.62
	Nitrogen Appl.	Corn	acre	1	0.64	0.64
		Wheat	acre	1	0.64	0.64
		Soybean	acre			
	Chemical Appl.	Corn	acre		5.01	0.00
		Wheat	acre		5.01	0.00
		Soybean	acre		5.01	0.00
Harvest Costs	Repairs	Corn	acre			9.60
		Wheat	acre			5.25
		Soybean	acre			5.18
	Fuel, Oil	Corn	acre			7.01
		Wheat	acre			4.77
		Soybean	acre			2.82
Nutrient Costs	Nitrogen	Corn	lb	130.00	0.57	74.10
		Wheat	lb	80.00	0.57	45.60
		Soybean	lb			
	Phosphorus	Corn	lb		0.26	0.00
		Wheat	lb		0.26	0.00
		Soybean	lb			
	Potassium	Corn	lb		0.14	0.00
		Wheat	lb		0.14	0.00
		Soybean	lb			
Chemical Costs		Corn				
		Wheat				
		Soybean				
Labor Cost		Corn	hour	1.78	4.50	8.01
		Wheat	hour	1.22	4.50	5.49
		Soybean	hour	1.55	4.50	6.98
		Mix	hour	0.29	4.50	1.31
					Total :	334.5

* Hauling and drying costs are not included in harvest costs.

** See Appendix B.4 for chemical costs.

Sources: Southeast Virginia Crop Budget Guides (1991), Diebel (1990)

Appendix B.4 Cemical Costs of Agricultural Managment Systems

AMS	Chemical Rate														
	1 Blazer	2 Lasso	3 Aatrex	4 Gemini	5 Bladex	6 Banvel	7 Harmony	8 Pydrin	9 Fusulade	10 Roundu	11 Lorox	12 Dual	13 Gramoxon	14 Trefla	15 2-4D
1			3.49	0.35			0.035	0.51	1.75			2.32	1.75		
1L			3.49	0.35			0.035	0.51	1.75			2.32	1.75		
2	1.75		4.65			0.586	0.035	0.51		2.33	1.16	3.5	3.5		0.586
2L	1.75		4.65			0.586	0.035	0.51		2.33	1.16	3.5	3.5		0.586
3			3.49						1.75				0.59		
3L			3.49						1.75				0.59		
4			3.49	0.35			0.035	0.51	1.75			2.32	1.75		
5L															
8	1.75		3.49				0.035	0.51	1.75		1.16	4.08	1.75		
8L	1.75		3.49				0.035	0.51	1.75		1.16	4.08	1.75		
11L															
15	1.75		3.49				0.035	0.51	1.75		1.16	4.08	1.75		
15L	1.75		3.49				0.035	0.51	1.75		1.16	4.08	1.75		
16L															
	Unit Prices of Chemicals ($)														
	14.08	6.06	2.87	36.12	5.18	17.97	404.80	28.14	21.57	20.25	14.78	14.42	9.34	7.15	3.28

AMS	Chemical Costs of Agricultural Management Systems ($/ac)															Total Cost
1	0.00	0.00	10.02	12.64	0.00	0.00	14.17	14.35	37.75	0.00	0.00	33.45	16.35	0.00	0.00	138.72
1L	0.00	0.00	10.02	12.64	0.00	0.00	14.17	14.35	37.75	0.00	0.00	33.45	16.35	0.00	0.00	138.72
2	24.64	0.00	13.35	0.00	0.00	10.53	14.17	14.35	0.00	47.18	17.14	50.47	32.69	0.00	1.92	226.44
2L	24.64	0.00	13.35	0.00	0.00	10.53	14.17	14.35	0.00	47.18	17.14	50.47	32.69	0.00	1.92	226.44
3	0.00	0.00	10.02	0.00	0.00	0.00	0.00	0.00	37.75	0.00	0.00	0.00	5.51	0.00	0.00	53.27
3L	0.00	0.00	10.02	0.00	0.00	0.00	0.00	0.00	37.75	0.00	0.00	0.00	5.51	0.00	0.00	53.27
4	0.00	0.00	10.02	12.64	0.00	0.00	14.17	14.35	37.75	0.00	0.00	33.45	16.35	0.00	0.00	138.72
5L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	24.64	0.00	10.02	0.00	0.00	0.00	14.17	14.35	37.75	0.00	17.14	58.83	16.35	0.00	0.00	193.25
8L	24.64	0.00	10.02	0.00	0.00	0.00	14.17	14.35	37.75	0.00	17.14	58.83	16.35	0.00	0.00	193.25
11L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	24.64	0.00	10.02	0.00	0.00	0.00	14.17	14.35	37.75	0.00	17.14	58.83	16.35	0.00	0.00	193.25
15L	24.64	0.00	10.02	0.00	0.00	0.00	14.17	14.35	37.75	0.00	17.14	58.83	16.35	0.00	0.00	193.25
16L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Notes:
(1) The unit of chemical rates is liter per hectare, except Gemini and Harmony using kilogram.
(2) Blaser, Gemini, Pydrin, Fusulade, Roundup, and Lorox are used for soybeans.
(3) Aatrex is used for corn.
(4) Banvel, Harmony, and 2-4D are used for wheat.
(5) Act. 2 and 2L use 1.75 liter Gramoxnoe. The rest of Gramoxnoe is used for soybeans.
(6) Act. 2 and 2L; Act. 8 and 8L; and Act. 15 and 15L use 1.75; 2.33 and 2.33 liter Dual, respectively.
The rest of Dual is used for soybeans.
(7) AMS represents agricultural management system.

Appendix C.1 Computer Program for the General MODP Model

```
C     THIS PROGRAM IS WRITTEN IN FORTRAN 77 (MICROSOFT FORTRAN,
C     VERSION 2.3)
C     THIS PROGRAM IS USED FOR SOLVING THE GENERAL MULTI-OBJECTIVE
C     DYNAMIC PROGRAMMING MODEL AND CAN BE USED FOR SENSITIVITY
C     ANALYSIS AND SCENARIOS THROUGH MODIFYING PARAMETERS
C     S IS MAXIMUM NO. OF STATES
C     G IS MAXIMUM NO. OF DECISIONS
C     C IS MAXIMUM NO. OF POSSIBLE FOLLOWING STAGES FROM ANY
C       DECISION)
C     N IS MAXIMUM NO. OF DECISION STAGES
C     DIMENSIONS OF ARRAY ARE:
C     A(S,N+1),B(S,N+1),D(S,N+1),F(S,N+1),Y$(S),I(S*G*C),J(S*G*C),
C     P(S*G*C),R(S,G),E(G),V$(G),Q(N+1),U(N+1),V(N+1),W(N+1)
      CHARACTER*8 M$,N$*12,N1$*12,M1$*4,M2$*4
      INTEGER B(25,11),D(25,11),I(0:1200),J(0:1200)
      INTEGER IE2,IE3,T,T2,I2,D2,L,L9,N,N1,N2,K,K9,IY,IYY
      REAL P(1200),FR(25,11),FSL(25,11),FFNL(25,11)
      REAL R(25,15),SL(25,15),NL(25,15),ASL(25,15),AR(25,15)
      REAL ANL(25,15),BR(25,11),BSL(25,11),BNL(25,11)
      REAL ER(15),ESL(15),ENL(15)
      REAL VCOST(14),LCOST(14),NCOST(14),CCOST(14)
      REAL R2,SL2,NL2,E2MAX,E3MAX,E2MIN,A2,D1,C0,C1,S1
      REAL E3MIN,DELTA2,DELTA3,E2,E3,E2N2,E3N3
      REAL CY,WY,SY,UTC,UTW,UTS,PCORN,PWHEAT,PBEAN,NIM,GIM,TCOST
      REAL CHCOST,WHCOST,SHCOST,HCOST
      REAL CBHCOST,CVHCOST,WBHCOST,WVHCOST,SBHCOST,SVHCOST
      M1$='.DAT'
      M2$='.OUT'
      PRINT *,'PROBLEM NAME'
      READ (*,'(A8)') M$
      N$=M$//M1$
      N1$=M$//M2$
C---------------------------OPEN FILE---------------------------
      OPEN(UNIT=1,FILE=N$,FORM='FORMATTED',ACCESS='SEQUENTIAL')
      OPEN(UNIT=12,FILE=N1$,FORM='FORMATTED',ACCESS='SEQUENTIAL')
C-----DEFINE STAGE, DISCOUNT RATE, CONSTANTS, AND GRID SIZE------
      N=5
      A2=13.12
      E2MAX=22
      E2MIN=11
      E3MAX=415
      E3MIN=160
      IE2=10
      IE3=10
      D1=1/(1+A2/100)
      DELTA2=(E2MAX-E2MIN)/IE2
      DELTA3=(E3MAX-E3MIN)/IE3
      C1=.9999
      C0=1-C1
      N1=N+1
C----------------------CROP PRICES ($/BU)------------------------
      PCORN=2.52
      PWHEAT=3.03
      PBEAN=6.13
C-------------------VARIABLE COSTS OF AMS ($/HA)-----------------


C-----CBHCOST, WBHCOST, AND SBHCOST ARE BASIC HARVEST COST OF CORN,
C-----WHEAT, AND SOYBEAN
C-----VOCST(#) IS OTHER VARIABLE COST OF AMS #
C-----LCOST(#) IS LABOR COST OF AMS #
C-----NCOST(#) IS NUTRIENT COST OF AMS #
C-----CCOST(#) IS CHEMICAL COST OF AMS #
```

```
      CBHCOST=41.03
      WBHCOST=24.75
      SBHCOST=19.76
      VCOST(1)=332.14
      VCOST(2)=333.03
      VCOST(3)=307.39
      VCOST(4)=333.72
      VCOST(5)=445.66
      VCOST(6)=426.69
      VCOST(7)=328.98
      VCOST(8)=329.87
      VCOST(9)=296.35
      VCOST(10)=298.43
      VCOST(11)=427.68
      VCOST(12)=378.13
      VCOST(13)=423.53
      VCOST(14)=391.30
      LCOST(1)=44.96
      LCOST(2)=44.65
      LCOST(3)=44.60
      LCOST(4)=46.17
      LCOST(5)=48.11
      LCOST(6)=45.90
      LCOST(7)=42.53
      LCOST(8)=42.21
      LCOST(9)=42.17
      LCOST(10)=53.78
      LCOST(11)=45.68
      LCOST(12)=54.23
      LCOST(13)=43.47
      LCOST(14)=53.78
      NCOST(1)=239.88
      NCOST(2)=279.99
      NCOST(3)=217.06
      NCOST(4)=239.88
      NCOST(5)=239.88
      NCOST(6)=239.88
      NCOST(7)=295.66
      NCOST(8)=377.32
      NCOST(9)=249.20
      NCOST(10)=291.44
      NCOST(11)=295.66
      NCOST(12)=295.66
      NCOST(13)=295.66
      NCOST(14)=295.66
      CCOST(1)=138.72
      CCOST(2)=226.44
      CCOST(3)=53.27
      CCOST(4)=138.72
      CCOST(5)=193.25
      CCOST(6)=193.25
      CCOST(7)=138.72
      CCOST(8)=226.44
      CCOST(9)=53.27
      CCOST(10)=0.00
      CCOST(11)=193.25
      CCOST(12)=0.00
      CCOST(13)=193.25
      CCOST(14)=0.00
C---------------------VALUES OF TERMINAL STAGE-------------------
      DO 700 I2=1,23
      FR(I2,1)=0
      FSL(I2,1)=0
      FFNL(I2,1)=0
 700  CONTINUE
```

```
C------------------------SIGN RHS' OF CONSTRAINTS---------------
      E3=E3MIN
      E2=E2MIN
      IY=0
      IYY=0
C-----------------BACKWARD RECURSION STARTS---------------------
C-----------READ OBJECTIVE VALUES FOR STAGE T2-------------------
C-----------CALCULATE CROP YIELDS AND TOTAL VARIABLE COST---------
  740 N2=2
  750 DO 760 K=1,1200
      READ (1,9) T2,I(K),D2,UTC,UTW,UTS,SL2,NL2,J(K),P(K)
      IF (I(K) .EQ. 0) GO TO 950
      CY=UTC*0.55*2.47/0.0135/56/1.123
      WY=UTW*0.55*2.47/0.0152/60/1.123
      SY=22.87*2.47
      GIM=CY*PCORN+WY*PWHEAT+SY*PBEAN
      CVHCOST=CY*0.45
      CHCOST=CBHCOST+CVHCOST
      WVHCOST=WY*0.15
      WHCOST=WBHCOST+WVHCOST
      SVHCOST=22.87*0.15
      SHCOST=SBHCOST+SVHCOST
      HCOST=CHCOST+WHCOST+SHCOST
      TCOST=VCOST(D2)+HCOST+LCOST(D2)+NCOST(D2)+CCOST(D2)
      NIM=GIM-TCOST
      R2=NIM
      IF (P(K) .GT. C0) THEN
      R(I(K),D2)=R2
      SL(I(K),D2)=SL2
      NL(I(K),D2)=NL2
      END IF
  760 CONTINUE
  9   FORMAT ( I6,I3,I3,5F8.2,I3,F8.4)
C-------------ASSIGN EXPECTED RETURNS FOR ALL DECISIONS----------
  950 K=0
  960 L=0
  970 S1=0
      L=L+1
      ER(L)=R(I(K+1),L)
      ESL(L)=SL(I(K+1),L)
      ENL(L)=NL(I(K+1),L)
 1000 K=K+1
      ER(L)=ER(L)+D1*P(K)*FR(J(K),N2-1)
      ESL(L)=ESL(L)+P(K)*FSL(J(K),N2-1)
      ENL(L)=ENL(L)+P(K)*FFNL(J(K),N2-1)
      S1=S1+P(K)
      IF (S1 .LT. C1) GO TO 1000
      IF (I(K+1) .EQ. 0) GO TO 1060
      IF (P(K+1) .EQ. 0) GO TO 1000
 1060 I2=I(K)
      IF (I(K) .EQ. I(K+1)) GO TO 970
C--------------------------FIND OPTIMAL DECISION-----------------
      E2N2=E2*(N2-1)/N
      E3N3=E3*(N2-1)/N
      K9=0
      DO 1140 L9= 1, L
      IF (ESL(L9) .LE. E2N2) THEN
      IF (ENL(L9) .LE. E3N3) THEN
      IF (ER(L9) .GT. 0) THEN
      IF (ESL(L9) .EQ. E2N2) THEN
      ASL(I2,L9)=ESL(L9)
      AR(I2,L9)=ER(L9)
      END IF
      IF (ENL(L9) .EQ. E3N3) THEN
      ANL(I2,L9)=ENL(L9)
```

```
      END IF
      IF (K9 .EQ. 0) THEN
      K9=L9
      END IF
      IF (ER(L9).GT.ER(K9)) THEN
      K9=L9
      END IF
      END IF
      END IF
      END IF
 1140 CONTINUE
      IF (K9 .EQ. 0) THEN
      IY=IY+1
      BR(I2,N2)=0
      BSL(I2,N2)=0
      BNL(I2,N2)=0
      D(I2,N2)=K9
      FR(I2,N2)=D1*FR(I2,N2-1)
      FSL(I2,N2)=FSL(I2,N2-1)+1
      FFNL(I2,N2)=FFNL(I2,N2-1)+25
      GOTO 1610
      END IF
 1150 D(I2,N2)=K9
      BR(I2,N2)=R(I2,K9)
      BSL(I2,N2)=SL(I2,K9)
      BNL(I2,N2)=NL(I2,K9)
      B(I2,N2)=J(K-L+K9)
      FR(I2,N2)=ER(K9)
      FSL(I2,N2)=ESL(K9)
      FFNL(I2,N2)=ENL(K9)
 1610 IF (I(K+1) .NE. 0) THEN
      GOTO 960
      ELSE IF (IY .EQ. 23) THEN
      IYY=IYY+2
      END IF
C-------------------PRINT RESULTS FOR STOCHASTIC PROBLEM----------
 1620 T=N+2-N2
      WRITE (12, 10) E2,E3,T
 10   FORMAT (F5.2,4X,F8.2,I3)
      DO 1700 I2=1, 23
      WRITE (12, 15) I2,D(I2,N2),FR(I2,N2),FSL(I2,N2),FFNL(I2,N2)
 1700 CONTINUE
 15   FORMAT (I3,I3,2X,3F9.2)
 1800 IF (N2 .LT. N1) THEN
      N2=N2+1
      IY=0
      GO TO 950
      ELSE IF (E2 .LT. E2MAX) THEN
      IY=0
      IYY=0
      N2=2
      E2=E2+DELTA2
      GO TO 950
      ELSE IF (E3 .LT. E3MAX) THEN
      IY=0
      IYY=0
      N2=2
      E3=E3+DELTA3
      E2=E2MIN
      GO TO 950
      END IF
      CLOSE (UNIT=1)
      CLOSE (UNIT=12)
      END
```

