Risk Analysis of Adopting Conservation Practices on a Representative Peanut-Cotton Farm in Virginia

by

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Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Science

in

Agricultural and Applied Economics

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September 26, 1997

Blacksburg, Virginia, U.S.A.

Keywords: Grain, Expected Utility, Target-MOTAD, Nonpoint Source Pollution

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(ABSTRACT)

The objective of this study is to evaluate the costs of reducing pesticide, nitrogen, phosphorus, and sediment losses of a representative risk-neutral and risk-averse peanut-cotton farmer in Southeast Virginia. Five currently popular rotations and eight alternative conservation rotations are evaluated for the representative farm. The Erosion-Productivity Impact Calculator (EPIC) model is used to simulate pesticide, nitrogen, phosphorus, and soil loss from each rotation using actual rainfall and temperature data from the study area. A Target-MOTAD mathematical programming model, REPVAFARM, is developed and solved with GAMS. The objective of the farmer is to maximize expected net return, while meeting a target income with certain allowable expected shortfall from the income target. The farmer is also constrained by land, labor, peanut quota, and levels of pesticide, nitrogen, phosphorus, and soil losses.

Major findings of this study are: reducing pesticide, nitrogen, phosphorus, and soil losses imposes costs to the farmer regardless of his risk attitude, with costs ranking from high to low in the order of reducing all pollutant losses, reducing nitrogen losses, reducing phosphorus losses, reducing soil losses, and reducing pesticide losses. Costs of reducing pollutant losses are higher for more risk-averse farmers than for less risk-averse and risk-neutral farmers implying that risk-aversion is an obstacle to the adoption of alternative conservation practices. Reducing pesticide losses has little impact on other pollutants. Reducing pesticide and nitrogen losses simultaneously achieves similar reductions in soil loss and phosphorus loss.

Acknowledgements

Thanks so much to Professor Darrell Bosch, my major advisor, for his always-reliable, tireless, warm-hearted, and efficient guidance, advice, and encouragement. His ways of helping and supervising students will surely be adopted in my future career. Thanks to Professor Daniel Taylor who helped me on programming models, to Professor James Pease who corrected many mistakes in my study and gave many good suggestions and advice. Together as my degree committee, Professor Bosch, Professor Pease, and Professor Taylor helped me so much that I am able to finish this study now.

Many thanks to Professor Pat Phipps, Mr. Guy Sturt, Mr. James Maitland, Professor Norris Powell, and Professor Ames Herbert who gave me advice and information on crop production practices and farm characteristics in the study area. Many thanks also to the following persons: Professor Azenegashe Abaye who gave me advice and information on cotton production practices and cover crops. Professor James Baker helped me to evaluate soil inputs and EPIC simulation model results. Professor Eluned Jones helped me on cotton prices and quality issues. Professor Anya McGuirk helped me on statistical problems in the study. Professor Kenyon helped me on corn prices. Professor Everett Peterson also helped me during the study.

Some fellow students also helped me in my study: Robert Parsons taught me how to use EPIC model and provided me with weather data and soil data; Laura VanDyke helped me a lot both in classes and my research, Wes Adcock helped with crop input to the EPIC model, and Sonali Mitra helped me with other data related to the study in the survey database.

Finally, my greatest thanks are to my dear wife, Mary, my son, Rick, and my daughter, Nancy. Without their love, patience, and companionship, I would never be able to achieve what I have done now. I appreciated every minute we spent together. Rick's Chinese is rusty now. It was my fault for not devoting enough time to teach him how to read and write Chinese and I hope I can correct that problem in the near future.

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Chapter 1. Introduction

1.1. Problematic situation

1.1.1 Nonpoint source pollution (NPSP)

Public concerns have been raised about effects of NPSP (nonpoint source pollution) on the nation's ground and surface waters in the United States in recent years. Concerns over NPSP stem from the fact that, in addition to presenting direct and indirect negative impacts on human health, ecology, and agriculture, contaminated water is difficult or even impossible to purify and there are many uses for which clean water has no substitutes. In order to restore and maintain the chemical, physical, and biological integrity of the Nation's water, the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act), enacted in 1972, has concentrated on efforts to reduce discharges of pollutants from point sources (Puckett). Yet, by 1990, approximately 37 percent of the U.S. river miles tested above pollution limits as assigned by the States (U.S. Environmental Protection Agency, 1992). Though it is recognized that NPSP contributes a big proportion of the United States' water pollution problem, a national strategy to prevent and control NPSP is still to be developed. Due to the difficulty in deciding the magnitudes of the various nonpoint sources, the 1987 Water Quality Act's nonpoint-source provision and EPA's pesticide-in-groundwater strategy have emphasized voluntary rather than mandatory controls, leaving the design and implementation of control measures to state and local officials (Crutchfield, Teague et).

NPSP is defined as "pollution caused by sediment, nutrient, and organic and toxic substances originating from land-use activities and/or from the atmosphere, which is carried to surface water bodies through runoff or to groundwater" (Office of Technology Assessment, p.31). As described by McSweeny (1986), NPSP is the diffuse loading of organic as well as inorganic materials into the water. "Nonpoint" describes sources which discharge pollutants to rivers and streams at numerous and widespread locations (Puckett). The nature and magnitude of pollution from nonpoint sources are difficult to measure and vary greatly from site to site. In many areas, agriculture alone is credited for over 50 per cent contribution to NPSP problem (Kerns; Galeta et al, p.36). Specifically, major types of pollutants resulting from agricultural NPSP are nutrients (mainly nitrates and phosphates), sediment, pesticides, and bacteria. In this study, bacteria pollution from agriculture will not be discussed since it is not a problem for a peanut-cotton farm, which is the focus of this study.

Sediment. Basically, natural forces such as rainfall and wind tend to achieve both soil formation and soil erosion. Some rough estimates show that soil formation tends to just offset soil erosion of around 5 tons per acre per year on most productive land in the United States (Wischmeier and Smith; CAST)[1]. For certain soils and agricultural practices in the United States, the annual rate of soil loss far exceeds that of formation. Despite nearly sixty years of soil conservation efforts by the U.S. government, soil erosion problems persist (McSweeny, 1986). The substantial increase in farm prices in the 1970's

[1] The soil loss tolerance value, or T-value, represents the estimated rate of soil formation. T-value is defined as "the maximum amount of soil loss, in tons per acre per year, that can be tolerated and still achieve...sustained economic production in the foreseeble future with present technology (USDA SCS, 1974, p.6).

and a shift toward all out production caused marginal lands to be put back into row crop production (McSweeny, 1986).

By measurement of volume, eroded sediment alone is the number one pollutant in the United States (Hoag et al). The annual soil loss in the United States is over 2 billion tons (USDA, 1980). Displaced soil, accompanied with runoff of soil nutrients and other agricultural chemicals, forms the major portion of NPSP in the United States. According to the General Accounting Office, over 50 percent of sediment deposited in surface waters in the United States is from agricultural activities.

Eroded sediment raises riverbeds, reduces the capacity of lakes, reservoirs, and drainage channels, damages water distribution systems, causes deterioration of aquatic habitats, and increases the risk of flooding. Sediment also makes recreational waters muddy, increases cost of water treatment, and carries agricultural chemicals into waters (CAST). Annual losses of applied agri-chemicals from U.S. cropland due to soil erosion were estimated at $0.35 billion to $1.2 billion (CAST). Hoag et al estimated that onsite damage from cropland erosion cost farmers nationwide a production loss of $1.7 billion in 1983 dollars while the offsite cost was about $4.2 billion in 1983 dollars. Ribaudo estimated the annual offsite damages from erosion even higher, at $7 billion in 1983 dollars, with the Northeast and Pacific regions ranking the highest in damages in the United States. Researchers also warned that reducing erosion alone could not eliminate all offsite pollution damages.

Nitrogen and Phosphorus. As a key component of amino acids and proteins, nitrogen is essential to plant growth. The main sources of nitrogen entering the soil include rain and irrigation water, fixation by legumes, organic or inorganic fertilizers, and plant residues (Hanley). Phosphorus plays an important role in some of the significant plant functions of photosynthesis, biological N2 fixation, crop maturation, and root development (Brady). Fertilizers and manure containing soluble phosphorus have to be applied to supplement available soil phosphorus for plant uptake since 98-99 percent native phosphorus in soil is unavailable to plants (insoluble) (Brady).

With highly capital intensive agriculture, commercial fertilizers have replaced animal manure to become major sources in the crop nutrient up-take, especially of nitrogen. Commercial fertilizers were applied to 75 percent of cropland in the United States (Office of Technology Assessment). Commercial fertilizer consumption in the United States rose sharply from a total of 7.5 million nutrient tons in 1960 to 20.3 million nutrient tons in 1991 (Vroomen and Taylor). Nitrogen, phosphate, and potash all shared in this increase. By 1991, nitrogen use was 11.5 million tons, or 55 percent of total fertilizer nutrient tonnage, up from 2.7 million tons, or 36.7 percent of total fertilizer nutrient tonnage in 1960. Relative potash use remained rather stable, while relative use of phosphate declined from 34.5 percent in 1960 to 20.4 percent of the total nutrient tonnage in 1991 (Vroomen and Taylor).

A portion of nitrogen loss from the soil through runoff, sediment, volatilization, denitrification, and leaching will eventually reach rivers and streams or groundwater. Phosphorus, which is mainly tied to soil particles, reaches surface water with sediment. However, if phosphorus application exceeds soil phosphorus holding capacity, phosphorus will fail to bond with soil particles, remain soluble, and leach or runoff with water movement. Studies show that soil phosphorus levels in many soils across the U.S. are high now due to decades of fertilization and manuring in excess of crop needs (Better Crops

With Plant Food) and it is estimated that it would take at least 8 to 10 years of cropping with no additional phosphorus to reduce this excessive phosphorus to a level just matching the needs of crops (McCollum).

Entering nutrients (mainly nitrate and phosphates) to surface water create the problem of eutrophication, causing excessive growth of algae and aquatic plants and accelerated oxygen depletion, leading to fish kills, foul odors and tastes. Recreational uses of lakes and slow-flowing rivers and streams are restricted and habitat loss can result. Evidence also shows that nutrient pollution to water may result in certain diseases in humans such as infant methemoglobinemia (Hall and Howett; Puckett; Hanley; Office of Technology Assessment). Two of the most important non-point sources of nitrogen loadings are commercial fertilizers and animal manure deposited by roaming livestock or hauled onto fields as fertilizers (Puckett).

Today, nitrates are the most commonly detected chemical in groundwater in the United States, with more than half of the nation's wells having been detected to be contaminated by nitrates, while 1.2 percent and 2.4 percent of community wells and rural wells, respectively, have concentrations above 10 mg/l (U.S. Environmental Protection Agency, 1992). The agricultural NPSP contribution to nitrate loss to water varies from watershed to watershed, from nearly 0 in some predominantly urban watersheds to nearly 100 percent in some agricultural or rural watersheds. According to a report of the U.S. Geological Survey (Puckett), in more than half of the watersheds studied, NPSP accounts for more than 90 percent of nitrate loading to streams; while in 90 percent of studied watersheds, NPSP contributes over 50 percent of nitrates loading to streams. In the Albemarle-Pamlico watershed, the nation's second largest and one of the most productive watershed systems, it was estimated that almost 80 percent of the nutrient pollution entering the receiving water came from NPSP, while 75 percent of the NPSP around this area comes from agricultural activities (NCDEM; Hall and Howett).

Pesticides. Divided into roughly three main categories, insecticides, herbicides, and fungicides, pesticides have been used to kill a wide variety of insects, nematodes, molds, and fungi that attack crops, and to control a wide range of weeds that compete with crops. In modern capital intensive farming, pesticide use has been an integral part of agricultural technology. As reported by Office of Technology Assessment, in 1986, pesticides were applied to 57 percent of farmland in the United States. Nielsen and Lee reported that agriculture pesticide usage had increased threefold in the previous decade.

Many pesticides, such as DDT, are subject to bioaccumulation and have a long half-life, presenting hazards to the environment. Some pesticides, such as alachlor and atrazine, are carcinogenic (Hubbard). Generally, both pesticide use and pesticide loss present hazards to producers (and farm workers), consumers, birds, and fish. Pesticides reach aquatic systems by direct application, in runoff (either dissolved, granular, or adsorbed onto soil particles), aerial drift, volatilization and subsequent atmospheric deposition, and uptake by biota and subsequent movement in the food web (Maas et al).

In 1988, as reported by EPA, 46 pesticides in groundwater in 26 states were detected, ostensibly from agricultural activities (Office of Technology Assessment). A large number of counties in the Southeast, which includes Virginia, have been identified as potentially vulnerable to groundwater contamination from pesticides and many of these counties also have high usage rates of soluble active ingredients (Gianessi et al). Over 90 active ingredients have been listed by EPA as suspected or known to leach (Gianessi et al).

In response to significant growing public concern over pesticide detection in groundwater, EPA proposed a strategy to prevent unacceptable levels of contamination. This strategy considers the possibility of state-wide or county-wide restrictions on the use of certain active ingredients, or application of some management measures to certain specific sites, for example, sites with shallow water tables (EPA, 1987).

The maximum contamination level (MCL[2]), set by the EPA, is one way to measure the hazard by pesticides. Yet, the long term effects of many pesticides on humans and the environment are not well known (Hubbard). The selection and dosage of pesticides have generally been based on cost and efficacy considerations rather than potential environmental impact partly due to the lack of formal methods to assist farmers to make environmentally based pesticide choices, leading to the wide use of some of the more toxic, mobile, and/or persistent pesticides (Teague et al, (1995); Kovach et al). Farmers commonly believe that pesticide application under label directions and/or according to recommendations of extension agents is environmentally safe since every pesticide is registered by the U.S. EPA (Kovach et al). The amount of the pesticides entering the water systems can not by itself represent the full degree of pollution. Toxicity varies among pesticides and toxicity of a given pesticide varies also for different species (fish, human, etc.) who come in contact with the pesticide.

1.1.2 Measurement of NPSP quantities and costs

The estimation of NPSP damage from agriculture is not straight forward, and it is difficult to assign values to the off-site damage. The NPSP problem is actually at least three-dimensional including contaminants (sediment, nutrients, and pesticides), environments (groundwater, and surface water), and consequences (human, wild species, and landscape). Maiga pointed out that "the true value of soil loss can only be assessed when an economic dimension is added to the erosion evaluation" (p.8). The same is true of other contaminants. Three relevant costs which could be used in evaluation of NPSP are costs due to the loss of soil productivity, costs due to loss of nutrients and pesticides, and costs due to the creation of pollution.

The concern to maintain soil productivity is a major reason for soil conservation efforts both from the perspective of policy makers and the perspective of farmers. Soil erosion, through the loss of topsoil, results in the loss of storage for plant-available water, loss of plant nutrients, degradation of soil structure, and decreased uniformity of soil conditions within a field (CAST). Soil erosion impairs long run soil productivity and reduces yields under current available technology. In addition, erosion reduces benefits from technological improvements, when comparing highly eroded soil versus less eroded soil (Taylor and Young). Reduction in soil productivity is a direct concern to the farmer, for it will result in increased input demand, reduced yields, and increased costs of agricultural products in the long run. The loss of fertilizers and pesticides generally accompanies the excessive soil loss. Since increased costs cannot be shifted totally to consumers, farmers suffer economic losses and further imbalanced exploitation of soils may ensue, which will cause more NPSP (CAST).

Productivity costs of erosion may be difficult to measure. First, erosion does not necessarily reduce crop yield, though the amount of input required to maintain yields, such

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[2] It is defined as the maximum permissible level of a contaminant in water (mg/l) which is delivered to any user of a public water system

as fertilizers, seeds, pesticides, and irrigation may be increased (Taylor and Young). Second, even this increase in input use may be overcome or masked economically by such factors as improved technology and management, new more productive seeds, and cheaper and more effective fertilizers and pesticides. Though the increased input presents a real economic cost, farmers may fail to realize the increase or have enough incentive to alter this trend, especially when they think any alternative practice to reduce soil erosion can be paid off only in the long run. Third, in the short run, conservation effort may increase the uncertainty of crop yields and net return, while many farmers tend to be risk-averse (risk-averse behavior will be discussed in section 1.1.6). Farmers may have to purchase new tillage equipment at high cost which makes their adoption of new conservation practices even more expensive. They may intend to use the land for only a short time and land sale values may not capture the conservation expenditures. Some farmers are simply producing on rented farmland and, if the leases are for short periods, they may not be able to recapture the returns from conservation investments. In these situations, the benefits from soil conservation are discounted more heavily by the farmers than the rest of the society, because of the uncertainty in return to soil erosion control in the long run and the probable sacrifice of profits in the short run. Maiga suggests that the evaluation of soil erosion and reduction of productivity should be carried out in a long run analysis.

The assessment of the offsite costs of pollution is a more difficult task. It is difficult to measure the amount of soil sediment, nutrient loss, and pesticide loss because of different physical features of farms and different production practices. In addition to

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(USEPA, 1996).

being carried by sediment, nutrient and pesticide losses also have dissolved components, which to some degree are negatively correlated with sediment amount. For instance, heavy reliance on tillage practices to reduce soil loss might result in increased soluble nitrogen and phosphorus losses (Kerns et al, 1982, 1984). Hoag and Hornsby showed that practices to control one source of pollution such as surface runoff often increase pollution from other sources such as deep percolation. Volatilized nitrate loss as NH_3, denitrified nitrate loss as N_2 and N_2O, and nitrogen leaching loss as NO_3 vary across crops, sites, and seasons (Hanley). Half lives of pesticides in soil and groundwater vary by factors such as temperature, organic content, soil moisture, clay content, and depth (Hubbard). Since field-specific data on pollution losses are very costly and lacking, in recent years, the major approach has been to rely on simulation models to provide basic data for assessment. Management models, at the same time, have to use simulated pollution outcomes as input without calibration (Zacharias and Heatwole).

The pollution assessment problem is aggregate, comprehensive, and multi-dimensional in nature. While contaminants can be roughly classified as nutrients (mainly nitrate and phosphate), pesticides, and sediment, their negative impacts on the environment are quite different. In addition to the wide array of environmental impacts caused by pollutants, several facts complicate the assessment of pollution from agriculture. First, production decisions by farmers, while reflecting a unique set of regional and economic conditions, may not adequately account for the pollution potential of fields. Thus, “sites with high leaching and sediment loading potential may be contributing a disproportionate share of nutrient, pesticide, and sediment loadings to groundwater and surface water” (quoted from Bosch et al (1992), p.47). Thus, targeting the erosion restrictions and chemical uses to farms with most highly erodible land (HEL) might be an efficient way to achieve water-quality goals (Bosch et al (1992); Crutchfield, et al).

Second, one important way to reduce NPSP from agriculture is to develop new production practices which reduce soil erosion, require less chemical and/or fertilizer input, and have no severe effect on yields and net return. However, up to now, evaluations of the effects on NPSP of potential practices are often lacking. Third, the factors which have the biggest influence on crop yields, soil erosion, and pollution are weather conditions, which are beyond farmers' control and risky.

In spite of the complexity of the NPSP from agriculture, separate tactics have been developed to measure the magnitudes and impacts of the three major contaminants, namely pesticides, nutrients (nitrogen and/or phosphorus), and sediments. For example, T-value, the soil erosion tolerance value, which is the limit of tons of annual soil loss allowed to maintain the soil productivity (without considering the potential downstream impacts), was used as a yardstick in the Conservation Compliance provision of the Food Security Act of 1985, in which it was stipulated that soil loss on highly erodible acreage must be below the soil tolerance level if farmers wished to receive commodity program benefits. Since phosphorus loss is mainly attached to sediment, it is rather straight forward to estimate the magnitude of phosphorus loss if site soil loss can be estimated with acceptable credibility. There are some well-developed empirical simulation models to estimate nitrate loss. On the whole, though the offsite impacts are very difficult to quantify, the quantity of soil loss and nutrient loss (phosphorus and nitrogen) from cropland can nevertheless be estimated by employing crop-growth/chemical transportation simulation models such as EPIC, the Erosion-Productivity Impact Calculator (Williams, et al). These models estimate losses from the site or below the root zone. But caution should be given due to the fact that the movement of nutrients to groundwater after they leave the root zone, or to surface water after they leave the site, is uncertain. For example, Hanley pointed out that nitrates may take up to forty years to travel from the soil to groundwater, depending on the nature of intervening rock layers. Thus policy to reduce nitrate pollution today may have no direct impact on water quality for years. As for pesticides loss, the amount of loss alone can not represent the magnitude of the offsite environmental hazard presented by pesticides loss. Thus various environmental risk indices to measure the aggregate environmental outcome have been constructed in recent years (Warner; Alt; and Teague et al (1994)). Alternative policy implications are then studied based on the results of this approach.

1.1.3 Externalities and policy justification

Although aware of NPSP from agricultural activities, farmers generally reject the notion that their farm activities are contributing to the current water quality problem (Bosch et al (1992); Guiranna et al). The probable explanation is that farmers have difficulties visualizing the impact of NPSP from agriculture, or that they cannot tell the erosion or leaching damage potential of the site (Bosch et al (1992)). Generally, farmers do not think they should account for offsite costs of NPSP, and as long as conservation reduces net return, they find it out of the question to enthusiastically take measures to control soil and nutrient losses (Dinehart and Libby; Giuranna et al).