Appendix C.2 Computer Program for Data Generate

```
10 REM THIS DATA GENERATING PROGRAM IS WRITTEN IN GW-BASIC, VERSION 3.2.
20 REM----SWT.DAT----
30 LET N$="SWT.DAT"
40 OPEN N$ FOR OUTPUT AS #1
50 REM----MODIFY MODEL----
60 LET C$=","
70 LET N=10
80 LET A2=5.6
90 LET E2MAX=42.8
100 LET E2MIN=21.6
110 LET E3MAX=828.2
120 LET E3MIN=318.8
130 LET IE2=10
140 LET IE3=10
150 PRINT #1, N
160 PRINT #1, A2
170 PRINT #1, E2MAX
180 PRINT #1, E2MIN
190 PRINT #1, E3MAX
200 PRINT #1, E3MIN
210 PRINT #1, IE2
220 PRINT #1, IE3
230 PRINT #1, "S"
240 PRINT #1, "Y"
250 PRINT #1, "Y"
260 REM---WRITE BLOCK B DATA (TERMINAL STETE VALUES)----
270 PRINT #1, "0,0"
280 REM---CONDITIONAL PROBALILITY AND WATER PERCOLATION----
290 OPTION BASE 1
300 DIM J(23), P(23), PM(23)
310 DIM P1C(10), P1W(11), P1S(4), P1WC(10)
320 DIM PER1C(10), PER1W(11), PER1S(4), PER1WC(10)
330 DIM P21C(10), P21W(11), P21S(4), P21WC(10)
340 DIM PER21C(10), PER21W(11), PER21S(4),PER21WC(10)
350 DIM P2C(10), P2W(11), P2S(5), P2WC(10)
360 DIM PER2C(10), PER2W(11), PER2S(5), PER2WC(10)
370 DIM P22C(10), P22W(11), P22S(5), P22WC(10)
380 DIM PER22C(10), PER22W(11), PER22S(5), PER22WC(10)
390 DIM P3C(10), P3W(11), P3S(5),P3WC(10)
400 DIM PER3C(10), PER3W(11), PER3S(5), PER3WC(10)
410 DIM P23C(10), P23W(11), P23S(5), P23WC(10)
420 DIM PER23C(10), PER23W(11), PER23S(5), PER23WC(10)
430 DIM P4C(10), P4W(11), P4S(4), P4WC(10)
440 DIM PER4C(10), PER4W(11), PER4S(4), PER4WC(10)
450 DIM P25C(10), P25W(12), P25S(4), P25WC(10)
460 DIM PER25C(10), PER25W(12), PER25S(4), PER25WC(10)
470 DIM P8C(7), P8W(11), P8S(5), P8WC(7)
480 DIM PER8C(7), PER8W(11), PER8S(5), PER8WC(7)
490 DIM P28C(7), P28W(11), P28S(5), P28WC(7)
500 DIM PER28C(7), PER28W(11), PER28S(5), PER28WC(7)
510 DIM P211C(7), P211W(11), P211S(5), P211WC(7)
520 DIM PER211C(7), PER211W(11), PER211S(5), PER211WC(7)
530 DIM P15C(7), P15W(11), P15S(5), P15WC(7)
540 DIM PER15C(7), PER15W(11), PER15S(5), PER15WC(7)
550 DIM P215C(7), P215W(11), P215S(5), P215WC(7)
560 DIM PER215C(7), PER215W(11), PER215S(5), PER215WC(7)
570 DIM P216C(7), P216W(11), P216S(5), P216WC(7)
580 DIM PER216C(7), PER216W(11), PER216S(5), PER216WC(7)
590 READ P1C(1),P1C(2),P1C(3),P1C(4),P1C(5),P1C(6)
600 READ P1C(7),P1C(8),P1C(9),P1C(10)
610 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
620 READ PER1C(1),PER1C(2),PER1C(3),PER1C(4),PER1C(5),PER1C(6)
630 READ PER1C(7),PER1C(8),PER1C(9),PER1C(10)
```

```
640 DATA 3,5,7,9,11,13,17,19,23,25
650 READ P1W(1),P1W(2),P1W(3),P1W(4),P1W(5),P1W(6)
660 READ P1W(7),P1W(8),P1W(9),P1W(10),P1W(11)
670 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
680 READ PER1W(1),PER1W(2),PER1W(3),PER1W(4),PER1W(5),PER1W(6)
690 READ PER1W(7),PER1W(8),PER1W(9),PER1W(10),PER1W(11)
700 DATA 1,7,9,11,13,15,19,21,23,27,35
710 READ P1S(1),P1S(2),P1S(3),P1S(4)
720 DATA .529,.235,.059,.176
730 READ PER1S(1),PER1S(2),PER1S(3),PER1S(4)
740 DATA 1,3,7,9
750 READ P1WC(1),P1WC(2),P1WC(3),P1WC(4),P1WC(5),P1WC(6)
760 READ P1WC(7),P1WC(8),P1WC(9),P1WC(10)
770 DATA .059,.118,.235,.118,.059,.059,.118,.118,.059,.059
780 READ PER1WC(1),PER1WC(2),PER1WC(3),PER1WC(4),PER1WC(5)
790 READ PER1WC(6),PER1WC(7),PER1WC(8),PER1WC(9),PER1WC(10)
800 DATA 3,5,7,9,13,15,17,19,21,23
810 READ P21C(1),P21C(2),P21C(3),P21C(4),P21C(5)
820 READ P21C(6),P21C(7),P21C(8),P21C(9),P21C(10)
830 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
840 READ PER21C(1),PER21C(2),PER21C(3),PER21C(4),PER21C(5)
850 READ PER21C(6),PER21C(7),PER21C(8),PER21C(9),PER21C(10)
860 DATA 3,5,7,9,11,13,17,19,23,25
870 READ P21W(1),P21W(2),P21W(3),P21W(4),P21W(5),P21W(6)
880 READ P21W(7),P21W(8),P21W(9),P21W(10),P21W(11)
890 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
900 READ PER21W(1),PER21W(2),PER21W(3),PER21W(4),PER21W(5)
910 READ ER21WC(6),PER21W(7),PER21W(8),PER21W(9),PER21W(10)
920 READ PER21W(11)
930 DATA 1,7,9,11,13,15,19,21,23,27,35
940 READ P21S(1),P21S(2),P21S(3),P21S(4)
950 DATA .529,.235,.059,.176
960 READ PER21S(1),PER21S(2),PER21S(3),PER21S(4)
970 DATA 1,3,7,9
980 READ P21WC(1),P21WC(2),P21WC(3),P21WC(4),P21WC(5),P21WC(6)
990 READ P21WC(7),P21WC(8),P21WC(9),P21WC(10)
1000 DATA .059,.118,.235,.118,.059,.059,.118,.118,.059,.059
1010 READ PER21WC(1),PER21WC(2),PER21WC(3),PER21WC(4),PER21WC(5)
1020 READ PER21WC(6),PER21WC(7),PER21WC(8),PER21WC(9),PER21WC(10)
1030 DATA 3,5,7,9,13,15,17,19,21,23
1040 READ P2C(1),P2C(2),P2C(3),P2C(4),P2C(5)
1050 READ P2C(6),P2C(7),P2C(8),P2C(9),P2C(10)
1060 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
1070 READ PER2C(1),PER2C(2),PER2C(3),PER2C(4),PER2C(5)
1080 READ PER2C(6),PER2C(7),PER2C(8),PER2C(9),PER2C(10)
1090 DATA 3,5,7,9,11,13,17,19,23,25
1100 READ P2W(1),P2W(2),P2W(3),P2W(4),P2W(5)
1110 READ P2W(6),P2W(7),P2W(8),P2W(9),P2W(10),P2W(11)
1120 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
1130 READ PER2W(1),PER2W(2),PER2W(3),PER2W(4),PER2W(5)
1140 READ PER2W(6),PER2W(7),PER2W(8),PER2W(9),PER2W(10),PER2W(11)
1150 DATA 1,7,9,11,13,15,19,21,25,27,35
1160 READ P2S(1),P2S(2),P2S(3),P2S(4),P2S(5)
1170 DATA .529,.235,.059,.118,.059
1180 READ PER2S(1),PER2S(2),PER2S(3),PER2S(4),PER2S(5)
1190 DATA 1,3,7,9,11
1200 READ P2WC(1),P2WC(2),P2WC(3),P2WC(4),P2WC(5)
1210 READ P2WC(6),P2WC(7),P2WC(8),P2WC(9),P2WC(10)
1220 DATA .059,.118,.176,.176,.059,.059,.118,.118,.059,.059
1230 READ PER2WC(1),PER2WC(2),PER2WC(3),PER2WC(4),PER2WC(5)
1240 READ PER2WC(6),PER2WC(7),PER2WC(8),PER2WC(9),PER2WC(10)
1250 DATA 3,5,7,9,13,15,17,19,21,23
1260 READ P22C(1),P22C(2),P22C(3),P22C(4),P22C(5),P22C(6),P22C(7),P22C(8),P22C(9),P22C(10)
1270 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
1280 READ PER22C(1),PER22C(2),PER22C(3),PER22C(4),PER22C(5)
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1290 READ PER22C(6),PER22C(7),PER22C(8),PER22C(9),PER22C(10)
1300 DATA 3,5,7,9,11,13,17,19,23,25
1310 READ P22W(1),P22W(2),P22W(3),P22W(4),P22W(5)
1320 READ P22W(6),P22W(7),P22W(8),P22W(9),P22W(10),P22W(11)
1330 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
1340 READ PER22W(1),PER22W(2),PER22W(3),PER22W(4),PER22W(5)
1350 READ PER22W(6),PER22W(7),PER22W(8),PER22W(9),PER22W(10)
1360 READ PER22W(11)
1370 DATA 1,7,9,11,13,15,19,21,25,27,35
1380 READ P22S(1),P22S(2),P22S(3),P22S(4),P22S(5)
1390 DATA .529,.235,.059,.118,.059
1400 READ PER22S(1),PER22S(2),PER22S(3),PER22S(4),PER22S(5)
1410 DATA 1,3,7,9,11
1420 READ P22WC(1),P22WC(2),P22WC(3),P22WC(4),P22WC(5)
1430 READ P22WC(6),P22WC(7),P22WC(8),P22WC(9),P22WC(10)
1440 DATA .059,.118,.176,.176,.059,.059,.118,.118,.059,.059
1450 READ PER22WC(1),PER22WC(2),PER22WC(3),PER22WC(4),PER22WC(5)
1460 READ PER22WC(6),PER22WC(7),PER22WC(8),PER22WC(9),PER22WC(10)
1470 DATA 3,5,7,9,13,15,17,19,21,23
1480 READ P3C(1),P3C(2),P3C(3),P3C(4),P3C(5)
1490 READ P3C(6),P3C(7),P3C(8),P3C(9),P3C(10)
1500 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
1510 READ PER3C(1),PER3C(2),PER3C(3),PER3C(4),PER3C(5)
1520 READ PER3C(6),PER3C(7),PER3C(8),PER3C(9),PER3C(10)
1530 DATA 3,5,7,9,11,13,17,19,23,25
1540 READ P3W(1),P3W(2),P3W(3),P3W(4),P3W(5)
1550 READ P3W(6),P3W(7),P3W(8),P3W(9),P3W(10),P3W(11)
1560 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
1570 READ PER3W(1),PER3W(2),PER3W(3),PER3W(4),PER3W(5)
1580 READ PER3W(6),PER3W(7),PER3W(8),PER3W(9),PER3W(10),PER3W(11)
1590 DATA 1,7,9,11,13,15,19,21,25,27,35
1600 READ P3S(1),P3S(2),P3S(3),P3S(4),P3S(5)
1610 DATA .529,.235,.059,.118,.059
1620 READ PER3S(1),PER3S(2),PER3S(3),PER3S(4),PER3S(5)
1630 DATA 1,3,7,9,11
1640 READ P3WC(1),P3WC(2),P3WC(3),P3WC(4),P3WC(5)
1650 READ P3WC(6),P3WC(7),P3WC(8),P3WC(9),P3WC(10)
1660 DATA .059,.118,.176,.176,.059,.059,.118,.118,.059,.059
1670 READ PER3WC(1),PER3WC(2),PER3WC(3),PER3WC(4),PER3WC(5)
1680 READ PER3WC(6),PER3WC(7),PER3WC(8),PER3WC(9),PER3WC(10)
1690 DATA 3,5,7,9,13,15,17,19,21,23
1700 READ P23C(1),P23C(2),P23C(3),P23C(4),P23C(5)
1710 READ P23C(6),P23C(7),P23C(8),P23C(9),P23C(10)
1720 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
1730 READ PER23C(1),PER23C(2),PER23C(3),PER23C(4),PER23C(5)
1740 READ PER23C(6),PER23C(7),PER23C(8),PER23C(9),PER23C(10)
1750 DATA 3,5,7,9,11,13,17,19,23,25
1760 READ P23W(1),P23W(2),P23W(3),P23W(4),P23W(5)
1770 READ P23W(6),P23W(7),P23W(8),P23W(9),P23W(10),P23W(11)
1780 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
1790 READ PER23W(1),PER23W(2),PER23W(3),PER23W(4),PER23W(5)
1800 READ ER23W(6),PER23W(7),PER23W(8),PER23W(9),PER23W(10)
1810 READ PER23W(11)
1820 DATA 1,7,9,11,13,15,19,21,25,27,35
1830 READ P23S(1),P23S(2),P23S(3),P23S(4),P23S(5)
1840 DATA .529,.235,.059,.118,.059
1850 READ PER23S(1),PER23S(2),PER23S(3),PER23S(4),PER23S(5)
1860 DATA 1,3,7,9,11
1870 READ P23WC(1),P23WC(2),P23WC(3),P23WC(4),P23WC(5)
1880 READ P23WC(6),P23WC(7),P23WC(8),P23WC(9),P23WC(10)
1890 DATA .059,.118,.176,.176,.059,.059,.118,.118,.059,.059
1900 READ PER23WC(1),PER23WC(2),PER23WC(3),PER23WC(4),PER23WC(5)
1910 READ PER23WC(6),PER23WC(7),PER23WC(8),PER23WC(9),PER23WC(10)
1920 DATA 3,5,7,9,13,15,17,19,21,23
1930 READ P4C(1),P4C(2),P4C(3),P4C(4),P4C(5)
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1940 READ P4C(6),P4C(7),P4C(8),P4C(9),P4C(10)
1950 DATA .059,.176,.235,.118,.059,.118,.059,.059,.059,.059
1960 READ PER4C(1),PER4C(2),PER4C(3),PER4C(4),PER4C(5)
1970 READ PER4C(6),PER4C(7),PER4C(8),PER4C(9),PER4C(10)
1980 DATA 3,5,7,9,11,13,17,19,23,25
1990 READ P4W(1),P4W(2),P4W(3),P4W(4),P4W(5),P4W(6)
2000 READ P4W(7),P4W(8),P4W(9),P4W(10),P4W(11)
2010 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
2020 READ PER4W(1),PER4W(2),PER4W(3),PER4W(4),PER4W(5)
2030 READ PER4W(6),PER4W(7),PER4W(8),PER4W(9),PER4W(10),PER4W(11)
2040 DATA 1,7,9,11,13,15,19,21,23,27,35
2050 READ P4S(1),P4S(2),P4S(3),P4S(4)
2060 DATA .529,.235,.059,.176
2070 READ PER4S(1),PER4S(2),PER4S(3),PER4S(4)
2080 DATA 1,3,7,9
2090 READ P4WC(1),P4WC(2),P4WC(3),P4WC(4),P4WC(5)
2100 READ P4WC(6),P4WC(7),P4WC(8),P4WC(9),P4WC(10)
2110 DATA .059,.118,.235,.118,.059,.059,.118,.118,.059,.059
2120 READ PER4WC(1),PER4WC(2),PER4WC(3),PER4WC(4),PER4WC(5)
2130 READ PER4WC(6),PER4WC(7),PER4WC(8),PER4WC(9),PER4WC(10)
2140 DATA 3,5,7,9,13,15,17,19,21,23
2150 READ P25C(1),P25C(2),P25C(3),P25C(4),P25C(5)
2160 READ P25C(6),P25C(7),P25C(8),P25C(9),P25C(10)
2170 DATA .059,.235,.176,.118,.059,.118,.059,.059,.059,.059
2180 READ PER25C(1),PER25C(2),PER25C(3),PER25C(4),PER25C(5)
2190 READ PER25C(6),PER25C(7),PER25C(8),PER25C(9),PER25C(10)
2200 DATA 3,5,7,9,11,13,15,19,21,25
2210 READ P25W(1),P25W(2),P25W(3),P25W(4),P25W(5),P25W(6)
2220 READ P25W(7),P25W(8),P25W(9),P25W(10),P25W(11),P25W(12)
2230 DATA .059,.176,.059,.118,.059,.059
2240 DATA .118,.059,.059,.059,.059,.118
2250 READ PER25W(1),PER25W(2),PER25W(3),PER25W(4),PER25W(5)
2260 READ PER25W(6),PER4W(7),PER25W(8),PER25W(9),PER25W(10)
2270 READ PER25W(11), PER25W(12)
2280 DATA 1,7,9,11,13,15,19,21,23,27,33,35
2290 READ P25S(1),P25S(2),P25S(3),P25S(4)
2300 DATA .529,.235,.059,.176
2310 READ PER25S(1),PER25S(2),PER25S(3),PER25S(4)
2320 DATA 1,3,7,9
2330 READ P25WC(1),P25WC(2),P25WC(3),P25WC(4),P25WC(5)
2340 READ P25WC(6),P25WC(7),P25WC(8),P25WC(9),P25WC(10)
2350 DATA .118,.059,.294,.059,.059,.118,.059,.118,.059,.059
2360 READ PER25WC(1),PER25WC(2),PER25WC(3),PER25WC(4),PER25WC(5)
2370 READ PER25WC(6),PER25WC(7),PER25WC(8),PER25WC(9),PER25WC(10)
2380 DATA 3,5,7,9,13,15,17,19,21,23
2390 READ P8C(1),P8C(2),P8C(3),P8C(4),P8C(5),P8C(6),P8C(7)
2400 DATA .294,.235,.118,.059,.059,.118,.118
2410 READ PER8C(1),PER8C(2),PER8C(3),PER8C(4),PER8C(5)
2420 READ PER8C(6),PER8C(7)
2430 DATA 1,3,5,7,11,15,23
2440 READ P8W(1),P8W(2),P8W(3),P8W(4),P8W(5)
2450 READ P8W(6),P8W(7),P8W(8),P8W(9),P8W(10),P8W(11)
2460 DATA .059,.118,.059,.118,.059,.118,.059,.118,.059,.059,.176
2470 READ PER8W(1),PER8W(2),PER8W(3),PER8W(4),PER8W(5)
2480 READ PER8W(6),PER8W(7),PER8W(8),PER8W(9),PER8W(10),PER8W(11)
2490 DATA 1,7,9,11,13,15,19,21,25,29,35
2500 READ P8S(1),P8S(2),P8S(3),P8S(4),P8S(5)
2510 DATA .412,.353,.059,.059,.118
2520 READ PER8S(1),PER8S(2),PER8S(3),PER8S(4),PER8S(5)
2530 DATA 1,3,5,9,11
2540 READ P8WC(1),P8WC(2),P8WC(3),P8WC(4),P8WC(5),P8WC(6),P8WC(7)
2550 DATA .235,.294,.059,.059,.235,.059,.059
2560 READ PER8WC(1),PER8WC(2),PER8WC(3),PER8WC(4),PER8WC(5)
2570 READ PER8WC(6),PER8WC(7)
2580 DATA 1,3,5,7,11,13,19
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2590 READ P28C(1),P28C(2),P28C(3),P28C(4),P28C(5),P28C(6),P28C(7)
2600 DATA .294,.235,.118,.059,.059,.118,.118
2610 READ PER28C(1),PER28C(2),PER28C(3),PER28C(4),PER28C(5)
2620 READ PER28C(6),PER28C(7)
2630 DATA 1,3,5,7,11,15,23
2640 READ P28W(1),P28W(2),P28W(3),P28W(4),P28W(5),P28W(6)
2650 READ P28W(7),P28W(8),P28W(9),P28W(10),P28W(11)
2660 DATA .059,.118,.059,.118,.059,.118,.059,.118,.059,.059,.176
2670 READ ER28W(1),PER28W(2),PER28W(3),PER28W(4),PER28W(5)
2680 READ PER28W(6),PER28W(7),PER28W(8),PER28W(9),PER28W(10)
2690 READ PER28W(11)
2700 DATA 1,7,9,11,13,15,19,21,25,29,35
2710 READ P28S(1),P28S(2),P28S(3),P28S(4),P28S(5)
2720 DATA .412,.353,.059,.059,.118
2730 READ PER28S(1),PER28S(2),PER28S(3),PER28S(4),PER28S(5)
2740 DATA 1,3,5,9,11
2750 READ P28WC(1),P28WC(2),P28WC(3),P28WC(4),P28WC(5)
2760 READ P28WC(6),P28WC(7)
2770 DATA .235,.294,.059,.059,.118,.176,.059
2780 READ PER28WC(1),PER28WC(2),PER28WC(3),PER28WC(4),PER28WC(5)
2790 READ PER28WC(6),PER28WC(7)
2800 DATA 1,3,5,9,11,13,19
2810 READ P211C(1),P211C(2),P211C(3),P211C(4),P211C(5)
2820 READ P211C(6),P211C(7)
2830 DATA .294,.235,.118,.059,.059,.118,.118
2840 READ PER211C(1),PER211C(2),PER211C(3),PER211C(4),PER211C(5),PER211C(6),PER211C(7)
2850 DATA 1,3,5,7,11,15,21
2860 READ P211W(1),P211W(2),P211W(3),P211W(4),P211W(5),P211W(6)
2865 READ P211W(7),P211W(8),P211W(9),P211W(10),P211W(11)
2870 DATA .059,.176,.059,.059,.118,.059,.059,.118,.059,.059,.176
2880 READ ER211W(1),PER211W(2),PER211W(3),PER211W(4),PER211W(5),PER211W(6)
2890 READ PER211W(7),PER211W(8),PER211W(9),PER211W(10),PER211W(11)
2900 DATA 1,7,9,11,13,15,19,21,25,31,35
2910 READ P211S(1),P211S(2),P211S(3),P211S(4),P211S(5)
2920 DATA .529,.235,.059,.118,.059
2930 READ PER211S(1),PER211S(2),PER211S(3),PER211S(4),PER211S(5)
2940 DATA 1,3,5,9,11
2950 READ P211WC(1),P211WC(2),P211WC(3),P211WC(4),P211WC(5),P211WC(6),P211WC(7)
2960 DATA .294,.235,.059,.118,.118,.118,.059
2970 READ PER211WC(1),PER211WC(2),PER211WC(3),PER211WC(4),PER211WC(5),PER211WC(6),PER211WC(7)
2980 DATA 1,3,5,9,11,13,17
2990 READ P15C(1),P15C(2),P15C(3),P15C(4),P15C(5),P15C(6),P15C(7)
3000 DATA .294,.235,.118,.059,.059,.118,.118
3010 READ PER15C(1),PER15C(2),PER15C(3),PER15C(4),PER15C(5),PER15C(6),PER15C(7)
3020 DATA 1,3,5,7,11,15,23
3030 READ P15W(1),P15W(2),P15W(3),P15W(4),P15W(5),P15W(6),P15W(7),P15W(8),P15W(9),P15W(10),P15W(11)
3040 DATA .059,.118,.118,.059,.059,.118,.059,.118,.059,.059,.176
3050 READ ER15W(1),PER15W(2),PER15W(3),PER15W(4),PER15W(5),PER15W(6)
3060 READ PER15W(7),PER15W(8),PER15W(9),PER15W(10),PER15W(11)
3070 DATA 1,7,9,11,13,15,19,21,25,29,35
3080 READ P15S(1),P15S(2),P15S(3),P15S(4),P15S(5)
3090 DATA .412,.353,.059,.059,.118
3100 READ PER15S(1),PER15S(2),PER15S(3),PER15S(4),PER15S(5)
3110 DATA 1,3,5,9,11
3120 READ P15WC(1),P15WC(2),P15WC(3),P15WC(4),P15WC(5),P15WC(6),P15WC(7)
3130 DATA .235,.294,.059,.059,.118,.176,.059
3140 READ PER15WC(1),PER15WC(2),PER15WC(3),PER15WC(4),PER15WC(5),PER15WC(6),PER15WC(7)
3150 DATA 1,3,5,9,11,13,19
3160 READ P215C(1),P215C(2),P215C(3),P215C(4),P215C(5),P215C(6),P215C(7)
3170 DATA .294,.235,.118,.059,.059,.118,.118
3180 READ PER215C(1),PER215C(2),PER215C(3),PER215C(4),PER215C(5),PER215C(6),PER215C(7)
3190 DATA 1,3,5,7,11,15,23
3200 READ P215W(1),P215W(2),P215W(3),P215W(4),P215W(5),P215W(6)
3205 READ P215W(7),P215W(8),P215W(9),P215W(10),P215W(11)
3210 DATA .059,.118,.118,.059,.059,.118,.059,.118,.059,.059,.176
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3220 READ ER215W(1),PER215W(2),PER215W(3),PER215W(4),PER215W(5),PER215W(6)
3230 READ PER215W(7),PER215W(8),PER215W(9),PER215W(10),PER215W(11)
3240 DATA 1,7,9,11,13,15,19,21,25,29,35
3250 READ P215S(1),P215S(2),P215S(3),P215S(4),P215S(5)
3260 DATA .412,.353,.059,.059,.118
3270 READ PER215S(1),PER215S(2),PER215S(3),PER215S(4),PER215S(5)
3280 DATA 1,3,5,9,11
3290 READ P215WC(1),P215WC(2),P215WC(3),P215WC(4),P215WC(5),P215WC(6),P215WC(7)
3300 DATA .235,.294,.059,.059,.118,.176,.059
3310 READ PER215WC(1),PER215WC(2),PER215WC(3),PER215WC(4),PER215WC(5),PER215WC(6),PER215WC(7)
3320 DATA 1,3,5,9,11,13,19
3330 READ P216C(1),P216C(2),P216C(3),P216C(4),P216C(5),P216C(6),P216C(7)
3340 DATA .294,.235,.118,.059,.059,.118,.118
3350 READ PER216C(1),PER216C(2),PER216C(3),PER216C(4),PER2156(5),PER216C(6),PER216C(7)
3360 DATA 1,3,5,7,11,15,23
3370 READ P216W(1),P216W(2),P216W(3),P216W(4),P216W(5),P216W(6)
3375 READ P216W(7),P216W(8),P216W(9),P216W(10),P216W(11)
3380 DATA .059,.176,.059,.059,.059,.118,.059,.118,.059,.059,.176
3390 READ ER216W(1),PER216W(2),PER216W(3),PER216W(4),PER216W(5),PER216W(6)
3400 READ PER216W(7),PER216W(8),PER216W(9),PER216W(10),PER216W(11)
3410 DATA 1,7,9,11,13,15,19,21,25,29,35
3420 READ P216S(1),P216S(2),P216S(3),P216S(4),P216S(5)
3430 DATA .529,.235,.059,.118,.059
3440 READ PER216S(1),PER216S(2),PER216S(3),PER216S(4),PER216S(5)
3450 DATA 1,3,5,9,11
3460 READ P216WC(1),P216WC(2),P216WC(3),P216WC(4),P216WC(5),P216WC(6),P216WC(7)
3470 DATA .294,.235,.059,.118,.118,.118,.059
3480 READ PER216WC(1),PER216WC(2),PER216WC(3),PER216WC(4),PER216WC(5),PER216WC(6),PER216WC(7)
3490 DATA 1,3,5,9,11,13,17
3500 FOR K=1 TO 23
3510 LET PM(K)=K*10
3520 NEXT K
3530 LET T=1
3540 FOR I=1 TO 23
3550 I1=I*10
3560 FOR D=1 TO 14
3570 PRINT I;C$;D
3580 LET R=0
3590 LET UT=0
3600 LET SL=0
3610 LET NL=0
3620 LET NLC=0
3630 LET NLW=0
3640 LET NLS=0
3650 LET NLWC=0
3660 LET SLC=0
3670 LET SLW=0
3680 LET SLS=0
3690 LET SLWC=0
3700 LET UTC=0
3710 LET UTW=0
3720 LET UTS=0
3730 LET UTWC=0
3740 IF D=1 GOTO 3880
3750 IF D=2 GOTO 3900
3760 IF D=3 GOTO 3920
3770 IF D=4 GOTO 3940
3780 IF D=5 GOTO 3960
3790 IF D=6 GOTO 3980
3800 IF D=7 GOTO 4000
3810 IF D=8 GOTO 4020
3820 IF D=9 GOTO 4040
3830 IF D=10 GOTO 4060
3840 IF D=11 GOTO 4080
3850 IF D=12 GOTO 4100
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3860 IF D=13 GOTO 4120
3870 IF D=14 GOTO 4140
3880 GOSUB 4240
3890 GOTO 4150
3900 GOSUB 4770
3910 GOTO 4150
3920 GOSUB 5300
3930 GOTO 4150
3940 GOSUB 5830
3950 GOTO 4150
3960 GOSUB 6360
3970 GOTO 4150
3980 GOSUB 6890
3990 GOTO 4150
4000 GOSUB 7420
4010 GOTO 4150
4020 GOSUB 7950
4030 GOTO 4150
4040 GOSUB 8480
4050 GOTO 4150
4060 GOSUB 9010
4070 GOTO 4150
4080 GOSUB 9540
4090 GOTO 4150
4100 GOSUB 10070
4110 GOTO 4150
4120 GOSUB 10600
4130 GOTO 4150
4140 GOSUB 11130
4150 FOR K=1 TO 23
4160 LET J(K)=0
4170 LET P(K)=0
4180 NEXT K
4190 NEXT D
4200 NEXT I
4210 PRINT #1, T, ",0,0,0,0,1"
4220 CLOSE #1
4230 END
4240 LET PCN=10
4250 LET PWN=11
4260 LET PSN=4
4270 LET PWCN=10
4280 LET SL=4.26
4290 FOR PC=1 TO PCN
4300 LET JC=19.19-9.399999E-02*PER1C(PC)+.463*I1
4310 FOR PW=1 TO PWN
4320 LET JW=19.19-9.399999E-02*PER1W(PW)+.463*JC-1.9
4330 FOR PS=1 TO PSN
4340 LET JS=19.19-9.399999E-02*PER1S(PS)+.463*JW+16.15
4350 FOR PWC=1 TO PWCN
4360 LET JWC=19.19-9.399999E-02*PER1WC(PWC)+.464*JS+4.47
4370 LET JWCR=JWC/10
4380 LET JJ=10*CINT(JWCR)
4390 GOSUB 11660
4400 LET CNLWC=(-31.147+.751*PER1WC(PWC)+.9*JS-19.866)*P1WC(PWC)*P1S(PS)*P1W(PW)*P1C(PC)
4410 IF CNLWC<0 THEN CNLWC=0
4420 LET NLWC=NLWC+CNLWC
4430 LET CUTWC=(-35.715-.817*PER1WC(PWC)+3.74*JS-145.6)*P1WC(PWC)*P1S(PS)*P1W(PW)*P1C(PC)
4440 IF CUTWC<0 THEN CUTWC=0
4450 LET UTWC=UTWC+CUTWC
4460 NEXT PWC
4470 LET CNLS=(-31.147+.751*PER1S(PS)+.9*JW)*P1S(PS)*P1W(PW)*P1C(PC)
4480 IF CNLS<0 THEN CNLS=0
4490 LET NLS=NLS+CNLS
4500 LET CUTS=(-35.715-.817*PER1S(PS)+3.74*JW-76.8)*P1S(PS)*P1W(PW)*P1C(PC)
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```
4510 IF CUTS<0 THEN CUTS=0
4520 LET UTS=UTS+CUTS
4530 NEXT PS
4540 LET CNLW=(-31.147+.751*PER1W(PW)+.9*JC)*P1W(PW)*P1C(PC)
4550 IF CNLW<0 THEN CNLW=0
4560 LET NLW=NLW+CNLW
4570 LET CUTW=(-35.715-.817*PER1W(PWC)+3.74*JC)*P1W(PW)*P1C(PC)
4580 IF CUTW<0 THEN CUTW=0
4590 LET UTW=UTW+CUTW
4600 NEXT PW
4610 LET CNLC=(-31.147+.751*PER1C(PC)+.9*I1)*P1C(PC)
4620 IF CNLC<0 THEN CNLC=0
4630 LET NLC=NLC+CNLC
4640 LET CUTC=(-35.715-.817*PER1C(PC)+3.74*I1)*P1C(PC)
4650 IF CUTC<0 THEN CUTC=0
4660 LET UTC=UTC+CUTC
4670 NEXT PC
4680 LET NL=NLC+NLW+NLS+NLWC
4690 FOR K=1 TO 23
4700 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
4710 NEXT K
4720 FOR P9=1 TO 23
4730 IF P(P9)=0 GOTO 4750
4740 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
4750 NEXT P9
4760 RETURN
4770 LET PCN=10
4780 LET PWN=11
4790 LET PSN=5
4800 LET PWCN=10
4810 LET SL=3.24
4820 FOR PC=1 TO PCN
4830 LET JC=18.96-.092*PER2C(PC)+.467*I1
4840 FOR PW=1 TO PWN
4850 LET JW=18.96-.092*PER2W(PW)+.467*JC-1.88
4860 FOR PS=1 TO PSN
4870 LET JS=18.96-.092*PER2S(PS)+.467*JW+16.2
4880 FOR PWC=1 TO PWCN
4890 LET JWC=18.96-.092*PER2WC(PWC)+.467*JS+4.45
4900 LET JWCR=JWC/10
4910 LET JJ=10*CINT(JWCR)
4920 GOSUB 11660
4930 LET CNLWC=(-25.474+1.346*PER2WC(PWC)+.709*JS-22.98)*P2WC(PWC)*P2S(PS)*P2W(PW)*P2C(PC)
4940 IF CNLWC<0 THEN CNLWC=0
4950 LET NLWC=NLWC+CNLWC
4960 LET CUTWC=(-32.222-1.161*PER2WC(PWC)+4.16*JS-166.37)*P2WC(PWC)*P2S(PS)*P2W(PW)*P2C(PC)
4970 IF CUTWC<0 THEN CUTWC=0
4980 LET UTWC=UTWC+CUTWC
4990 NEXT PWC
5000 LET CNLS=(-25.474+1.346*PER2S(PS)+.709*JW)*P2S(PS)*P2W(PW)*P2C(PC)
5010 IF CNLS<0 THEN CNLS=0
5020 LET NLS=NLS+CNLS
5030 LET CUTS=(-32.222-1.161*PER2S(PS)+4.16*JW-91.51)*P2S(PS)*P2W(PW)*P2C(PC)
5040 IF CUTS<0 THEN CUTS=0
5050 LET UTS=UTS+CUTS
5060 NEXT PS
5070 LET CNLW=(-25.474+1.346*PER2W(PW)+.709*JC+13.578)*P2W(PW)*P2C(PC)
5080 IF CNLW<0 THEN CNLW=0
5090 LET NLW=NLW+CNLW
5100 LET CUTW=(-32.222-1.161*PER2W(PWC)+4.16*JC)*P2W(PW)*P2C(PC)
5110 IF CUTW<0 THEN CUTW=0
5120 LET UTW=UTW+CUTW
5130 NEXT PW
5140 LET CNLC=(-25.474+1.346*PER2C(PC)+.709*I1)*P2C(PC)
5150 IF CNLC<0 THEN CNLC=0
```

```
5160 LET NLC=NLC+CNLC
5170 LET CUTC=(-32.222-1.161*PER2C(PC)+4.16*I1)*P2C(PC)
5180 IF CUTC<0 THEN CUTC=0
5190 LET UTC=UTC+CUTC
5200 NEXT PC
5210 LET NL=NLC+NLW+NLS+NLWC
5220 FOR K=1 TO 23
5230 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
5240 NEXT K
5250 FOR P9=1 TO 23
5260 IF P(P9)=0 GOTO 5280
5270 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
5280 NEXT P9
5290 RETURN
5300 LET PCN=10
5310 LET PWN=11
5320 LET PSN=5
5330 LET PWCN=10
5340 LET SL=3.7
5350 FOR PC=1 TO PCN
5360 LET JC=18.96-.092*PER3C(PC)+.467*I1
5370 FOR PW=1 TO PWN
5380 LET JW=18.96-.092*PER3W(PW)+.467*JC-1.876
5390 FOR PS=1 TO PSN
5400 LET JS=18.96-.092*PER3S(PS)+.467*JW+16.204
5410 FOR PWC=1 TO PWCN
5420 LET JWC=18.96-.092*PER3WC(PWC)+.467*JS+4.453
5430 LET JWCR=JWC/10
5440 LET JJ=10*CINT(JWCR)
5450 GOSUB 11660
5460 LET CNLWC=(-27.09+.643*PER3WC(PWC)+.802*JS-17.726)*P3WC(PWC)*P3S(PS)*P3W(PW)*P3C(PC)
5470 IF CNLWC<0 THEN CNLWC=0
5480 LET NLWC=NLWC+CNLWC
5490 LET CUTWC=(19.969-.619*PER3WC(PWC)+2.01*JS-115.3)*P3WC(PWC)*P3S(PS)*P3W(PW)*P3C(PC)
5500 IF CUTWC<0 THEN CUTWC=0
5510 LET UTWC=UTWC+CUTWC
5520 NEXT PWC
5530 LET CNLS=(-27.09+.643*PER3S(PS)+.802*JW)*P3S(PS)*P3W(PW)*P3C(PC)
5540 IF CNLS<0 THEN CNLS=0
5550 LET NLS=NLS+CNLS
5560 LET CUTS=(19.969-.619*PER3S(PS)+2.01*JW-73.847)*P3S(PS)*P3W(PW)*P3C(PC)
5570 IF CUTS<0 THEN CUTS=0
5580 LET UTS=UTS+CUTS
5590 NEXT PS
5600 LET CNLW=(-27.09+.643*PER3W(PW)+.802*JC)*P3W(PW)*P3C(PC)
5610 IF CNLW<0 THEN CNLW=0
5620 LET NLW=NLW+CNLW
5630 LET CUTW=(19.969-.619*PER3W(PWC)+2.01*JC)*P3W(PW)*P3C(PC)
5640 IF CUTW<0 THEN CUTW=0
5650 LET UTW=UTW+CUTW
5660 NEXT PW
5670 LET CNLC=(-27.09+.643*PER3C(PC)+.802*I1)*P3C(PC)
5680 IF CNLC<0 THEN CNLC=0
5690 LET NLC=NLC+CNLC
5700 LET CUTC=(19.969-.619*PER3C(PC)+2.01*I1)*P3C(PC)
5710 IF CUTC<0 THEN CUTC=0
5720 LET UTC=UTC+CUTC
5730 NEXT PC
5740 LET NL=NLC+NLW+NLS+NLWC
5750 FOR K=1 TO 23
5760 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
5770 NEXT K
5780 FOR P9=1 TO 23
5790 IF P(P9)=0 GOTO 5810
5800 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
```

```
5810 NEXT P9
5820 RETURN
5830 LET PCN=10
5840 LET PWN=11
5850 LET PSN=4
5860 LET PWCN=10
5870 LET SL=4.26
5880 FOR PC=1 TO PCN
5890 LET JC=19.13-.093*PER4C(PC)+.464*I1
5900 FOR PW=1 TO PWN
5910 LET JW=19.13-.093*PER4W(PW)+.464*JC-1.876
5920 FOR PS=1 TO PSN
5930 LET JS=19.13-.093*PER4S(PS)+.464*JW+16.17
5940 FOR PWC=1 TO PWCN
5950 LET JWC=19.13-.093*PER4WC(PWC)+.464*JS+4.48
5960 LET JWCR=JWC/10
5970 LET JJ=10*CINT(JWCR)
5980 GOSUB 11660
5990 LET CNLWC=(-33.582+.664*PER4WC(PWC)+.966*JS-19.829)*P4WC(PWC)*P4S(PS)*P4W(PW)*P4C(PC)
6000 IF CNLWC<0 THEN CNLWC=0
6010 LET NLWC=NLWC+CNLWC
6020 LET CUTWC=(-49.308-.596*PER4WC(PWC)+3.968*JS-145.947)*P4WC(PWC)*P4S(PS)*P4W(PW)*P4C(PC)
6030 IF CUTWC<0 THEN CUTWC=0
6040 LET UTWC=UTWC+CUTWC
6050 NEXT PWC
6060 LET CNLS=(-33.582+.664*PER4S(PS)+.966*JW)*P4S(PS)*P4W(PW)*P4C(PC)
6070 IF CNLS<0 THEN CNLS=0
6080 LET NLS=NLS+CNLS
6090 LET CUTS=(-49.308-.596*PER4S(PS)+3.968*JW-67.289)*P4S(PS)*P4W(PW)*P4C(PC)
6100 IF CUTS<0 THEN CUTS=0
6110 LET UTS=UTS+CUTS
6120 NEXT PS
6130 LET CNLW=(-33.582+.664*PER4W(PW)+.966*JC)*P4W(PW)*P4C(PC)
6140 IF CNLW<0 THEN CNLW=0
6150 LET NLW=NLW+CNLW
6160 LET CUTW=(-49.308-.596*PER4W(PWC)+3.968*JC)*P4W(PW)*P4C(PC)
6170 IF CUTW<0 THEN CUTW=0
6180 LET UTW=UTW+CUTW
6190 NEXT PW
6200 LET CNLC=(-33.582+.664*PER4C(PC)+.966*I1)*P4C(PC)
6210 IF CNLC<0 THEN CNLC=0
6220 LET NLC=NLC+CNLC
6230 LET CUTC=(-49.308-.596*PER4C(PC)+3.968*I1)*P4C(PC)
6240 IF CUTC<0 THEN CUTC=0
6250 LET UTC=UTC+CUTC
6260 NEXT PC
6270 LET NL=NLC+NLW+NLS+NLWC
6280 FOR K=1 TO 23
6290 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
6300 NEXT K
6310 FOR P9=1 TO 23
6320 IF P(P9)=0 GOTO 6340
6330 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
6340 NEXT P9
6350 RETURN
6360 LET PCN=7
6370 LET PWN=11
6380 LET PSN=5
6390 LET PWCN=7
6400 LET SL=2.18
6410 FOR PC=1 TO PCN
6420 LET JC=14.335-.141*PER8C(PC)+.648*I1-6.468
6430 FOR PW=1 TO PWN
6440 LET JW=14.335-.141*PER8W(PW)+.648*JC
6450 FOR PS=1 TO PSN
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6460 LET JS=14.335-.141*PER8S(PS)+.648*JW+15.134
6470 FOR PWC=1 TO PWCN
6480 LET JWC=14.335-.141*PER8WC(PWC)+.648*JS
6490 LET JWCR=JWC/10
6500 LET JJ=10*CINT(JWCR)
6510 GOSUB 11660
6520 LET CNLWC=(21.191+.953*PER8WC(PWC)-.45*JS)*P8WC(PWC)*P8S(PS)*P8W(PW)*P8C(PC)
6530 IF CNLWC<0 THEN CNLWC=0
6540 LET NLWC=NLWC+CNLWC
6550 LET CUTWC=(35.096-.81*PER8WC(PWC)+2.119*JS-134.638)*P8WC(PWC)*P8S(PS)*P8W(PW)*P8C(PC)
6560 IF CUTWC<0 THEN CUTWC=0
6570 LET UTWC=UTWC+CUTWC
6580 NEXT PWC
6590 LET CNLS=(21.191+.953*PER8S(PS)-.45*JW-7.065)*P8S(PS)*P8W(PW)*P8C(PC)
6600 IF CNLS<0 THEN CNLS=0
6610 LET NLS=NLS+CNLS
6620 LET CUTS=(35.096-.81*PER8S(PS)+2.119*JW-96.332)*P8S(PS)*P8W(PW)*P8C(PC)
6630 IF CUTS<0 THEN CUTS=0
6640 LET UTS=UTS+CUTS
6650 NEXT PS
6660 LET CNLW=(21.191+.953*PER8W(PW)-.45*JC)*P8W(PW)*P8C(PC)
6670 IF CNLW<0 THEN CNLW=0
6680 LET NLW=NLW+CNLW
6690 LET CUTW=(35.096-.81*PER8W(PWC)+2.119*JC)*P8W(PW)*P8C(PC)
6700 IF CUTW<0 THEN CUTW=0
6710 LET UTW=UTW+CUTW
6720 NEXT PW
6730 LET CNLC=(21.191+.953*PER8C(PC)-.45*I1)*P8C(PC)
6740 IF CNLC<0 THEN CNLC=0
6750 LET NLC=NLC+CNLC
6760 LET CUTC=(35.096-.81*PER8C(PC)+2.119*I1)*P8C(PC)
6770 IF CUTC<0 THEN CUTC=0
6780 LET UTC=UTC+CUTC
6790 NEXT PC
6800 LET NL=NLC+NLW+NLS+NLWC
6810 FOR K=1 TO 23
6820 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
6830 NEXT K
6840 FOR P9=1 TO 23
6850 IF P(P9)=0 GOTO 6870
6860 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
6870 NEXT P9
6880 RETURN
6890 LET PCN=7
6900 LET PWN=11
6910 LET PSN=5
6920 LET PWCN=7
6930 LET SL=2.17
6940 FOR PC=1 TO PCN
6950 LET JC=59.65-.307*PER15C(PC)+.618*I1
6960 FOR PW=1 TO PWN
6970 LET JW=59.65-.307*PER15W(PW)+.618*JC-34
6980 FOR PS=1 TO PSN
6990 LET JS=59.65-.307*PER15S(PS)+.618*JW-21.218
7000 FOR PWC=1 TO PWCN
7010 LET JWC=59.65-.307*PER15WC(PWC)+.618*JS-30.883
7020 LET JWCR=JWC/10
7030 LET JJ=10*CINT(JWCR)
7040 GOSUB 11660
7050 LET CNLWC=(-28.476+1.478*PER15WC(PWC)+.284*JS)*P15WC(PWC)*P15S(PS)*P15W(PW)*P15C(PC)
7060 IF CNLWC<0 THEN CNLWC=0
7070 LET NLWC=NLWC+CNLWC
7080 LET CUTWC=(122.369-.277*PER15WC(PWC)+.474*JS-151.837)*P15WC(PWC)*P15S(PS)*P15W(PW)*P15C(PC)
7090 IF CUTWC<0 THEN CUTWC=0
7100 LET UTWC=UTWC+CUTWC
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7110 NEXT PWC
7120 LET CNLS=(-28.476+1.478*PER15S(PS)+.284*JW)*P15S(PS)*P15W(PW)*P15C(PC)
7130 IF CNLS<0 THEN CNLS=0
7140 LET NLS=NLS+CNLS
7150 LET CUTS=(122.369-.277*PER15S(PS)+.474*JW-133.984)*P15S(PS)*P15W(PW)*P15C(PC)
7160 IF CUTS<0 THEN CUTS=0
7170 LET UTS=UTS+CUTS
7180 NEXT PS
7190 LET CNLW=(-28.476+1.478*PER15W(PW)+.284*JC)*P15W(PW)*P15C(PC)
7200 IF CNLW<0 THEN CNLW=0
7210 LET NLW=NLW+CNLW
7220 LET CUTW=(122.369-.277*PER15W(PWC)+.474*JC-64.555)*P15W(PW)*P15C(PC)
7230 IF CUTW<0 THEN CUTW=0
7240 LET UTW=UTW+CUTW
7250 NEXT PW
7260 LET CNLC=(-28.476+1.478*PER15C(PC)+.284*I1+5.815)*P15C(PC)
7270 IF CNLC<0 THEN CNLC=0
7280 LET NLC=NLC+CNLC
7290 LET CUTC=(122.369-.277*PER15C(PC)+.474*I1)*P15C(PC)
7300 IF CUTC<0 THEN CUTC=0
7310 LET UTC=UTC+CUTC
7320 NEXT PC
7330 LET NL=NLC+NLW+NLS+NLWC
7340 FOR K=1 TO 23
7350 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
7360 NEXT K
7370 FOR P9=1 TO 23
7380 IF P(P9)=0 GOTO 7400
7390 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
7400 NEXT P9
7410 RETURN
7420 LET PCN=10
7430 LET PWN=11
7440 LET PSN=4
7450 LET PWCN=10
7460 LET SL=4.26
7470 FOR PC=1 TO PCN
7480 LET JC=100.05-.262*PER21C(PC)+.227*I1+35.137
7490 FOR PW=1 TO PWN
7500 LET JW=100.05-.262*PER21W(PW)+.227*JC
7510 FOR PS=1 TO PSN
7520 LET JS=100.05-.262*PER21S(PS)+.227*JW
7530 FOR PWC=1 TO PWCN
7540 LET JWC=100.05-.262*PER21WC(PWC)+.227*JS+59.114
7550 LET JWCR=JWC/10
7560 LET JJ=10*CINT(JWCR)
7570 GOSUB 11660
7580 LET CNLWC=(-18.529+1.366*PER21WC(PWC)+.15*JS-9.196)*P21WC(PWC)*P21S(PS)*P21W(PW)*P21C(PC)
7590 IF CNLWC<0 THEN CNLWC=0
7600 LET NLWC=NLWC+CNLWC
7610 LET CUTWC=(91.86901-.747*PER21WC(PWC)+.155*JS-103.606)*P21WC(PWC)*P21S(PS)*P21W(PW)*P21C(PC)
7620 IF CUTWC<0 THEN CUTWC=0
7630 LET UTWC=UTWC+CUTWC
7640 NEXT PWC
7650 LET CNLS=(-18.529+1.366*PER21S(PS)+.15*JW)*P21S(PS)*P21W(PW)*P21C(PC)
7660 IF CNLS<0 THEN CNLS=0
7670 LET NLS=NLS+CNLS
7680 LET CUTS=(91.86901-.747*PER21S(PS)+.155*JW-69.851)*P21S(PS)*P21W(PW)*P21C(PC)
7690 IF CUTS<0 THEN CUTS=0
7700 LET UTS=UTS+CUTS
7710 NEXT PS
7720 LET CNLW=(-18.529+1.366*PER21W(PW)+.15*JC)*P21W(PW)*P21C(PC)
7730 IF CNLW<0 THEN CNLW=0
7740 LET NLW=NLW+CNLW
7750 LET CUTW=(91.86901-.747*PER21W(PWC)+.155*JC-50.158)*P21W(PW)*P21C(PC)
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7760 IF CUTW<0 THEN CUTW=0
7770 LET UTW=UTW+CUTW
7780 NEXT PW
7790 LET CNLC=(-18.529+1.366*PER21C(PC)+.15*I1)*P21C(PC)
7800 IF CNLC<0 THEN CNLC=0
7810 LET NLC=NLC+CNLC
7820 LET CUTC=(91.86901-.747*PER21C(PC)+.155*I1)*P21C(PC)
7830 IF CUTC<0 THEN CUTC=0
7840 LET UTC=UTC+CUTC
7850 NEXT PC
7860 LET NL=NLC+NLW+NLS+NLWC
7870 FOR K=1 TO 23
7880 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
7890 NEXT K
7900 FOR P9=1 TO 23
7910 IF P(P9)=0 GOTO 7930
7920 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
7930 NEXT P9
7940 RETURN
7950 LET PCN=10
7960 LET PWN=11
7970 LET PSN=5
7980 LET PWCN=10
7990 LET SL=3.24
8000 FOR PC=1 TO PCN
8010 LET JC=112.18-.239*PER22C(PC)+.265*I1+47.457
8020 FOR PW=1 TO PWN
8030 LET JW=112.18-.239*PER22W(PW)+.265*JC
8040 FOR PS=1 TO PSN
8050 LET JS=112.18-.239*PER22S(PS)+.265*JW
8060 FOR PWC=1 TO PWCN
8070 LET JWC=112.18-.239*PER22WC(PWC)+.265*JS+68.041
8080 LET JWCR=JWC/10
8090 LET JJ=10*CINT(JWCR)
8100 GOSUB 11660
8110 LET CNLWC=(-23.631+1.843*PER22WC(PWC)+.154*JS-13.63)*P22WC(PWC)*P22S(PS)*P22W(PW)*P22C(PC)
8120 IF CNLWC<0 THEN CNLWC=0
8130 LET NLWC=NLWC+CNLWC
8140 LET CUTWC=(111.401-1.034*PER22WC(PWC)+.143*JS-121.731)*P22WC(PWC)*P22S(PS)*P22W(PW)*P22C(PC)
8150 IF CUTWC<0 THEN CUTWC=0
8160 LET UTWC=UTWC+CUTWC
8170 NEXT PWC
8180 LET CNLS=(-23.631+1.843*PER22S(PS)+.154*JW)*P22S(PS)*P22W(PW)*P22C(PC)
8190 IF CNLS<0 THEN CNLS=0
8200 LET NLS=NLS+CNLS
8210 LET CUTS=(111.401-1.034*PER22S(PS)+.143*JW-82.637)*P22S(PS)*P22W(PW)*P22C(PC)
8220 IF CUTS<0 THEN CUTS=0
8230 LET UTS=UTS+CUTS
8240 NEXT PS
8250 LET CNLW=(-23.631+1.843*PER22W(PW)+.154*JC)*P22W(PW)*P22C(PC)
8260 IF CNLW<0 THEN CNLW=0
8270 LET NLW=NLW+CNLW
8280 LET CUTW=(111.401-1.034*PER22W(PWC)+.143*JC-52.396)*P22W(PW)*P22C(PC)
8290 IF CUTW<0 THEN CUTW=0
8300 LET UTW=UTW+CUTW
8310 NEXT PW
8320 LET CNLC=(-23.631+1.843*PER22C(PC)+.154*I1)*P22C(PC)
8330 IF CNLC<0 THEN CNLC=0
8340 LET NLC=NLC+CNLC
8350 LET CUTC=(111.401-1.034*PER22C(PC)+.143*I1)*P22C(PC)
8360 IF CUTC<0 THEN CUTC=0
8370 LET UTC=UTC+CUTC
8380 NEXT PC
8390 LET NL=NLC+NLW+NLS+NLWC
8400 FOR K=1 TO 23
```