Thus consequences of farmers' production decisions on water quality are shared by society as a whole. Though onsite NPSP damage presents costs to farmers in the form of loss of soil productivity, loss of fertilizers, loss of pesticides, and potential health problem to farmers themselves, the off-site damage is generally regarded as an externality, that is, offsite costs are not borne by those who cause them and thus remain external to the farmers' decision environment (Dahlman; Crosson). It was estimated that costs due to offsite damage are 1.5 times larger than that of onsite damage (Hoag et al 1986). On the other hand, benefits from adopting conservation practices are shared by the society as a whole. Since private incentives alone are not sufficient to achieve a socially optimal rate of NPSP from agricultural activities, government action has been called for to set up abatement and compensatory mechanisms.

1.1.4 Government approaches to control NPSP

The extension of the cross-compliance provisions of the 1985 and 1990 Farm Bills to include water quality protection, California's Proposition 128 which prohibits the use of certain chemicals, incentive payments for water quality protection schemes in the 1990 Farm Bill, and research and development on "low-input" production methods are some policy approaches dealing with reducing agricultural impacts on water quality (Abler and Shortle). The economic criteria for assessment of these policies, following from the efficiency/fairness paradigm of modern welfare economics, include "(1) the benefits of achieving water quality protection goals; (2) costs of adjustments in agricultural production practices; (3) costs of administration and enforcement; (4) incentives created for the development and adoption of less-polluting production methods, shifts to products which are less intensive in polluting inputs, and reallocation of production away from environmentally sensitive areas; and (5) distribution of the costs among different groups" (Quoted from Abler and Shortle, p.53). The political viability of these policies includes the effect of each policy on the influential political interest groups with a large stake in the policy, impacts on federal, state, and/or local government budgets, and administration and enforcement costs (Abler and Shortle). Currently, voluntary programs, such as educational and cost-share programs through USDA and various state agencies, to control agricultural pollution are preferred by many policy makers and most farmers (Pease and Bosch).

An example of these voluntary programs is the conservation "Cross-Compliance" policy by which farmers' access to the benefits of farm programs depends on whether or not the farmers practice "acceptable" conservation on highly erodible lands (HEL), while "acceptable" practices are also called best management practices, or BMPs (McSweeny, 1986). Benefits of farm programs may include "price and income support policies ... low interest loans, tax credits and accelerated depreciation, lower crop insurance premiums and/or larger crop insurance benefits, higher price and income support payments, as well as a relaxation of the absolute payment limitation to producers covered by ASCS commodity programs" (quoted from McSweeny, 1986).

In some cases, conservation plans may not be as profitable in the short term as traditional cropping practices, while long term effects of conservation might be regarded as not visible and economically important by the farmers (Lee et al). During periods of high prices in which market prices exceed target prices, a cross-compliance program would offer little incentive for conservation behavior (CAST). Grumbach argued that cross-compliance approach would be most effective in area like the Great Plains and North Central regions where the government commodity program participation is highest. Ervin et al indicated that cross-compliance is likely to benefit larger farms and high-equity firms relative to smaller or more highly leveraged operations and may provide the greatest economic incentive for erosion control on land for which the net social benefits may be small compared to those on more erosive land. Furthermore, conservation efforts can be negatively affected by some aspects of government commodity programs. For example, farmers might be encouraged to plant crops on highly erodible land under some acreage reduction programs to sustain base acreage and provide a low-cost source of land to idle (Hoag et al). Research in the Texas High Plains shows that with strict enforcement of base-acreage requirements, farmers would be better off by not following rotations which limited soil-loss levels (Lee et al). Disincentives to conservation in commodity programs were eliminated with the Federal Agriculture Improvement and Reform Act of 1996 (FAIR) (USDA, 1996).

More restrictive policies may be adopted if evidence shows voluntary control programs are too costly or ineffective in achieving pollution control (Pease and Bosch, p.477). As discussed by Wise and Johnson, possible mandatory policies include zoning regulations, permit requirements, taxes on commercial fertilizers and pesticides, pesticide and fertilizer recordkeeping requirements, holding agrichemical users liable for property damage from chemical pollution, and restrictions on timing, amounts, and handling of fertilizer and pesticide applications. In order to formulate more effective policy, knowledge of producers' behavior in making adjustments in production practices and technologies in response to alternative water quality policies and economic conditions is required (Bernardo, et al).

1.1.5 Risk impacts of NPSP control

Farmers' behavior is determined by their individual characteristics such as their socioeconomic standing, personality, and communication behavior. Farmers' responses to conservation policy reflects their objectives, access and ability to use information on innovations, their attitudes toward risk, and their need for and access to additional inputs (Norris).

Studies show repeatedly that many, if not most, farmers are risk-averse (e.g. Lin et al; Binswanger; Dillon and Scandizzo; King and Robison; Saha et al; Botes et al). That is, they often prefer farm plans that provide a satisfactory level of security even if this means sacrificing income on average. Farmers may choose to produce less of risky enterprises, diversify into a greater number of enterprises to spread risks, use established technologies rather than venturing into new technologies and, especially, in the case of small-scale farmers, grow a larger share of family food requirements than required for profit maximization (Hazel and Norton, p.76). The tendency of many farmers to use more agri-chemicals or irrigation water than are needed to maximize profit can be explained as a result of risk-averse behavior[3] since there exists uncertainty about crop water or nutrient requirements and about potential pest eruption. Risk-averse farmers in order to maximize expected utility are willing to forego some amount of expected profit in exchange for reducing the risk that profits will fall below some minimum level (Hey). Thus, risk-averse farmers might prefer highly erosive activities that generate relatively stable returns, while even inexpensive practices to reduce soil and nutrient loss might not be acceptable to them if these practices increase risk of income (Miranowski).

Conservation recommendations based on cost effectiveness may fail to get a positive response from farmers if the risk impacts of the policy and farmers' ability to bear risk are ignored. Though a National Academy of Science study concluded that substantial reductions in pesticide use are possible without large impacts on production and/or prices (Richardson et al, p.27), low-input practices aiming at reduction of pesticide use nevertheless might be viewed by farmers as a significant source of income risk. Thus, producers with greater concerns about reducing income risk would be most severely affected by pesticide restrictions (Feinerman et al). The increased labor requirements of some low-input practices also present risk to farmers because the availability of labor at specific times is uncertain. Many conservation approaches credit organic nitrogen in manure, soil organic matter, and legume carryover to reduce inorganic fertilizer applications. These practices may increase farmers' risk because the mineralization rate of organic nitrogen depends on weather, and crop yields may be reduced due to slow mineralization of organic nitrogen (Feinerman et al). To reduce this risk, soil nitrogen and plant tissue tests combined with split applications of nitrogen fertilizer are recommended (Bosch, Fuglie, and Keim). Yet, field conditions may not allow the farmer to make a second application. Thus, to avoid risk of yield loss, more risk averse farmers may simply rely on one application of inorganic nitrogen at planting rather than crediting the less reliable organic sources or risking a second inorganic nitrogen application (Feinerman et al; McSweeny and Shortle).

There may exist a gap between farmer's perceptions and the real risks which come from recommended conservation practices. For example, a literature review by Norton and Mullen finds that integrated pest management (IPM[4]) reduces income risks for farmers. Yet a study by Fernandez-Cornejo et al of vegetable producers in Florida, Michigan, and Texas, found that farmers who adopt IPM tend to be less risk averse and

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[3] An argument is made by Pannell in a literature review in which he concluded that different variables of risk have different effect ons pesticide use under risk averse attitude. For example, uncertainty about pest density and pest mortality leads to higher optimal pesticide use, while uncertainty about output price and yield leads to lower optimal levels of pesticide use since more pesticide use means higher application cost and input cost. Thus the total outcome is uncertain (Pannell).

[4] IPM "is an approach to making pest control decisions with increased information and the use of multiple tactics to manage pest populations in an economically efficient and ecologically sound manner. The IPM concept emphasizes the integration of pest suppression technologies such as biological control, e.g., using beneficial organisms against pest organisms; cultural control, e.g., using rotations and

their farms tend to be larger. Personal attributes such as education level, skills and experience, and managerial time on farm activities are listed as related to the rate of adoption of the IPM practices in the latter case.

However, in some cases, higher levels of risk aversion led to the increased adoption of environmentally sound practices. For example, in empirical research on Texas High Plains, Lee et al reported that increasing risk aversion in crop mix selection resulted in a lower per-acre wind erosion rate. As to uncertainty of labor availability, Vaughan et al estimated that soybean and corn farmers can reduce spring labor requirements by forty-two percent by adopting reduced tillage and by seventy-seven percent by practicing notill. In peanut production in Virginia, reduced till require less than half of the labor compared to conventional tillage, while notill requires less than one third of the labor compared to conventional tillage (Delvo et al).

1.1.6 Production of peanut and cotton in Virginia

Historically peanut accounts for 15 percent of the cash receipts from the sale of all crops in Virginia, with only tobacco and soybeans generating higher receipts (Mutangadura, et al). Peanut production in Virginia, combined with that of Georgia, Texas, and North Carolina, accounts for 71 percent of peanut planted in the United States (Delvo et al). Virginia peanut production is likely to compete favorably with other areas, because Virginia peanut is of higher quality compared to peanuts produced in other areas of the United States and is used in higher value consumer products such as premium salted nuts. By contrast, imported peanuts and those produced in other regions of the U.S. (runners and Spanish peanuts) end up in relatively lower value products (Mutangadura et

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cultivations to reduce pest problems; legal control, e.g., abiding by state and federal regulations that prevent the spread of pest organisms;

al). Yields of peanut in Virginia tend to be higher than the United States average, with a higher average net returns of $120 per ton of sales (1994 dollars), while the national average is $79 (USDA, 1994). The peanut acreage in Virginia is mainly located in the southeastern part of Virginia in Surry, Sussex, Southampton, Isle of Wight counties, and the City of Suffolk, which account for 85 percent of the total state peanut acreage, or 85 percent of the state peanut poundage (Virginia Agricultural Statistics Service).

As a staple crop in the eastern part of Virginia, where 12 percent of the farmland is identified as highly erodible land (HEL) (SCS), peanut production is tillage, pesticide, and management intensive and highly profitable. In spite of the evergrowing emphasis on reduced tillage or notill tillage in crop production, peanut has been characterized by conventional tillage, with spring moldboard plowing, followed by secondary tillage to smooth and pulverize the soil, and/or weed-control by row cultivator during the growing season (Haith and Loehr). In contrast, other crops in this area, such as corn, cotton, soybean, wheat, and barley, have increasingly been planted by notill or reduced tillage. Up to 27 types of pesticides have been applied to peanut in this area (Phillips and Shabman). According to 1997 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt), per acre pesticide cost alone for peanut is $192.81, while the corresponding numbers for cotton, wheat, corn, and soybean are $85.26, $11.54, $24.4, and $30.91, respectively. Total production cost is also much higher for peanut as compared with other crops, reflecting the tillage and management intensity in peanut production.

One important way to reduce pesticide use is by planting rotational crops to disrupt insect and disease cycles. Some research shows that management strategies based

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and chemical control, e.g., judiciusly using pesticides and other chemicals in a responsible manner" (quoted from Norton and Mullen, p. i).

on crop rotations are at present the only viable long-term solution to nematode problems in peanut (Rodriguez-Kabana et al). It was also reported that due to the extensive rotation with peanut, cotton in northeastern North Carolina has no significant nematodes problem (Bailey). In the past, peanut in eastern Virginia was rotated mainly with corn or double cropped wheat/soybean (Delvo et al). In recent years, cotton has been increasing rapidly. According to Virginia Agricultural Statistics Service, state total acreage of cotton in 1987-1994 were respectively 1.8, 3.2, 2.7, 5.3, 17.7, 22.1, 30.1, and 42.2 thousand acres. By 1995, state total acreage of cotton had jumped to 100.7 thousand acres. Cotton in the peanut-producing region in Virginia, is mainly rotated with peanut. Cotton is now more favored by farmers than corn because cotton is more profitable than corn, and can sustain stable yields even in face of severe drought while corn suffers drastic yield loss (Personal communications with Dalton, Sturt, and Phipps). As noted, pesticide cost of cotton production is much higher than that of corn, wheat, and soybean. This fact generally means that cotton is more pesticide and management intensive compared with corn, wheat, and soybean.

1.2. Objectives

This study will analyze the economic and environmental impacts of wide-scale adoption of low-input agricultural practices on cotton-peanut farms in a major crop producing watershed, the Albemarle-Pamlico watershed. The study focus is on the costs of reducing pesticide, nitrogen, phosphorus, and sediment losses where costs are defined as reductions in average net farm returns. Specifically, the objectives of this research are:

1. To evaluate the costs to a representative risk-neutral peanut-cotton farmer in Southeast Virginia of reducing pesticide, nitrogen, phosphorus, and sediment losses.

2. To evaluate the effects of varying levels of risk aversion on the costs of reducing pesticide, nitrogen, phosphorus, and sediment losses.

1.3. Basic assumptions and limitations

1. The environmental and economic impacts of pollution from alternative practices can be assessed with an annual model on an average basis. (In reality, most pesticides have effect on environment only for very short terms. It may take years to reverse the buildup of phosphorus in soil which increases phosphorus loss. Nitrogen travel to groundwater may take up to 40 years (Hanley)).

2. Adequate information and recommendations for adoption of low input practices are available to farmers at zero cost.

3. Farmers are assumed to maximize expected utility based on utility functions which reflect their risk preferences. Risk preferences are assumed to vary from risk neutrality to risk aversion. Implications of changing practices for risk seeking farmers are not considered.

1.4. Study area and model size

This research will concentrate on the coastal plains in southeastern Virginia, located in Albemarle-Pamlico watershed, where widespread water degradation problems exist. According to results from a survey carried out jointly by Natural Resources

Conservation Service, Economic Research Service, and National Agricultural Statistics Service (1992), 184 out of 925 surveyed farms around Albemarle-Pamlico watershed (20 percent) are classified as "other crops" farms, which refers to peanut farms in this area.

According to the Virginia Agricultural Statistics 1994 Bulletin, the major peanut-producing counties in southeastern Virginia, which include the County of Surry, the County of Sussex, the County of Southampton, the City of Suffolk, and the County of Isle of Wight, account for 85 percent (78,160 acres out of 92,000 acres) of the total state peanut acreage, or 85 percent (247.33 million pounds out of 291.18 million pounds) of the state peanut poundage, while for cotton, the respective numbers are 79.2 percent (33,410 acres out of 42,200), and 73.7 percent (60,404 bales out of 82,000 bales).

More specifically, the focal area is the City of Suffolk. Major reasons to justify this decision include :

- This county ranks second in agricultural sales in the State of Virginia, and is one of the major peanut and cotton producing counties in Southeastern Virginia.
- The weather pattern and its effects on crop yields on the City of Suffolk reflects well that of southeastern Virginia.
- Historical daily rainfall and temperature data are available from a site near the City of Suffolk, the Tidewater Agricultural Research and Extension Center (TAREC) in Holland, Virginia. Weather data will be used in EPIC-PST simulation program.
- Field experimental data are available from TAREC for peanut, cotton, corn, wheat, and soybeans. Actual field experimental data will be used to verify the basic EPIC-PST model setting.

- Quality advice and help from extension agents, researchers, and farmers are readily available in this area.

1.5. The organization of this thesis

The remainder of this study is organized as follows: Chapter 2, Decision Making Under Risk, will discuss the behavior of decision making under risk, lay out the expected utility paradigm, discuss risk measurements and efficiency standards, and lay out the theoretical Target MOTAD model which will be used in this study. Chapter 3, The Empirical Model, will present fully the realization of theoretical approach laid out in Chapter 2. Chapter 4, Results and Discussion, will present the empirical output, then interpret the output, and discuss the significance of the results, the implications and possible extrapolations of the basic results. Chapter 5, Summary and Conclusion, will review results to meet the original objectives of this study, and give an overall evaluation of the study. Then suggested directions for further study will be presented.

Chapter Two. Decision Making Under Risk

2.1. Risk management and decision making in agriculture

Risk sources. “Risk management in agriculture has commanded substantial resources from farmers, agricultural lenders, agribusinesses, and the public sector (Barry, p.3)”. As Sonka and George (p.97-101) identified, farmers face five types of business risk:

(1) Production or technical risk. This kind of risk is generally caused by variation of weather and diseases and pests in crops. The main indicator of this risk is yield variability.

(2) Market or price risk. The variability of commodity prices is a major risk to farmers. Short-run fluctuations in input prices present risk of income loss and cash shortfalls. Volatility of inflation and interest rates are also risk sources influencing farmers’ long-run decision making.

(3) Technological risk. For example, improvement of technology in the future might make farmers’ investments in durable goods unprofitable; or a decision to adopt technology may reduce future benefits from technological progress.

(4) Legal and social risk. More dependence on nonfarm capital, increasing demand for marketing techniques, and unexpected changes in government policies are all risk sources. Other possible legal and social risks exist such as liability to health and property damage caused by farm-emitted pollution, or newly imposed mandatory

regulation in regard to NPSP problems.

(5) Human sources of risk. Labor reliability, management performance, teamwork of the farming family, and health condition of the key personnel all present human sources of risk. Sonka and George commented that “human uncertainty has likely contributed to the mechanization of agriculture for machine inputs that are considered more dependable than labor inputs (p.100).”

While technical risk is inherent in agriculture, some uncertainty is induced by government policy actions which lead to different expectations of commodity prices, availability of credit, costs of inputs, and terms of trade (Gardner et al, p.255). Uncertainty of legislative changes, and uncertainty of rule changes by administrative officers under legislative authority are two examples (Gardner et al, p.256). Uncertainty of legislative changes imposes risk on farmers’ decisions to incur costs in adjusting their farms organization to new policies and at the same time to maintain sufficient flexibility to respond to new, unanticipated changes in policy (Gardner et al, p.256). Uncertainty of rule changes imposes short-run risks as interpretations of legislative rules may change. For example, regulation to adopt unprofitable conservation practices may increase income risk for farmers and fail to achieve conservation goals at the same time.

Policy risks increase uncertainty of farmers' returns. Due to the small-scale, noncorporate structure of most farms in the United states, these risks are borne mainly by individual farmers or farm families and farmers' decision making will surely reflect their willingness and capacities to accept these risks (Barry, p.3).

Decision making process and decision rules. Decision making is a process of evaluating and selecting alternative actions. In the static view, this process takes six steps:

1) define the problem and goals; 2) get ideas, make observations, and list major alternatives; 3) analyze the alternatives and determine the outcomes; 4) choose an alternative; 5) act; and 6) bear responsibility for the outcome (Herbst). As described by Selley, deciding under risk has five components:

(1) Mutually exclusive actions, A_j $(j = 1, \ldots, m)$;

(2) Mutually exclusive states of nature, S_i $(i=1,\ldots,n)$;

(3) Probability function $P(S_i)$;

(4) Consequences $C_i(S_i)$;

(5) Criterion for ordering the preferences over actions.

The actual specification of the components of a decision problem may vary with the type of analysis such as behavioral, prescriptive, or predictive (Selley, p.53). For example, much research in farm management and production economics has assumed farmers are profit maximizers, making decisions subject to technical or resource constraints. Generally, the goal of decision making or the rule of decision making is to seek an optimal choice and well-formulated rules should provide an orderly, efficient approach to achieving the goal of decision making under risk. Economic evaluation and analysis of decision making behavior and policy effects in agriculture are concerned with both positive and normative questions. That is, economists have to describe and predict trends and effects of institutional changes which are subject to demonstration and observation. By addressing both farmers' desires to achieve optimal personal gains as rational economic agents and government's desire to achieve optimal social welfare as a social planner, economists also have to argue which of the policy alternatives is most desirable. In searching for a tool, which is efficient analytically, and a guide to actions, which is normative in nature and testable both on the individual base and the societal base, economists generally turn to expected utility theory as their fundamental base of analysis and starting point to address specific problems.

2.2. Expected Utility (EU) theory

2.2.1. Rationality postulate.

To begin economic study, economists make assumptions about human motivations and behavior, the interrelationships among components of economic systems, and the empirical magnitudes of important variables and parameters (Randall, p.61). Mainstream economic models start with the assumption that the economic agent (decision maker in the market) is rational. Rationality, in addition to common use to mean that the decision process is coherent and logically consistent, is specified by economists here to describe characteristics of a "preference ordering" such that (1) the decision maker has coherent and consistent preferences which allow him to rank alternatives, (2) his preference is complete and transitive, and (3) given constraints, he is able to determine the preferred choice among alternatives (Randall, p.61).

Formally, a "rational preference, ϕ , on *X*" is a relation which satisfies (Mas-Colell et al, p.42):

(1) $\forall x, y \in X$, then $x \phi y$, or $y \phi x$ or both (Completeness);

(2) $\forall x, y, z \in X$, if $x \phi y$, $y \phi z$ then $x \phi z$ (Transitivity);

where "ϕ" is read "at least as preferred as" (in the following discussion, $x \phi y \Leftrightarrow x$ is at least as good as *y*).