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8410 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
8420 NEXT K
8430 FOR P9=1 TO 23
8440 IF P(P9)=0 GOTO 8460
8450 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
8460 NEXT P9
8470 RETURN
8480 LET PCN=10
8490 LET PWN=11
8500 LET PSN=5
8510 LET PWCN=10
8520 LET SL=3.7
8530 FOR PC=1 TO PCN
8540 LET JC=93.99299-.277*PER23C(PC)+.209*I1+30.634
8550 FOR PW=1 TO PWN
8560 LET JW=99.99299-.277*PER23W(PW)+.209*JC
8570 FOR PS=1 TO PSN
8580 LET JS=99.99299-.277*PER23S(PS)+.209*JW
8590 FOR PWC=1 TO PWCN
8600 LET JWC=99.99299-.277*PER23WC(PWC)+.209*JS+44.662
8610 LET JWCR=JWC/10
8620 LET JJ=10*CINT(JWCR)
8630 GOSUB 11660
8640 LET CNLWC=(-14.145+1.259*PER23WC(PWC)+.127*JS-8.913999)*P23WC(PWC)*P23S(PS)*P23W(PW)*P23C(PC)
8650 IF CNLWC<0 THEN CNLWC=0
8660 LET NLWC=NLWC+CNLWC
8670 LET CUTWC=(76.589-.647*PER23WC(PWC)+.162*JS-88.525)*P23WC(PWC)*P23S(PS)*P23W(PW)*P23C(PC)
8680 IF CUTWC<0 THEN CUTWC=0
8690 LET UTWC=UTWC+CUTWC
8700 NEXT PWC
8710 LET CNLS=(-14.145+1.259*PER23S(PS)+.127*JW)*P23S(PS)*P23W(PW)*P23C(PC)
8720 IF CNLS<0 THEN CNLS=0
8730 LET NLS=NLS+CNLS
8740 LET CUTS=(76.589-.647*PER23S(PS)+.162*JW-57.269)*P23S(PS)*P23W(PW)*P23C(PC)
8750 IF CUTS<0 THEN CUTS=0
8760 LET UTS=UTS+CUTS
8770 NEXT PS
8780 LET CNLW=(-14.145+1.259*PER23W(PW)+.127*JC)*P23W(PW)*P23C(PC)
8790 IF CNLW<0 THEN CNLW=0
8800 LET NLW=NLW+CNLW
8810 LET CUTW=(76.589-.647*PER23W(PWC)+.162*JC-38.922)*P23W(PW)*P23C(PC)
8820 IF CUTW<0 THEN CUTW=0
8830 LET UTW=UTW+CUTW
8840 NEXT PW
8850 LET CNLC=(-14.145+1.259*PER23C(PC)+.127*I1)*P23C(PC)
8860 IF CNLC<0 THEN CNLC=0
8870 LET NLC=NLC+CNLC
8880 LET CUTC=(76.589-.647*PER23C(PC)+.162*I1)*P23C(PC)
8890 IF CUTC<0 THEN CUTC=0
8900 LET UTC=UTC+CUTC
8910 NEXT PC
8920 LET NL=NLC+NLW+NLS+NLWC
8930 FOR K=1 TO 23
8940 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
8950 NEXT K
8960 FOR P9=1 TO 23
8970 IF P(P9)=0 GOTO 8990
8980 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
8990 NEXT P9
9000 RETURN
9010 LET PCN=10
9020 LET PWN=12
9030 LET PSN=4
9040 LET PWCN=10
9050 LET SL=3.37
```