As Blaug (p.229) pointed out, one of the most characteristic features of neoclassical economics is "its insistence on methodological individualism: the attempt to derive all economic behavior from the action of individuals seeking to maximize their utility, subject to the constraints of technology and endowments. This is the so-called 'rationality postulate'. ... (R)ationality means choosing in accordance with a preference ordering that is complete and transitive, subject to perfect and costlessly acquired information; where there is uncertainty about future outcomes, rationality means maximizing expected utility, that is, the utility of an outcome multiplied by the probability of its occurrence." In the development of the economic theory on probabilistic choice, or decision making under risk as it is commonly called, EU theory is also of central importance, for "so strong and pervasive has been the hold of the rationality postulate on modern economics that some (economists) have seriously denied that it is possible to construct any economic theory not based on utility maximization (Blaug, p.230)."

2.2.2. Basic setting of N-M theory of expected utility

As early as 1738, Bernoulli, explaining the famous St.Petersburg Paradox in which people would pay only a small amount for a game of infinite mathematical expectation, proposed that people maximize expected utility ("moral wealth") rather than expected monetary value. He even presented a descriptive utility model which has diminishing increases in utility for equal increments in wealth (Schoemaker, p.531). Modern EU theory was first developed by von Neumann and Morgenstern (N-M) in 1944. N-M proved that a set of basic axioms about decision maker's preference implied the existence of numerical utilities for outcomes. N-M utility applies to any type of outcomes, not merely monetary outcomes (Schoemaker, p.531).

As Savage (p.73) defined, utility is a function U associating real numbers with consequences in such a way that, if $f = \sum \rho_i f_i$ and $g = \sum \sigma_i g_i$ where f and g are gambles with, respectively, possible outcomes $(f_1, \ldots, f_K)$, and $(g_1, \ldots, g_M)$, $\sum_{i=1}^{K} \rho_i = 1, \sum_{i=1}^{M} \sigma_i = 1, (\rho_i, \sigma_i \geq 0)$; then $f \succ g$ iff $\sum \rho_i U(f_i) \geq \sum \sigma_i U(g_i)$, i.e. $U(f) \geq U(g)$. In this definition, since f_i and g_j are not necessarily the same kind of outcomes, K and M are not necessarily equal or even finite.

The concept of lottery, a formal device to represent risky alternatives, is the basic building block for N-M expected utility theory. For the purpose of simplicity, presentation of the concept of "lottery" will be in the form of finite outcomes, though it can be expanded to infinite, countable or non-countable, cases. A *simple lottery* is a list $L = (p_1, \ldots, p_N)$, $p_n \geq 0$ for all n and $\sum_n p_n = 1$, where p_n is the probability of outcome n occurring; an n-stage *compound lottery* is a lottery the outcomes of which are $(n-1)$-stage compound lotteries, while a 1-stage compound lottery is a simple lottery (Mas-Colell et al, p.169). An *N-M expected utility function* then is a linear function $U: \mathcal{L} \rightarrow \mathbf{R}$ with an assignment of numbers $(u_1, \ldots, u_N)$ to N outcomes of the simple lotteries. The expression is

$$U(L) = \sum_{n=1}^{N} u_n p_n, \forall L = (p_1, .., p_n) \in \mathcal{L}$$

Let L^n denote the lottery that yields outcome n with probability one, then $U(L^n) = u_n$. Then the expression above can be rewritten as,

$$U(\sum_{k=1}^{K} p_k L_k) = \sum_{k=1}^{K} p_k U(L_k)$$

Following Schoemaker (p.531-532) as one of the alternative presentations, the fundamental N-M EU theory is structured on the following axioms over preference:

- <u>Axiom 1 (Rationality).</u> Preferences for lotteries L_i are complete and transitive, i.e., rational (for definition see section 2.1);
- <u>Axiom 2 (Continuity).</u> $\forall x \phi\ y \phi\ z, \exists p \in [0,1]$ such that px + *(1-p)z* ϕ y and $y \phi\ px + (1-p)z$. If x is preferred to y which is preferred to z, then there is a lottery $L_1 = (p, 1-p)$ on x and z which yields the same utility for the decision maker as the lottery L_2 = (p = 1) on y;
- <u>Axiom 3 (Independence).</u> If $x \phi\ y$ and $y \phi\ x$, then $\forall p \in [0,1]$ and z, $px + (1-p)z \phi\ py + (1-p)z$ and $py + (1-p)z \phi\ px + (1-p)z$. A decision maker's preference between two lotteries, x and y, should determine which of the two he prefers to have as part of a compound lottery regardless of the other possible outcome of this compound lottery. This axiom is the heart of N-M EU theory;
- <u>Axiom 4 (Unequal probability).</u> Let L_1 = (p, $1-p$) and L_2 = (q, $1-q$) contain the same outcomes (x_1, x_2). If $x_1 \phi\ x_2$ then L_1 will be weakly preferred over L_2 *iff* $p > q$.
- <u>Axiom 5 (Complexity).</u> A compound lottery is equally attractive as the simple lottery that would result when multiplying probabilities through according to standard probability theory.

The Expected Utility Theorem then guarantees the existence of an N-M utility function. Suppose that the rational preference relation ϕ on the space of lotteries $\mathcal{L}$ satisfies axioms 1 through 5. Then ϕ admits a utility representation of the expected utility form. That is, we can assign a number u_n to each outcome $n=1, ..., N$ in such a manner that for any two lotteries $L = (p_1, \ldots, p_N)$ and $L' = (p_1', \ldots, p_N')$, we have $L \; \phi \; L'$ iff $\sum_{n=1}^{N} u_n p_n \geq \sum_{n=1}^{N} u_n p_n'$ (Mas-Colell et al, p.176) .

The Expected Utility Theorem also implies that N-M utility as defined is unique up to a positive linear transformation. Thus, N-M EU theory was proved to be a rational decision criterion, i.e., derivable from several appealing axioms. In other words, if a decision maker's preference confirms the above axioms, then the theoretical choice resulting from the maximization of an expected utility function as derived from those axioms will represent (confirm) his actual choice. As Schoemaker said (p.532-533), "... utility, in the NM context, is used to represent preferences whereas in neoclassical theory it determines (or precedes) preference. ... Nevertheless it (N-M EU approach) *implicitly* assumes that a neoclassical type of utility exists, otherwise it would not be possible psychologically to determine the certainty equivalence of a lottery." So, N-M EU serves as a tool and a guide for economists to utilize the expected utility theory to carry out empirical studies, deriving the utility function of decision makers by using various methods. One of the major factors determining preferences over risky outcomes (lotteries as to N-M utility) is the attitude toward risk (Schoemaker, p.533).

<u>2.2.3. Risk attitude</u>

Under assumptions of the expected utility theorem, let continuous variable X denote the payoff (monetary) of the lottery, the probability that the realized payoff is less or equal to *x* is $P\{X \le x\} = F(x) = \int_{-\infty}^{x} f(t)dt$, where *f*(*x*) is the density function of the lottery. Let *u*(*x*) denote the utility value assigned to nonnegative payoff amount *x*. Then N-M expected utility function over *F(x)* can be regeneralized as $U(F) = \int u(x)dF(x)$, where *u(x)* is called a *Bernoulli utility function* (or just a utility function as it is called when no uncertainty is considered) (Mas-Colell et al, p.184).

Then a decision maker's risk attitude can be expressed as follows: if the degenerate lottery that yields the amount $\int xdF(x)$ with certainty is viewed by the decision maker as being at least as good as the lottery $F(\bullet)$ itself, then the decision maker is risk averse. If he is indifferent between the lotteries, he is risk neutral. If he prefers the lottery, then he is a risk-seeker (Mas-Colell et al, p.185). Expressed in terms of $u(x)$ and $F(\bullet)$:

$$\int u(x)dF(x) \le u(\int xdF(x)), \quad \forall F(\bullet) \Leftrightarrow \text{risk averse;}$$

$$\int u(x)dF(x) = u(\int xdF(x)), \quad \forall F(\bullet) \Leftrightarrow \text{risk neutral;}$$

$$\int u(x)dF(x) \ge u(\int xdF(x)), \quad \forall F(\bullet) \Leftrightarrow \text{risk preferring.}$$

The first inequality is called *Jensen's inequality*, it is actually the defining property of a concave function. Thus, a decision maker's risk attitude could be seen from the shape of his utility function. If $u(x)$ is concave, it indicates the decision maker is risk averse; convex indicates risk preferring, while a straight line indicates risk neutral. So a risk averse person would not take a risky action at a price equal to the action's expected return because zero gain results in utility loss. The amount of return with certainty, $c(F,u)$, that makes the risk averter indifferent to the risky action (gamble), $F(\bullet)$, itself is called the *certainty equivalent*, i.e. $u(c(F,u)) = \int u(x)dF(x)$. The difference between the expected return, $\int xdF(x)$, and $c(F,u)$ is called a *risk premium*, p, which compensates the risk averter to take risky action while keeping his utility level at $u(c(F,u))$.

The magnitude of the second derivative of the risk averter's utility function, $u''(x)$, which is negative, indicating a diminishing marginal utility on monetary income, will determine the magnitude of the risk premium. However, $u''(x)$ alone cannot be used to make interpersonal comparisons of risk aversion because the individual utility function is unique up to a linear transformation. To justify interpersonal comparisons, the Arrow-Pratt (A-P) coefficient was proposed by Arrow and Pratt (Robison et al, p.17). For a twice differentiable Bernoulli utility function, $u(x)$, the A-P absolute risk aversion coefficient is $r_a(x) = -\frac{u''(x)}{u'(x)}$, and the A-P relative risk aversion coefficient is $r_r(x) = -x\frac{u''(x)}{u'(x)}$. Because risk attitude is a local measure, that is, a decision maker's utility function could have both concave and convex segments, the comparison of risk aversion can be made only at specific outcomes (Robison et al, p.17). Following the logic of A-P coefficient, it is also reasonable to compare the local curvature of the utility function. For example, assume *u(x)* to be thrice-differentiable, then the sign of $\frac{d}{dx}(-\frac{u''(x)}{u'(x)})$ and $\frac{d}{dx}(-x\frac{u''(x)}{u'(x)})$ can tell if the decision maker is more (absolutely or relatively respectively) risk averse with the increase of his wealth. A negative sign means less risk averse, while a positive sign means more risk averse. By using this new curvature coefficient, the interpersonal comparison can be expanded to a small neighborhood of some specific outcomes. One example is the empirical study reported by Saha et al of Kansas farmers' risk preferences. They are risk averse, while their absolute risk aversion is decreasing and relative risk aversion is increasing.

The more risk averse the decision maker is, the larger the risk premium he would be willing to give up to ensure a certain outcome. So, as long as alternative practices bring income risk to the farmer, it is expected that risk averse farmers are willing to take measures to reduce risk. As discussed in section 1.1.5, some aspects of the alternative practices in reducing NPSP may be risk-increasing. If so, risk aversion of the farmers will be a barrier to the adoption of these alternative practices.

2.2.4. Some comments on EU theory as relevant to this study

Schoemaker commented that "the key characteristics of this (EU) general maximization model are (1) a holistic evaluation of alternatives, (2) separable transformations on probabilities and outcomes, and (3) an expectation-type operation that combines probabilities and outcomes multiplicatively (after certain transformations) (p.530)." One of the major advantages of the EU theory is that it is an extremely convenient analytic tool. In fact, N-M's work has "practically defined numerical utility as being that thing for which a calculus of expectations is legitimate (N-M, p.28)". As Mas-Colell said (p.178), "It is very easy to work with expected utility and very difficult to do without it". Another advantage of EU theory is its normativeness. For example, if a decision maker, having difficulty choosing risky alternatives, believes his preferences conform with the axioms as stated above, then he can use the EU theory as a guide in his decision process (Mas-Colell et al, p.178). Yet another advantage of EU theory is that it follows the tradition of economic theory and thus has great appeal to economists.

In applications, different ways to measure utility, different types of probability transformations $F(\bullet)$ allowed, and different standards to measure outcomes of the lottery will result in different settings of the model (Schoemaker, p.531). For example, Payne (1973) commented that EU theory centers on two basic concepts: the idea that people choose the best alternative and the principle of using expected value as a measure of best. Central to these expectation models is the explicit acceptance of the description of prospects as probability distributions over sets of outcomes. Choice among such alternatives or distributions is then made on the basis of some function of each distribution's central tendency (expected values or "moments"). Thus, the risky outcomes of the lottery need not be monetary such as dollars of income or net return. In fact, utility maximization may be achieved by alternative approaches such as maximization of the probability of winning; maximization of the amount of winning; minimization of the probability of losing; and minimization of the magnitude of loss, according to actual problem settings.

Though it seems that, within the EU paradigm, the most direct way to carry out the risk decision analysis in applications is to determine the specific forms of the decision maker's utility function (single-valued indices of desirability), operationally, this task presents the most serious difficulties. Estimated utility functions are subject to errors because of the shortcomings in interview procedures, statistical errors, and other problems (King and Robison, p.69). Most seriously, an individual may not clearly know his own preferences, that is, "people are intendedly rational, but lack the mental capacity to abide by EU theory." (Quoted from Schoemaker, p.545). As such, empirical measurements of individuals' preferences are very sensitive to the problem presentation and the nature of the response requested (Schoemaker, p.545). In order to overcome some of these problems, in agricultural economics, a popular alternative to the direct elicitation of utility functions is the risk efficiency approach, which will be discussed in the next section.

2.3. Payoff distribution in terms of return and risk

When the functional forms of decision makers' utilities are not known and/or difficult and/or costly to elicitate, then an alternative though not equally powerful way to think about the decision makers' ordering of alternative choices is the following. Under some less demanding restrictions (assumptions) about decision makers' utility functions, alternative choices could be divided into two mutually exclusive sets. One set is called the inefficient set and no decision makers concerned will ever choose the activities in this set. Another is called the efficient set and it contains all the preferred choices of every individual decision maker whose preferences conform to the restrictions. By setting up different restrictions on decision makers' preferences, several popular efficiency criteria have been established. Among them, first degree stochastic dominance (FSD), second degree stochastic dominance (SSD), mean-variance (M-V), mean-absolute deviation (MOTAD), and stochastic dominance with respect to a function (SDRF) are most popular (King and Robison, p.68-81). For the purpose of this study, only FSD and SSD will be discussed.

First introduced into economics by Rothschild and Stiglitz in 1970, FSD and SSD are to answer questions about payoff distribution $F(\bullet)$ and $G(\bullet)$ of the choices. Specifically, FSD concerns which distribution yields unambiguously higher returns among them, and SSD concerns which one is more risky among them (Mas-Colell et al, p.195).

Formally, $F(\bullet)$ is said to FSD $G(\bullet)$ if for any non-decreasing function $u(X): R \rightarrow R$ (thus ${du}/{dx} \geq 0$), $\int u(x)dF(x) \geq \int u(x)dG(x)$. It directly follows that $F(\bullet)$ FSD $G(\bullet) \Leftrightarrow F(x) \leq G(x)$ for every *x*. FSD is following "the more, the better" logic (though it should be warned that the ranking of expected means alone does not mean FSD). FSD is not very discriminating which has limited its usefulness (King and Robison, p.69-70).

When we restrict the utility function $u(x)$ to be concave (thus, the decision makers are risk averse or equivalently, ${du}/{dx} \geq 0$ and $\frac{d^2u}{dx^2} \leq 0$) in the definition of FSD, then we get the definition of SSD. It follows that $F(\bullet)$ SSD $G(\bullet)$ $\Leftrightarrow \int_0^x F(t)dt \leq \int_0^x G(t)dt$ for every *x*. Given equal means of $F(\bullet)$ and $G(\bullet)$, $G(\bullet)$ is a mean-preserving spread of $F(\bullet)$ and is thus more risky (Mas-Colell et al, p.198-199).

When used in empirical studies, SSD approach might present a problem since the risk-aversion assumption may not be met, and SSD might not be able to eliminate enough alternatives as desired, although it has greater discriminating power than FSD. In this study, however, SSD is used as the efficiency criterion because decision makers are assumed to be risk averse and EU maximizers. Since in this study, no attempt is made to elicitate or to assume farmers' level of risk aversion, SSD is a more accommodating approach. As discussed before, there are many ways to express the risk discerned by the decision maker. In this study, the risk the farmers face is modeled as the expected shortfall from some preset levels of income and farmers' problem is expressed by a Target-

MOTAD mathematical programming model which is discussed in the next section. As it turns out, the efficient plans traced out by the Target-MOTAD, which is the central instrument in this study, turn out to be SSD efficient (Tauer).

2.4. Target MOTAD model

2.4.1. The theoretical model

Target MOTAD, as described by Tauer (p.607), is a two-attribute risk and return model. In this model, return is measured as the sum of products of expected per unit return of activity and magnitude of activities. Risk is measured as the expected sum of the negative deviations of the solution results from a target-return level. Allowable levels of risk are varied parametrically so that a risk-return frontier is traced out.

According to Tauer (1983), target MOTAD can be laid out mathematically as

(1) $$Maximize \quad E(z) = \sum_{j=1}^{n} c_j x_j$$

Subject to

(2) $$\sum_{j=1}^{n} a_{kj} x_j \leq b_k, \qquad k = 1, \ldots, m$$

(3) $$T - \sum_{j=1}^{n} c_{rj} x_j - y_r \leq 0, \qquad r = 1, \ldots, s$$

(4) $$\sum_{r=1}^{s} p_r y_r = \lambda, \qquad \lambda = M \rightarrow 0$$

where: $E(z)$ is expected return of the farm plan;

c_j is expected return of activity j;

x_j is level of activity j;

a_{kj} is technical requirement of activity j for resource k;

b_k is level of resource or constraint k;

T is target level of return;

c_{rj} is return of activity j for state of nature or observation r;

y_r is return deviation below T for state of nature or observation r;

p_r is probability that state of nature or observation r will occur;

λ , risk aversion measure, is a constant parameterized from M to 0;

m is the number of resource constraints;

s is number of states of nature or observations;

M is a large number.

The decision rule of a target-MOTAD model as set up above is to seek a firm plan whose negative deviations from the target do not exceed a set level while maximizing expected return. Hazell and Norton (p.101-103) labeled target-MOTAD as one example of *Safety-first* models. Safety-first rules usually describe three types: 1) decision maker will maximize expected return subject to the constraint that the probability of income below some specific level is small enough (such as Telser's rule); 2) he will maximize income at the lower confidence limit subject to the constraint that the probability of income being lower than the lower limit does not exceed a specified value (Kataoka's rule); or 3) he simply minimizes the probability that income will be lower than some specified level (Roy's rule) (Robison et al. p.19-21).

The term "safety-first" has much intuitive attraction because it implies that a decision maker first satisfies a preference for safety in organizing a firm's activities, and then maximizes his profit within this safety scheme. For example, a farmer might set a threshold income level ("survival level") to cover at least his family's obligations for living expenses, debt repayments, and operating expenses (Robison et al). "A farmer may wish to market his stored crop at the highest expected price but worries about selling below his cost of production. A farmer expanding or reorganizing his business may wish to maximize his expected net cash flow but is worried about a negative cash flow in any given year" (quoted from Tauer, p.607). However, it should be noted that some theoretical generalization of "safety-first" decision rules leads to a *Lexicographic Utility* (LU) preference which is inconsistent with the EU approach. There is no utility function that could represent LU preference because of the lack of continuity. Target-MOTAD model, on the other hand, is consistent with the EU approach (Tauer). In fact, Markowitz proved that an appropriate utility function based on expected returns and expected losses below a target is $u = c + aR + b \cdot \min(R - T,\ \ 0) \quad (a, b > 0)$, where *R* is monetary income and *T* is target income. This utility function is increasing and concave over *R*. Tauer proved that the efficient plan determined by target-MOTAD is also efficient by SSD, except for plans with equal means and deviations.

2.4.2 The modified Target MOTAD used in this study

In this study, in addition to resource constraints, environmental constraints will be imposed to analyze their effects on tradeoff between expected net return and income risk. Thus, constraint (2) in this study becomes:

$$(2a) \qquad \sum_{j=1}^{n} a_{kj} x_j \le b_k, \qquad k = 1,\ \ldots,\ m$$

$$(2b) \qquad \sum_{j=1}^{n} PNS_{ij} x_j \le TSO_i \qquad i = 1,\ \ldots, l$$

where PNS_{ij} is expected level of loss of pollutant *i* from activity *j*, TSO_i is total level of loss allowed for pollutant *i*, and other terms are similar to those in Tauer's model, only adopted to the representative farm.

Thus, theoretically, the Target MOTAD model used for this study is exactly the same as Tauer's original setting. In this study, TSO_i is parameterized to simulate several scenarios of reducing pollution from the farm (see Chapter 4 for detail). For each given TSO_i level, a risk frontier is traced out by further parameterizing λ to simulate different levels of risk aversion. Discussion of costs of reducing pollution is then based on these risk frontiers.