```
9060 FOR PC=1 TO PCN
9070 LET JC=20.683-.783*PER25C(PC)+.753*I1+19.041
9080 FOR PW=1 TO PWN
9090 LET JW=20.683-.783*PER25W(PW)+.753*JC
9100 FOR PS=1 TO PSN
9110 LET JS=20.683-.783*PER25S(PS)+.753*JW
9120 FOR PWC=1 TO PWCN
9130 LET JWC=20.683-.783*PER25WC(PWC)+.753*JS+69.326
9140 LET JWCR=JWC/10
9150 LET JJ=10*CINT(JWCR)
9160 GOSUB 11660
9170 LET CNLWC=(-8.016+1.345*PER25WC(PWC)+.088*JS-10.336)*P25WC(PWC)*P25S(PS)*P25W(PW)*P25C(PC)
9180 IF CNLWC<0 THEN CNLWC=0
9190 LET NLWC=NLWC+CNLWC
9200 LET CUTWC=(83.97-.747*PER25WC(PWC)+.191*JS-98.014)*P25WC(PWC)*P25S(PS)*P25W(PW)*P25C(PC)
9210 IF CUTWC<0 THEN CUTWC=0
9220 LET UTWC=UTWC+CUTWC
9230 NEXT PWC
9240 LET CNLS=(-8.016+1.345*PER25S(PS)+.088*JW)*P25S(PS)*P25W(PW)*P25C(PC)
9250 IF CNLS<0 THEN CNLS=0
9260 LET NLS=NLS+CNLS
9270 LET CUTS=(83.97-.747*PER25S(PS)+.191*JW-67.965)*P25S(PS)*P25W(PW)*P25C(PC)
9280 IF CUTS<0 THEN CUTS=0
9290 LET UTS=UTS+CUTS
9300 NEXT PS
9310 LET CNLW=(-8.016+1.345*PER25W(PW)+.088*JC)*P25W(PW)*P25C(PC)
9320 IF CNLW<0 THEN CNLW=0
9330 LET NLW=NLW+CNLW
9340 LET CUTW=(83.97-.747*PER25W(PWC)+.191*JC-48.419)*P25W(PW)*P25C(PC)
9350 IF CUTW<0 THEN CUTW=0
9360 LET UTW=UTW+CUTW
9370 NEXT PW
9380 LET CNLC=(-8.016+1.345*PER25C(PC)+.088*I1)*P25C(PC)
9390 IF CNLC<0 THEN CNLC=0
9400 LET NLC=NLC+CNLC
9410 LET CUTC=(83.97-.747*PER25C(PC)+.191*I1)*P25C(PC)
9420 IF CUTC<0 THEN CUTC=0
9430 LET UTC=UTC+CUTC
9440 NEXT PC
9450 LET NL=NLC+NLW+NLS+NLWC
9460 FOR K=1 TO 23
9470 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
9480 NEXT K
9490 FOR P9=1 TO 23
9500 IF P(P9)=0 GOTO 9520
9510 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
9520 NEXT P9
9530 RETURN
9540 LET PCN=7
9550 LET PWN=11
9560 LET PSN=5
9570 LET PWCN=7
9580 LET SL=2.18
9590 FOR PC=1 TO PCN
9600 LET JC=145.912-.662*PER28C(PC)+.108*I1
9610 FOR PW=1 TO PWN
9620 LET JW=145.912-.662*PER28W(PW)+.108*JC
9630 FOR PS=1 TO PSN
9640 LET JS=145.912-.662*PER28S(PS)+.108*JW-24.462
9650 FOR PWC=1 TO PWCN
9660 LET JWC=145.912-.662*PER28WC(PWC)+.108*JS-32.784
9670 LET JWCR=JWC/10
9680 LET JJ=10*CINT(JWCR)
9690 GOSUB 11660
9700 LET CNLWC=(-14.676+1.363*PER28WC(PWC)+.119*JS)*P28WC(PWC)*P28S(PS)*P28W(PW)*P28C(PC)
```

```
9710 IF CNLWC<0 THEN CNLWC=0
9720 LET NLWC=NLWC+CNLWC
9730 LET CUTWC=(100.104-.857*PER28WC(PWC)+.151*JS-99.221)*P28WC(PWC)*P28S(PS)*P28W(PW)*P28C(PC)
9740 IF CUTWC<0 THEN CUTWC=0
9750 LET UTWC=UTWC+CUTWC
9760 NEXT PWC
9770 LET CNLS=(-14.676+1.363*PER28S(PS)+.119*JW-5.679)*P28S(PS)*P28W(PW)*P28C(PC)
9780 IF CNLS<0 THEN CNLS=0
9790 LET NLS=NLS+CNLS
9800 LET CUTS=(101.104-.857*PER28S(PS)+.151*JW-75.52201)*P28S(PS)*P28W(PW)*P28C(PC)
9810 IF CUTS<0 THEN CUTS=0
9820 LET UTS=UTS+CUTS
9830 NEXT PS
9840 LET CNLW=(-14.676+1.363*PER28W(PW)+.119*JC)*P28W(PW)*P28C(PC)
9850 IF CNLW<0 THEN CNLW=0
9860 LET NLW=NLW+CNLW
9870 LET CUTW=(101.104-.857*PER28W(PWC)+.151*JC-53.053)*P28W(PW)*P28C(PC)
9880 IF CUTW<0 THEN CUTW=0
9890 LET UTW=UTW+CUTW
9900 NEXT PW
9910 LET CNLC=(-14.676+1.363*PER28C(PC)+.119*I1)*P28C(PC)
9920 IF CNLC<0 THEN CNLC=0
9930 LET NLC=NLC+CNLC
9940 LET CUTC=(101.104-.857*PER28C(PC)+.151*I1)*P28C(PC)
9950 IF CUTC<0 THEN CUTC=0
9960 LET UTC=UTC+CUTC
9970 NEXT PC
9980 LET NL=NLC+NLW+NLS+NLWC
9990 FOR K=1 TO 23
10000 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
10010 NEXT K
10020 FOR P9=1 TO 23
10030 IF P(P9)=0 GOTO 10050
10040 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
10050 NEXT P9
10060 RETURN
10070 LET PCN=7
10080 LET PWN=11
10090 LET PSN=5
10100 LET PWCN=7
10110 LET SL=2.38
10120 FOR PC=1 TO PCN
10130 LET JC=87.45-.128*PER211C(PC)+.326*I1+36.444
10140 FOR PW=1 TO PWN
10150 LET JW=87.45-.128*PER211W(PW)+.326*JC
10160 FOR PS=1 TO PSN
10170 LET JS=87.45-.128*PER211S(PS)+.326*JW
10180 FOR PWC=1 TO PWCN
10190 LET JWC=87.45-.128*PER211WC(PWC)+.326*JS
10200 LET JWCR=JWC/10
10210 LET JJ=10*CINT(JWCR)
10220 GOSUB 11660
10230 LET CNLWC=(-18.719+1.489*PER211WC(PWC)+.126*JS)*P211WC(PWC)*P211S(PS)*P211W(PW)*P211C(PC)
10240 IF CNLWC<0 THEN CNLWC=0
10250 LET NLWC=NLWC+CNLWC
10260LETCUTWC=(110.906-.807*PER211WC(PWC)+9.399999E-02*JS)*P211WC(PWC)*P211S(PS)*P211W(PW)*P211C(PC)
10270 IF CUTWC<0 THEN CUTWC=0
10280 LET UTWC=UTWC+CUTWC
10290 NEXT PWC
10300 LET CNLS=(-18.719+1.489*PER211S(PS)+.126*JW)*P211S(PS)*P211W(PW)*P211C(PC)
10310 IF CNLS<0 THEN CNLS=0
10320 LET NLS=NLS+CNLS
10330 LET CUTS=(110.906-.807*PER211S(PS)+9.399999E-02*JW-102.014)*P211S(PS)*P211W(PW)*P211C(PC)
10340 IF CUTS<0 THEN CUTS=0
10350 LET UTS=UTS+CUTS
```

```
10360 NEXT PS
10370 LET CNLW=(-18.719+1.489*PER211W(PW)+.126*JC)*P211W(PW)*P211C(PC)
10380 IF CNLW<0 THEN CNLW=0
10390 LET NLW=NLW+CNLW
10400 LET CUTW=(110.906-.807*PER211W(PWC)+9.399999E-02*JC-78.747)*P211W(PW)*P211C(PC)
10410 IF CUTW<0 THEN CUTW=0
10420 LET UTW=UTW+CUTW
10430 NEXT PW
10440 LET CNLC=(-18.719+1.489*PER211C(PC)+.124*I1+4.669)*P211C(PC)
10450 IF CNLC<0 THEN CNLC=0
10460 LET NLC=NLC+CNLC
10470 LET CUTC=(110.906-.807*PER211C(PC)+9.399999E-02*I1-56.318)*P211C(PC)
10480 IF CUTC<0 THEN CUTC=0
10490 LET UTC=UTC+CUTC
10500 NEXT PC
10510 LET NL=NLC+NLW+NLS+NLWC
10520 FOR K=1 TO 23
10530 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
10540 NEXT K
10550 FOR P9=1 TO 23
10560 IF P(P9)=0 GOTO 10580
10570 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
10580 NEXT P9
10590 RETURN
10600 LET PCN=7
10610 LET PWN=11
10620 LET PSN=5
10630 LET PWCN=7
10640 LET SL=21.7
10650 FOR PC=1 TO PCN
10660 LET JC=182.39-.608*PER215C(PC)+.349*I1
10670 FOR PW=1 TO PWN
10680 LET JW=182.39-.608*PER215W(PW)+.349*JC-58.526
10690 FOR PS=1 TO PSN
10700 LET JS=182.39-.608*PER215S(PS)+.349*JW-75.205
10710 FOR PWC=1 TO PWCN
10720 LET JWC=182.39-.608*PER215WC(PWC)+.349*JS-81.037
10730 LET JWCR=JWC/10
10740 LET JJ=10*CINT(JWCR)
10750 GOSUB 11660
10760 LET CNLWC=(-30.062+1.746*PER215WC(PWC)+.151*JS)*P215WC(PWC)*P215S(PS)*P215W(PW)*P215C(PC)
10770 IF CNLWC<0 THEN CNLWC=0
10780 LET NLWC=NLWC+CNLWC
10790LETCUTWC=(118.779-.815*PER215WC(PWC)+.161*JS-120.467)*P215WC(PWC)*P215S(PS)*P215W(PW)*P215C(PC)
10800 IF CUTWC<0 THEN CUTWC=0
10810 LET UTWC=UTWC+CUTWC
10820 NEXT PWC
10830 LET CNLS=(-30.062+1.746*PER215S(PS)+.151*JW)*P215S(PS)*P215W(PW)*P215C(PC)
10840 IF CNLS<0 THEN CNLS=0
10850 LET NLS=NLS+CNLS
10860 LET CUTS=(118.779-.815*PER215S(PS)+.161*JW-90.36799)*P215S(PS)*P215W(PW)*P215C(PC)
10870 IF CUTS<0 THEN CUTS=0
10880 LET UTS=UTS+CUTS
10890 NEXT PS
10900 LET CNLW=(-30.062+1.746*PER215W(PW)+.151*JC)*P215W(PW)*P215C(PC)
10910 IF CNLW<0 THEN CNLW=0
10920 LET NLW=NLW+CNLW
10930 LET CUTW=(118.779-.815*PER215W(PWC)+.161*JC-75.71601)*P215W(PW)*P215C(PC)
10940 IF CUTW<0 THEN CUTW=0
10950 LET UTW=UTW+CUTW
10960 NEXT PW
10970 LET CNLC=(-30.062+1.746*PER215C(PC)+.151*I1+9.908)*P215C(PC)
10980 IF CNLC<0 THEN CNLC=0
10990 LET NLC=NLC+CNLC
11000 LET CUTC=(118.779-.815*PER215C(PC)+.161*I1)*P215C(PC)
```

```
11010 IF CUTC<0 THEN CUTC=0
11020 LET UTC=UTC+CUTC
11030 NEXT PC
11040 LET NL=NLC+NLW+NLS+NLWC
11050 FOR K=1 TO 23
11060 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
11070 NEXT K
11080 FOR P9=1 TO 23
11090 IF P(P9)=0 GOTO 11110
11100 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
11110 NEXT P9
11120 RETURN
11130 LET PCN=7
11140 LET PWN=11
11150 LET PSN=5
11160 LET PWCN=7
11170 LET SL=2.16
11180 FOR PC=1 TO PCN
11190 LET JC=182.18-.644*PER216C(PC)+.356*I1
11200 FOR PW=1 TO PWN
11210 LET JW=182.18-.644*PER216W(PW)+.356*JC-58.968
11220 FOR PS=1 TO PSN
11230 LET JS=182.18-.644*PER216S(PS)+.356*JW-75.733
11240 FOR PWC=1 TO PWCN
11250 LET JWC=182.18-.644*PER216WC(PWC)+.356*JS-81.418
11260 LET JWCR=JWC/10
11270 LET JJ=10*CINT(JWCR)
11280 GOSUB 11660
11290 LET CNLWC=(-28.972+1.79*PER216WC(PWC)+.144*JS)*P216WC(PWC)*P216S(PS)*P216W(PW)*P216C(PC)
11300 IF CNLWC<0 THEN CNLWC=0
11310 LET NLWC=NLWC+CNLWC
11320 LET CUTWC=(117.62-.812*PER216WC(PWC)+.167*JS-120.642)*P216WC(PWC)*P216S(PS)*P216W(PW)*P216C(PC)
11330 IF CUTWC<0 THEN CUTWC=0
11340 LET UTWC=UTWC+CUTWC
11350 NEXT PWC
11360 LET CNLS=(-28.971+1.79*PER216S(PS)+.144*JW)*P216S(PS)*P216W(PW)*P216C(PC)
11370 IF CNLS<0 THEN CNLS=0
11380 LET NLS=NLS+CNLS
11390 LET CUTS=(117.62-.812*PER216S(PS)+.167*JW-90.64499)*P216S(PS)*P216W(PW)*P216C(PC)
11400 IF CUTS<0 THEN CUTS=0
11410 LET UTS=UTS+CUTS
11420 NEXT PS
11430 LET CNLW=(-28.971+1.79*PER216W(PW)+.144*JC)*P216W(PW)*P216C(PC)
11440 IF CNLW<0 THEN CNLW=0
11450 LET NLW=NLW+CNLW
11460 LET CUTW=(117.62-.812*PER216W(PWC)+.167*JC-75.645)*P216W(PW)*P216C(PC)
11470 IF CUTW<0 THEN CUTW=0
11480 LET UTW=UTW+CUTW
11490 NEXT PW
11500 LET CNLC=(-28.971+1.79*PER216C(PC)+.144*I1+9.260999)*P216C(PC)
11510 IF CNLC<0 THEN CNLC=0
11520 LET NLC=NLC+CNLC
11530 LET CUTC=(117.62-.812*PER216C(PC)+.167*I1)*P216C(PC)
11540 IF CUTC<0 THEN CUTC=0
11550 LET UTC=UTC+CUTC
11560 NEXT PC
11570 LET NL=NLC+NLW+NLS+NLWC
11580 FOR K=1 TO 23
11590 LET P(K)=J(K)/PCN/PWN/PSN/PWCN
11600 NEXT K
11610 FOR P9=1 TO 23
11620 IF P(P9)=0 GOTO 11640
11630 PRINT #1, T;C$; I;C$; D;C$; UTC;C$; UTW;C$; UTS;C$;SL;C$; NL;C$; P9;C$; P(P9)
11640 NEXT P9
11650 RETURN
```

```
11660 IF JJ=10 GOTO 11890
11670 IF JJ=20 GOTO 11910
11680 IF JJ=30 GOTO 11930
11690 IF JJ=40 GOTO 11950
11700 IF JJ=50 GOTO 11970
11710 IF JJ=60 GOTO 11990
11720 IF JJ=70 GOTO 12010
11730 IF JJ=80 GOTO 12030
11740 IF JJ=90 GOTO 12050
11750 IF JJ=100 GOTO 12070
11760 IF JJ=110 GOTO 12090
11770 IF JJ=120 GOTO 12110
11780 IF JJ=130 GOTO 12130
11790 IF JJ=140 GOTO 12150
11800 IF JJ=150 GOTO 12170
11810 IF JJ=160 GOTO 12190
11820 IF JJ=170 GOTO 12210
11830 IF JJ=180 GOTO 12230
11840 IF JJ=190 GOTO 12250
11850 IF JJ=200 GOTO 12270
11860 IF JJ=210 GOTO 12290
11870 IF JJ=220 GOTO 12310
11880 IF JJ=230 GOTO 12330
11890 LET J(1)=J(1)+1
11900 GOTO 12340
11910 LET J(2)=J(2)+1
11920 GOTO 12340
11930 LET J(3)=J(3)+1
11940 GOTO 12340
11950 LET J(4)=J(4)+1
11960 GOTO 12340
11970 LET J(5)=J(5)+1
11980 GOTO 12340
11990 LET J(6)=J(6)+1
12000 GOTO 12340
12010 LET J(7)=J(7)+1
12020 GOTO 12340
12030 LET J(8)=J(8)+1
12040 GOTO 12340
12050 LET J(9)=J(9)+1
12060 GOTO 12340
12070 LET J(10)=J(10)+1
12080 GOTO 12340
12090 LET J(11)=J(11)+1
12100 GOTO 12340
12110 LET J(12)=J(12)+1
12120 GOTO 12340
12130 LET J(13)=J(13)+1
12140 GOTO 12340
12150 LET J(14)=J(14)+1
12160 GOTO 12340
12170 LET J(15)=J(15)+1
12180 GOTO 12340
12190 LET J(16)=J(16)+1
12200 GOTO 12340
12210 LET J(17)=J(17)+1
12220 GOTO 12340
12230 LET J(18)=J(18)+1
12240 GOTO 12340
12250 LET J(19)=J(19)+1
12260 GOTO 12340
12270 LET J(20)=J(20)+1
12280 GOTO 12340
12290 LET J(21)=J(21)+1
12300 GOTO 12340
```

```
12310 LET J(22)=J(22)+1
12320 GOTO 12340
12330 LET J(23)=J(23)+1
12340 RETURN
```

Appendix D.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3

IPOTM = 35.6 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	502.8	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4
(2)	11.7	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	502.8	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4
(3)	12.5	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	502.8	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4	509.4
(4)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	502.8	509.4	509.4	511.8	512.0	512.0	512.0	512.0	512.0	512.0	512.0	512.0	512.0	512.0
(5)	13.9	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	518.0	518.1	518.1	518.1	518.2	518.2	518.2	518.2	518.2	518.2	518.2	518.2	518.2	518.2
(6)	14.7	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
(7)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
(8)	16.1	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
(9)	16.9	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
(10)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
(11)	18.3	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	368.3	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0	520.0
(12)	19.1	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	369.4	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.1	520.1	520.1	520.1	520.1	520.1	520.1	520.1
(13)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	369.4	492.4	519.7	519.9	520.0	520.0	520.0	520.0	520.1	520.1	520.1	520.1	520.1	520.1	520.1	520.1
(14)	20.5	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	369.4	492.4	519.7	519.9	520.0	520.0	520.0	520.1	520.1	520.1	520.1	520.1	520.1	520.1	520.1	520.1
(15)	21.3	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	369.4	492.4	519.7	519.9	520.0	520.0	520.0	520.1	520.1	520.1	520.1	520.1	520.1	520.1	520.1	520.1
(16)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	369.4	492.4	519.7	519.9	520.0	520.9	520.9	521.0	521.1	521.1	521.1	521.1	521.1	521.1	521.1	521.1

Notation:

AMS --- Optimal Agricultural Management System

PVENR --- Present Value of Expected Net Retruen ($/ac)

IPOTM --- Initial potentially mineralizable nitrogen

* Numbers in parenthesis represent row or column numbers.

Appendix D.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3
IPOTM = 35.6 (lb/ac)
(Continued)

			E2 (lb/ac)															
E3 (ton/ac)			(1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	145.5	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(2)	11.7	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	145.5	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(3)	12.5	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	145.5	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(4)	13.2	ESL	10.9	10.9	10.9	10.9	10.9	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
		ENL	140.4	145.5	155.4	154.9	154.9	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5
(5)	13.9	ESL	10.9	10.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
		ENL	140.4	145.5	152.7	152.8	152.8	152.8	152.8	152.8	152.8	152.9	152.9	152.9	152.9	152.9	152.9	152.9
(6)	14.7	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	145.5	153.8	153.9	153.9	153.9	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.0
(7)	15.4	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	145.5	153.8	153.9	153.9	153.9	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.0
(8)	16.1	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	145.5	153.8	153.9	153.9	153.9	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.0
(9)	16.9	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	145.5	153.8	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.0	153.9	153.9	154.1
(10)	17.6	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	145.5	153.8	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.0	154.0	154.0	154.1
(11)	18.3	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	145.5	153.8	153.9	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.0	154.0	154.0	154.1
(12)	19.1	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	145.5	153.8	153.9	153.9	153.9	154.0	154.0	152.9	152.9	152.9	153.0	153.0	153.0	153.0	153.0
(13)	19.8	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	145.5	153.8	153.9	153.9	153.9	154.0	154.0	152.9	152.9	152.9	153.0	153.0	153.0	153.0	153.0
(14)	20.5	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	145.5	153.8	153.9	153.9	153.9	154.0	154.0	152.9	152.9	152.9	152.9	152.9	152.9	152.9	152.9
(15)	21.3	ESL	10.9	10.9	12.3	12.3	12.3	12.3	12.3	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	145.5	153.8	153.9	153.9	153.9	154.0	154.0	152.9	152.9	152.9	152.9	152.9	152.9	152.9	152.9
(16)	22.0	ESL	10.9	10.9	12.3	12.3	12.3	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	140.5	145.5	153.8	153.9	153.9	153.8	153.8	153.9	153.9	153.9	153.9	153.9	153.9	153.9	153.9	153.9

Notation:
ESL --- Expected Soil Loss over the planning period (ton/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
IPOTM --- Initial potentially mineralizable nitrogen
* Numbers in parenthesis represent row or column numbers.

Appendix D.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3
IPOTM = 53.4 (lb/ac)
(Continued)

			E2 (lb/ac)															
E3 (ton/ac)			(1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	300.4	515.4	528.3	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(2)	11.7	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	300.4	515.4	528.3	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0	538.0
(3)	12.5	AMS	8	8	3	3	2	2	2	2	2	2	2	2	2	2	2	2
		PVENR	300.4	515.4	575.6	575.6	607.7	607.7	607.7	607.7	607.7	607.7	607.7	607.7	607.7	607.7	607.7	607.7
(4)	13.2	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
(5)	13.9	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
(6)	14.7	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
(7)	15.4	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
(8)	16.1	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8	618.8
(9)	16.9	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.8	618.8	618.9
(10)	17.6	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.9
(11)	18.3	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	300.4	515.4	618.8	618.8	618.8	618.8	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.9	618.9
(12)	19.1	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	301.6	515.4	618.8	618.8	618.8	618.8	618.9	618.9	618.9	618.9	618.9	619.0	619.0	619.0	619.0	619.0
(13)	19.8	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	301.6	515.4	618.8	618.8	618.8	618.8	618.9	618.9	618.9	618.9	618.9	619.0	619.0	619.0	619.0	619.0
(14)	20.5	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	301.6	515.4	618.8	618.8	618.8	618.8	618.9	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0
(15)	21.3	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	301.6	515.4	618.8	618.8	618.8	618.8	618.9	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0
(16)	22.0	AMS	8	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4
		PVENR	301.6	515.4	618.8	618.8	618.8	619.0	619.0	619.2	619.2	619.2	619.3	619.3	619.3	619.3	619.3	619.3

Notation:
AMS --- Optimal Agricultural Management System
PVENR --- Present Value of Expected Net Retruen ($/ac)
IPOTM --- Initial potentially mineralizable nitrogen
* Numbers in parenthesis represent row or column numbers.

Appendix D.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3
IPOTM = 53.4 (lb/ac)
(Continued)

			E2 (lb/ac)															
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
E3 (ton/ac)			142.5	157.7	172.8	187.9	203.1	218.2	233.4	248.5	263.6	278.8	293.9	309.1	324.2	339.4	354.5	369.6
(1)	11.0	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	162.8	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
(2)	11.7	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	162.8	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
(3)	12.5	ESL	10.9	10.9	12.4	12.4	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	139.4	142.1	168.6	168.6	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5
(4)	13.2	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(5)	13.9	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9	172.9	172.9
(6)	14.7	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9	172.9	172.9
(7)	15.4	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9	172.9	172.9
(8)	16.1	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9	172.9	172.9
(9)	16.9	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.7	172.7	173.0
(10)	17.6	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.9	172.9	173.0
(11)	18.3	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	172.7	172.7	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.8	172.8	172.9	172.9	173.0
(12)	19.1	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	172.7	172.7	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.9	172.9	172.9	172.9	172.9
(13)	19.8	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	172.7	172.7	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.9	172.9	172.9	172.9	172.9
(14)	20.5	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	172.7	172.7	172.7	172.7	172.8	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9
(15)	21.3	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	172.7	172.7	172.7	172.7	172.8	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9	172.9
(16)	22.0	ESL	10.9	10.9	13.0	13.0	13.0	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
		ENL	139.5	142.1	172.7	172.7	172.7	176.6	176.6	176.7	176.7	176.7	176.7	176.7	176.7	176.7	176.7	176.7

Notation:
ESL --- Expected Soil Loss over the planning period (ton/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
IPOTM --- Initial potentially mineralizable nitrogen
* Numbers in parenthesis represent row or column numbers.

Appendix D.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3

IPOTM = 62.3 (lb/ac)

(Continued)

			E2 (lb/ac)															
E3 (ton/ac)			(1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
(2)	11.7	AMS	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
(3)	12.5	AMS	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
(4)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
(5)	13.9	AMS	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		PVENR	350.2	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1	565.1
(6)	14.7	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	350.2	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
(7)	15.4	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	350.2	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
(8)	16.1	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	350.2	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
(9)	16.9	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	350.2	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
(10)	17.6	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	350.2	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
(11)	18.3	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	350.2	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6	566.6
(12)	19.1	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	351.3	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7	566.7	566.7	566.7
(13)	19.8	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	351.3	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7	566.7	566.7	566.7
(14)	20.5	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	351.3	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7	566.7	566.7	566.7
(15)	21.3	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	351.3	565.1	566.0	566.3	566.6	566.6	566.6	566.6	566.7	566.7	566.7	566.7	566.7	566.7	566.7	566.7
(16)	22.0	AMS	8	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		PVENR	351.3	565.1	566.0	566.3	566.6	568.0	568.0	568.0	568.1	568.1	568.2	568.2	568.2	568.2	568.2	568.2

Notation:
AMS --- Optimal Agricultural Management System
PVENR --- Present Value of Expected Net Retruen ($/ac)
IPOTM --- Initial potentially mineralizable nitrogen
* Numbers in parenthesis represent row or column numbers.

Appendix D.1 The Optimal Decision, Present Value of Expected Net Return, and Nitrate Leaching and Soil Loss over the Planning Period with 15 Grids of the E2 and E3
IPOTM = 62.3 (lb/ac)
(Continued)

			E2 (lb/ac)															
	E3 (ton/ac)		(1) 142.5	(2) 157.7	(3) 172.8	(4) 187.9	(5) 203.1	(6) 218.2	(7) 233.4	(8) 248.5	(9) 263.6	(10) 278.8	(11) 293.9	(12) 309.1	(13) 324.2	(14) 339.4	(15) 354.5	(16) 369.6
(1)	11.0	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(2)	11.7	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(3)	12.5	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(4)	13.2	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(5)	13.9	ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.3	142.3	142.3	142.3	142.3	142.3	142.3
(6)	14.7	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.2	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(7)	15.4	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.2	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(8)	16.1	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.2	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(9)	16.9	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.2	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(10)	17.6	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.2	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(11)	18.3	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.2	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(12)	19.1	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.2	164.4	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(13)	19.8	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.2	164.4	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(14)	20.5	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.2	164.4	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(15)	21.3	ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.2	164.4	164.4	164.4	164.4	164.4	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(16)	22.0	ESL	10.9	10.9	13.0	13.0	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	139.5	142.1	164.2	164.4	164.4	164.1	164.1	164.1	164.2	164.2	164.2	164.2	164.2	164.2	164.2	164.2

Notation:
ESL --- Expected Soil Loss over the planning period (ton/ac)
ENL --- Expected Nitrate Leaching over the planning period (lb/ac)
* Numbers in parenthesis represent row or column numbers.

Appendix D.2 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 2 percent
IPOTM = 35.6 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	604.7	609.4	609.4	609.4	609.4	609.4	609.4	609.4	609.4	609.4
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	604.7	609.4	609.4	609.4	609.4	609.4	609.4	609.4	609.4	609.4
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	604.7	609.4	609.8	610.0	610.0	610.0	610.0	610.0	610.0	610.0
		ESL	10.9	10.9	10.9	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
		ENL	140.4	155.4	154.9	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	617.1	617.2	617.2	617.3	617.3	617.3	617.3	617.3	617.3	617.3
		ESL	10.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
		ENL	140.4	152.7	152.8	152.8	152.8	152.8	152.8	152.8	152.8	152.8	152.8
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	617.1	619.3	619.4	619.4	619.4	619.4	619.4	619.4	619.4	619.4
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	153.9	153.9	153.9	153.9	153.9	153.9	153.9
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	617.1	619.3	619.4	619.4	619.4	619.4	619.4	619.4	619.4	619.5
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	154.0	154.0	154.0	154.0	154.0	153.9	154.1
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	419.5	617.1	619.3	619.4	619.4	619.4	619.4	619.4	619.4	619.4	619.5
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	154.0	154.0	154.0	154.0	154.0	153.9	154.1
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	421.1	617.1	619.3	619.8	619.8	619.8	620.0	620.0	620.0	620.0	620.0
		ESL	10.9	11.9	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	152.8	152.9	152.9	152.9	153.0	153.0	153.0	153.0
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	421.1	617.1	619.3	619.8	619.8	619.8	620.0	620.0	620.0	620.0	620.0
		ESL	10.9	11.9	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	152.8	152.9	152.9	152.9	153.0	153.0	153.0	153.0
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	421.1	617.1	619.3	619.8	619.8	619.9	620.0	620.0	620.0	620.0	620.0
		ESL	10.9	11.9	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	152.8	152.9	152.9	152.9	152.9	152.9	152.9	152.9
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	421.1	617.1	619.3	621.1	621.1	621.2	621.4	621.5	621.5	621.5	621.5
		ESL	10.9	11.9	12.3	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	140.5	152.7	153.9	153.8	153.8	153.9	153.9	153.9	153.9	153.9	153.9

Appendix D.2 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 2 percent (Continued)

IPOTM = 44.5 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	295.0	618.2	624.2	624.2	624.2	624.2	624.2	624.2	624.2	624.2	624.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	295.0	618.2	624.2	624.2	624.2	624.2	624.2	624.2	624.2	624.2	624.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(3)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	295.0	634.4	634.4	634.4	634.4	634.4	634.4	634.4	634.4	634.4	634.4
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(4)	14.3	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	295.0	634.4	634.4	634.4	634.4	634.4	634.4	634.4	634.4	634.4	634.4
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(5)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	295.0	634.4	636.9	637.0	637.0	637.0	637.0	637.0	637.0	637.0	637.0
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.1	157.1	157.1	157.1	157.1	157.1	157.1	157.1	157.1
(6)	16.5	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	295.0	634.4	636.9	637.0	637.0	637.0	637.0	637.0	637.0	637.0	637.1
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.1	157.2
(7)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	295.0	634.4	636.9	637.0	637.0	637.0	637.0	637.0	637.0	637.0	637.1
		ESL	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	157.5	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.1	157.2
(8)	18.7	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	296.6	634.4	636.9	637.5	637.5	637.5	637.7	637.7	637.7	637.7	637.7
		ESL	10.9	13.0	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.1	155.7	155.8	155.8	155.8	155.9	155.9	155.9	155.9
(9)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	296.6	634.4	636.9	637.5	637.5	637.5	637.7	637.7	637.7	637.7	637.7
		ESL	10.9	13.0	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.1	155.7	155.8	155.8	155.8	155.9	155.9	155.9	155.9
(10)	20.9	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	296.6	634.4	636.9	637.5	637.5	637.6	637.7	637.7	637.7	637.7	637.7
		ESL	10.9	13.0	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	157.5	157.1	155.7	155.8	155.8	155.8	155.8	155.8	155.8	155.8
(11)	22.0	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	296.6	634.4	636.9	639.2	639.2	639.3	639.4	639.5	639.5	639.5	639.5
		ESL	10.9	13.0	12.6	12.3	12.3	12.3	12.4	12.4	12.4	12.4	12.4
		ENL	142.0	157.5	157.1	156.9	156.9	157.0	157.0	157.0	157.0	157.0	157.0

Appendix D.2 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 2 percent (Continued)

IPOTM = 53.4 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	342.1	630.7	637.5	637.5	637.5	637.5	637.5	637.5	637.5	637.5	637.5
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	162.8	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
(2)	12.1	AMS	8	15	15	2	2	2	2	2	2	2	2
		PVENR	342.1	630.7	637.5	705.9	705.9	705.9	705.9	705.9	705.9	705.9	705.9
		ESL	10.9	10.9	10.9	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	139.4	162.8	162.0	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5
(3)	13.2	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	342.1	630.7	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	162.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	342.1	648.6	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(5)	15.4	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	342.1	648.6	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(6)	16.5	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	342.1	648.6	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.1
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.7	173.0
(7)	17.6	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	342.1	648.6	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.0	717.1
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.7	173.0
(8)	18.7	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	343.7	648.6	717.0	717.0	717.0	717.0	717.0	717.1	717.1	717.1	717.1
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	172.7	172.8	172.8	172.8	172.9	172.9	172.9	172.9
(9)	19.8	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	343.7	648.6	717.0	717.0	717.0	717.0	717.0	717.1	717.1	717.1	717.1
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	172.7	172.8	172.8	172.8	172.9	172.9	172.9	172.9
(10)	20.9	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	343.7	648.6	717.0	717.0	717.0	717.2	717.2	717.2	717.2	717.2	717.2
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	172.7	172.8	172.9	172.9	172.9	172.9	172.9	172.9
(11)	22.0	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	343.7	648.6	717.0	717.3	717.3	717.5	717.6	717.6	717.6	717.6	717.6
		ESL	10.9	12.3	13.0	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
		ENL	139.5	158.8	172.7	176.6	176.6	176.7	176.7	176.7	176.7	176.7	176.7

Appendix D.2 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 2 percent (Continued)

IPOTM = 62.3 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	391.9	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	391.9	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	391.9	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(4)	14.3	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	391.9	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3	663.3
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(5)	15.4	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	391.9	663.3	665.0	665.2	665.2	665.2	665.2	665.2	665.2	665.2	665.2
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(6)	16.5	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	391.9	663.3	665.0	665.2	665.2	665.2	665.2	665.2	665.2	665.2	665.2
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(7)	17.6	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	391.9	663.3	665.0	665.2	665.2	665.2	665.2	665.2	665.2	665.2	665.2
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(8)	18.7	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	393.5	663.3	665.0	665.8	665.8	665.8	666.0	666.0	666.0	666.0	666.0
		ESL	10.9	10.9	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.4	162.7	162.7	162.7	162.8	162.8	162.8	162.8	162.8
(9)	19.8	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	393.5	663.3	665.0	665.8	665.8	665.8	666.0	666.0	666.0	666.0	666.0
		ESL	10.9	10.9	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.4	162.7	162.7	162.7	162.8	162.8	162.8	162.8	162.8
(10)	20.9	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	393.5	663.3	665.0	665.8	665.8	665.9	666.0	666.0	666.0	666.0	666.0
		ESL	10.9	10.9	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	142.1	164.4	162.7	162.7	162.7	162.8	162.8	162.8	162.8	162.8
(11)	22.0	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	393.5	663.3	665.0	667.8	667.8	667.9	668.0	668.2	668.2	668.2	668.2
		ESL	10.9	10.9	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	139.5	142.1	164.4	164.1	164.1	164.1	164.2	164.2	164.2	164.2	164.2

Appendix D.3 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 10 percent

IPOTM = 35.6 (lb/ac)

E2 (lb/ac)

			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E3 (ton/ac)			142.5	165.2	187.9	210.6	233.4	256.1	278.8	301.5	324.2	346.9	369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	425.1	427.9	427.9	427.9	427.9	427.9	427.9	427.9	427.9	427.9
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	148.7	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	425.1	427.9	427.9	427.9	427.9	427.9	427.9	427.9	427.9	427.9
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	148.7	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	425.1	427.9	431.5	431.6	431.6	431.6	431.6	431.6	431.6	431.6
		ESL	10.9	10.9	10.9	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
		ENL	140.4	148.7	154.9	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	436.7	436.8	436.8	436.8	436.8	436.9	436.9	436.9	436.9	436.9
		ESL	10.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
		ENL	140.4	152.7	152.8	152.8	152.8	152.8	152.9	152.9	152.9	152.9	152.9
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	436.7	438.3	438.3	438.3	438.3	438.3	438.3	438.3	438.3	438.3
		ESL	10.9	11.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	140.4	152.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	436.7	438.3	438.3	438.3	438.3	438.3	438.3	438.3	438.3	438.3
		ESL	10.9	11.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	140.4	152.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	324.5	436.7	438.3	438.3	438.3	438.3	438.3	438.3	438.3	438.3	438.3
		ESL	10.9	11.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	140.4	152.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7	154.7
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	325.4	436.7	438.3	438.3	438.3	438.3	438.3	438.4	438.4	438.4	438.4
		ESL	10.9	11.9	13.0	13.0	13.0	13.0	13.0	12.3	12.3	12.3	12.3
		ENL	140.5	152.7	154.7	154.7	154.7	154.7	154.7	154.0	154.0	154.0	154.0
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	325.4	436.7	438.3	438.3	438.3	438.3	438.3	438.4	438.4	438.4	438.4
		ESL	10.9	11.9	13.0	13.0	13.0	13.0	13.0	12.3	12.3	12.3	12.3
		ENL	140.5	152.7	154.7	154.7	154.7	154.7	154.7	154.0	154.0	154.0	154.0
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	325.4	436.7	438.3	438.3	438.3	438.4	438.4	438.4	438.4	438.4	438.4
		ESL	10.9	11.9	13.0	13.0	13.0	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.5	152.7	154.7	154.7	154.7	154.0	154.0	154.0	154.0	154.0	154.0
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	325.4	436.7	438.3	438.6	438.6	438.6	438.7	438.7	438.7	438.7	438.7
		ESL	10.9	11.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	140.5	152.7	154.7	154.7	154.7	154.7	154.9	154.9	154.9	154.9	154.9

Appendix D.3 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 10 percent (Continued)

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	218.2	439.7	443.2	443.2	443.2	443.2	443.2	443.2	443.2	443.2	443.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	150.5	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	218.2	439.7	443.2	443.2	443.2	443.2	443.2	443.2	443.2	443.2	443.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	150.5	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(3)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	218.2	456.5	456.5	456.5	456.5	456.5	456.5	456.5	456.5	456.5	456.5
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(4)	14.3	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	218.2	456.5	456.5	456.5	456.5	456.5	456.5	456.5	456.5	456.5	456.5
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.7	157.7	157.7	157.7	157.7
(5)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	218.2	456.5	456.5	456.6	456.6	456.6	456.6	456.6	456.6	456.6	456.6
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(6)	16.5	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	218.2	456.5	456.5	456.6	456.6	456.6	456.6	456.6	456.6	456.6	456.6
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(7)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	218.2	456.5	456.5	456.6	456.6	456.6	456.6	456.6	456.6	456.6	456.6
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(8)	18.7	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	219.0	456.5	456.5	456.6	456.6	456.6	456.6	456.6	456.6	456.6	456.6
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	12.6	12.6	12.6	12.6
		ENL	142.0	157.5	157.5	157.5	157.5	157.5	157.5	157.2	157.2	157.2	157.2
(9)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	219.0	456.5	456.5	456.6	456.6	456.6	456.6	456.6	456.6	456.6	456.6
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	12.6	12.6	12.6	12.6
		ENL	142.0	157.5	157.5	157.5	157.5	157.5	157.5	157.2	157.2	157.2	157.2
(10)	20.9	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	219.0	456.5	456.5	456.6	456.6	456.6	456.6	456.6	456.6	456.6	456.6
		ESL	10.9	13.0	13.0	13.0	13.0	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	142.0	157.5	157.5	157.5	157.5	157.2	157.2	157.2	157.2	157.2	157.2
(11)	22.0	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	219.0	456.5	456.5	456.9	456.9	456.9	456.9	457.0	457.0	457.0	457.0
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	142.0	157.5	157.5	157.6	157.6	157.6	157.7	157.7	157.7	157.7	157.7

Appendix D.3 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 10 percent (Continued)

IPOTM = 53.4 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	266.0	452.9	456.9	456.9	456.9	456.9	456.9	456.9	456.9	456.9	456.9
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	153.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
(2)	12.1	AMS	8	15	15	2	2	2	2	2	2	2	2
		PVENR	266.0	452.9	456.9	527.8	527.8	527.8	527.8	527.8	527.8	527.8	527.8
		ESL	10.9	10.9	10.9	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	139.4	153.0	162.0	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5
(3)	13.2	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.0	452.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	153.0	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.0	469.7	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9
(5)	15.4	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.0	469.7	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.9	172.9	172.9	172.9	172.9
(6)	16.5	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.0	469.7	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9	539.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.7	173.0
(7)	17.6	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.0	469.7	538.9	538.9	538.9	538.9	538.9	538.9	538.9	538.9	539.0
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.9	173.0
(8)	18.7	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.8	469.7	538.9	538.9	538.9	538.9	538.9	539.0	539.0	539.0	539.0
		ESL	10.9	12.3	13.0	17.2	17.2	17.2	17.2	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	197.1	197.1	197.1	197.1	172.9	172.9	172.9	172.9
(9)	19.8	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.8	469.7	538.9	538.9	538.9	538.9	538.9	539.0	539.0	539.0	539.0
		ESL	10.9	12.3	13.0	17.2	17.2	17.2	17.2	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	197.1	197.1	197.1	197.1	172.9	172.9	172.9	172.9
(10)	20.9	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.8	469.7	538.9	538.9	538.9	539.0	539.0	539.0	539.0	539.0	539.0
		ESL	10.9	12.3	13.0	17.2	17.2	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	158.8	172.7	197.1	197.1	172.9	172.9	172.9	172.9	172.9	172.9
(11)	22.0	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	266.8	469.7	538.9	539.2	539.2	539.2	539.3	539.4	539.4	539.4	539.4
		ESL	10.9	12.3	13.0	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
		ENL	139.5	158.8	172.7	197.3	197.3	197.3	197.3	197.4	197.4	197.4	197.4

Appendix D.3 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 10 percent (Continued)

IPOTM = 62.3 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	315.7	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	315.7	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	315.7	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(4)	14.3	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	315.7	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2	485.2
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.3	142.3	142.3	142.3	142.3
(5)	15.4	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	315.7	485.2	485.2	485.3	485.3	485.3	485.3	485.3	485.3	485.3	485.3
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	142.1	164.5	164.5	164.5	164.5	164.5	164.5	164.5	164.5
(6)	16.5	AMS	8	8	8	15	15	15	15	15	15	15	15
		PVENR	315.7	485.2	485.2	485.3	485.3	485.3	485.3	485.3	485.3	485.3	485.3
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	142.1	164.5	164.5	164.5	164.5	164.5	164.5	164.5	164.5
(7)	17.6	AMS	8	8	8	15	15	15	15	15	15	15	15
		PVENR	315.7	485.2	485.2	485.3	485.3	485.3	485.3	485.3	485.3	485.3	485.3
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	142.1	142.1	164.5	164.5	164.5	164.5	164.5	164.5	164.5	164.5
(8)	18.7	AMS	8	8	8	15	15	15	15	15	15	15	15
		PVENR	316.6	485.2	485.2	485.3	485.3	485.3	485.3	485.3	485.3	485.3	485.3
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	142.1	164.5	164.5	164.5	164.5	164.4	164.4	164.4	164.4
(9)	19.8	AMS	8	8	8	15	15	15	15	15	15	15	15
		PVENR	316.6	485.2	485.2	485.3	485.3	485.3	485.3	485.3	485.3	485.3	485.3
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	142.1	164.5	164.5	164.5	164.5	164.4	164.4	164.4	164.4
(10)	20.9	AMS	8	8	8	15	15	15	15	15	15	15	15
		PVENR	316.6	485.2	485.2	485.3	485.3	485.3	485.3	485.3	485.3	485.3	485.3
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	142.1	164.5	164.5	164.4	164.4	164.4	164.4	164.4	164.4
(11)	22.0	AMS	8	8	8	15	15	15	15	15	15	15	15
		PVENR	316.6	485.2	485.2	485.5	485.5	485.5	485.6	485.7	485.7	485.7	485.7
		ESL	10.9	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.5	142.1	142.1	164.5	164.5	164.5	164.6	164.6	164.6	164.6	164.6

Appendix D.4 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 0 percent

IPOTM = 35.6 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	664.50	668.19	668.19	668.19	668.19	668.19	668.19	668.19	668.19	668.19
		ESL	10.87	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	664.50	668.19	668.19	668.19	668.19	668.19	668.19	668.19	668.19	668.19
		ESL	10.87	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	664.50	668.19	668.19	668.40	668.40	668.40	668.40	668.40	668.40	668.40
		ESL	10.87	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.98	154.98	154.98	154.98	154.98	154.98	154.98
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	675.10	675.27	675.27	675.36	675.36	675.36	675.36	675.36	675.36	675.36