2.4.2. Measurement of costs of reducing pollution

When farmers are forced to reduce pollution from their farms by certain level, they have to adopt farm plans which may reduce their expected net income (ENI). Reduction of ENI is called type one cost of pollution reduction in this thesis. In addition, a more risk-averse farmer may be unable to find a farm plan which can achieve the pre-set pollution reduction as well as his target income, while a less-risk averse farmer or risk-neutral farmer can still find optimal farm plans. This more risk-averse farmer then has to take more risk in order to stay in business. Increased risk lowers his utility and the amount of reduction of his utility due to increased risk is referred to as type two cost in this study. A graph below illustrates the two types of costs to a risk-averse farmer when a constraint is imposed on pollution from his farm.

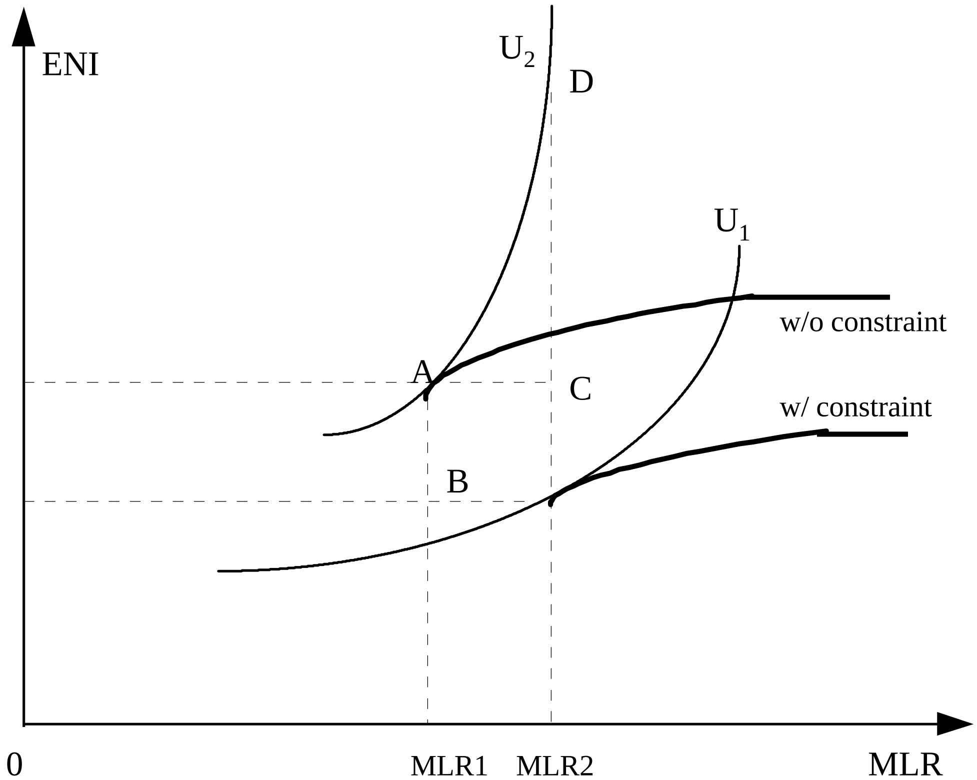

Figure 2-1. Costs of imposing constraint for a risk averter

In above figure, MLR is the minimum level of risk (λ) a farmer has to take in order to find a feasible (optimal) farm plan. The two curves with thick lines stand for the efficient frontier with and without a constraint on pollution reduction respectively for farmers of various risk averse levels. MLR1 and MLR2 are the smallest levels of risk a farmer has to take in order to find feasible (optimal) farm plans with and without constraint respectively. U1 and U2 are iso-utility curves. So it can be seen that for a farmer whose risk level is MLR1 the type one cost of imposing the constraint is AB, while the type two cost is CD. Whenever a farmer is forced to receive a level of risk which is higher than he would like to receive before, the type two cost is positive. If the farmer's risk averse level is fixed at MLR2 thus he is always able to find optimal farm plans with or without the constraint imposed, his type two cost is zero.

In Chapter 3, the empirical model is laid out in detail.

Chapter 3. The Empirical Model

3.0. Brief introduction to this chapter

In this chapter, the empirical model is presented in detail. Optimal farm plans are solved using a Target MOTAD mathematical programming model (this model is called REPVAFARM hereafter). Crop yields, pesticide loss, nutrient loss, and soil loss will be simulated with EPIC-PST(Williams et al). In the following sections, a generic layout of REPVAFARM model is presented (the GAMS program listed in Appendix F), physical, financial, and managerial situations of the representative farm are described, EPIC-PST model calibration and verification are presented, and environmental indices are developed.

3.1. Generic layout of the empirical Target-MOTAD model

Based on the theoretical model expressed in Chapter 2, the empirical Target-MOTAD model is the following:

Objective function is:

$$Max \quad Cprice_1 * Sellquota + Cprice_2 * Selladd + \sum_{i=3}^{I} Cprice_i * \sum_{j=1}^{J}\sum_{k=1}^{K} Cyield_{ijk} * Cacre_{ijk}$$
$$- \sum_{i=1}^{I}\sum_{j=1}^{J} Inputnolab_{ij} \sum_{k=1}^{K} Cacre_{ijk} - Pricelab * \sum_{m=1}^{4} Hiredlab_m + Progpaymt \quad (3.1)$$

where $Cprice_i$ is unit price (in dollars per pound for cotton, and peanut; in dollars per bushel for other crops) for crop i; *Sellquota* is peanut poundage sold as quota peanut; *Selladd* is peanut poundage sold as additional peanut; $Cyield_{ijk}$ is per acre yield for crop *i* in rotation *j* planted on slope *k*; $Cacre_{ijk}$ is acreage of slope *k* devoted to crop *i* in rotation *j*; $Inputnolab_{ij}$ is per acre input cost not including labor cost, fixed land cost, and fixed machinery cost for crop *i* in rotation *j*[5]; *Pricelab* is per hour wage rate for hired part-time labor; $Hiredlab_m$ is total hours of hired part-time labor for season *m*; and *Progpaymt* is the payment from participating government programs. The objective function represents returns to management, owner land, owner capital, fixed machine cost, and owner and full-time hired labor.

In this study, *I* = 8 is the total different types of “crops” planted, including quota peanut, additional peanut, cotton, corn, winter wheat, soybean, winter cover (wheat), and annual cover (quota peanut differs from additional peanut only in sales prices), *J* equals 13 to indicate the total of 13 rotations in this study, *K* equals 3 to indicate three slopes used for this study. See following sections in this chapter for more information.

The farm is subject to the following constraints:

- Peanut sales (*i* = 1,2):

$$\sum_{i=1}^{2}\sum_{j=1}^{J}\sum_{k=1}^{K} Cyield_{ijk} * Cacre_{ijk} - Sellquota - Selladd = 0 \qquad (3.2)$$

$$Sellquota - Quota0 \leq 0 \qquad (3.3)$$

where *Quota0* is the total poundage of peanut quota allocated to the farm. Equation 3.2 says that total peanut yields on the farm are divided into quota

[5] The reason to separate labor cost from other input costs is that only when availability of full-time labor is not sufficient will extra labor be hired. The cost of full-time labor has already been incorporated into the farmer’s income target and does not enter the objective function.

peanut and additional peanut. Equation 3.3 allows no more than allocated quota peanut to be sold at the quota price.

- Acreage (rotational, distributional, and total) constraints:

$$Cacre_{ijk} - RotaC_{ij} * RotaTAc_{jk} = 0, \text{ all } (i, j)*(j,k) \text{ and } (i, j, k) \tag{3.5}$$

$$\sum_{j} RotaTAc_{jk} - totalacre_{k} = 0 \quad k = 1,\ 2,\ 3 \tag{3.6}$$

where $RotaC_{ij}$ is rotational acreage factor for crop *i* in rotation *j*. For two-year rotations, this parameter is 0.5 and for three-year rotations, this parameter is 0.333 for all crops, while for one-year rotation (permanent cover only), it is 1. $RotaTAc_{jk}$ is total acreage of k^{th} slope land devoted to rotation *j*; $totalacre_k$ is the total acreage of cropland of slope type *k* for the representative farm.

- Labor requirement constraints (by season):

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Chour_{1ij} * \sum_{k=1}^{K} Cacre_{ijk} - Hiredlab_{1} \le 1{,}250 \tag{3.7}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Chour_{2ij} * \sum_{k=1}^{K} Cacre_{ijk} - Hiredlab_{2} \le 1{,}000 \tag{3.8}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Chour_{3ij} * \sum_{k=1}^{K} Cacre_{ijk} - Hiredlab_{3} \le 1{,}250 \tag{3.9}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} Chour_{4ij} * \sum_{k=1}^{K} Cacre_{ijk} - Hiredlab_{4} \le 1{,}000 \tag{3.10}$$

where $Chour_{mij}$ is seasonal (*m*) per acre labor requirement for crop *i* in rotation *j*; and m = 1, 2, 3, and 4 stands for March to May, June to August, September to November, and December to February respectively; and $Hiredlab_m$ is part-time labor-hours required for season *m*.

- Pesticide index constraint:

$$\sum_{j=1}^{J}\sum_{k=1}^{K} Ndxpest_{jk} * RotaTAc_{jk} \leq pestndx \tag{3.12}$$

where $Ndxpest_{jk}$ is per acre index of pesticide losses for rotation j planted on k^{th} slope; and *pestndx* is the maximum pesticide index allowed on the farm.

- Nitrogen index constraint:

$$\sum_{j=1}^{J}\sum_{k=1}^{K} Ndxnit_{jk} * RotaTAc_{jk} \leq nitrndx \tag{3.13}$$

where $Ndxnit_{jk}$ is per acre index of nitrogen loss for rotation j planted on the k^{th} slope, and *nitrndx* is the maximum nitrogen index allowed on the farm.

- Phosphorus index constraint:

$$\sum_{j=1}^{J}\sum_{k=1}^{K} Ndxpho_{jk} * RotaTAc_{jk} \leq phondx \tag{3.14}$$

where $Ndxpho_{jk}$ is per acre index of phosphorus losses for rotation j planted on k^{th} slope, and *phondx* is the maximum phosphorus index allowed on the farm.

- Soil loss constraint:

$$\sum_{j=1}^{J}\sum_{k=1}^{K} soilloss_{jk} * RotaTAc_{jk} \leq maxsoilloss \tag{3.15}$$

where $soilloss_{jk}$ is tons of per acre soil loss (water erosion and wind erosion combined) for rotation j planted on the k^{th} slope; and *maxsoilloss* is the maximum soil loss allowed on the farm.

- Annual income target constraints:

$$T - (Cprice_{1s} * Sellquota_s + Cprice_{2s} * Selladd_s + \sum_{i=3}^{I} Cprice_{is} * \sum_{j=1}^{J}\sum_{k=1}^{K} Cyield_{ijks} * Cacre_{ijk}$$
$$- \sum_{i=1}^{I}\sum_{j=1}^{J} Cvainput_{ij} \sum_{k=1}^{K} Cacre_{ijk} - Pricelab * \sum_{m=1}^{4} Hiredlab_m + Progpaymt) - y_s \leq 0$$
$$s = 1,\ldots,S \qquad (3.16)$$

Annual peanut sales in income target constraints:

$$\sum_{i=1}^{2}\sum_{j=1}^{J}\sum_{k=1}^{K} Cyield_{ijk} * Cacre_{ijk} - Sellquota_s - Selladd_s = 0 \qquad (3.17)$$

$$Sellquota_s - Quota0 \leq 0 \qquad (3.18)$$

In (3.16) T is the income target and y_s is a negative income deviation from the income target under the current feasible farm plan in state of nature *s*. $Cvainput_{ij}$ represents variable cash operating costs excluding labor cost and fixed cost for machinery. Labor cost is calculated separately and fixed machine cost has already been included in income target T (see the following section of this chapter for more information)[6]. Equations (3.17) and (3.18) are conditions to divide total peanut poundage produced for state of nature *s* into quota peanut and conditional peanut and they correspond to (3.2) and (3.3).

- Tolerance of expected negative income deviation:

$$\lambda - \sum_{s=1}^{S} Prob_s * y_s = 0, \ \lambda = \mathrm{M} \rightarrow 0 \qquad (3.22)$$

Where λ is the tolerance of expected negative income deviation, which reflects the degree of risk-aversion of the decision maker. $Prob_s$ is the probability that state of nature *s* will happen and *M* is a number which reflects the level of risk aversion of

[6] Adding a cost item to *Cvainput* has the same effect on the equation as adding the cost to *T* because *Cvainput* is preceded by a minus sign and is in brackets preceded by another minus sign.

the decision maker. A larger value of *M* corresponds to less risk aversion on the part of the decision maker.

- Nonnegativity constraints:

All variables and values representing acreage, price, cost, hours, probabilities, and other amounts are nonnegative, which is a standard constraint in mathematical programming models.

The empirical specification of variables is described in the following sections. To solve for the optimal farm plan, GAMS, the General Algebraic Modeling System (Brooke et al) is used. The program is listed in Appendix F.

3.2. Description of Representative Farm

3.2.1. Sources of information for the construction of the representative farm

The construction of the representative farm is based on data collected in the Albemarle-Pamlico watershed by the 1992 Area Studies Survey, or ASS, a collaborative effort of the USDA Economic Research Service (ERS), National Agricultural Statistics Service, Soil Conservation Service (now Natural Resource Conservation Service (NRCS)), and U.S. Department of Interior's Geological Survey. This survey was conducted to obtain information on agricultural practices related to water quality on randomly sampled fields on 980 farms in the watershed. Information on farming practices carried out on the field from 1990-1992, farm area, crop acreage, livestock numbers, and sales category was obtained. Physical characteristics of each sample site were available from the National Resource Inventory and SOILS5 database (Soil Conservation Service, 1992). Of these 980 farms, 184 farms are categorized as "other crop farms" on which peanut enterprises account for a large share of farm income. Data from those 184 farm surveys were used in this study.

In addition to data from 1992 Area Studies Survey, Soil Survey of City of Suffolk, Virginia (USDA-SCS, 1981), Virginia Agricultural Statistics Service Bulletin, 1995-1997 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff), an extensive literature review on peanut-cotton production practices, expert opinions (major advisors are Guy Sturt, James Maitland, Azenegashe Abaye, and Pat Phipps), and farm visits also serve as important information sources in the construction of the representative farm.

3.2.2. The physical situations of the representative farm

Location. The representative farm is located in the City of Suffolk. According to USDA-SCS report (1981, p.1), "the City of Suffolk is in southeastern Virginia, west of the Portsmouth-Norfolk metropolitan area. The city has an area of about 430 square miles, or 275,200 acres. ... (F)arming and woodland have been the main land uses, ..., Most farms produce peanuts, corn and soybeans; some farms raise hogs and beef cattle, and there are a few dairy farms." A small acreage is used for tobacco, wheat, and for permanent pasture. In recent years, cotton acreage has been increased rapidly in this area. By 1994, cotton acreage had reached more than one third that of corn in Suffolk (Virginia Agricultural Statistics Service). About 164,690 acres, or nearly 60 percent of the area, is classified as prime farmland, which as defined by USDA-SCS (1981, p.28), "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 of crops when it is treated and managed using acceptable farming methods.

Prime farmland produces the highest yields with minimal inputs of energy and economic resources, and farming it results in the least damage to the environment."

The climate of the City of Suffolk, as recorded in the period of 1951 to 1975 at Holland Weather Station, Virginia, can be described as: winter average temperature is 41 degrees Fahrenheit and the average daily minimum temperature is 30 degrees Fahrenheit; in summer, the daily average and average of daily maximum temperatures are 76 degrees Fahrenheit and 86 degrees Fahrenheit, respectively. Total annual precipitation is 48 inches, of which 27 inches falls in April through September, covering the growing season for most crops. In about one out of five years, less than 13.4 inches of rainfall in April through September is recorded. Average wind speed is the highest, at 12 mph, in March (USDA-SCS, 1981, p.1).

Soil types and soil slopes. Most of the City of Suffolk is on the Isle of Wight Plain of the middle Coastal Plain. Most fields are nearly level and gently sloping, but some small areas near drainage ways are sloping to moderately steep. The many small streams and drainage ways throughout the survey area have narrow side slopes that bend into gently sloping area of well drained soils. The drainage pattern is well established on the Isle of Wight Plain (USDA-SCS, 1981, p.2). According to ASS, the single largest portion of the study area is classified as Emporia soil, which makes up 22.6 percent of soil on 107 of the 184 Virginia peanut farms (the number of surveyed farms in Virginia with soil data available is 107). Emporia soil type is also closely related with Eunola-Kenansville-Suffolk association[7], which makes up 41 percent of the area. This association is on upland and can be described as moderately well drained and well drained soils that have a subsoil of mostly fine sandy loam and sandy clay loam (USDA-SCS, 1981, p.3). Thus, Emporia will be used as the soil type in this study.

The breakdown of the acreage by slope is based on data from ASS about the distribution of soil slopes for Virginia peanut-cotton growers reporting Emporia soil. Forty percent, fifty percent, and ten percent, of the crop land on the representative farm is assumed to be of one percent, three percent, and five percent slope, respectively.

Crop land: acreage, ownership, rent rate, and irrigation system. The representative farm has 750 acres of crop land, based on expert opinion (Sturt), which is close to the ASS average of 723 acres for peanut farms in that area. Of the 750 acres, 550 acres are rented and 200 acres are owned (Sturt). For owned land, there is a $5 per acre real estate tax, plus $1.50 per acre for insurance (Sturt). For rented land, determination of rental rate is discussed in the next section. The farmer is not allowed to rent more land in the model. All crop land is non-irrigated, which is typical in the study area.

Assuming the same distributional pattern by slope for both owned and rented land, the 750 acres of land are broken down by ownership and by slope as shown in the following table:

[7] A soil association is defined as a group of soils geographically associated in a characteristic repeating pattern and defined and delineated as single map unit (USDA-SCS, 1981).

Table 3.1. Acre-distribution of farmland by ownership and slopes for the representative Suffolk peanut-cotton farm

	Slope of 1%	Slope of 3%	Slope of 5%	total
Owned	80	100	20	200
Rented	220	275	55	550
Total	300	375	75	750

3.2.3. The operation and management of the representative farm

Cropping systems. Based on a literature search, expert opinion, and farm visits in the study area, a set of rotations which are currently in use or which potentially could be grown in the study area is selected for the representative farm. Each rotation consists of three components: crops and crop sequences (corn, peanut, cotton, and wheat/soybean), winter cover (wheat or rye cover or winter fallow), and tillage system (conventional till, alternative till, and no-till). Allowable combinations of these production practices included in the model are:

Currently in use:

1. Conventional cotton - winter fallow - conventional peanut -winter fallow.
2. Notill corn - winter fallow - conventional peanut - winter fallow.
3. Conventional peanut - minimum till wheat - notill soybean - winter fallow - conventional cotton - winter fallow.
4. Minimum till wheat - notill soybean - winter fallow - notill corn - winter fallow - conventional peanut.
5. Minimum till wheat - notill soybean - winter fallow - conventional cotton - winter fallow.

Alternatives:

6. Minimum till wheat - notill soybean - rye cover- notill cotton. This rotation is a conservation alternative to rotation 5.
7. Conventional cotton - wheat cover - conventional peanut - wheat cover. This rotation is a conservation alternative to rotation 1.
8. Notill cotton - wheat cover - conventional peanut - wheat cover. This rotation is a conservation alternative to rotation 1.
9. Strip-till cotton - wheat cover - conventional peanut - wheat cover. This rotation is a conservation alternative to rotation 1.
10. Notill cotton - wheat cover - strip-till peanut - wheat cover. This rotation is a conservation alternative to rotation 1.
11. Notill corn - wheat cover - conventional peanut - wheat cover. This rotation is a conservation alternative to rotation 2.
12. Strip till peanut - minimum till wheat - soybean - rye cover - notill cotton - wheat cover . This rotation is a conservation alternative to rotation 3.

In order to see the effect of imposing restrictions on environmental damages by farming activities, one more alternative production activity, the idle land option, (Phipps) is added, that is,

13. Annual wheat cover.

Rotations 1 to 5 are commonly used cropping practices in the study area. Rotations 6 to 13 are alternatives that may potentially reduce soil erosion and loading of nutrients and pesticides by providing more soil cover, less soil disturbance, or both. Rotations 5 and 6 do not include peanuts and are included to insure that the peanut quota does not limit use of cropland. Notice that no alternative rotation is suggested for rotation

4 for it is considered that notill corn residue already provides an adequate winter cover (York et al). In rotation 6 and rotation 12, the winter cover crop after soybean is rye, because soybeans are harvested too late to establish a good wheat cover. In other rotations, winter wheat cover is preferred to other cover crops for it is easy to establish and to burn down, the seed is cheap, and the dead stalks of wheat, not like those of rye, do not hinder reduced till operations (York et al). Single year wheat cover (rotation 13) is an established practice in the study area and, as can be seen later in this chapter, is very effective to reduce the soil, pesticide, and nutrient losses. According to Phipps, rotation 13 is typically carried out in the study area just for one year. That is, farmers grow annual wheat in winter, let it grow until mid June next year when wheat will naturally die or is chemically killed. Then the following year, another crop will be planted. Detailed descriptions of these practices are listed in Appendix A of this thesis.