		ESL	10.87	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89	11.89
		ENL	140.35	152.68	152.76	152.76	152.83	152.83	152.83	152.83	152.83	152.83	152.83
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	675.10	677.54	677.66	677.66	677.66	677.66	677.66	677.66	677.66	677.66
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	153.90	153.90
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	675.10	677.54	677.66	677.66	677.66	677.66	677.66	677.66	677.66	677.73
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	153.90	154.10
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	448.66	675.10	677.54	677.66	677.66	677.66	677.66	677.66	677.66	677.66	677.73
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	153.90	154.10
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	450.58	675.10	677.54	678.16	678.18	678.18	678.32	678.40	678.40	678.40	678.40
		ESL	10.93	11.89	12.25	11.72	11.73	11.73	11.73	11.73	11.73	11.73	11.73
		ENL	140.47	152.68	153.89	152.80	152.87	152.87	152.93	152.99	152.99	152.99	152.99
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	450.58	675.10	677.54	678.16	678.18	678.18	678.32	678.40	678.40	678.40	678.40
		ESL	10.93	11.89	12.25	11.72	11.73	11.73	11.73	11.73	11.73	11.73	11.73
		ENL	140.47	152.68	153.89	152.80	152.87	152.87	152.93	152.99	152.99	152.99	152.99
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	450.58	675.10	677.54	678.16	678.18	678.28	678.43	678.43	678.43	678.43	678.43
		ESL	10.93	11.89	12.25	11.72	11.73	11.73	11.73	11.73	11.73	11.73	11.73
		ENL	140.47	152.68	153.89	152.80	152.87	152.88	152.94	152.94	152.94	152.94	152.94
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	450.58	675.10	677.54	679.71	679.71	679.84	679.98	680.09	680.09	680.09	680.09
		ESL	10.93	11.89	12.25	12.03	12.03	12.04	12.04	12.04	12.04	12.04	12.04
		ENL	140.47	152.68	153.89	153.80	153.80	153.88	153.94	153.95	153.95	153.95	153.95

Appendix D.4 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 0 percent (Continued)

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	319.56	678.11	682.83	682.83	682.83	682.83	682.83	682.83	682.83	682.83	682.83
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	141.88	159.11	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	319.56	678.11	682.83	682.83	682.83	682.83	682.83	682.83	682.83	682.83	682.83
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	141.88	159.11	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40
(3)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	319.56	692.16	692.16	692.16	692.16	692.16	692.16	692.16	692.16	692.16	692.16
		ESL	10.88	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
		ENL	141.88	157.48	157.48	157.48	157.48	157.48	157.48	157.48	157.48	157.48	157.48
(4)	14.3	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	319.56	692.16	692.16	692.16	692.16	692.16	692.16	692.16	692.16	692.16	692.16
		ESL	10.88	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
		ENL	141.88	157.48	157.48	157.48	157.48	157.48	157.48	157.48	157.48	157.48	157.48
(5)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	319.56	692.16	694.82	694.98	694.98	694.98	694.98	694.98	694.98	694.98	694.98
		ESL	10.88	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64
		ENL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	157.14	157.14
(6)	16.5	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	319.56	692.16	694.82	694.98	694.98	694.98	694.98	694.98	694.98	694.98	695.01
		ESL	10.88	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64
		ENL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	157.14	157.24
(7)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	319.56	692.16	694.82	694.98	694.98	694.98	694.98	694.98	694.98	694.98	695.01
		ESL	10.88	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64
		ENL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	157.14	157.24
(8)	18.7	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	321.45	692.16	694.82	695.62	695.63	695.63	695.81	695.85	695.85	695.85	695.85
		ESL	10.93	13.00	12.64	11.95	11.96	11.96	11.96	11.96	11.96	11.96	11.96
		ENL	141.98	157.48	157.13	155.73	155.76	155.76	155.84	155.87	155.87	155.87	155.87
(9)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	321.45	692.16	694.82	695.62	695.63	695.63	695.81	695.85	695.85	695.85	695.85
		ESL	10.93	13.00	12.64	11.95	11.96	11.96	11.96	11.96	11.96	11.96	11.96
		ENL	141.98	157.48	157.13	155.73	155.76	155.76	155.84	155.87	155.87	155.87	155.87
(10)	20.9	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	321.45	692.16	694.82	695.62	695.63	695.68	695.86	695.86	695.86	695.86	695.86
		ESL	10.93	13.00	12.64	11.95	11.96	11.96	11.96	11.96	11.96	11.96	11.96
		ENL	141.98	157.48	157.13	155.73	155.76	155.76	155.84	155.84	155.84	155.84	155.84
(11)	22.0	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	321.45	692.16	694.82	697.60	697.60	697.66	697.85	697.98	697.98	697.98	697.98
		ESL	10.93	13.00	12.64	12.34	12.34	12.34	12.35	12.35	12.35	12.35	12.35
		ENL	141.98	157.48	157.13	156.91	156.91	156.96	157.04	157.05	157.05	157.05	157.05

Appendix D.4 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 0 percent (Continued)

IPOTM = 53.4 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	366.45	690.66	696.02	696.02	696.02	696.02	696.02	696.02	696.02	696.02	696.02
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	162.78	161.98	161.98	161.98	161.98	161.98	161.98	161.98	161.98	161.98
(2)	12.1	AMS	8	15	15	2	2	2	2	2	2	2	2
		PVENR	366.45	690.66	696.02	763.68	763.68	763.68	763.68	763.68	763.68	763.68	763.68
		ESL	10.88	10.90	10.90	11.96	11.96	11.96	11.96	11.96	11.96	11.96	11.96
		ENL	139.41	162.78	161.98	194.46	194.46	194.46	194.46	194.46	194.46	194.46	194.46
(3)	13.2	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	366.45	690.66	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79
		ESL	10.88	10.90	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
		ENL	139.41	162.78	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	366.45	706.07	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79
		ESL	10.88	12.34	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
		ENL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72
(5)	15.4	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	366.45	706.07	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79
		ESL	10.88	12.34	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
		ENL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72
(6)	16.5	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	366.45	706.07	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.89
		ESL	10.88	12.34	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.01
		ENL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	173.03
(7)	17.6	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	366.45	706.07	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.79	774.89
		ESL	10.88	12.34	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.01
		ENL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	173.03
(8)	18.7	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	368.33	706.07	774.79	774.79	774.81	774.81	774.81	774.94	774.94	774.94	774.94
		ESL	10.93	12.34	13.00	13.00	13.01	13.01	13.01	13.01	13.01	13.01	13.01
		ENL	139.52	158.77	172.72	172.72	172.84	172.84	172.84	172.94	172.94	172.94	172.94
(9)	19.8	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	368.33	706.07	774.79	774.79	774.81	774.81	774.81	774.94	774.94	774.94	774.94
		ESL	10.93	12.34	13.00	13.00	13.01	13.01	13.01	13.01	13.01	13.01	13.01
		ENL	139.52	158.77	172.72	172.72	172.84	172.84	172.84	172.94	172.94	172.94	172.94
(10)	20.9	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	368.33	706.07	774.79	774.79	774.81	774.98	774.98	774.98	774.98	774.98	774.98
		ESL	10.93	12.34	13.00	13.00	13.01	13.01	13.01	13.01	13.01	13.01	13.01
		ENL	139.52	158.77	172.72	172.72	172.84	172.86	172.86	172.86	172.86	172.86	172.86
(11)	22.0	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	368.33	706.07	774.79	775.15	775.15	775.35	775.42	775.47	775.47	775.47	775.47
		ESL	10.93	12.34	13.00	13.36	13.36	13.37	13.37	13.37	13.37	13.37	13.37
		ENL	139.52	158.77	172.72	176.56	176.56	176.69	176.73	176.73	176.73	176.73	176.73

Appendix D.4 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with an Interest of 0 percent (Continued)

IPOTM = 62.3 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	416.17	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	416.17	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	416.17	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(4)	14.3	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	416.17	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06	721.06
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(5)	15.4	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	416.17	721.06	722.68	722.97	722.97	722.97	722.97	722.97	722.97	722.97	722.97
		ESL	10.88	10.90	12.97	12.97	12.97	12.97	12.97	12.97	12.97	12.97	12.97
		ENL	139.41	142.11	164.40	164.43	164.43	164.43	164.43	164.43	164.43	164.43	164.43
(6)	16.5	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	416.17	721.06	722.68	722.97	722.97	722.97	722.97	722.97	722.97	722.97	722.97
		ESL	10.88	10.90	12.97	12.97	12.97	12.97	12.97	12.97	12.97	12.97	12.97
		ENL	139.41	142.11	164.40	164.43	164.43	164.43	164.43	164.43	164.43	164.43	164.44
(7)	17.6	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	416.17	721.06	722.68	722.97	722.97	722.97	722.97	722.97	722.97	722.97	722.97
		ESL	10.88	10.90	12.97	12.97	12.97	12.97	12.97	12.97	12.97	12.97	12.97
		ENL	139.41	142.11	164.40	164.43	164.43	164.43	164.43	164.43	164.43	164.43	164.44
(8)	18.7	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	418.05	721.06	722.68	723.72	723.72	723.72	723.95	723.95	723.95	723.95	723.95
		ESL	10.93	10.90	12.97	12.16	12.16	12.16	12.16	12.16	12.16	12.16	12.16
		ENL	139.52	142.11	164.40	162.74	162.74	162.74	162.84	162.84	162.84	162.84	162.84
(9)	19.8	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	418.05	721.06	722.68	723.72	723.72	723.72	723.95	723.95	723.95	723.95	723.95
		ESL	10.93	10.90	12.97	12.16	12.16	12.16	12.16	12.16	12.16	12.16	12.16
		ENL	139.52	142.11	164.40	162.74	162.74	162.74	162.84	162.84	162.84	162.84	162.84
(10)	20.9	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	418.05	721.06	722.68	723.72	723.72	723.73	723.95	723.95	723.95	723.95	723.95
		ESL	10.93	10.90	12.97	12.16	12.16	12.16	12.16	12.16	12.16	12.16	12.16
		ENL	139.52	142.11	164.40	162.74	162.74	162.74	162.84	162.84	162.84	162.84	162.84
(11)	22.0	AMS	8	8	15	15	15	15	15	15	15	15	15
		PVENR	418.05	721.06	722.68	726.08	726.08	726.08	726.30	726.46	726.46	726.46	726.46
		ESL	10.93	10.90	12.97	12.61	12.61	12.61	12.62	12.62	12.62	12.62	12.62
		ENL	139.52	142.11	164.40	164.09	164.09	164.10	164.20	164.21	164.21	164.21	164.21

Appendix D.5 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected
Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 year planning period

IPOTM = 35.6 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	811.3	811.3	811.3	811.3	811.3	811.3	811.3	811.3	811.3	811.3
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	282.3	287.7	287.7	287.7	287.7	287.7	287.7	287.7	287.7	287.7	287.7
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	811.3	811.3	811.4	811.4	811.4	811.4	811.4	811.4	811.4	811.4
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	282.3	287.7	287.7	287.9	287.9	287.9	287.9	287.9	287.9	287.9	287.9
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	812.3	812.4	812.4	812.4	812.4	812.4	812.4	812.4	812.4	812.4
		ESL	21.8	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
		ENL	282.3	298.0	298.2	298.1	298.1	298.1	298.1	298.1	298.1	298.1	298.1
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	812.3	812.5	812.6	812.6	812.6	812.6	812.6	812.6	812.6	812.6
		ESL	21.8	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
		ENL	282.3	298.0	298.2	298.3	298.3	298.5	298.5	298.5	298.5	298.5	298.5
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	812.7	813.0	813.0	813.0	813.0	813.0	813.0	813.0	813.0	813.0
		ESL	21.8	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
		ENL	282.3	299.9	300.1	300.2	300.2	300.3	300.3	300.3	300.3	300.3	300.3
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	812.7	813.0	813.0	813.0	813.0	813.0	813.0	813.0	813.1	813.1
		ESL	21.8	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
		ENL	282.3	299.9	300.2	300.2	300.2	300.2	300.2	300.2	300.2	300.4	300.4
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	508.5	812.7	813.0	813.0	813.0	813.0	813.0	813.0	813.0	813.1	813.1
		ESL	21.8	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
		ENL	282.3	299.9	300.2	300.2	300.2	300.2	300.2	300.2	300.3	300.4	300.4
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	509.1	812.7	813.0	813.0	813.0	813.1	813.1	813.1	813.1	813.1	813.1
		ESL	21.8	22.7	22.7	22.7	22.7	22.4	22.4	22.4	22.4	22.4	22.4
		ENL	282.4	299.9	300.2	300.2	300.3	299.6	299.6	299.6	299.6	299.6	299.7
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	509.1	812.7	813.0	813.0	813.0	813.1	813.1	813.1	813.1	813.1	813.1
		ESL	21.8	22.7	22.7	22.7	22.7	22.4	22.4	22.4	22.4	22.4	22.4
		ENL	282.4	299.9	300.2	300.2	300.3	299.6	299.6	299.6	299.6	299.6	299.7
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	509.1	812.7	813.0	813.0	813.1	813.1	813.1	813.1	813.1	813.1	813.1
		ESL	21.8	22.7	22.7	22.7	22.7	22.4	22.4	22.4	22.4	22.4	22.4
		ENL	282.4	299.9	300.2	300.2	300.3	299.6	299.6	299.6	299.6	299.6	299.6
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	509.1	812.7	813.0	813.4	813.5	813.5	813.5	813.5	813.5	813.5	813.5
		ESL	21.8	22.7	22.7	22.7	22.8	22.8	22.8	22.8	22.8	22.8	22.8
		ENL	282.4	299.9	300.2	302.0	302.1	302.1	302.1	302.1	302.1	302.1	302.1

Appendix D.5 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 year planning period (Continued)

IPOTM = 44.5 (lb/ac)

E2 (lb/ac)

E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	830.2	830.2	830.2	830.2	830.2	830.2	830.2	830.2	830.2	830.2
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	283.8	290.5	290.5	290.5	290.5	290.5	290.5	290.5	290.5	290.5	290.5
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	830.2	830.2	830.3	830.3	830.3	830.3	830.3	830.3	830.3	830.3
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	283.8	290.5	290.5	290.7	290.7	290.7	290.7	290.7	290.7	290.7	290.7
(3)	13.2	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	830.8	830.9	830.9	830.9	830.9	830.9	830.9	830.9	830.9	830.9
		ESL	21.8	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
		ENL	283.8	297.6	297.8	297.7	297.7	297.7	297.7	297.7	297.7	297.7	297.7
(4)	14.3	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	830.8	831.1	831.1	831.1	831.1	831.1	831.1	831.1	831.1	831.1
		ESL	21.8	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
		ENL	283.8	297.6	297.8	297.9	297.9	298.1	298.1	298.1	298.1	298.1	298.1
(5)	15.4	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	831.2	831.4	831.5	831.5	831.5	831.5	831.5	831.5	831.5	831.5
		ESL	21.8	22.5	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6
		ENL	283.8	300.1	300.3	300.4	300.4	300.5	300.5	300.5	300.5	300.5	300.5
(6)	16.5	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	831.2	831.5	831.5	831.5	831.5	831.5	831.5	831.5	831.6	831.6
		ESL	21.8	22.5	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6
		ENL	283.8	300.1	300.4	300.4	300.4	300.4	300.4	300.4	300.4	300.6	300.6
(7)	17.6	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.1	831.2	831.5	831.5	831.5	831.5	831.5	831.5	831.5	831.6	831.6
		ESL	21.8	22.5	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6
		ENL	283.8	300.1	300.4	300.4	300.4	300.4	300.4	300.4	300.5	300.6	300.6
(8)	18.7	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.8	831.2	831.5	831.5	831.5	831.6	831.6	831.6	831.6	831.6	831.6
		ESL	21.8	22.5	22.6	22.6	22.6	22.3	22.3	22.3	22.3	22.3	22.3
		ENL	283.9	300.1	300.4	300.4	300.4	299.9	299.9	299.9	299.9	299.9	300.0
(9)	19.8	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.8	831.2	831.5	831.5	831.5	831.6	831.6	831.6	831.6	831.6	831.6
		ESL	21.8	22.5	22.6	22.6	22.6	22.3	22.3	22.3	22.3	22.3	22.3
		ENL	283.9	300.1	300.4	300.4	300.4	299.9	299.9	299.9	299.9	299.9	300.0
(10)	20.9	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.8	831.2	831.5	831.5	831.6	831.6	831.6	831.6	831.6	831.6	831.6
		ESL	21.8	22.5	22.6	22.6	22.6	22.3	22.3	22.3	22.3	22.3	22.3
		ENL	283.9	300.1	300.4	300.4	300.4	299.9	299.9	299.9	299.9	299.9	299.9
(11)	22.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	393.8	831.2	831.5	831.9	831.9	832.0	832.0	832.0	832.0	832.0	832.0
		ESL	21.8	22.5	22.6	22.7	22.7	22.7	22.7	22.7	22.7	22.7	22.7
		ENL	283.9	300.1	300.4	302.5	302.6	302.7	302.7	302.7	302.7	302.7	302.7

Appendix D.5 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 year planning period (Continued)

IPOTM = 53.4 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	440.6	846.0	846.0	846.0	846.0	846.0	846.0	846.0	846.0	846.0	846.0
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	281.4	293.7	293.7	293.7	293.7	293.7	293.7	293.7	293.7	293.7	293.7
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	440.6	846.0	846.0	846.1	846.1	846.1	846.1	846.1	846.1	846.1	846.1
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	281.4	293.7	293.7	293.9	293.9	293.9	293.9	293.9	293.9	293.9	293.9
(3)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	440.6	909.8	909.9	909.9	909.9	909.9	909.9	909.9	909.9	909.9	909.9
		ESL	21.8	25.3	25.4	25.3	25.3	25.3	25.3	25.3	25.3	25.3	25.3
		ENL	281.4	329.6	329.7	329.7	329.7	329.7	329.7	329.7	329.7	329.7	329.7
(4)	14.3	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	440.6	909.8	909.9	910.0	910.0	910.0	910.0	910.0	910.0	910.0	910.0
		ESL	21.8	25.3	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4
		ENL	281.4	329.6	329.7	329.8	329.8	330.0	330.0	330.0	330.0	330.0	330.0
(5)	15.4	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	440.6	910.4	910.6	910.6	910.6	910.6	910.6	910.6	910.6	910.6	910.6
		ESL	21.8	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2
		ENL	281.4	330.0	330.2	330.3	330.3	330.4	330.4	330.4	330.4	330.4	330.4
(6)	16.5	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	440.6	910.4	910.6	910.6	910.6	910.6	910.6	910.6	910.6	910.7	910.7
		ESL	21.8	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2
		ENL	281.4	330.0	330.2	330.3	330.3	330.3	330.3	330.3	330.2	330.4	330.4
(7)	17.6	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	440.6	910.4	910.6	910.6	910.6	910.6	910.6	910.6	910.6	910.7	910.7
		ESL	21.8	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.2
		ENL	281.4	330.0	330.2	330.3	330.3	330.3	330.3	330.3	330.3	330.4	330.4
(8)	18.7	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	441.2	910.4	910.6	910.6	910.6	910.7	910.7	910.7	910.7	910.7	910.7
		ESL	21.8	25.2	25.2	25.2	25.2	24.7	24.7	24.7	24.7	24.7	24.7
		ENL	281.5	330.0	330.2	330.2	330.3	329.3	329.4	329.4	329.4	329.4	329.4
(9)	19.8	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	441.2	910.4	910.6	910.6	910.6	910.7	910.7	910.7	910.7	910.7	910.7
		ESL	21.8	25.2	25.2	25.2	25.2	24.7	24.7	24.7	24.7	24.7	24.7
		ENL	281.5	330.0	330.2	330.2	330.3	329.3	329.4	329.4	329.4	329.4	329.4
(10)	20.9	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	441.2	910.4	910.6	910.6	910.7	910.7	910.7	910.7	910.7	910.7	910.7
		ESL	21.8	25.2	25.2	25.2	25.2	24.7	24.7	24.7	24.7	24.7	24.7
		ENL	281.5	330.0	330.2	330.2	330.3	329.3	329.3	329.3	329.3	329.3	329.4
(11)	22.0	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	441.2	910.4	910.6	911.1	911.2	911.2	911.3	911.3	911.3	911.3	911.3
		ESL	21.8	25.2	25.2	25.1	25.1	25.1	25.1	25.1	25.1	25.1	25.1
		ENL	281.5	330.0	330.2	331.2	331.2	331.3	331.3	331.3	331.3	331.3	331.3

Appendix D.5 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 year planning period (Continued)

IPOTM = 62.3 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	859.4	859.4	859.4	859.4	859.4	859.4	859.4	859.4	859.4	859.4
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	281.4	297.4	297.4	297.4	297.4	297.4	297.4	297.4	297.4	297.4	297.4
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	859.4	859.4	859.5	859.5	859.5	859.5	859.5	859.5	859.5	859.5
		ESL	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8	21.8
		ENL	281.4	297.4	297.4	297.6	297.6	297.6	297.6	297.6	297.6	297.6	297.6
(3)	13.2	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	859.7	859.9	859.9	859.9	859.9	859.9	859.9	859.9	859.9	859.9
		ESL	21.8	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
		ENL	281.4	301.7	302.0	301.9	301.9	301.9	301.9	301.9	301.9	301.9	301.9
(4)	14.3	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	859.7	860.1	860.2	860.2	860.2	860.2	860.2	860.2	860.2	860.2
		ESL	21.8	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
		ENL	281.4	301.7	301.9	302.1	302.1	302.3	302.3	302.3	302.3	302.3	302.3
(5)	15.4	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	860.2	860.4	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5
		ESL	21.8	22.4	22.4	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
		ENL	281.4	304.7	304.9	305.1	305.1	305.2	305.2	305.2	305.2	305.2	305.2
(6)	16.5	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	860.2	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5
		ESL	21.8	22.4	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
		ENL	281.4	304.7	305.0	305.1	305.1	305.1	305.1	305.1	305.0	305.2	305.2
(7)	17.6	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	490.4	860.2	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5
		ESL	21.8	22.4	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
		ENL	281.4	304.7	305.0	305.1	305.1	305.1	305.1	305.1	305.2	305.2	305.2
(8)	18.7	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	491.0	860.2	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.6
		ESL	21.8	22.4	22.5	22.5	22.5	22.2	22.2	22.2	22.2	22.2	22.2
		ENL	281.5	304.7	305.0	305.0	305.1	304.6	304.7	304.7	304.7	304.7	304.7
(9)	19.8	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	491.0	860.2	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.5	860.6
		ESL	21.8	22.4	22.5	22.5	22.5	22.2	22.2	22.2	22.2	22.2	22.2
		ENL	281.5	304.7	305.0	305.0	305.1	304.6	304.7	304.7	304.7	304.7	304.7
(10)	20.9	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	491.0	860.2	860.5	860.5	860.5	860.6	860.6	860.6	860.6	860.6	860.6
		ESL	21.8	22.4	22.5	22.5	22.5	22.2	22.2	22.2	22.2	22.2	22.2
		ENL	281.5	304.7	305.0	305.0	305.1	304.6	304.6	304.6	304.6	304.6	304.7
(11)	22.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	491.0	860.2	860.5	860.8	860.8	860.9	860.9	860.9	860.9	860.9	860.9
		ESL	21.8	22.4	22.5	22.6	22.6	22.6	22.6	22.6	22.6	22.6	22.6
		ENL	281.5	304.7	305.0	307.5	307.6	307.6	307.7	307.7	307.7	307.7	307.7

Appendix D.6 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 30 Percent Increasing Commercial Nitrogen Price

IPOTM = 35.6 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	436.2	442.8	442.8	442.8	442.8	442.8	442.8	442.8	442.8	442.8
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	436.2	442.8	442.8	442.8	442.8	442.8	442.8	442.8	442.8	442.8
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	140.4	155.4	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9	154.9
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	436.2	442.8	442.9	443.0	443.0	443.0	443.0	443.0	443.0	443.0
		ESL	10.9	10.9	10.9	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
		ENL	140.4	155.4	154.9	170.5	170.5	170.5	170.5	170.5	170.5	170.5	170.5
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	452.7	452.8	452.8	452.9	452.9	452.9	452.9	452.9	452.9	452.9
		ESL	10.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9
		ENL	140.4	152.7	152.8	152.8	152.8	152.8	152.8	152.8	152.8	152.8	152.8
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	452.7	453.2	453.3	453.3	453.3	453.3	453.3	453.3	453.3	453.3
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	153.9	153.9	153.9	153.9	153.9	153.9	153.9
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	452.7	453.2	453.3	453.3	453.3	453.3	453.3	453.3	453.3	453.4
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	154.0	154.0	154.0	154.0	154.0	153.9	154.1
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	301.8	452.7	453.2	453.3	453.3	453.3	453.3	453.3	453.3	453.3	453.4
		ESL	10.9	11.9	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
		ENL	140.4	152.7	153.9	153.9	154.0	154.0	154.0	154.0	154.0	154.0	154.1
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	302.8	452.7	453.2	454.2	454.2	454.2	454.3	454.3	454.3	454.3	454.3
		ESL	10.9	11.9	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	152.9	153.0	153.0	153.0	153.1	153.1	153.1	153.1
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	302.8	452.7	453.2	454.2	454.2	454.2	454.3	454.3	454.3	454.3	454.3
		ESL	10.9	11.9	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	152.9	153.0	153.0	153.0	153.1	153.1	153.1	153.1
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	302.8	452.7	453.2	454.2	454.2	454.3	454.4	454.4	454.4	454.4	454.4
		ESL	10.9	11.9	12.3	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
		ENL	140.5	152.7	153.9	152.9	153.0	153.0	153.0	153.0	153.0	153.0	153.0
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	302.8	452.7	453.2	454.3	454.3	454.4	454.5	454.5	454.5	454.5	454.5
		ESL	10.9	11.9	12.3	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	140.5	152.7	153.9	153.8	153.8	153.9	153.9	153.9	153.9	153.9	153.9

Appendix D.6 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 30 Percent Increasing Commercial Nitrogen Price (Continued)

IPOTN = 44.5 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	186.5	449.4	457.9	457.9	457.9	457.9	457.9	457.9	457.9	457.9	457.9
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	186.5	449.4	457.9	457.9	457.9	457.9	457.9	457.9	457.9	457.9	457.9
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	141.9	159.1	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4	158.4
(3)	13.2	AMS	8	4	4	4	4	4	4	4	4	4	4
		PVENR	186.5	469.7	469.7	469.7	469.7	469.7	469.7	469.7	469.7	469.7	469.7
		ESL	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	141.9	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5	157.5
(4)	14.3	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	186.5	470.6	470.8	470.8	470.8	470.8	470.8	470.8	470.8	470.8	470.8
		ESL	10.9	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	141.9	155.6	155.7	155.7	155.8	155.8	155.8	155.8	155.8	155.8	155.8
(5)	15.4	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	186.5	470.6	471.3	471.4	471.4	471.4	471.4	471.4	471.4	471.4	471.4
		ESL	10.9	12.2	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	155.6	157.1	157.1	157.1	157.1	157.1	157.1	157.1	157.1	157.1
(6)	16.5	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	186.5	470.6	471.3	471.4	471.4	471.4	471.4	471.4	471.4	471.4	471.4
		ESL	10.9	12.2	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	155.6	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.1	157.2
(7)	17.6	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	186.5	470.6	471.3	471.4	471.4	471.4	471.4	471.4	471.4	471.4	471.4
		ESL	10.9	12.2	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	141.9	155.6	157.1	157.1	157.2	157.2	157.2	157.2	157.2	157.2	157.2
(8)	18.7	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	187.5	470.6	471.3	472.5	472.5	472.5	472.6	472.6	472.6	472.6	472.6
		ESL	10.9	12.2	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	155.6	157.1	155.8	155.8	155.8	155.9	155.9	155.9	155.9	155.9
(9)	19.8	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	187.5	470.6	471.3	472.5	472.5	472.5	472.6	472.6	472.6	472.6	472.6
		ESL	10.9	12.2	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	155.6	157.1	155.8	155.8	155.8	155.9	155.9	155.9	155.9	155.9
(10)	20.9	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	187.5	470.6	471.3	472.5	472.5	472.5	472.6	472.6	472.6	472.6	472.6
		ESL	10.9	12.2	12.6	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	142.0	155.6	157.1	155.8	155.8	155.8	155.9	155.9	155.9	155.9	155.9
(11)	22.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	187.5	470.6	471.3	472.6	472.6	472.6	472.7	472.8	472.8	472.8	472.8
		ESL	10.9	12.2	12.6	12.3	12.3	12.3	12.4	12.4	12.4	12.4	12.4
		ENL	142.0	155.6	157.1	156.9	156.9	157.0	157.0	157.0	157.0	157.0	157.0

Appendix D.6 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 30 Percent Increasing Commercial Nitrogen Price (Continued)

IPOTM = 53.4 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	234.0	461.7	471.4	471.4	471.4	471.4	471.4	471.4	471.4	471.4	471.4
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	162.8	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	234.0	461.7	471.4	536.5	536.5	536.5	536.5	536.5	536.5	536.5	536.5
		ESL	10.9	10.9	10.9	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
		ENL	139.4	162.8	162.0	194.5	194.5	194.5	194.5	194.5	194.5	194.5	194.5
(3)	13.2	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	234.0	461.7	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2
		ESL	10.9	10.9	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	162.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	234.0	485.7	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(5)	15.4	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	234.0	485.7	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7	172.7
(6)	16.5	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	234.0	485.7	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.3
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.7	173.0
(7)	17.6	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	234.0	485.7	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.2	552.3
		ESL	10.9	12.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	158.8	172.7	172.7	172.8	172.8	172.8	172.8	172.8	172.9	173.0
(8)	18.7	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	235.0	485.7	552.2	552.4	552.4	552.4	552.5	552.5	552.5	552.5	552.5
		ESL	10.9	12.3	13.0	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
		ENL	139.5	158.8	172.7	176.3	176.4	176.4	176.4	176.5	176.5	176.5	176.5
(9)	19.8	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	235.0	485.7	552.2	552.4	552.4	552.4	552.5	552.5	552.5	552.5	552.5
		ESL	10.9	12.3	13.0	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
		ENL	139.5	158.8	172.7	176.3	176.4	176.4	176.4	176.5	176.5	176.5	176.5
(10)	20.9	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	235.0	485.7	552.2	552.4	552.4	552.5	552.6	552.6	552.6	552.6	552.6
		ESL	10.9	12.3	13.0	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
		ENL	139.5	158.8	172.7	176.3	176.4	176.4	176.4	176.4	176.4	176.4	176.4
(11)	22.0	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	235.0	485.7	552.2	552.4	552.4	552.6	552.6	552.6	552.6	552.6	552.6
		ESL	10.9	12.3	13.0	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
		ENL	139.5	158.8	172.7	176.6	176.6	176.7	176.7	176.7	176.7	176.7	176.7

Appendix D.6 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 30 Percent Increasing Commercial Nitrogen Price (Continued)
IPOTM = 62.3 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	283.7	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	283.7	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	283.7	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5	498.5
		ESL	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	139.4	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1	142.1
(4)	14.3	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	283.7	498.8	499.1	499.1	499.2	499.2	499.2	499.2	499.2	499.2	499.2
		ESL	10.9	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
		ENL	139.4	162.5	162.7	162.7	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(5)	15.4	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	283.7	498.8	499.7	499.9	499.9	499.9	499.9	499.9	499.9	499.9	499.9
		ESL	10.9	12.4	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	162.5	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(6)	16.5	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	283.7	498.8	499.7	499.9	499.9	499.9	499.9	499.9	499.9	499.9	499.9
		ESL	10.9	12.4	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	162.5	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(7)	17.6	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	283.7	498.8	499.7	499.9	499.9	499.9	499.9	499.9	499.9	499.9	499.9
		ESL	10.9	12.4	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	139.4	162.5	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
(8)	18.7	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	284.7	498.8	499.7	501.2	501.2	501.2	501.3	501.3	501.3	501.3	501.3
		ESL	10.9	12.4	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	162.5	164.4	162.7	162.7	162.7	162.8	162.8	162.8	162.8	162.8
(9)	19.8	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	284.7	498.8	499.7	501.2	501.2	501.2	501.3	501.3	501.3	501.3	501.3
		ESL	10.9	12.4	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	162.5	164.4	162.7	162.7	162.7	162.8	162.8	162.8	162.8	162.8
(10)	20.9	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	284.7	498.8	499.7	501.2	501.2	501.2	501.3	501.3	501.3	501.3	501.3
		ESL	10.9	12.4	13.0	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
		ENL	139.5	162.5	164.4	162.7	162.7	162.7	162.8	162.8	162.8	162.8	162.8
(11)	22.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	284.7	498.8	499.7	501.3	501.3	501.3	501.5	501.6	501.6	501.6	501.6
		ESL	10.9	12.4	13.0	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
		ENL	139.5	162.5	164.4	164.1	164.1	164.1	164.2	164.2	164.2	164.2	164.2

Appendix D.7 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Decreasing Crop Prices

IPOTM = 35.6 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	46.6	44.3	44.3	44.3	44.3	44.4	44.4	44.4	44.4	44.4	44.4
		ESL	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
		ENL	140.3	143.5	143.5	143.5	143.5	143.5	143.5	143.5	143.5	143.5	143.5
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	46.6	46.6	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7
		ESL	10.3	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
		ENL	140.3	144.8	144.9	144.9	144.9	144.9	144.9	144.9	144.9	144.9	144.9
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	46.6	61.1	61.1	61.2	61.2	61.2	61.2	61.2	61.2	61.2	61.2
		ESL	10.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	140.3	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7	148.7
(4)	14.3	AMS	15	3	15	15	15	15	15	15	15	15	15