Livestock. According to ASS, peanut farms in the study area on average have virtually no livestock except an average of 23 non-dairy cattle. In this study no livestock will be considered.

Peanut prices and peanut quota. Under the new peanut program in the Federal Agriculture Improvement and Reform Act of 1996 (FAIR), the price for quota peanut is set at $610 per ton for the years 1996 through 2002 (USDA, 1996). For additional peanut poundage harvested beyond the quota poundage, the price is $375 per ton. In this study, it is assumed that there are no differences between quota peanut and additional peanut regarding planting practices, management, input cost, quality, and yields. Only sales prices will be different.

Peanut quota poundage for the representative farm is set at 589,975 pounds. This is the average value of the ASS sampled peanut farms in Virginia (98 farms in all which have peanut quota information available to ASS). This quantity is the sum on farmer's owned quota and rented quota (assuming the farmer also rents the attached peanut quota to the 550 rented acres). Sturt suggested a simple way to calculate the amount of owned quota poundage and rented quota poundage for this study:

$$\text{Owned quota (lb)} = 589975 * \frac{200}{750} = 157327$$
$$\text{Rented quota (lb)} = 589975 * \frac{550}{750} = 432648$$

This rented quota is assumed to be the total peanut quota attached to the rented 550 acres cropland. Since renting quota peanut is profitable, the farmer is assumed to rent all of it along with the cropland itself. For the rented quota peanut, the farmer pays five cents for each pound, i.e. $0.05*432,648 or $21,632.40 in all (Sturt). The typical rental fee for one acre of crop land with no peanut quota attached in study area is $30 (Sturt). Thus, the average actual rental fee for this farm is estimated as:

$550*30 + $21,632.40 = $38132.5 or $69.30 per acre

Based on averages in the Virginia Agricultural Statistics over 1985-1994, actual prices farmers received for their peanut were lower than the support price except for two years (Mutangadura et al), which probably indicates that farmers tended to plant a little more than required to fulfill their quota in a normal year to insure they could fulfill their quotas in a year with below normal yields. Under the new peanut program in FAIR, unused peanut quota of current year cannot be automatically carried over to the next year (unlike earlier program), which increases the risk the peanut farmers faces. If the farmers do not plant enough peanut poundage to match their quota quantity each year, they suffer potential loss from the unrealized income. Possibly farmers who are risk averse (Hey) will plant a little more acreage for peanut than they require on average to meet their quota.

Government program and payment scheme: It is assumed that the farmer takes part 100 percent in the government commodity programs. Program crops are corn, cotton, and winter wheat. The government payment is calculated as:

$$\text{Payment} = \text{Base acreage} * \text{program yield} * 0.85 * \text{payment rates} \qquad (3.23)$$

ASS data based on 111 Virginia farms (mainly peanut) shows that in 1992, average base acreage for cotton, corn, and wheat are 38.936, 167.89, and 57.266 respectively. Based on the fact of rapid increase of cotton acreage in the study area, it is assumed (Sturt) that for the representative farm, base acreage for cotton is 150 acres. For wheat, base is 90 acres; and for corn, base is 180 acres. Program yields are fixed by county. According to Sturt, program yield for wheat is 39 bushels per acre, for cotton 500 pounds per acre, and for corn 79 bushels per acre.

Payment rates are based on 1996 Farm Bill News Release (Amontree and Stuart), on the estimated contract commodity payment rates, which are based on the amount of the 1995 deficiency payments required to be repaid for 1996-2002. Data from this news release are then deflated by the estimated GNP deflator (FAPRI) to 1995 dollars. Then simple averages of each of the payment rates computed for 1996-2002 give the final payment rates for cotton, wheat, and corn to be used in this study. The resulting payment rate is 6.43 cents per pound for cotton, 52.60 cents per bushel for wheat, and 27.72 cents per bushel for corn (see Appendix C, Table C-3). Thus, annual government program payments for the representative farm are: $4,099.13 for cotton; $3,350.52 for corn; and $1,569.32 for wheat. The yearly total is $9,018.97.

Labor. The representative farm will be run by the farmer himself (the operator), and he will hire one full-time hired laborer. One contracted full-time laborer costs the farmer $22,500 per year (including social security payments and taxes) and provides about 2,250 hours labor per year ((40 hours/week)*(50 weeks) + (125 more hours for spring) + (125 more hours for fall)). The farmer himself works as many hours as the full-time laborer. Thus, total full-time labor hours per year are 4,500 hours (Sturt).

The availability of full-time labor is further constrained by season. In spring and fall, the maximum full-time labor-hours available are 1,250 hours (625 from each full-timer) and in summer and winter, maximum full-time labor-hours available are 1,000 hours for each season. Seasons are: winter (December to February), spring (March to May), summer (June to August), and fall (September to November).

When full-time labor availability does not meet seasonal requirement, extra part-time labor can be hired at a wage rate of $6.00 per hour. It is assumed that there is no limit on the availability of extra part-time labor. According to the opinions of extension agents and farmers, hired laborers vary greatly in their farming skills and wages these laborers are willing to accept due to different skill levels. In this study, however, it is assumed that all full-time and part-time laborers are of the same skill level.

Machinery. Based on extension agents' opinions, farm visits, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia, the representative farm is assumed to have machinery investment of $250,000 with a debt ratio of 50 percent. Major pieces of owned machinery are as the following:

one tractor of 80 hp
one tractor of 110 hp
one tractor of 135 hp
two field cultivators (15')
two row cultivators
two sprayers (8 row)
two spreaders
two disk harrows (17')
one flip plow (4 bottom)
one subsoiler (spider)
two conventional planters (4 row), one for peanut, one for other crops
one no-till planter (4 row)
one rotary mower (14')
one drill (12')
two diggers (4 row)
two peanut combines (2-4R)
one combine for corn, soybeans, and small grain
one cotton picker

It is also assumed that operations such as planting, spraying, cultivation, and stalk-chopping are done by using an 80-hp tractor with appropriate implements attached, while 110-hp, and 135-hp tractors are to do heavy jobs such as disking and subsoiling. Detailed information on machinery used can be found in Appendix A of this thesis.

Analysis of machinery costs is described in Appendix B. Machinery costs in this study are in per-hour terms, and per-hour fixed costs[8] of the machinery will depend on total number of hours the machine is used each year. Annual use, in turn, will depend on farm plans concerning tillage and cropping systems. For simplicity, this study uses the assumed machine-use hours in the 1996 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff). Machinery costs are based on 75 percent of new cost. It is further assumed that the farmer cannot rent extra machinery for his farm operation.

[8] Fixed costs include depreciation and interest recovery, interest on salvage, insurance, taxes, and housing.

Liabilities facing the farmer and cash-flow situation. As suggested by Sturt and Maitland, the representative farmer has the following liabilities and fixed annual cash payments:

- land debt: $150,000 on 15-year term with annual payment of $19,725 (interest rate 10 percent);
- machinery debt: $125,000 on 5-year term with annual payment of $32,975 (interest rate 10 percent);
- social security tax, family living expenses, and income tax, totaling $40,000 per year for the farmer's family;
- payment of $22,500 per year to the one full-time hired worker;
- real estate tax and insurance for owned land: $6.50*200 = $1,300; and
- annual land rental fee of $38,132.50.

The total of $145,458 is the income target (explained in next section).

3.2.4. The fluctuation and expectation of crop yields and prices

The farmer in this study is concerned about minimizing income risk and maximizing net income. He is assumed to adopt a farm plan whose possible negative deviations from the income target ($145,458) do not exceed a set level while maximizing expected return. The farmer is assumed to expect next year's crop yields to be uncertain but to follow the same variation pattern as the past (1986-1995). Output prices are expected to vary around a forecast by FAPRI, the Food and Agricultural Policy Research Institute, with the same variation pattern as the past (1986-1995). Input prices and production technology are assumed not to change over the next year. The period 1986-1995 is chosen because the 1985 Farm Bill encouraged greater flexibility and made prices of program crops more reflective of the world market by lowering prices floors expressed as loan rates (Glaser).

The most important factor which affects crop yields is weather condition. Because all crops are under the same weather conditions, it is reasonable to assume that observed historical yields preserve well the underlying yield correlation among the crops. There are no actual "observed" historical yields data available for each of the five crops in each of the twelve rotations on the Emporia soil for each of the three field slopes (0, 3, and 5 percent) for each of the ten years (1986-1995) for the representative farm. Therefore, simulation will be used to estimate yields. A calibrated and verified EPIC-PST model using actual daily weather data for 1986-1995 from the study area will be run to obtain these data. The discussion of EPIC-PST and resultant simulated yields are presented in Section 3.3.

The prices for the states of nature are selected as follows. First, annual historical prices are selected for each crop and expressed in 1995 dollars. Cotton prices are for the Southeastern region taken from Cotton Price Statistics 1986-1995 (USDA, Agricultural Marketing Service, Cotton Division). Specifically cotton prices are averaged on grade 41-43 (leaf 4) and grade 31-34 (leaf 4) as suggested by Jones. Prices of corn, wheat, and soybean are seasonal average prices from Virginia Agricultural Statistics. All prices are adjusted to 1995 dollars by the GDP deflator from the President's Economic Report. For example, 1986 nominal prices for corn, wheat, and soybean in Virginia are, respectively, \$1.70, \$2.55, and \$4.90 per bushel. The GDP deflator for 1986 is 75.1 (that for 1995 is 100). Divided by 100/75.1, the nominal prices then give corn, wheat, and soybean prices in 1995 dollars of \$2.26, \$3.40, and \$6.52 per bushel, respectively, for Virginia (See

Appendix C for more information). The historical prices in 1995 dollars are listed in Table 3-2 in the column labeled "Hist.".

Second, deviations of historical prices from the average historical price are calculated. Deviation of historical prices from average historical prices are then expressed as $\frac{\text{yearly price}}{\text{average price}}$ and results are listed in columns labeled as "Dev." of Table 3-2.

Third, estimated prices used in the model are calculated. The model prices are calculated by multiplying the FAPRI (average) forecast price by the deviation of historical price from average historical price for each crop. The resulting prices used in the model are shown in Table 3-2 below (see Appendix C, Table C-4 for more detail on the FAPRI price forecasts and how they are adjusted for Virginia).

Table 3-2. State of nature prices for the representative farm[a]

State	Cotton ($/lb)			Corn ($/bu)			Wheat ($/bu)			Soybean ($/bu)			Peanut additionals ($/lb)		
i	Hist[b]	Dev[c]	Model[d]	Hist[b]	Dev[c]	Model[d]	Hist[b]	Dev[c]	Model[d]	Hist[b]	Dev[c]	Model[d]	Hist[b]	Dev[c]	Model[d]
1	0.69	0.91	0.53	2.26	0.82	1.93	3.40	0.98	2.90	6.52	0.98	5.22	0.17	0.98	0.17
2	0.83	1.08	0.62	2.65	0.96	2.26	3.29	0.95	2.81	7.82	1.17	6.23	0.17	1.17	0.20
3	0.72	0.94	0.54	3.62	1.31	3.08	4.30	1.24	3.67	9.23	1.38	7.35	0.17	1.38	0.24
4	0.85	1.11	0.64	3.11	1.13	2.66	4.13	1.19	3.52	6.82	1.02	5.43	0.17	1.02	0.17
5	0.87	1.14	0.66	2.88	1.05	2.47	3.38	0.98	2.90	6.36	0.95	5.06	0.17	0.95	0.16
6	0.64	0.83	0.48	2.87	1.04	2.44	2.98	0.86	2.55	6.06	0.91	4.85	0.17	0.91	0.15
7	0.61	0.80	0.46	2.41	0.88	2.07	3.33	0.96	2.84	5.90	0.89	4.74	0.17	0.89	0.15
8	0.71	0.92	0.53	2.77	1.01	2.37	2.85	0.82	2.43	6.75	1.01	5.38	0.17	1.01	0.17
9	0.89	1.17	0.68	2.40	0.87	2.04	2.91	0.84	2.49	5.41	0.81	4.31	0.17	0.81	0.14
10	0.84	1.10	0.63	2.57	0.93	2.19	4.04	1.17	3.46	5.83	0.87	4.63	0.17	0.87	0.15
Average	0.77	1.00	0.58	2.75	1.00	2.35	3.46	1.00	2.96	6.67	1.00	5.32	0.17	1.00	0.17
Median[e]			0.58			2.31			2.87			5.14			0.17

a. "State" years are from 1986-1995. For more information, see Appendix C.
b. Historical prices for Virginia in adjusted to 1995 dollars. For additional peanut, a fixed "historical price" of $0.17 per pound is used (explained in the text that follows this table) varied in the same pattern as soybean.
c. Deviation from average historical price. The formula is (historical price)/(average historical prices);
d. Model prices equal price deviation * FAPRI forecast prices.
e. Defined as average of the two middle values.

As mentioned before, the new Farm Bill (FAIR) set price for peanut quota at $610 per ton and the price for additional peanut at $132 per ton for the year 1996 through 2002. In this study, peanut quota prices are fixed at a nominal value of $610/ton from 1996 to 2002. After deflating these values for each year from 1996 to 2002 using the

FAPRI projected inflation rates, averages are taken, yielding an expected average price of $0.251 per pound for peanut quota.

Currently, additional peanut can be marketed either by being placed under contract for export or by being placed under loan. About 15 percent of crop in Virginia is marketed by the first method in which case the price is the contract price received at harvest time, currently estimated at $375 per ton (according to Dell Cotton, manager of Peanut Growers Cooperative Marketing Association). About 10 percent of crop in Virginia is marketed by being placed under loan in which case the additionals price is the loan price received at harvest (set at $132 per ton through the year 2002) plus the dividend price, if any, received in the following July after harvest ($415.75 per ton for the year 1996 in Virginia-North Carolina) (Dell Cotton). Since the loan market can effectively absorb only a limited amount of additionals due to the pressing of supply on demand, it is assumed in this study that all additional peanuts are placed under contract for export. Experience prior to 1996 is little guide to future additionals prices, because the 1996 Farm Bill (FAIR) made it impossible to carry forward unused quota to subsequent years. Therefore, $375 per ton is used in this study as the long term average price in 1995 dollars for peanut additionals. Due to the fact that peanut is similar to soybean in marketing, the fluctuation pattern of the prices for additonals is set to follow that of soybean. By going through the similar procedure that determines the prices of soybean, the prices for peanut addtionals are obtained as shown in Table 3-2 above.

No correlation is assumed to exist between prices and yields. This point can be confirmed by the estimated yield-price correlation coefficients from observed data 1986-1995 (Table 3-3). In Table 3-3, the first number is the Pearson correlation coefficient. The numbers in parentheses are P-values under the hypothesis H_0: $\rho = 0$. From the p-values, estimates should fail to reject that correlation coefficients are zero except for soybean price vs. cotton yield at 0.05 level. Though the sample size is small, the estimates imply that there is no strong correlation between crop prices and crop yields in the study area.

Table 3-3. Sample price-yield correlation coefficients[a]

	COTTON PRICE	WHEAT PRICE	CORN PRICE	SOYBEAN PRICE
Cotton yield	0.06982[b]	-0.31211	-0.34738	-0.68573
	(0.8480)[b]	(0.3800)	(0.3254)	(0.0286)
Wheat yield	0.01218	-0.15676	-0.36841	-0.63038
	(0.9734)	(0.6654)	(0.2949)	(0.0507)
Corn yield	0.14716	0.49275	0.24490	-0.07136
	(0.6850)	(0.1479)	(0.4953)	(0.8447)
Soybean yield	0.00695	0.08125	0.38408	0.14274
	(0.9848)	(0.8234)	(0.2732)	(0.6940)

a. The yield data used in the calculation are for the City of Suffolk (Virginia Agricultural Statistics, 1986-1995). Prices are deflated data for the State of Virginia (as described bove).
b. First number is Pearson correlation coefficient, and the second number is the p-value for H_0: $\rho = 0$.

3.3. EPIC-PST model and verification

3.3.1. Introduction to EPIC-PST

EPIC, the Erosion-Productivity Impact Calculator, is a crop-growth simulation model. The EPIC model was developed as a result of the Soil and Water Resource Conservation Act of 1977 (RCA), which required the USDA to obtain and maintain information on the status of soil, water, and related resources of the nation (Williams and Renard). Major biophysical processes simulated or “components” of EPIC are: weather, hydrology, erosion, nutrient cycling, pesticide fate, soil temperature, tillage, crop growth, crop and soil management, and economics. This model is capable of measuring the effects of erosion on productivity and long range resource capacity. EPIC works through simulating the interactions among weather, hydrology, erosion, plant nutrients, plant growth, soil tillage and management, and plant environmental control (Putman and Dyke).

For simulation of pesticide fate, the program subroutines from GLEAMS are contained in EPIC.

GLEAMS, the Groundwater Loading Effects of Agricultural Management Systems, developed by USDA, is a process-based "management" model which is capable of evaluating the effects of agricultural management systems on the movement of agricultural chemicals within and through the plant root zone. The model is a continuous, field-scale hydrology and chemical transport model that operates on a daily time step. The model simulates chemical transport in runoff, erosion, and with percolating water, considering foliar washoff, equilibrium absorption, and first-order decay in foliage and soil. Data input requirements include pesticide solubility, pesticide half-life (for each soil horizon and on foliage), wash off fraction, and the soil organic carbon (absorption) partitioning coefficient, K_{oc}. Chemical application can be partitioned between plant foliage and the soil surface. Soil-applied chemicals can be surface-applied, incorporated to a specified depth, or applied by chemigation (Zacharias and Heatwole). Detailed description of GLEAMS can be found in Leonard et al.

With the pesticide subroutines from the GLEAMS model combined, the EPIC model now is often referred to as EPIC-PST. "Williams (1989) evaluated EPIC's ability to simulate yields of maize, wheat, rice, sunflower, barley and soybeans using a total of 227 measured yields reported by independent research groups around the world. For these crops, mean simulated yields were always within 7 percent of mean measured yields. For 118 comparisons of measured and simulated maize yields, mean measured yield and its standard deviation were 103 bushels per acre and 49 bushels per acre, respectively. The measured and simulated means were not significantly different at the 95% confidence level. He (Williams) also demonstrated that EPIC can accurately simulate maize responses to irrigation at locations in the western USA and to fertilizer nitrogen in Hawaii" (EPIC 5320 Manual). In addition to test research in crop productivity, model tests of soil degradation, input levels and management practices, response to climates and soils, climate change and water quality analysis are numerous and positive (EPIC 5320 Manual). Other favorable model test results for GLEAMS use can also be found in works done by Zacharias and Heatwole, and Smith et al.

To achieve objectives of this study, results from the EPIC-PST model simulation are used to provide input data for the Target MOTAD mathematical programming model of the representative farm. These data include runoff and percolation of nitrogen, phosphorous, and pesticides, and sediment erosion from production activities. In the next two sub-sections, EPIC-PST input requirements, the nature of EPIC output data, and the calibration and validation of the model will be discussed.

3.3.2. Input and output of EPIC-PST

Input. EPIC-PST data input is divided into four files, an operation- and site-specific general file, a crop parameters file, a tillage and experimental parameters file, and a pesticide parameters file.

The operation- and site-specific general file contains general input information related to the run, the program control codes, general data on the drainage area, water erosion data, weather data, wind erosion data, soil data, economic data, and management information (operation codes, operation variables, and operation schedule). Example data items in this file are: number of years of simulation, the beginning year, the beginning month, the printing code which dictates whether the output data are for daily, monthly, or yearly simulation, drainage area, field slope, soil information, and date and dose of operations. Detailed data forms for this part and data realized for this study are presented in Appendix D. Some of the data items can be generated by EPIC itself by relevant inner stochastic processes. For example, the daily weather data can be generated by EPIC if average monthly weather data have been input already.

The other three data files contain parameters for crops, tillage, and pesticides. They are based on research results, extension recommendations and machinery specifications, and manufacturers labeling and EPA registration data. EPIC-PST contains parameters for over 200 pesticides, over 50 crops, over 50 tillage operations, 737 soil series, and weather data sets from 135 weather stations around the United States. Nevertheless, users can edit, add, or even create their own data base for more specific situations. In this study, as much as possible, data and parameters from the original EPIC database are used. Adjustments needed to adapt to specific situations are mentioned and presented in Appendix E. Generally, any adjustment is made under consultation from specialists either from EPIC technical supporting staff in the Texas Agricultural Experiment Station, Blackland Research Center at Texas A&M University, or from experts at Virginia Tech. Because of the amount of data in these three data files, detailed information will not be presented in this thesis. Nevertheless they can be found in the EPIC 5320 User's Manual.

Output. Output from EPIC simulation output can be divided into three major sections: "(1) input values and initial conditions, (2) simulation results reported daily, monthly, or annually, and (3) summary tables. The summary table after each period contains outputs on the state of the environmental variables, erosion rate and crop production" (quoted from Maiga, pp.112-113). Environmental variables include nitrogen loss in runoff, in sub-lateral flow, in leaching, and with sediment; phosphorus loss in runoff and phosphorus loss with sediment; and variables related to pesticide losses such as pesticides leached below the soil profile, pesticides in sediment, pesticide in runoff, and pesticides in subsurface flow. Data on final condition of the soil are given at the end of each output file.

Environmental indices of nitrogen loss, phosphorus loss, pesticide loss, and sediment for each of the thirteen rotations are calculated, using methods as presented in Section 3.4 in this chapter, from simulated values by EPIC-PST over 1986-1995. These indices then form the basis to set environmental constraints for the Target MOTAD model. This aspect of model construction will be discussed in Section 3.4.

3.3.3. Verification of EPIC-PST

Once a proven simulation model is chosen, it must be compared and, if necessary, calibrated against known research results to make sure that model results are reasonably accurate in predicting actual outcomes such as field experiment results. In cases such as EPIC-PST, which produces results on many parameters for which field experimental data are not readily available to make a comparison, calibration procedures rely on expert appraisal to make sure that the simulated results are not unexpected (Parsons, p.57-58)[9]. Thus, by forcing the model to produce reasonable output as appraised by experts, basic input parameters of the final model can be set. Technically, calibration is iterative to

[9] Some scientists argued that the "validation" as described here actually is only "verification" because verification is at best a confirmation of measured results while model validation implies that the model is soundly grounded on facts, evidence, logic and therefore is free from errors. In this sense, models like EPIC, no matter how complex they are, are just very primitive mathematical and statistical abstractions of some far more complicated biological or biophysical systems, and are full of potential errors. Thus, some scientists even claim that these kinds of model cannot be validated (Konikow and Bredehoeft). In this study, however, no attempt is made to distinguish the concepts "verification" and "validation".

determine if additional calibration of model parameters is required. The procedures for calibration and validation of the EPIC-PST model in this study are as follows:

1). **Time and place**. It was decided that crop yields for the period of 1991 to 1995 will be simulated and compared to experimental fields at Tidewater Agricultural Research and Extension Center (TAREC) in Suffolk, Virginia. Actual daily rainfall and temperature data from the TAREC is used, while long-term average wind data are for nearby Matthew, Virginia, coming from EPIC original data file.

2). **Field reports**. Under guidance of Phipps, plant pathologist at TAREC, field experimental data are selected from experiments reported in Phipps (1991-1995) for cotton (1992-1995), wheat (1991-1995), soybean (1991-1994), and peanut (1995). Four years' peanut field experimental data are from Mozingo (1991-1994). Corn data are from Virginia Corn Performance Trials in 1990-1995 (Brann et al). Basically, field reports contain information on soil series, previous crops planted on the site (1 to 4 years), field preparation, planting dates and varieties, cultivation, chemical and fertilizer use, dates of harvest, and yields.

3). **Expert evaluation of input parameters.** Soil data for Eunola, Emporia, Nansemond, Goldsboro, Suffolk, and Kenansville are used in this study. Emporia soil is for the representative farm simulation, while others are used to calibrate and validate the EPIC-PST model. Parameters for these soil types come from the EPIC supplementary soil file. Professor James Baker of Crop and Soil Environmental Sciences (CSES) of Virginia Tech examined parameters of these soil files and made necessary corrections. Phipps offered suggestions in setting up peanut plant parameters. Wesley Adcock, a graduate student of the CSES Department at

Virginia Tech reviewed some of the important plant parameters such as heat unit, harvest index, plant density, and temperature for plant optimal growth for the study crops. Professor Azenegashe Abaye of CSES gave much detailed information as to cotton growth and advised on the expected effect of notill cotton and cover crops on cotton yields.

4). **Simulation of 1991-1995 crop yields.** EPIC-PST simulates each crop for each year, using soil type, and operation dates as described in the field reports. As long as information is available about previous crops (at least names of the crops), they are also simulated. Previous crops are very important in fertilizer carryover, soil disturbance, and basic soil nutrient buildups, which will affect yields of current crops as simulated by EPIC. Because generally little is known about dates and types of field operations, and names and amounts of fertilizers and pesticides for previous crops, “standard” practices as described in Appendix A of this thesis are used for the previous crops. Specifically, for cotton and peanut, conventional tillage is used, for corn, notill, for soybean, notill, and for wheat, minimum-till.

In order to get simulated yields reasonably close to actual yields, parameters in EPIC files are adjusted as described in Appendix E. At this stage of the EPIC calibration, some EPIC parameters such as tillage parameters (depths of tillage, and mixing efficiencies, for example), and crop parameters (potential heat unit, plant density, and leaf decline stage at harvesting, for example) are determined (see Appendix E for more information). When average simulated yields fall within 10 percent of actual average yields and yearly variations are similar to that of field reports, the yield calibration is complete. A brief report on simulated yields for the calibration procedure is in Table 3-4. below.

Table 3-4. Actual and simulated crop yields[a]

	Peanut (lb/ac)		Cotton (lb/ac)[b]		Corn (bu/ac)		Wheat (bu/ac)		Soybean (bu/ac)	
Year	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated
1991	3600	3439	1146.6	1248.7	103.3	129.3	73.9	60.0	47.6	39.2
1992	3746	3507	980.1	923.5	107.6	139.8	70.4	74.7	38.3	42.9
1993	3517	3533	416.3	463.3	60.2	46.5	64.4	71.2	18.3	25.9
1994	3650	3896	1253.4	1212.0	120.9	128.7	72.4	71.9	42.0	44.4
1995	4527	3144	994.9	936.4	141.6	129.8	94.3	76.6		
Average	3808.0	3503.7	958.3	956.8	106.7	114.8	75.1	70.9	36.6	38.1
Ratio[c]	1.09		1.00		0.93		1.06		0.96	

a. See Appendix E for information sources, EPIC setting, and other information.
b. Lint yield only. See Appendix E for original field report on yields of seed cotton.
c. Formula is sum(actual)/sum(simulated).

In Table 3-4, average simulated yields are all within 10 percent of the average actual yields, and generally follow the same pattern of variation of the actual yields. For example, in 1993 most crops yielded dramatically lower than in other years because of drought in summer. Winter wheat was not affected very much by this condition as indicated by both actual yield and simulated yield being close to their averages. For peanut and wheat in 1995, simulated yields are much lower than reported actual field yields which are high. Reported peanut yield in 1995 is for irrigated peanut and 1995 is a dry year for non-irrigated peanut (Phipps). Some discrepancy between actual and simulated yield patterns, such as that of wheat in 1995, are expected because not all of the specific characteristics of the land, weather condition, and managerial skills are captured by the EPIC model. For the purpose for this study, the results are deemed reasonable based on the relative closeness of simulated and actual mean values.

A final adjustment was made to insure consistency of simulated yields. As can be seen from the table above, simulated yields of peanut and wheat are less than the means of the experimental results, simulated yields of corn and soybean are larger than average actual yields, while simulated and actual averages of cotton are same. So a simple method is used to correct this inconsistency by multiplying all simulated yields by the ratios as listed in Table 3-4. This step is taken to avoid possible bias in understating the profitability of some crops relative to others. The resulting simulated yields for all crops for the representative farm are shown in Table 3-5.

Table 3-5. Crop Yields Simulated by EPIC for years 1986-1995[ab]

Var	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Ave.	Med.[c]
Ypt011	3877.1	3611.2	3743.1	4030.8	4125.7	3877.1	3869.5	2699.9	4223.8	3529.4	3758.8	3873.3
Ypt013	3878.2	3590.5	3740.9	4025.4	4107.1	3877.1	3868.4	2648.7	4205.2	3505.4	3744.7	3872.8
Ypt015	3878.2	3573.0	3739.8	4015.6	4072.2	3878.2	3868.4	2616.0	4190.0	3477.1	3730.9	3873.3
Ypt021	3877.1	3612.3	3742.0	4031.9	4125.7	3876.0	3868.4	2699.9	4223.8	3529.4	3758.6	3872.2
Ypt023	3878.2	3591.6	3740.9	4025.4	4108.2	3876.0	3868.4	2649.8	4205.2	3505.4	3744.9	3872.2
Ypt025	3878.2	3575.2	3738.7	4016.7	4073.3	3877.1	3868.4	2617.1	4188.9	3477.1	3731.1	3872.8
Ypt031	3865.1	3606.8	3743.1	4005.8	4122.4	3878.2	3849.9	2699.9	4206.3	3737.6	3771.5	3857.5
Ypt033	3866.2	3585.0	3743.1	3999.2	4094.0	3878.2	3849.9	2648.7	4206.3	3720.2	3759.1	3858.1
Ypt035	3866.2	3559.9	3740.9	3993.8	4055.9	3878.2	3849.9	2616.0	4191.1	3696.2	3744.8	3858.1
Ypt041	3865.1	3606.8	3744.2	4004.7	4124.6	3876.0	3848.8	2698.8	4223.8	3737.6	3773.0	3857.0
Ypt043	3865.1	3585.0	3742.0	3998.1	4095.1	3876.0	3849.9	2648.7	4205.2	3720.2	3758.5	3857.5
Ypt045	3865.1	3559.9	3740.9	3993.8	4055.9	3877.1	3848.8	2616.0	4190.0	3697.3	3744.5	3857.0
Ypt071	3877.1	3609.0	3745.2	4037.4	4122.4	3877.1	3869.5	2730.5	4228.1	3529.4	3762.6	3873.3
Ypt073	3878.2	3588.3	3742.0	4034.1	4091.9	3878.2	3869.5	2681.4	4225.9	3503.3	3749.3	3873.9
Ypt075	3879.3	3563.2	3740.9	4025.4	4053.7	3879.3	3869.5	2652.0	4193.2	3476.0	3733.3	3874.4
Ypt081	3877.1	3609.0	3745.2	4037.4	4122.4	3877.1	3869.5	2729.4	4228.1	3529.4	3762.5	3873.3
Ypt083	3878.2	3588.3	3742.0	4034.1	4091.9	3878.2	3869.5	2681.4	4225.9	3503.3	3749.3	3873.9
Ypt085	3879.3	3563.2	3740.9	4025.4	4053.7	3878.2	3869.5	2652.0	4193.2	3476.0	3733.1	3873.9
Ypt091	3877.1	3609.0	3745.2	4037.4	4121.3	3877.1	3868.4	2730.5	4227.0	3527.2	3762.0	3872.8
Ypt093	3878.2	3588.3	3742.0	4034.1	4091.9	3877.1	3868.4	2681.4	4224.8	3501.1	3748.7	3872.8
Ypt095	3879.3	3563.2	3740.9	4025.4	4053.7	3878.2	3868.4	2650.9	4196.5	3473.8	3733.0	3873.3
Ypt101	3489.4	3248.1	3370.7	3633.6	3709.2	3488.4	3481.6	2457.4	3804.3	3174.5	3385.7	3485.0
Ypt103	3490.4	3229.5	3367.8	3630.7	3682.7	3488.4	3481.6	2414.2	3802.4	3152.0	3374.0	3485.0
Ypt105	3491.4	3206.9	3366.8	3622.8	3649.5	3489.4	3481.6	2388.7	3775.9	3127.4	3360.0	3485.5
Ypt111	3877.1	3610.1	3744.2	4037.4	4122.4	3875.0	3868.4	2729.4	4225.9	3527.2	3761.7	3871.7
Ypt113	3878.2	3588.3	3742.0	4034.1	4091.9	3876.0	3868.4	2681.4	4223.8	3501.1	3748.5	3872.2
Ypt115	3878.2	3563.2	3740.9	4025.4	4054.8	3877.1	3868.4	2619.3	4191.1	3479.3	3729.8	3872.8
Ypt121	3478.6	3250.1	3368.8	3603.9	3704.3	3489.4	3463.9	2435.8	3803.3	3364.8	3396.3	3471.3
Ypt123	3479.6	3237.3	3368.8	3598.2	3667.0	3489.4	3463.9	2391.7	3803.3	3349.1	3384.8	3471.8
Ypt125	3479.5	3217.7	3367.8	3593.4	3626.8	3490.4	3463.9	2363.3	3783.7	3328.5	3371.5	3471.7
Yct011	1247.0	926.0	1151.0	1192.0	1154.0	1234.0	1266.0	580.0	1265.0	955.0	1097.0	1173.0
Yct013	1241.0	917.0	1125.0	1185.0	1132.0	1226.0	1262.0	566.0	1251.0	941.0	1084.6	1158.5
Yct015	1240.0	903.0	1096.0	1178.0	1110.0	1218.0	1255.0	557.0	1234.0	928.0	1071.9	1144.0
Yct031	1247.0	917.0	1185.0	1216.0	1133.0	1231.0	1281.0	567.0	1218.0	956.0	1095.1	1200.5
Yct033	1243.0	917.0	1168.0	1207.0	1133.0	1224.0	1280.0	567.0	1196.0	942.0	1087.7	1182.0
Yct035	1239.0	904.0	1150.0	1198.0	1113.0	1215.0	1276.0	558.0	1178.0	932.0	1076.3	1164.0
Yct051	1180.0	884.0	1126.0	1173.0	1126.0	1194.0	1229.0	573.0	1171.0	1016.0	1067.2	1148.5
Yct053	1180.0	879.0	1126.0	1188.0	1126.0	1177.0	1229.0	561.0	1171.0	1005.0	1064.2	1148.5
Yct055	1152.0	871.0	1076.0	1185.0	1072.0	1158.0	1157.0	553.0	1125.0	992.0	1034.1	1100.5
Yct061	1180.0	883.0	1126.0	1173.0	1126.0	1194.0	1129.0	573.0	1171.0	1016.0	1057.1	1127.5
Yct063	1165.0	879.0	1103.0	1188.0	1100.0	1177.0	1196.0	561.0	1152.0	1005.0	1052.6	1127.5
Yct065	1152.0	871.0	1076.0	1185.0	1072.0	1158.0	1157.0	553.0	1125.0	992.0	1034.1	1100.5
Yct071	1245.0	925.0	1156.0	1206.0	1149.0	1228.0	1261.0	587.0	1278.0	955.0	1099.0	1181.0
Yct073	1238.0	916.0	1136.0	1194.0	1125.0	1221.0	1255.0	573.0	1260.0	941.0	1085.9	1165.0
Yct075	1237.0	898.0	1114.0	1183.0	1101.0	1215.0	1248.0	558.0	1247.0	930.0	1073.1	1148.5
Yct081	1245.0	925.0	1156.0	1206.0	1149.0	1238.0	1261.0	587.0	1278.0	955.0	1100.0	1181.0
Yct083	1238.0	916.0	1136.0	1194.0	1125.0	1221.0	1355.0	573.0	1260.0	941.0	1095.9	1165.0
Yct085	1237.0	898.0	1114.0	1183.0	1101.0	1215.0	1248.0	558.0	1247.0	930.0	1073.1	1148.5

Var	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Ave.	Med.[c]
Yct091	1245.0	925.0	1156.0	1206.0	1149.0	1228.0	1262.0	587.0	1279.0	955.0	1099.2	1181.0
Yct093	1238.0	916.0	1136.0	1194.0	1125.0	1222.0	1255.0	574.0	1260.0	941.0	1086.1	1165.0
Yct095	1237.0	898.0	1114.0	1183.0	1101.0	1215.0	1249.0	566.0	1248.0	929.0	1074.0	1148.5
Yct101	1245.0	927.0	1156.0	1207.0	1150.0	1229.0	1262.0	588.0	1279.0	956.0	1099.9	1181.5
Yct103	1238.0	918.0	1137.0	1195.0	1126.0	1222.0	1255.0	574.0	1261.0	943.0	1086.9	1166.0
Yct105	1237.0	899.0	1115.0	1184.0	1102.0	1215.0	1248.0	567.0	1249.0	932.0	1074.8	1149.5
Yct121	1247.0	922.0	1186.0	1227.0	1116.0	1226.0	1277.0	568.0	1216.0	958.0	1094.3	1201.0
Yct123	1243.0	922.0	1169.0	1216.0	1116.0	1219.0	1273.0	568.0	1196.0	947.0	1086.9	1182.5
Yct125	1239.0	909.0	1157.0	1209.0	1085.0	1210.0	1265.0	560.0	1175.0	937.0	1074.6	1166.0
Ycn021	108.8	92.1	102.3	101.4	107.0	106.0	105.1	72.5	105.1	104.2	100.4	104.6
Ycn023	107.9	92.1	101.4	102.3	106.0	105.1	103.2	70.7	105.1	104.2	99.8	103.7
Ycn025	107.9	91.1	100.4	101.4	106.0	104.2	101.4	69.8	104.2	103.2	99.0	102.3
Ycn041	112.5	94.9	112.5	110.7	117.2	112.5	116.3	73.5	112.5	112.5	107.5	112.5
Ycn043	111.6	94.9	111.6	110.7	117.2	111.6	114.4	72.5	112.5	111.6	106.9	111.6
Ycn045	110.7	93.9	109.7	110.7	115.3	111.6	111.6	71.6	111.6	109.7	105.6	110.7
Ycn111	107.9	90.2	101.4	104.2	107.0	106.0	105.1	73.5	105.1	104.2	100.4	104.6
Ycn113	107.9	90.2	100.4	103.2	107.0	105.1	103.2	71.6	105.1	104.2	99.8	103.7
Ycn115	107.0	89.3	99.5	102.3	106.0	105.1	102.3	68.8	104.2	103.2	98.8	102.8
Ywt031	77.4	75.3	92.2	86.9	75.3	85.9	99.6	92.2	78.4	93.3	85.6	86.4
Ywt033	77.4	74.2	91.2	86.9	74.2	85.9	99.6	92.2	78.4	93.3	85.3	86.4
Ywt035	76.3	74.2	91.2	86.9	73.1	84.8	99.6	91.2	78.4	92.2	84.8	85.9
Ywt041	77.4	75.3	92.2	86.9	74.2	85.9	100.7	92.2	78.4	94.3	85.8	86.4
Ywt043	77.4	74.2	91.2	86.9	73.1	85.9	100.7	92.2	78.4	93.3	85.3	86.4
Ywt045	77.4	74.2	91.2	86.9	73.1	84.8	99.6	91.2	78.4	93.3	85.0	85.9
Ywt051	88.0	71.0	73.1	85.9	99.6	81.6	80.6	89.0	79.5	88.0	83.6	83.7
Ywt053	86.9	71.0	73.1	85.9	99.6	81.6	80.6	89.0	78.4	88.0	83.4	83.7
Ywt055	86.9	70.0	73.1	84.8	98.6	83.7	80.6	88.0	78.4	86.9	83.1	84.3
Ywt061	72.1	71.0	88.0	85.9	73.1	81.6	99.6	89.0	80.6	88.0	82.9	83.7
Ywt063	72.1	71.0	86.9	85.9	73.1	81.6	99.6	89.0	80.6	86.9	82.7	83.7
Ywt065	71.0	70.0	85.9	84.8	73.1	80.6	98.6	88.0	79.5	86.9	81.8	82.7
Ywt121	77.4	75.3	92.2	86.9	74.2	85.9	100.7	92.2	78.4	93.3	85.6	86.4
Ywt123	77.4	74.2	92.2	86.9	74.2	85.9	100.7	92.2	78.4	93.3	85.5	86.4
Ywt125	77.4	74.2	92.2	86.9	74.2	85.9	99.6	92.2	78.4	93.3	85.4	86.4
Ysb031	41.3	40.3	40.3	41.3	44.2	39.4	45.1	20.2	45.1	33.6	39.1	40.8
Ysb033	41.3	39.4	40.3	41.3	44.2	36.5	45.1	19.2	44.2	33.6	38.5	40.8
Ysb035	41.3	36.5	40.3	41.3	44.2	35.5	45.1	18.2	42.2	31.7	37.6	40.8
Ysb041	42.2	40.3	40.3	41.3	44.2	39.4	45.1	20.2	45.1	35.5	39.4	40.8
Ysb043	41.3	39.4	40.3	41.3	44.2	37.4	45.1	19.2	44.2	33.6	38.6	40.8
Ysb045	41.3	38.4	40.3	41.3	44.2	35.5	45.1	18.2	42.2	31.7	37.8	40.8
Ysb051	42.2	38.4	44.2	41.3	44.2	39.4	44.2	22.1	41.3	35.5	39.3	41.3
Ysb053	42.2	38.4	44.2	41.3	44.2	39.4	43.2	22.1	39.4	35.5	39.0	40.3
Ysb055	41.3	36.5	44.2	41.3	44.2	35.5	41.3	20.2	37.4	32.6	37.4	39.4
Ysb061	41.3	38.4	42.2	41.3	44.2	39.4	44.2	22.1	44.2	35.5	39.3	41.3
Ysb063	41.3	37.4	42.2	41.3	44.2	37.4	44.2	21.1	43.2	34.6	38.7	41.3
Ysb065	41.3	36.5	44.2	41.3	44.2	35.5	41.3	20.2	37.4	32.6	37.4	39.4
Ysb121	41.3	40.3	40.3	41.3	44.2	40.3	45.1	20.2	46.1	33.6	39.3	40.8
Ysb123	41.3	39.4	40.3	41.3	44.2	38.4	45.1	19.2	45.1	33.6	38.8	40.8
Ysb125	41.3	38.4	40.3	41.3	44.2	36.5	45.1	18.2	44.2	31.7	38.1	40.8

a. Adjusted by ratios in Table 3-4. That is, yields listed in this table which are simulated crop yields are multiplied by the corresponding ratios listed in Table 3-4.
b. For variable *Yaabbc*, *Y* means yield; *aa* means crop: pt for peanut, ct for cotton, cn for corn, wt for wheat, and sb for soybean; *bb* means rotation (01 to 13); *c* is slope of the land (1, 3, 5 %).
c. Calculated as average of two middle values.