		PVENR	46.6	61.7	71.7	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8
		ESL	10.3	13.1	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
		ENL	140.3	148.9	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
(5)	15.4	AMS	15	3	15	15	15	15	15	15	15	15	15
		PVENR	46.6	61.7	71.7	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9
		ESL	10.3	13.1	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
		ENL	140.3	148.9	156.5	156.6	156.6	156.6	156.6	156.6	156.6	156.6	156.6
(6)	16.5	AMS	15	3	3	3	3	3	3	3	3	3	3
		PVENR	46.6	61.7	86.3	86.3	86.3	86.3	86.3	86.3	86.3	86.3	86.3
		ESL	10.3	13.1	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8
		ENL	140.3	148.9	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(7)	17.6	AMS	15	3	3	3	3	3	3	3	3	3	3
		PVENR	46.6	61.7	86.3	86.3	86.3	86.3	86.3	86.3	86.3	86.3	86.3
		ESL	10.3	13.1	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8
		ENL	140.3	148.9	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8	162.8
(8)	18.7	AMS	15	3	3	3	3	3	3	3	3	3	3
		PVENR	46.6	61.9	86.6	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8
		ESL	10.3	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	140.3	149.0	163.2	178.5	178.5	178.5	178.5	178.5	178.5	178.5	178.5
(9)	19.8	AMS	15	3	3	3	3	3	3	3	3	3	3
		PVENR	46.6	61.9	86.6	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8
		ESL	10.3	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	140.3	149.0	163.2	178.5	178.5	178.5	178.5	178.5	178.5	178.5	178.5
(10)	20.9	AMS	15	3	3	3	3	3	3	3	3	3	3
		PVENR	46.6	61.9	86.6	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8
		ESL	10.3	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	140.3	149.0	163.2	178.5	178.5	178.5	178.5	178.5	178.5	178.5	178.5
(11)	22.0	AMS	15	3	3	3	3	3	3	3	3	3	3
		PVENR	46.6	61.9	86.6	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8
		ESL	10.3	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	140.3	149.0	163.2	178.5	178.5	178.5	178.5	178.5	178.5	178.5	178.5

Appendix D.7 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Decreasing Crop Prices (Continued)

IPOTM = 44.5 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	0	15	15	15	15	15	15	15	15	15	15
		PVENR	26.3	57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0
		ESL	7.4	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1	10.1
		ENL	124.9	143.7	143.7	143.7	143.7	143.8	143.8	143.8	143.8	143.8	143.8
(2)	12.1	AMS	0	15	15	15	15	15	15	15	15	15	15
		PVENR	26.3	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1	58.1
		ESL	7.4	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
		ENL	124.9	144.4	144.4	144.4	144.4	144.5	144.5	144.5	144.5	144.5	144.5
(3)	13.2	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	97.2	97.2	97.2	97.2	97.2	97.2	97.2	97.2	97.2	97.2
		ESL	7.4	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
		ENL	124.9	162.3	162.3	162.3	162.3	162.3	162.3	162.3	162.3	162.3	162.3
(4)	14.3	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0
		ESL	7.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
		ENL	124.9	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6
(5)	15.4	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0	98.0
		ESL	7.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
		ENL	124.9	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6	162.6
(6)	16.5	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8
		ESL	7.4	13.2	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
		ENL	124.9	162.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6
(7)	17.6	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8	125.8
		ESL	7.4	13.2	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
		ENL	124.9	162.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6	178.6
(8)	18.7	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	126.1	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4
		ESL	7.4	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	124.9	162.6	178.9	194.3	194.3	194.3	194.3	194.3	194.3	194.3	194.3
(9)	19.8	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	126.1	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4
		ESL	7.4	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	124.9	162.6	178.9	194.3	194.3	194.3	194.3	194.3	194.3	194.3	194.3
(10)	20.9	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	126.1	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4
		ESL	7.4	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	124.9	162.6	178.9	194.3	194.3	194.3	194.3	194.3	194.3	194.3	194.3
(11)	22.0	AMS	0	3	3	3	3	3	3	3	3	3	3
		PVENR	26.3	98.0	126.1	147.4	147.4	147.4	147.4	147.4	147.4	147.4	147.4
		ESL	7.4	13.2	16.0	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
		ENL	124.9	162.6	178.9	194.3	194.3	194.3	194.3	194.3	194.3	194.3	194.3

Appendix D.7 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Decreasing Crop Prices (Continued)

IPOTM = 53.4 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	22.9	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0	68.0
		ESL	8.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		ENL	128.5	145.4	145.4	145.4	145.4	145.4	145.4	145.4	145.4	145.4	145.4
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	22.9	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4
		ESL	8.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		ENL	128.5	145.6	145.6	145.6	145.6	145.6	145.6	145.6	145.6	145.6	145.6
(3)	13.2	AMS	8	15	3	2	2	2	2	2	2	2	2
		PVENR	22.9	68.4	130.4	130.5	130.5	130.5	130.5	130.5	130.5	130.5	130.5
		ESL	8.5	10.0	13.0	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
		ENL	128.5	145.6	175.4	201.3	201.3	201.3	201.3	201.3	201.3	201.3	201.3
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	22.9	68.4	145.1	145.1	145.1	145.1	145.1	145.1	145.1	145.1	145.1
		ESL	8.5	10.0	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
		ENL	128.5	145.6	176.7	176.7	176.7	176.7	176.7	176.7	176.7	176.7	176.7
(5)	15.4	AMS	8	15	2	2	2	2	2	2	2	2	2
		PVENR	22.9	68.4	160.2	160.2	160.2	160.2	160.2	160.2	160.2	160.2	160.2
		ESL	8.5	10.0	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
		ENL	128.5	145.6	218.2	218.2	218.2	218.2	218.2	218.2	218.2	218.2	218.2
(6)	16.5	AMS	8	15	2	4	4	4	4	4	4	4	4
		PVENR	22.9	68.4	160.2	180.7	180.7	180.7	180.7	180.7	180.7	174.7	174.7
		ESL	8.5	10.0	15.4	16.4	16.4	16.4	16.4	16.4	16.4	16.1	16.1
		ENL	128.5	145.6	218.2	196.5	196.5	196.5	196.5	196.5	196.5	192.9	192.9
(7)	17.6	AMS	8	15	2	4	4	4	4	4	4	2	2
		PVENR	22.9	68.4	160.2	180.7	180.7	180.7	180.7	180.7	180.7	162.8	162.8
		ESL	8.5	10.0	15.4	16.4	16.4	16.4	16.4	16.4	16.4	17.3	17.3
		ENL	128.5	145.6	218.2	196.5	196.5	196.5	196.5	196.5	196.5	256.1	256.1
(8)	18.7	AMS	8	15	2	3	3	2	2	2	2	2	2
		PVENR	22.9	68.4	160.2	181.8	181.8	181.8	181.8	181.8	181.8	181.8	181.8
		ESL	8.5	10.0	15.4	18.6	18.6	18.1	18.1	18.1	18.1	18.1	18.1
		ENL	128.5	145.6	218.2	208.1	208.1	234.0	234.0	234.0	234.0	234.0	234.0
(9)	19.8	AMS	8	15	2	3	4	4	4	4	4	4	4
		PVENR	22.9	68.4	160.2	181.8	202.3	202.3	202.3	202.3	202.3	202.3	202.3
		ESL	8.5	10.0	15.4	18.6	19.2	19.2	19.2	19.2	19.2	19.2	19.2
		ENL	128.5	145.6	218.2	208.1	212.3	212.3	212.3	212.3	212.3	212.3	212.3
(10)	20.9	AMS	8	15	2	3	4	4	4	4	4	4	4
		PVENR	22.9	68.4	160.2	181.8	202.3	202.3	202.3	202.3	202.3	202.3	202.3
		ESL	8.5	10.0	15.4	18.6	19.2	19.2	19.2	19.2	19.2	19.2	19.2
		ENL	128.5	145.6	218.2	208.1	212.3	212.3	212.3	212.3	212.3	212.3	212.3
(11)	22.0	AMS	8	15	2	3	4	4	4	4	4	4	4
		PVENR	22.9	68.4	160.2	181.8	202.3	202.3	202.3	202.3	202.3	202.3	202.3
		ESL	8.5	10.0	15.4	18.6	19.2	19.2	19.2	19.2	19.2	19.2	19.2
		ENL	128.5	145.6	218.2	208.1	212.3	212.3	212.3	212.3	212.3	212.3	212.3

Appendix D.7 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Decreasing Crop Prices (Continued)

IPOTM = 62.3 (lb/ac)

E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
			E2 (lb/ac)										
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	81.9	81.9	81.9	81.9	82.0	82.0	82.0	82.0	82.0	82.0
		ESL	8.5	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		ENL	128.5	142.1	142.1	142.1	142.1	142.3	142.3	142.3	142.3	142.3	142.3
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3
		ESL	8.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
		ENL	128.5	148.9	148.9	148.9	148.9	148.9	148.9	148.9	148.9	148.9	148.9
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3	94.3
		ESL	8.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5
		ENL	128.5	148.9	148.9	148.9	148.9	148.9	148.9	148.9	148.9	148.9	148.9
(4)	14.3	AMS	8	8	6	6	6	6	6	6	6	6	6
		PVENR	61.3	95.2	108.6	108.9	108.9	108.9	108.9	108.9	108.9	108.9	108.9
		ESL	8.5	11.7	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
		ENL	128.5	149.2	166.1	166.3	166.3	166.5	166.5	166.5	166.5	166.5	166.5
(5)	15.4	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.1	124.1	124.1	124.1	124.1	124.1	124.1	124.1	124.1
		ESL	8.5	11.7	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3
		ENL	128.5	149.2	165.9	165.9	165.9	165.9	165.9	165.9	165.9	165.9	165.9
(6)	16.5	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.1	124.1	124.1	124.1	124.1	124.1	124.1	124.1	124.1
		ESL	8.5	11.7	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3
		ENL	128.5	149.2	165.9	165.9	165.9	165.9	165.9	165.9	165.9	165.9	165.9
(7)	17.6	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.1	124.1	124.1	124.1	124.1	124.1	124.1	126.7	126.7
		ESL	8.5	11.7	14.3	14.3	14.3	14.3	14.3	14.3	14.3	16.2	16.2
		ENL	128.5	149.2	165.9	165.9	165.9	165.9	165.9	165.9	165.9	203.8	203.8
(8)	18.7	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.4	145.7	145.7	145.7	145.7	145.7	145.7	145.7	145.7
		ESL	8.5	11.7	14.5	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
		ENL	128.5	149.2	166.2	181.7	181.7	181.7	181.7	181.7	181.7	181.7	181.7
(9)	19.8	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.4	145.7	145.7	145.7	145.7	145.7	145.7	145.7	145.7
		ESL	8.5	11.7	14.5	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
		ENL	128.5	149.2	166.2	181.7	181.7	181.7	181.7	181.7	181.7	181.7	181.7
(10)	20.9	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.4	145.7	145.7	145.7	145.7	145.7	145.7	145.7	145.7
		ESL	8.5	11.7	14.5	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
		ENL	128.5	149.2	166.2	181.7	181.7	181.7	181.7	181.7	181.7	181.7	181.7
(11)	22.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	61.3	95.2	124.4	145.7	145.7	145.7	145.7	145.7	145.7	145.7	145.7
		ESL	8.5	11.7	14.5	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
		ENL	128.5	149.2	166.2	181.7	181.7	181.7	181.7	181.7	181.7	181.7	181.7

Appendix D.8 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Increasing Crop Prices (Continued)

IPOTM = 35.6 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.51	(2) 165.22	(3) 187.94	(4) 210.65	(5) 233.36	(6) 256.07	(7) 278.79	(8) 301.50	(9) 324.21	(10) 346.92	(11) 369.64
(1)	11	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	970.06	978.34	978.34	978.34	978.34	978.34	978.34	978.34	978.34	978.34
		SL	10.87	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	970.06	978.34	978.34	978.34	978.34	978.34	978.34	978.34	978.34	978.34
		SL	10.87	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	970.06	978.34	980.36	980.58	980.58	980.58	980.58	980.58	980.58	980.58
		SL	10.87	10.9	10.9	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58
		NL	140.35	155.44	154.89	170.45	170.55	170.55	170.55	170.55	170.55	170.55	170.55
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	975.58	978.41	980.43	980.58	980.58	980.58	980.58	980.58	980.58	980.58
		SL	10.87	11.89	10.9	11.59	11.58	11.58	11.58	11.58	11.58	11.58	11.58
		NL	140.35	152.68	154.91	170.47	170.55	170.55	170.55	170.55	170.55	170.55	170.55
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	975.58	984.22	984.37	984.37	984.37	984.37	984.37	984.37	984.37	984.37
		SL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
		NL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	153.90	153.90
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	975.58	984.22	984.37	984.37	984.37	984.37	984.37	984.37	985.81	985.88
		SL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.47
		NL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	167.39	167.58
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	806.19	975.58	984.22	984.37	984.37	984.37	984.37	984.37	984.37	985.81	985.88
		SL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.47
		NL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	167.39	167.58
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	808.45	975.58	984.22	984.37	984.37	984.37	984.37	984.42	984.42	985.88	985.94
		SL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.48
		NL	140.47	152.68	153.89	153.90	153.90	153.90	153.90	154.04	154.04	167.45	167.65
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	808.45	975.58	984.22	984.37	984.37	984.37	984.37	984.42	984.42	985.95	985.95
		SL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.48	11.48
		NL	140.47	152.68	153.89	153.90	153.90	153.90	153.90	154.04	154.04	167.60	167.60
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	808.45	975.58	984.22	984.37	984.37	984.43	984.43	984.43	984.43	985.95	985.95
		SL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.48	11.48
		NL	140.47	152.68	153.89	153.90	153.90	153.99	153.99	153.99	153.99	167.60	167.60
(11)	22	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	808.45	975.58	984.22	988.03	988.03	988.11	988.17	988.27	988.27	988.27	988.27
		SL	10.93	11.89	12.25	12.02	12.02	12.03	12.03	12.03	12.03	12.03	12.03
		NL	140.47	152.68	153.89	153.69	153.69	153.77	153.83	153.84	153.84	153.84	153.84

Appendix D.8 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Increasing Crop Prices (Continued)
IPOTN = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.51	(2) 165.22	(3) 187.94	(4) 210.65	(5) 233.36	(6) 256.07	(7) 278.79	(8) 301.50	(9) 324.21	(10) 346.92	(11) 369.64
(1)	11	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	666.17	986.30	996.91	996.91	996.91	996.91	996.91	996.91	996.91	996.91	996.91
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	141.88	159.11	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	666.17	986.30	996.91	996.91	996.91	996.91	996.91	996.91	996.91	996.91	996.91
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	141.88	159.11	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40
(3)	13.2	AMS	8	4	4	15	15	15	15	15	15	15	15
		PVENR	666.17	997.62	997.62	999.50	999.78	999.78	999.78	999.78	999.78	999.78	999.78
		SL	10.88	13	13	11.77	11.78	11.78	11.78	11.78	11.78	11.78	11.78
		NL	141.88	157.48	157.48	178.35	178.47	178.47	178.47	178.47	178.47	178.47	178.47
(4)	14.3	AMS	8	4	4	15	15	15	15	15	15	15	15
		PVENR	666.17	997.62	997.62	999.60	999.78	999.78	999.78	999.78	999.78	999.78	999.78
		SL	10.88	13	13	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78
		NL	141.88	157.48	157.48	178.38	178.47	178.47	178.47	178.47	178.47	178.47	178.47
(5)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	666.17	997.62	1004.45	1004.64	1004.64	1004.64	1004.64	1004.64	1004.64	1004.64	1004.64
		SL	10.88	13	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64
		NL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	157.14	157.14
(6)	16.5	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	666.17	997.62	1004.45	1004.64	1004.64	1004.64	1004.64	1004.64	1004.64	1006.49	1006.52
		SL	10.88	13	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.63	11.63
		NL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	174.42	174.52
(7)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	666.17	997.62	1004.45	1004.64	1004.64	1004.64	1004.64	1004.64	1004.64	1006.49	1006.52
		SL	10.88	13	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.63	11.63
		NL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	174.42	174.52
(8)	18.7	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	668.38	997.62	1004.45	1004.64	1004.64	1004.64	1004.64	1004.66	1004.66	1006.57	1006.61
		SL	10.93	13	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.63	11.63
		NL	141.98	157.48	157.13	157.14	157.14	157.14	157.14	157.21	157.21	174.50	174.60
(9)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	668.38	997.62	1004.45	1004.64	1004.64	1004.64	1004.64	1004.66	1004.66	1006.61	1006.61
		SL	10.93	13	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.64	11.64
		NL	141.98	157.48	157.13	157.14	157.14	157.14	157.14	157.21	157.21	174.57	174.57
(10)	20.9	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	668.38	997.62	1004.45	1004.64	1004.64	1004.67	1004.67	1004.67	1004.67	1006.61	1006.61
		SL	10.93	13	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.64	11.64
		NL	141.98	157.48	157.13	157.14	157.14	157.18	157.18	157.18	157.18	174.57	174.57
(11)	22	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	668.38	997.62	1004.45	1009.33	1009.33	1009.37	1009.46	1009.58	1009.58	1009.58	1009.58
		SL	10.93	13	12.64	12.33	12.33	12.34	12.34	12.34	12.34	12.34	12.34
		NL	141.98	157.48	157.13	156.86	156.86	156.90	156.98	156.99	156.99	156.99	156.99

Appendix D.8 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Increasing Crop Prices (Continued)
IPOTM = 53.4 (lb/ac)
E2 (lb/ac)

E3 (ton/ac)			(1) 142.51	(2) 165.22	(3) 187.94	(4) 210.65	(5) 233.36	(6) 256.07	(7) 278.79	(8) 301.50	(9) 324.21	(10) 346.92	(11) 369.64
(1)	11	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	724.56	1001.44	1013.47	1013.47	1013.47	1013.47	1013.47	1013.47	1013.47	1013.47	1013.47
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	139.41	162.78	161.98	161.98	161.98	161.98	161.98	161.98	161.98	161.98	161.98
(2)	12.1	AMS	8	15	15	2	2	2	2	2	2	2	2
		PVENR	724.56	1001.44	1013.47	1097.39	1097.39	1097.39	1097.39	1097.39	1097.39	1097.39	1097.39
		SL	10.88	10.9	10.9	11.96	11.96	11.96	11.96	11.96	11.96	11.96	11.96
		NL	139.41	162.78	161.98	194.46	194.46	194.46	194.46	194.46	194.46	194.46	194.46
(3)	13.2	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	724.56	1001.44	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17
		SL	10.88	10.9	13	13	13	13	13	13	13	13	13
		NL	139.41	162.78	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72
(4)	14.3	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	724.56	1009.46	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17
		SL	10.88	12.34	13	13	13	13	13	13	13	13	13
		NL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72
(5)	15.4	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	724.56	1009.46	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17
		SL	10.88	12.34	13	13	13	13	13	13	13	13	13
		NL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72
(6)	16.5	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	724.56	1009.46	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.28
		SL	10.88	12.34	13	13	13	13	13	13	13	13	13.01
		NL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	173.03
(7)	17.6	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	724.56	1009.46	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.17	1099.28
		SL	10.88	12.34	13	13	13	13	13	13	13	13	13.01
		NL	139.41	158.77	172.72	172.72	172.72	172.72	172.72	172.72	172.72	172.72	173.03
(8)	18.7	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	726.76	1009.46	1099.17	1099.17	1099.17	1099.17	1099.17	1099.26	1099.26	1099.17	1099.28
		SL	10.93	12.34	13	13	13	13	13	13.01	13.01	13	13.01
		NL	139.52	158.77	172.72	172.72	172.72	172.72	172.72	172.94	172.94	172.72	173.03
(9)	19.8	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	726.76	1009.46	1099.17	1099.17	1099.17	1099.17	1099.17	1099.26	1099.26	1099.28	1099.28
		SL	10.93	12.34	13	13	13	13	13	13.01	13.01	13.01	13.01
		NL	139.52	158.77	172.72	172.72	172.72	172.72	172.72	172.94	172.94	172.95	172.95
(10)	20.9	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	726.76	1009.46	1099.17	1099.17	1099.17	1099.26	1099.26	1099.26	1099.26	1099.28	1099.28
		SL	10.93	12.34	13	13	13	13.01	13.01	13.01	13.01	13.01	13.01
		NL	139.52	158.77	172.72	172.72	172.72	172.86	172.86	172.86	172.86	172.95	172.95
(11)	22	AMS	8	15	4	4	4	4	4	4	4	4	4
		PVENR	726.76	1009.46	1099.17	1099.17	1099.17	1099.30	1099.30	1099.30	1099.30	1099.30	1099.30
		SL	10.93	12.34	13	13	13	13.02	13.02	13.02	13.02	13.02	13.02
		NL	139.52	158.77	172.72	172.72	172.72	172.86	172.86	172.86	172.86	172.86	172.86

Appendix D.8 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with a 20 Percent Increasing Crop Prices (Continued)

IPOTM = 62.3 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.51	(2) 165.22	(3) 187.94	(4) 210.65	(5) 233.36	(6) 256.07	(7) 278.79	(8) 301.50	(9) 324.21	(10) 346.92	(11) 369.64
(1)	11	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(4)	14.3	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(5)	15.4	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(6)	16.5	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.42
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.91
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.43
(7)	17.6	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	785.66	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.42
		SL	10.88	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.91
		NL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.43
(8)	18.7	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	787.86	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.40	1048.40	1048.32	1048.42
		SL	10.93	10.9	10.9	10.9	10.9	10.9	10.9	10.91	10.91	10.9	10.91
		NL	139.52	142.11	142.11	142.11	142.11	142.11	142.11	142.32	142.32	142.11	142.43
(9)	19.8	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	787.86	1048.32	1048.32	1048.32	1048.32	1048.32	1048.32	1048.40	1048.40	1048.43	1048.43
		SL	10.93	10.9	10.9	10.9	10.9	10.9	10.9	10.91	10.91	10.91	10.91
		NL	139.52	142.11	142.11	142.11	142.11	142.11	142.11	142.32	142.32	142.34	142.34
(10)	20.9	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	787.86	1048.32	1048.32	1048.32	1048.32	1048.40	1048.40	1048.40	1048.40	1048.43	1048.43
		SL	10.93	10.9	10.9	10.9	10.9	10.91	10.91	10.91	10.91	10.91	10.91
		NL	139.52	142.11	142.11	142.11	142.11	142.24	142.24	142.24	142.24	142.34	142.34
(11)	22	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	787.86	1048.32	1048.32	1048.32	1048.32	1048.44	1048.44	1048.44	1048.44	1048.44	1048.44
		SL	10.93	10.9	10.9	10.9	10.9	10.92	10.92	10.92	10.92	10.92	10.92
		NL	139.52	142.11	142.11	142.11	142.11	142.25	142.25	142.25	142.25	142.25	142.25

Appendix D.9 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with the Price Impacts of Commodoty Program

IPOTM = 35.6 (lb/ac)

E3 (ton/ac)			E2 (lb/ac)										
			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	858.47	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74
		ESL	26.00	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	858.47	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74
		ESL	10.87	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	858.47	866.74	868.77	868.98	868.98	868.98	868.98	868.98	868.98	868.98
		ESL	10.87	10.90	10.90	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58
		ENL	140.35	155.44	154.89	170.45	170.55	170.55	170.55	170.55	170.55	170.55	170.55
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	866.81	868.84	868.98	868.98	868.98	868.98	868.98	868.98	868.98
		ESL	10.87	11.89	10.90	11.59	11.58	11.58	11.58	11.58	11.58	11.58	11.58
		ENL	140.35	152.68	154.91	170.47	170.55	170.55	170.55	170.55	170.55	170.55	170.55
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	872.62	872.77	872.77	872.77	872.77	872.77	872.77	872.77	872.77
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	153.90	153.90
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	872.62	872.77	872.77	872.77	872.77	872.77	872.77	874.21	874.28
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.47
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	167.39	167.58
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	872.62	872.77	872.77	872.77	872.77	872.77	872.77	874.21	874.28
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.47
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	167.39	167.58
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	872.77	872.77	872.77	872.77	872.83	872.83	874.28	874.35
		ESL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.48
		ENL	140.47	152.68	153.89	153.90	153.90	153.90	153.90	154.04	154.04	167.45	167.65
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	872.77	872.77	872.77	872.77	872.83	872.83	874.35	874.35
		ESL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.48	11.48
		ENL	140.47	152.68	153.89	153.90	153.90	153.90	153.90	154.04	154.04	167.60	167.60
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	872.77	872.77	872.83	872.83	872.83	872.83	874.35	874.35
		ESL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.48	11.48
		ENL	140.47	152.68	153.89	153.90	153.90	153.99	153.99	153.99	153.99	167.60	167.60
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	876.43	876.43	876.51	876.58	876.68	876.68	876.68	876.68
		ESL	10.93	11.89	12.25	12.02	12.02	12.03	12.03	12.03	12.03	12.03	12.03
		ENL	140.47	152.68	153.89	153.69	153.69	153.77	153.83	153.84	153.84	153.84	153.84

Appendix D.9 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with the Price Impacts of Commodoty Program (Continued)

IPOTM = 44.5 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	554.94	874.71	885.31	885.31	885.31	885.31	885.31	885.31	885.31	885.31	885.31
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	141.88	159.11	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40
(2)	12.1	AMS	8	15	15	15	15	15	15	15	15	15	15
		PVENR	554.94	874.71	885.31	885.31	885.31	885.31	885.31	885.31	885.31	885.31	885.31
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	141.88	159.11	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40	158.40
(3)	13.2	AMS	8	4	4	15	15	15	15	15	15	15	15
		PVENR	554.94	886.02	886.02	887.91	888.19	888.19	888.19	888.19	888.19	888.19	888.19
		ESL	10.88	13.00	13.00	11.77	11.78	11.78	11.78	11.78	11.78	11.78	11.78
		ENL	141.88	157.48	157.48	178.35	178.47	178.47	178.47	178.47	178.47	178.47	178.47
(4)	14.3	AMS	8	4	4	15	15	15	15	15	15	15	15
		PVENR	554.94	886.02	886.02	888.00	888.19	888.19	888.19	888.19	888.19	888.19	888.19
		ESL	10.88	13.00	13.00	11.78	11.78	11.78	11.78	11.78	11.78	11.78	11.78
		ENL	141.88	157.48	157.48	178.38	178.47	178.47	178.47	178.47	178.47	178.47	178.47
(5)	15.4	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	554.94	886.02	892.85	893.04	893.04	893.04	893.04	893.04	893.04	893.04	893.04
		ESL	10.88	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64	12.64
		ENL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	157.14	157.14
(6)	16.5	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	554.94	886.02	892.85	893.04	893.04	893.04	893.04	893.04	893.04	894.89	894.93
		ESL	10.88	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.63	11.63
		ENL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	174.42	174.52
(7)	17.6	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	554.94	886.02	892.85	893.04	893.04	893.04	893.04	893.04	893.04	894.89	894.93
		ESL	10.88	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.63	11.63
		ENL	141.88	157.48	157.13	157.14	157.14	157.14	157.14	157.14	157.14	174.42	174.52
(8)	18.7	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	556.79	886.02	892.85	893.04	893.04	893.04	893.04	893.07	893.07	894.98	895.01
		ESL	10.93	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.63	11.63
		ENL	141.98	157.48	157.13	157.14	157.14	157.14	157.14	157.21	157.21	174.50	174.60
(9)	19.8	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	556.79	886.02	892.85	893.04	893.04	893.04	893.04	893.07	893.07	895.01	895.01
		ESL	10.93	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.64	11.64
		ENL	141.98	157.48	157.13	157.14	157.14	157.14	157.14	157.21	157.21	174.57	174.57
(10)	20.9	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	556.79	886.02	892.85	893.04	893.04	893.07	893.07	893.07	893.07	895.01	895.01
		ESL	10.93	13.00	12.64	12.64	12.64	12.64	12.64	12.64	12.64	11.64	11.64
		ENL	141.98	157.48	157.13	157.14	157.14	157.18	157.18	157.18	157.18	174.57	174.57
(11)	22.0	AMS	8	4	15	15	15	15	15	15	15	15	15
		PVENR	556.79	886.02	892.85	897.74	897.74	897.78	897.86	897.99	897.99	897.99	897.99
		ESL	10.93	13.00	12.64	12.33	12.33	12.34	12.34	12.34	12.34	12.34	12.34
		ENL	141.98	157.48	157.13	156.86	156.86	156.90	156.98	156.99	156.99	156.99	156.99

Appendix D.9 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with the Price Impacts of Commodoty Program (Continued)
IPOTM = 53.4 (lb/ac)

E3 (ton/ac)			E2 (lb/ac) (1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	858.47	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74
		ESL	10.87	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(2)	12.1	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	858.47	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74	866.74
		ESL	10.87	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	140.35	155.44	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89	154.89
(3)	13.2	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	858.47	866.74	868.77	868.98	868.98	868.98	868.98	868.98	868.98	868.98
		ESL	10.87	10.90	10.90	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58
		ENL	140.35	155.44	154.89	170.45	170.55	170.55	170.55	170.55	170.55	170.55	170.55
(4)	14.3	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	866.81	868.84	868.98	868.98	868.98	868.98	868.98	868.98	868.98
		ESL	10.87	11.89	10.90	11.59	11.58	11.58	11.58	11.58	11.58	11.58	11.58
		ENL	140.35	152.68	154.91	170.47	170.55	170.55	170.55	170.55	170.55	170.55	170.55
(5)	15.4	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	872.62	872.77	872.77	872.77	872.77	872.77	872.77	872.77	872.77
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	12.26	12.26
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	153.90	153.90
(6)	16.5	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	872.62	872.77	872.77	872.77	872.77	872.77	872.77	874.21	874.28
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.47
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	167.39	167.58
(7)	17.6	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	694.97	863.98	872.62	872.77	872.77	872.77	872.77	872.77	872.77	874.21	874.28
		ESL	10.87	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.47
		ENL	140.35	152.68	153.89	153.90	153.90	153.90	153.90	153.90	153.90	167.39	167.58
(8)	18.7	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	872.77	872.77	872.77	872.77	872.83	872.83	874.28	874.35
		ESL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.47	11.48
		ENL	140.47	152.68	153.89	153.90	153.90	153.90	153.90	154.04	154.04	167.45	167.65
(9)	19.8	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	872.77	872.77	872.77	872.77	872.83	872.83	874.35	874.35
		ESL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.48	11.48
		ENL	140.47	152.68	153.89	153.90	153.90	153.90	153.90	154.04	154.04	167.60	167.60
(10)	20.9	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	872.77	872.77	872.83	872.83	872.83	872.83	874.35	874.35
		ESL	10.93	11.89	12.25	12.26	12.26	12.26	12.26	12.26	12.26	11.48	11.48
		ENL	140.47	152.68	153.89	153.90	153.90	153.99	153.99	153.99	153.99	167.60	167.60
(11)	22.0	AMS	15	15	15	15	15	15	15	15	15	15	15
		PVENR	696.85	863.98	872.62	876.43	876.43	876.51	876.58	876.68	876.68	876.68	876.68
		ESL	10.93	11.89	12.25	12.02	12.02	12.03	12.03	12.03	12.03	12.03	12.03
		ENL	140.47	152.68	153.89	153.69	153.69	153.77	153.83	153.84	153.84	153.84	153.84

Appendix D.9 Optimal Decision (AMS), Present Value of Expected Net Return (PVENR), and Expected Nitrate Leaching (ENL) and Soil Loss (ESL) with the Price Impacts of Commodoty Program (Continued)

IPOTM = 62.3 (lb/ac)

			E2 (lb/ac)										
E3 (ton/ac)			(1) 142.5	(2) 165.2	(3) 187.9	(4) 210.6	(5) 233.4	(6) 256.1	(7) 278.8	(8) 301.5	(9) 324.2	(10) 346.9	(11) 369.6
(1)	11.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(2)	12.1	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(3)	13.2	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(4)	14.3	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(5)	15.4	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11
(6)	16.5	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.83
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.91
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.43
(7)	17.6	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	674.43	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.72	936.83
		ESL	10.88	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.90	10.91
		ENL	139.41	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.11	142.43
(8)	18.7	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	676.27	936.72	936.72	936.72	936.72	936.72	936.72	936.81	936.81	936.72	936.83
		ESL	10.93	10.90	10.90	10.90	10.90	10.90	10.90	10.91	10.91	10.90	10.91
		ENL	139.52	142.11	142.11	142.11	142.11	142.11	142.11	142.32	142.32	142.11	142.43
(9)	19.8	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	676.27	936.72	936.72	936.72	936.72	936.72	936.72	936.81	936.81	936.83	936.83
		ESL	10.93	10.90	10.90	10.90	10.90	10.90	10.90	10.91	10.91	10.91	10.91
		ENL	139.52	142.11	142.11	142.11	142.11	142.11	142.11	142.32	142.32	142.34	142.34
(10)	20.9	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	676.27	936.72	936.72	936.72	936.72	936.81	936.81	936.81	936.81	936.83	936.83
		ESL	10.93	10.90	10.90	10.90	10.90	10.91	10.91	10.91	10.91	10.91	10.91
		ENL	139.52	142.11	142.11	142.11	142.11	142.24	142.24	142.24	142.24	142.34	142.34
(11)	22.0	AMS	8	8	8	8	8	8	8	8	8	8	8
		PVENR	676.27	936.72	936.72	936.72	936.72	936.85	936.85	936.85	936.85	936.85	936.85
		ESL	10.93	10.90	10.90	10.90	10.90	10.92	10.92	10.92	10.92	10.92	10.92
		ENL	139.52	142.11	142.11	142.11	142.11	142.25	142.25	142.25	142.25	142.25	142.25

Vita

Minkang Zhu was born on November 17, 1945 in Shanghai, China. After graduating from Hu-Xi High School in Shanghai, China in 1962, he enrolled in the Shanghai Polytechnic Institute, Shanghai, China where he received a Bachelor of Science degree in Mechanical Engineering in 1967. In the twenty years following his graduation, he worked as a machinist, engineer, and lecturer in China. In 1987, He had a chance to continue his education in the Department of Agricultural Economics at Virginia Polytechnic Institute and State University in the United States. He received a Ph.D. degree in Agricultural Economics in January 1992.

Minkang Zhu

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