5). **Simulation of nutrient losses, pesticide losses, and soil losses for calibration purpose.** For the purpose of calibration, nutrient loss, pesticide loss, and soil loss can not be evaluated the same way as yields because no such field data are available to make comparisons. Thus, calibration consists of having experts judge if the data obtained from EPIC are reasonable and making adjustments if the data are not. After calibration for yields, the EPIC model is set up for the representative farm (see subsection 3.3.4, The final EPIC-PST setup). Soil loss data from the EPIC output for the representative farm and Emporia soil are presented to experts for evaluation (see below). The focus is on the average annual values of soil loss because soil losses reflect well the effects of weather conditions (mainly amounts and distributions of rainfall and wind) and soil conditions. Also, soil losses are closely related to nutrient losses and pesticide losses. The simulated average soil, nutrient, and pesticide losses along with the evaluations by experts are described in the subsection 3.4.3, "Empirical results for soil loss, and environmental indices for nitrogen, phosphorus, and pesticides."

<u>3.3.4. The final EPIC-PST setup</u>

Rotations, slopes, and soil type. After calibrating the EPIC yield simulations, the EPIC model is set for the representative farm. Emporia is selected as the sole soil type for the whole farm and field slopes are set to one, three, and five percent. For each rotation-slope combination (39 in all), one separate EPIC model is set up and all production operations for all crops are exactly as those described in Appendix A.

Initial soil conditions. Because EPIC results are sensitive to initial soil conditions, it is advisable to initialize soil conditions for each combination of the 13 rotations and three soil slopes. In this study, initialization is done by running one extra rotation before the study starting year (i.e. 1986) using actual weather data for each rotation-slope combination. For example, for rotation 11 (a three-year rotation) on five percent slope, the simulation starting year is 1983 and results for the first rotation (1983-1985) are not used. When the simulation goes into the second rotation cycle (i.e. 1986-1988), the soil condition has been initialized.

Partition of one acre for each crop-rotation-slope. The farm model incorporates yield and price risk by including "states of nature" that reflect varying price and yield conditions. In the model, ten states of nature are generated for 1986 to 1995 weather and price conditions for the study area. It is assumed that equal portions of each crop in a rotation are grown each year. For example, in rotation 11 on five percent slope in 1986, wheat/soybean double cropping (counted as one crop), cotton, and peanut should each be planted on one third of the acreage devoted to this rotation. This is accomplished by using three different starting years for the rotation. The first starting year is 1983, which results in wheat/soybean being grown in 1983, 1986, 1989, 1992, and 1995. The second starting year is 1984, which results in wheat/soybean being grown in 1984, 1987, 1990, and 1993. The third starting year is 1985, which results in wheat/soybean grown in 1985, 1988, 1991, and 1994. Putting together yield data from these three runs provides yearly yield data for each crop in each crop-rotation-slope combination from 1986 to 1995. Resultant simulated yields are in Table 3-5.

Only average values of pesticide loss, nutrient loss, and soil loss are used in this study. The time span for EPIC simulations is increased to 1976-1995 to provide average values that more closely approximate the long-term averages based on long-term weather conditions. The rotation is set so that each crop is planted for most years from 1976 to 1995. To illustrate how this is done, consider rotation 3 (conventional peanut, wheat/soybean double cropping, conventional cotton). To ensure planting each crop almost every year, three sets of 20-year simulations are selected. The first 20-year simulation starts in 1974 with peanut and ends in 1993 with wheat/soybean. The second 20-year simulation starts in 1975 with peanut and ends in 1994 with wheat/soybean. The third 20-year simulation starts in 1976 with peanut and ends in 1995 with wheat/soybean. So in the years from 1976 to 1993, each crop in the rotation is grown once in each year while following the same rotational sequences. In other years (1974, 1975, 1994, and 1995) of simulation, at least one of the crops is never grown for each year. The use of a longer time span should make estimated soil, pesticide, and nutrient losses less sensitive to initial conditions and the missing of some crops in one or two years.

Detailed results are listed in Appendix D. In subsection 3.3.5 below, yield data are summarized, while summary information about soil, pesticide, and nutrient losses can be found in Section 3.4, which describes environmental indices based on simulated pesticide losses, nutrient losses, and soil losses.

3.3.5. The simulated yields for the representative farm

As can be seen in Table 3-5, average yields are slightly higher on lesser slopes. There are no big yield differences for cotton in regard to tillage, which agrees with the findings in the literature review. Corn yields are slightly higher when rotated with double-cropped wheat/soybean than with peanut. The year 1993 is a very bad year for all crops, except wheat, because of severe drought during July and August of that year.

Simulated yields from EPIC-PST are insensitive to change in tillage, while previous studies find that peanut yields are sensitive to change of tillage. For example, no-till peanut systems are susceptible to severe disease infestations from crop residue, weed competition, and digging problems which lower yields (Grichar and Boswell), or late maturity and lower grades (Wright). Some reports show that minimum-till systems with in-row subsoiling may result in comparable yields and no problem of reduced quality because deep tillage methods are used (Colvin et al). However, experimental data in 1996 from TAREC in Suffolk show difference of average yields of 4,909 lb/ac for conventional versus 3,972 lb/ac for strip-till, although the difference is not significant at $p < 0.05$ (Phipps). Phipps suggested that strip-till peanut yields be assumed to be 10 percent lower than that of conventional peanut. After this adjustment, the resultant "state of nature" yields are listed in Table 3-5, maintaining the assumption of no quality differences in regard to tillage, rotational pattern, and slope.

3.4. Environmental risk indices

Sections 3.4.1 and 3.4.2 discuss procedures to develop indices that measure potential environmental losses of pesticide, nutrient (nitrogen and phosphorus), and soil to the environment. Section 3.4.3 discusses the empirical results from EPIC simulations for the representative farm.

3.4.1. Pesticide index

In order to simplify the multi-dimensional data which reflect the different environmental effects of pesticides, several indices have been developed, which reduce the estimates of potential environmental impacts to a single value known as an environmental risk index (Warner; Alt; Cabe et al; Kovach et al). An environmental risk index accounts for differences in chemical attributes and aggregate environmental outcomes across several forms of contaminants and loss pathways. Thus agricultural practices can be rank-ordered with respect to their composite environmental consequences. One straight forward application of this approach of aggregating environmental impacts of agricultural production practices is to evaluate income and environmental tradeoffs (Hoag and Hornsby; Teague, Bernardo, and Mapp).

In one study by Teague, Mapp, and Bernardo (1994), three environmental risk indices, EIQ, CINDEX, and CONC, were developed and evaluated which incorporate different information concerning the environmental effects of pesticide use. In one study by Teague, Mapp, and Bernardo, CINDEX is used as a measure of environmental risk from pesticides to evaluate the tradeoffs between income and environmental risks on a representative farm in the Central High Plain. A similar index is developed for nitrogen. Their study shows that "expected income is sensitive to nitrate loading restrictions, and relatively less sensitive to pesticide loading restrictions". The authors selected CINDEX to measure potential losses because this method factors in estimates of expected annual runoff and percolation loading of the pesticide in the calculation of the environmental risk.

CINDEX is defined as:

$$CINDEX_j = \sum_{i=1}^{n} EIC_{ij}$$

where $CINDEX_j$ is the chemical environmental index for crop activity j, which is a crop-rotation-slope combination;

EIC_{ij} is the environmental index for chemical i of crop activity j; and

n is the number of chemicals applied in crop activity j.

Additivity is assumed in constructing pesticide indices.

EIC_{ij} is defined as:

$$EIC_{ij} = PERC_{ij} * HA_i * 0.5 + RUNOFF_{ij} * LC_i * 0.5$$

where, EIC_{ij} is the environmental index for chemical *i* of crop activity *j*;

$PERC_{ij}$ is quantity of chemical *i* of crop activity *j* lost in percolation (lb/ac); and

$RUNOFF_{ij}$ is the quantity of chemical *i* of crop activity *j* lost in runoff (lb/ac).

Original data from EPIC for $PERC_{ij}$, and $RUNOFF_{ij}$ are reported in grams per hectare. Then the units are transformed to pounds per acre for the calculation of indices.

$$HA_i = \begin{cases} 5 \text{ if } HAL_i \leq 10 \text{ or the EPA carcinogenic Risk Category is A, B, B1, B2, or C} \\ 3 \text{ if } 10 < HAL_i \leq 200 \\ 1 \text{ if } HAL_i > 200 \end{cases}$$

where HAL_i is lifetime Health Advisory Limit[10] (in mg/l) set by EPA for chemical *i* (EPA, 1996). HAL is used as a proxy for threats to human health through ground water. HA_i serves as a toxicity weight for chemicals lost to percolation, which affect ground water. The weighting system for HAL was developed by Teague, Bernardo, and Mapp based on weights for the oral and dermal LD_{50} of each chemical (Criswell and Campbell). If a chemical has an EPA carcinogenic risk rating of A, B, B1, B2, or C[11], it is weighted with a 5 regardless of the value of the lifetime HAL.

LC_i serves as the toxicity weight for runoff, which affects surface water:

[10] HAL is defined as the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety (USEPA, 1996).

[11] Definitions by EPA (1986):
Group A is human carcinogen: Sufficient evidence in epidemiologic studies to support causal association between exposure and cancer. Group B is probable human carcinogen: limited evidence in epidemiologic studies (Group B1) and/or sufficient evidence from animal studies (Group B2). Group C is possible human carcinogen: limited evidence from animal studies and inadequate or no data in humans.

$$LC_i = \begin{cases} 5 \text{ if } LC_{50} < 1 \\ 3 \text{ if } 1 \le LC_{50} \le 10 \\ 1 \text{ if } LC_{50} > 10 \end{cases}$$

where LC_{50} represents the chemical concentration (ppm) required to kill 50 percent of fish after 96 hours of exposure. LC_{50} is used as a proxy for threats to aquatic life in surface water. In this study, LC_{50} for "fish" is an average of the LC_{50} for rainbow trout and for bluegill sunfish. The weighting system of 1, 3, and 5 for the aquatic LC_{50} is taken from Kovach et al.

As was done by Teague, Bernardo, and Mapp, in this study, equal weights are assigned to each of the two environments, namely ground water and surface water. The expected annual runoff and percolation loading of alternative production practices are provided by EPIC-PST simulation output and resultant CINDEX indices are reported and discussed in Section 3.4.3.

3.4.2. Nitrogen, phosphorus, and soil loss indices

The nitrate environmental index is calculated for each crop activity as

$$NEI_j = NPERC_j * 0.5 + NRUNOFF_j * 0.5$$

where NEI_j is the nitrate environmental index for crop activity j, $NPERC_j$ is the quantity of nitrate lost in percolation for crop activity j (lb/acre), and $NRUNOFF_j$ is the quantity of nitrate lost in runoff for crop activity j (lb/acre). Equal weights are assigned to runoff and percolation of nitrate. This method is used by Teague, Bernardo, and Mapp. A similar index is also developed for phosphorus loss in this study:

$$PEI_j = PPERC_j * 0.2 + PRUNOFF_j * 0.8$$

where PEI_j is the phosphorus environmental index for crop activity *j*, while $PPERC_j$ and $PRUNOFF_j$ are the quantity of phosphorus (lb/ac) lost in percolation and runoff, respectively, for crop activity *j* (lb/acre). Uneven weights are assigned to runoff and percolation because generally phosphorus loss via percolation is very small. Finally, the soil index is simply the sum of water erosion and wind erosion in tons per acre for each rotation-slope combination. Because the phosphorus indices developed this way are very small in numerical values, they are multiplied by 1000 to avoid rounding problem in solving the Target-MOTAD model.

3.4.3. Resultant environmental indices for soil, nitrogen, phosphorus, and pesticide loss

In EPIC model, actual daily weather data used are rainfall, highest temperature, and lowest temperature. Other data needed by EPIC model are automatically generated by EPIC itself. In Table 3-6, monthly and yearly rainfall data from 1976 to 1995 for the study area are listed.

Table 3-6. Precipitation (inches) in Suffolk, Virginia (1976-1995)[a]

Mon	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Jan	3.3	2.2	4.6	4.8	3.7	0.6	4.7	2.1	2.1	2.4	2.9	8.4	3.3	2.4	2.8	4.4	4.4	4.9	4.5	3.4
Feb	2.1	1.0	0.6	5.1	0.4	2.9	6.7	2.7	2.7	3.4	2.1	3.4	3.9	5.3	3.8	1.0	2.7	1.9	4.1	3.4
Mar	3.1	2.2	4.9	3.5	5.9	3.0	4.2	5.5	5.5	2.1	1.6	3.3	1.8	9.5	3.2	5.2	2.5	6.6	10.5	3.8
Apr	1.2	4.9	6.8	4.4	4.7	3.2	3.1	7.1	7.1	2.1	1.8	5.1	3.5	6.9	3.8	4.3	2.4	4.8	0.8	1.5
May	2.8	2.6	4.0	2.8	2.9	4.8	4.8	4.2	4.2	4.6	1.0	2.0	5.3	4.4	6.3	1.2	5.6	3.2	3.6	5.1
Jun	9.1	5.8	1.9	5.4	2.5	2.4	3.8	5.0	5.0	2.6	4.5	2.7	3.7	6.5	2.0	1.6	1.8	2.2	3.8	5.4
Jul	3.4	2.1	5.3	4.4	6.5	5.8	3.0	2.2	2.2	3.7	6.9	2.4	4.6	7.7	3.1	8.2	5.2	2.3	8.3	3.0
Aug	3.4	6.7	3.3	2.5	2.3	3.1	4.6	1.9	1.9	7.8	8.7	5.8	5.1	6.3	7.9	4.7	14.3	2.1	4.7	3.1
Sep	3.7	4.1	2.6	6.3	1.0	3.5	2.1	2.3	2.3	0.5	0.5	6.3	2.8	4.4	1.1	5.3	3.5	2.1	2.8	3.1
Oct	9.5	6.6	1.3	3.3	3.0	4.3	3.7	6.0	6.0	2.9	3.0	1.6	2.9	3.7	3.5	4.3	3.7	3.3	2.4	5.0
Nov	1.6	7.9	2.9	4.0	2.3	0.6	4.0	3.2	3.2	7.2	1.7	3.4	4.3	5.0	1.3	1.5	4.2	1.5	4.0	4.6
Dec	2.9	1.8	5.2	1.4	1.0	2.7	3.0	5.1	5.1	0.8	4.7	3.5	0.6	3.5	3.0	2.6	3.4	3.5	1.2	2.0
Total	46.2	47.8	43.4	47.9	36.2	36.9	47.7	47.2	47.2	40.0	39.4	47.8	41.9	65.4	42.0	44.3	53.7	38.5	50.7	43.4

a. Data are calculated for original records provided by Phipps (1996).

3.4.3.1. Soil loss

Original EPIC output soil data are presented in Tables D-14 to D-52 in Appendix D. Table 3-7 below is a summary.

Table 3-7. Annual average soil loss (tons/acre)[a] by crop, rotation, and slope

			Rotation[b]												
Slope	**Erosion**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
5 %	Wind	Max	10.35	2.01	3.36	2.88	3.30	2.80	3.61	3.49	3.78	2.80	2.52	2.93	0.33
		Min	0.47	0.17	0.52	0.10	0.08	0.16	0.47	0.50	0.50	0.32	0.34	0.19	0.00
		Avg	1.87	1.07	1.69	1.15	0.73	0.73	1.62	1.50	1.56	1.19	1.09	1.48	0.07
	Water	Max	10.13	8.78	9.62	7.09	7.21	7.11	11.66	10.36	10.57	8.06	9.10	8.59	2.79
		Min	3.87	3.12	3.00	2.48	1.69	1.53	3.60	3.28	3.23	2.51	2.93	2.62	0.10
		Avg	6.66	5.32	5.95	4.99	4.77	4.57	6.77	6.30	6.35	5.27	5.63	5.71	0.46
	Total	Max	20.48	10.73	10.14	8.93	10.14	8.93	13.90	12.57	12.78	9.70	10.38	9.64	3.12
		Min	5.04	3.68	5.41	3.98	1.98	1.73	4.27	3.88	3.84	2.83	3.52	4.33	0.11
		Avg	8.53	6.96	7.64	6.14	5.50	5.30	8.39	7.80	7.90	6.46	6.72	7.19	0.53
3 %	Wind	Max	10.64	3.13	3.04	2.71	2.25	2.84	3.91	3.64	3.63	3.20	3.34	3.03	0.58
		Min	0.55	0.44	0.30	0.34	0.16	0.19	0.78	0.60	0.61	0.25	0.41	0.41	0.00
		Avg	2.08	1.26	1.51	1.08	0.73	0.80	1.75	1.61	1.66	1.30	1.30	1.48	0.10
	Water	Max	4.43	3.94	4.09	2.91	3.20	3.20	5.05	4.42	4.51	3.32	3.54	3.56	1.29
		Min	1.50	1.18	1.19	0.90	0.59	0.61	1.28	1.15	1.16	0.99	1.27	1.02	0.04
		Avg	2.75	2.24	2.43	2.05	1.98	1.92	2.80	2.61	2.64	2.19	2.38	2.36	0.20
	Total	Max	14.98	6.32	5.75	5.31	5.12	5.39	7.92	7.29	7.29	5.77	5.69	5.72	1.87
		Min	2.46	1.93	3.10	1.74	0.78	0.80	2.44	1.93	1.98	1.50	1.87	2.19	0.04
		Avg	4.83	3.50	3.94	3.13	2.71	2.72	4.55	4.22	4.29	3.49	3.67	3.83	0.29
1 %	Wind	Max	11.40	3.43	3.17	2.71	2.29	2.84	3.66	3.72	3.69	2.71	3.43	3.46	0.59
		Min	0.62	0.30	0.46	0.19	0.20	0.15	0.68	0.65	0.68	0.37	0.30	0.52	0.00
		Avg	2.34	1.20	1.52	1.11	0.79	0.83	1.91	1.71	1.75	1.36	1.32	1.50	0.10
	Water	Max	1.24	1.13	1.09	0.90	1.01	1.01	1.39	1.23	1.26	0.97	1.07	1.07	0.42
		Min	0.38	0.31	0.29	0.24	0.14	0.15	0.35	0.32	0.32	0.26	0.34	0.24	0.01
		Avg	0.77	0.64	0.69	0.57	0.56	0.55	0.78	0.73	0.74	0.61	0.68	0.67	0.06
	Total	Max	12.64	4.15	3.97	3.45	3.01	3.55	4.78	4.75	4.73	3.44	4.12	4.25	1.01
		Min	1.40	0.96	1.43	0.93	0.34	0.31	1.12	1.20	1.21	0.71	0.94	1.13	0.01
		Avg	3.11	1.83	2.21	1.68	1.35	1.38	2.69	2.44	2.49	1.97	2.00	2.18	0.19
Weighted average[c]			4.51	3.18	3.62	2.85	2.44	2.44	4.19	3.86	3.93	3.18	3.31	3.51	0.27

a. This table is derived from information in Appendix D for 1976-1995 weather data from Holland Station, Suffolk, Virginia.
b. Rotations are described in Section 3.2.3 and Appendix A.
c. Formula is Sum(average for 5% slope*0.1, average for 3% slope* 0.5, and average for 1% slope*0.4). See Section 1 in this Chapter for acreage breakdown by slope for the representative farm.

Slope effects. As illustrated in Table 3-7, total soil loss increases with the increase of slope. The amount of increase depends on rotation. For example, for rotation 1, total soil loss roughly follows a ratio of 2:3:5 when slopes are one, three, and five percent, respectively, while for rotation 2, the ratio is 1:2:4. However, wind erosion is generally not reduced by decrease of slope. Actually, for all rotations except rotations 3 and 4, wind erosion is larger with less slope. Water erosion decreases greatly with the decrease of slope. Water erosion on five percent slope is generally around 10 times larger than that on one percent slope. When slopes are five percent and three percent, water erosion for every rotation is much larger than that of wind erosion. However, when slope is one percent, wind erosion is larger than water erosion in all rotations. This result confirms that in the study area where most farm land exhibits gentle slopes, wind erosion does present a big concern in spring time when fields are exposed to elements without cover crops (Phipps, 1996), similar to the findings by Lee et al in Texas.

Rotation effects. The variation of soil loss across rotations is large since soil erosion for a given soil type and set of weather conditions is sensitive to tillage (degree and timing of soil disturbances), and how well the surface is covered, which varies with changes in rotational pattern. On five percent slope, when conventional peanut is involved, soil erosion is very high for any two-year rotation (rotation 1, 7, 8, and 9), while in three-year rotations with peanut (3 and 12), water erosion is reduced because all three-year rotations involve wheat/soybean double-cropping, which is less erosive. Double cropping does not disturb the soil very much while providing cover year round. Soil erosion is the least when wheat/soybean are double-cropped in two-year rotations (rotation 5 and 6 vs other rotations). Rotations involved with peanuts generally have higher soil losses (rotation 5 vs 3). As expected, rotation 13 has the lowest soil loss regardless of slope. Absolute values for rotation 13 are also very small even on five percent slope.

When shifting from cotton to corn (8 vs 11), total soil losses, wind erosion, and water erosion (by average, or maximum, or minimum values) all decrease. The reduction may be due to the fact that cotton is conventionally tilled while corn is no-till. By total average loss for all slope, the level of erosion decreases is around 15 to 20 percent. When shifting from peanut to wheat/soybean double-cropping (1 vs 5, and 10 vs 6), soil loss is reduced also.

Cover effects. Total soil loss in the conventional peanut - conventional cotton rotation is reduced slightly when winter wheat cover is planted (rotation 1 vs 7). In notill corn - conventional peanut rotation cover reduces total soil loss slightly on five percent slope while increasing soil loss slightly on three percent slope and one percent slope (rotation 2 vs 11). A probable explanation for this case is that corn crop residue already provides adequate cover for the field (York et al) while planting winter cover disturbs the soil to increase erosion. Wind erosion was high in 1989 (shown as maximum values in Table 3-7) regardless of slope in the conventional peanut and conventional cotton rotation without cover (rotation 1). Wind erosion for rotation 1 in 1989 is generally three times that of other rotations on the same slope. When a cover crop is planted (rotation 7), the effects of wind erosion diminish (down from over 10 tons/acre to about 3.6 tons/acre regardless of slopes). This result indicates that the rotation of conventional peanut and conventional cotton is vulnerable to wind erosion in extreme weather conditions if cover crop is not planted. Under average weather conditions, the cover crop reduces soil loss from wind erosion, especially for five percent slope when conventional peanut is rotated with cotton (rotation 1 vs 7), but has little effect on average soil loss when peanut is rotated with corn (rotation 2 vs 11). Water erosion increases (average or maximum level) when cover crop is planted (rotation 1 vs 7, and 2 vs 11) regardless of slope. This fact can be explained as resulting from increased soil disturbance.

Tillage effects. Soil losses are clearly lower in rotations of strip-till peanut and notill cotton compared to other rotations with conventional peanuts and/or conventional cotton (rotation 10 vs 1, 7, 8, and 9; rotation 12 vs 3). Rotations of conventional peanut and conventional cotton are the most soil erosive compared to other tillage (rotation 1 and 7 vs 3, 5, 9, 10, and 12). Notill cotton reduces soil loss a little more than strip till cotton (rotation 8 vs 9). It can be seen from the above summary table and Table D-53 that reduced till, combined with a cover crop, results in reduced soil loss compared to conventional till generally (rotation 1 vs 8, 1 vs 9, 1 vs 10, 3 vs 12, 5 vs 6, 7 vs 8, 7 vs 9, and 7 vs 10). Notill cotton reduces soil loss slightly compared to strip-till (rotation 8 vs 9).

When taking into consideration the weighted soil erosion tolerance level of 4.395 per acre for the City of Suffolk, Virginia (McSweeny, 1988)[12], rotation 1 alone exceeds the presumed soil erosion tolerance level for the representative farm. The weighted average soil loss for rotation 1 is 4.51 tons per acre (see Table 3-7).

3.4.3.2. Nitrogen and phosphorus indices

Table 3-8 is summarized from Table D-53. Data in this table are expressed in values of indices rather than original nutrient losses. Discussion that follows refers to Table D-53 also.

Table 3-8. Nitrogen and phosphorus loss indices by crop, rotation, and slope[a]

[12] This value is calculated by McSweeny who used the tolerance levels for each soil (USDA, 1981) and weighted these tolerance levels by the percentage of the total acreage in the City of Suffolk comprised by each soil (McSweeny, 1988).

Rotation[b]	slope = 5%		slope = 3%		slope = 1%	
	N[c]	P[d]	N[c]	P[d]	N[c]	P[d]
1. conventional cotton + conventional peanut (w/o cv)	33.38	3.54	21.14	2.18	12.41	1.37
2. notill corn + conventional peanut (w/o cover)	30.32	2.72	19.42	1.74	10.73	1.07
3. conventional peanut + wheat/soybean + conventional cotton (w/o cover)	38.14	3.18	24.91	1.93	15.17	1.19
4. wheat/soybean + notill corn + conventional peanut (w/o cover)	36.90	2.56	23.08	1.59	14.77	0.99
5. wheat/soybean + conventional cotton (w/o cover)	35.27	2.55	23.08	1.53	13.76	0.90
6. notill cotton + wheat/soybean (w/ cover)	36.33	2.74	24.04	1.67	14.33	0.97
7. conventional cotton + conventional peanut (w/ cover)	32.55	3.47	20.16	2.10	11.07	1.26
8. notill cotton + conventional peanut (w/ cover)	32.04	3.60	20.05	2.18	11.06	1.29
9. striptill cotton + conventional peanut (w/ cover)	31.20	3.39	19.35	2.06	10.58	1.24
10. notill cotton + striptill peanut (w/ cover)	28.54	3.54	17.79	2.17	9.68	1.30
11. notill corn + conventional peanut (w/ cover)	30.28	2.68	18.97	1.67	10.08	0.99
12. striptill peanut + wheat/soybean + notill cotton (w/ cover)	35.81	3.36	23.50	2.11	14.33	1.39
Mean[e]	33.40	3.11	21.29	1.91	12.33	1.16
13. annual wheat cover	7.70	0.75	5.16	0.59	3.13	0.50

a. This table is derived from information listed in Appendix D for weather data 1976-1995.
b. Refer to rotations described in Section 3.2.3.
c, d. Values of environmental indices per acre.
e. Only for rotation 1 to rotation 12.

Slope effects. Similar to soil loss, total nutrient loss (both nitrogen and phosphorus) increases with the increase of slope. However, as can be seen in Table D-53, slope effects are different for different loss pathways of the nitrogen and phosphorus. For example, for nitrogen loss, mineral nitrogen loss in percolate (PRKN) to ground water actually increases with the decrease of slope (roughly following a ratio 1:1.5:2 with respect to one, three, and five percent slopes), while NO_3 loss in surface runoff (YNO_3), mineral nitrogen loss in subsurface flow (SSFN), and organic nitrogen loss with sediment (YON) are decreasing when slope decreases. For phosphorus loss, mineral phosphorus loss in percolate (PRKP) is actually increasing with the decrease of slope, while soluble phosphorus loss in runoff (YAP) is decreasing rather slowly and phosphorus loss with sediment (YP) is decreasing dramatically with decreasing slope. Since phosphorus loss is primarily with sediment, the total trend is for phosphorus loss to decline with decreasing slope.

Rotation effects. Nutrient losses do not vary greatly across rotational patterns except rotation 13. For either nitrogen or phosphorus on each specific slope, the highest average indices are generally within twenty percent of the mean across rotations 1 to 12 on the same slope. One possible explanation for lack of variation in nitrogen and phosphorus losses is that though fertilized differently across rotations, the crop management practices maintain rather similar soil fertility levels, taking into consideration the nitrogen fixation effect of peanut and soybean (see Appendix A to see the amount of nitrogen and phosphorus applied to each crop). Nitrogen losses are the highest for rotations involved with wheat/soybean double-cropping (rotations 3, 4, 5, 6, and 12), while rotations involved with cotton plus peanut (rotations 1, 3, 7, 8, 9, 10, and 12) have the highest losses in phosphorus. Notill corn rotated with peanut reduces both nitrogen and phosphorus losses as compared with cotton rotated with peanut (rotation 2 vs 1, and rotation 11 vs 7, 8, and 9). Phosphorus loss tends to be smallest when cotton is rotated with wheat/soybean in two-year rotations (rotations 5 and 6).

When shifting cotton to corn (rotation 1 vs 2, 3 vs 4, and 7 vs 11), nitrogen indices and phosphorus indices all decrease regardless of slope. When shifting peanut to wheat/soybean double-cropping (1 vs 5, and 10 vs 6), nitrogen indices increase while phosphorus indices decrease.

Cover effects. With cover crop, nitrogen and phosphorus losses generally are reduced (rotation 1 vs 7, and 2 vs 11). As to different pathways of nitrogen loss, YON3, SSFN, and PRKN are all smaller with cover, while YON is slightly larger with cover. As to pathways of phosphorus loss, YP, PRKP, and YAP are all smaller with cover in conventional peanut - conventional cotton rotation (1 vs 7), while YP, PRKP, and YAP are slightly larger with cover on 5% slope but slightly smaller on lesser slopes in conventional peanut - notill corn rotations (2 vs 11) (see Table D-53).

Tillage effects. Reduced tillage reduces nitrogen loss (rotation 12 vs 3, 10 vs 1, 7, 8, and 9). Strip-till peanut plus notill cotton (rotation 10) has the smallest nitrogen loss among all rotations except annual cover, but higher than average phosphorus loss. When conventional peanut is involved, alternative tillage for the non-peanut crop in the rotation reduces nitrogen loss only slightly (rotation 7 vs 8, and 9). In two-year rotations, notill corn has lower nutrient losses than notill cotton in rotations with peanut (rotation 11 vs 8).

3.4.3.3. Pesticide indices

Based on data reported in Table D-0 to D-13, Appendix D, pesticide indices are constructed for each crop rotation on various slopes and results are reported in Table 3-9 below.

Table 3-9. Twenty-year average pesticide loss index by crop, rotation, and slope[a]

Rotation description[b]	Slope = 1 %	Slope = 3 %	Slope = 5 %
1. conventional cotton + conventional peanut (w/o cover)	86.61	164.08	240.72
2. notill corn + conventional peanut (w/o cover)	87.98	169.26	235.98
3. conventional peanut-wheat/soybean-conventional cotton (w/o cover)	65.23	124.36	170.67
4. wheat/soybean + notill corn + conventional peanut (w/o cover)	70.91	118.75	179.05
5. wheat/soybean + conventional cotton (w/o cover)	18.20	28.70	46.58
6. notill cotton + wheat/soybean (w/ cover)	28.46	51.40	80.70
7. conventional cotton + conventional peanut (w/ cover)	88.12	171.90	242.15
8. notill cotton + conventional peanut (w/ cover)	94.55	186.32	275.68
9. strip till cotton + conventional peanut (w/ cover)	107.72	208.32	306.40
10. notill cotton + strip till peanut (w/ cover)	63.83	116.78	176.08
11. notill corn + conventional peanut (w/ cover)	88.36	173.35	241.99
12. strip till peanut + wheat/soybean + notill cotton (w/ cover)	42.51	68.85	110.06
13. annual wheat cover[c]	1.21	2.43	4.05

a. This table is derived from information in Appendix D for 1976-1995 weather data.
b. Rotations are described in Section 3.2.3.
c. Cover is assumed to be chemically burnt.

Slope effects. Pesticide indices for each rotation increase with slope. Index values for five percent slope are nearly three times that of one percent slope for each rotation, while that of three percent slope are nearly twice of that of one percent slope except in rotation 12, where indices are only about to fifty percent larger. The steeper the land the more potential loss of pesticides in soluble runoff or adsorbed to sediment. From Table D-14 to Table D-53 in Appendix D it can be seen that soil losses are also dramatically increasing with the slope so that soil loss is also related closely with pesticide loss.

Rotation effects. Pesticide indices decline when more pesticide-intensive crops are rotated with less pesticide-intensive crops. For example, when wheat/soybeans are rotated with any other crops, the pesticide indices are reduced compared to rotations without wheat/soybean (rotation 1 vs rotation 3, rotation 2 vs rotation 4, and rotation 10 vs rotation 12). Double cropped wheat/soybean is not pesticide intensive and lowers the pesticide index for the whole rotation. When rotated with peanuts on five percent slope, notill corn has a similar contribution to the pesticide index as cotton regardless of tillage (rotation 1 vs rotation 2, rotation 3 vs rotation 4, and rotation 1 vs rotation 11). On slopes of three percent and one percent, however, notill corn causes a dramatic reduction in pesticide indices for the whole rotation compared to rotations with cotton (rotation 11 vs 9, 8, 7, and 1). Peanut is the most pesticide intensive in that all rotations with peanuts have much higher indices than those without peanuts (rotation 5, 6, and 13). Highest pesticide indices are found when peanut is rotated with strip-till cotton (rotation 9). The lowest index for rotations with peanuts occurs when peanuts are rotated with wheat/soybean and notill cotton (rotation 12). Cotton, when rotated with wheat/soybean (rotation 5 and 6), results in the lowest indices across all rotations except rotation 13 which represents idle land with cover.

When shifting cotton to corn (rotation 1 vs 2, 3 vs 4, and 7 vs 11), there is no clear pattern of increased or decreased pesticide indices. For example, pesticide indices are higher in rotation 1 on 3 percent or five percent slopes while that in rotation 2 is higher on one percent slope; pesticide indices for rotation 3 is larger on three percent slope while those for rotation 4 are larger on 5 percent and one percent slope. When shifting peanut to wheat/soybean double-cropping (1 vs 5, and 10 vs 6), pesticide indices decrease by more than fifty percent.

Cover effects. Though pesticide use is higher when cover crop is planted because cover crop is chemically burnt down, for all slopes, pesticide indices for rotations with cover are only slightly higher than similar rotations without cover crop (rotation 1 vs 7, and 2 vs 11). From Table D-14 through Table D-53, it is generally true that heavier soil losses tend to mean higher pesticide indices. However, rotation 9 has the highest pesticide indices for all slopes (Table 3.9) while its soil losses (Table 3.8) are ranked as second for five percent slope, third for three percent slope, and fourth for one percent slope.

Tillage effects. The rotation with reduced till cotton has a higher pesticide index than the rotation with conventional cotton (e.g. rotation 7 vs 8, and 7 vs 9) because reduced-till cotton uses more pesticides. Reduction of pesticide indices in reduced-till cotton through reduction in soil losses is clearly more than offset by increased use of pesticides as compared with conventional cotton (rotation 8 and 9 vs 7. See Table 3-9). However notill cotton has a smaller contribution to pesticide indices than does strip-till cotton (rotation 8 vs rotation 9). Notill cotton uses slightly more pesticides than does strip-till cotton, but the reduced soil loss more than offsets the increased pesticides. Strip-till peanut (rotation 10 and 12) greatly reduces pesticide indices in that it does not use Metam which has a big share of the index in conventional peanut (rotation 1, 2, 3, 4, 7, 8, 9, and 11). Peanut pesticide indices are very sensitive to the use of Metam (Vapam) due to large amount of active ingredient used as compared to other pesticides (See Table D-1 to

Table D-13 where conventional peanuts are involved. Also see Table A-4). For all rotations with only peanut and cotton involved, rotation 10 (notill cotton - strip till peanut) has the smallest pesticide index, comparable to those of three-year rotations (rotation 3, 4, and 12) in which peanut, cotton, and wheat/soybeans are involved.

3.4.3.4 Summary

Table 3-10 gives a qualitative summary of discussion above.

Table 3-10. Effects of tillage, rotation, cover, and slope on soil, nitrogen, phosphorus, and pesticide loss indices

Type of variation	Pesticide loss index	Nitrogen loss index	Phosphorus loss index	Soil loss index
Slope decreases (5 to 1%)	decrease: 60-65%	decrease: 50 ~ 65%	decrease: 55 ~ 65%	Total decrease: 60 ~ 74%. Often wind erosion ↑, but water erosion always ↓.
Cotton tillage: conventional to strip till (7 vs 9)	increase: 18-21%	decrease: 4-5%	decrease: 1-2%	decrease: 4-8%
Cotton tillage: strip till to notill (9 vs 8)	decrease: 10-12%	increase: 3-4%	increase: 4-6%	decrease: 1-2%
Peanut tillage: Conventional to strip till (8 vs 10)	decrease: 48-60%	decrease: 12-14%.	decrease: 0-1%	decrease: 21-24%
Cover w/ cotton (1 to 7)	increase: 1-5%	decrease: 3-12%	decrease: 2-9%	decrease: 2-16%
Cover w/ corn (2 to 11)	increase: 0-2%	decrease: 0-6%	decrease: 1-8%	decrease on 5% slope: 3% increase on lesser slopes: 5-8%
cotton shifts to corn (8 vs 11)	decrease: 7-14%	decrease: 5-10%	decrease: 30-34%	decrease: 15-22%
Peanut shifts to wheat/soybean (1 to 5 and 10 to 6)	decrease: 67-85%	increase: 6-48%	decrease: 30-52%	decrease: 12-43%.

From above summary table, it can be seen that with slope decreases, all pollutant losses decrease. With the decreases of tillage, pesticide loss increases while nitrogen, phosphorus and soil losses decrease. When cover crop is planted to peanut - cotton rotation, pesticide loss increases while nitrogen, phosphorus and soil losses decrease. When cover crop is planted to peanut - corn rotation, pesticide, nitrogen, and phosphorus losses are reduced but soil loss is increased a little bit, indicating the sufficiency of cover provided by residue from the notill corn. When crop shifts from cotton to corn, response of pesticide loss is mixed, while nitrogen, phosphorus, and soil losses are all decreased.

When crop shifts from peanut to wheat/soybean double-cropping, pesticide, phosphorus, and soil losses decrease while nitrogen loss increases.

Finally, for the purpose of illustration, the expected net return for each rotation on one percent slope is presented in Table 3-11 below using average and median crop prices and yields shown in Table 3-2 and 3-5, respectively,

Table 3-11. Expected net return for each rotation[a]

rotation	expected net return	
	(avg. value)[b]	(med. value)[c]
1. conventional cotton + conventional peanut (w/o cover)	370.26	410.04
2. notill corn + conventional peanut (w/o cover)	230.52	248.00
3. conventional peanut-wheat/soybean-conventional cotton (w/o cover)	289.11	314.97
4. wheat/soybean + notill corn + conventional peanut (w/o cover)	195.94	206.94
5. wheat/soybean + conventional cotton (w/o cover)	239.62	264.08
6. notill cotton + wheat/soybean (w/ cover)	209.80	232.51
7. conventional cotton + conventional peanut (w/ cover)	350.20	389.98
8. notill cotton + conventional peanut (w/ cover)	340.44	378.47
9. strip till cotton + conventional peanut (w/ cover)	348.71	390.18
10. notill cotton + strip till peanut (w/ cover)	301.49	334.56
11. notill corn + conventional peanut (w/ cover)	210.46	227.94
12. strip till peanut + wheat/soybean + notill cotton (w/ cover)	243.26	264.65
13. annual wheat cover	-40.12	-40.12

a. Fixed machine cost and labor cost are excluded. Values are calculated by splitting one acre among rotational crops as discussed earlier. Costs included are seed, fertilizers, pro-rated spread, plaster, lime, chemicals, fuel and oil, repair and gas, marketing, crop insurance, interest, and miscellaneous. All peanut is assumed to be quota peanut.
b. Average prices (FAPRI forecast) and average yields on one percent slope (for some specific rotations. See Table 3-5).
c. Median prices (see Table 3-2) and median simulated yields (for some specific rotations. See Table 3-5).

From the above table, it can be seen that use of median values generally caused net returns to be about eight to eleven percent higher than when average values are used. However, the relative ranking of all the rotations are fixed no matter whether average or median values are used. For example, rotation 1 is most profitable 4 under both scenarios. Also, the differences (in dollars) between rotations are quite similar. For example, rotation 8 is $29.88 less profitable than rotation 1 when using average values and is $31.57 less profitable than rotation 1 when using median values (rotation 8 is suggested conservation alternative rotation to rotation 1). So with no further sufficient information suggesting using median values rather than average values (which are also mathematical expected values with the assumed probabilistic distribution used in this study), average values of prices and yields are used as expected values in this study.

From above table it can be seen that expected net returns for rotations with cotton and conventional peanut are generally high, with rotation 1 the highest. Rotation 5 has higher expected net return than rotation 6 which is the conservation alternative to rotation 5. Rotations with corn (2 and 4) have lower expected net return. Rotation 13 has negative net return. Returns from rotation with peanuts are lower than would be achieved if current market prices were used and the profitability of peanut is understated when judged by current market prices. The consequence and implication of this price will be discussed in Chapter 4, in which results from the Target-MOTAD model will be presented and discussed.

Chapter 4. Results and Discussion

Introduction

As mentioned in the previous chapter, the empirical model derives optimal farm plans corresponding to different levels of risk aversion of the farmer when environmental losses must be reduced. In this chapter, the results of the Target MOTAD model (REPVAFARM) as developed in Chapter 2 and Chapter 3 are presented. There are six model settings:

- Model setting 1: No constraints on (P)esticide, (N)utrient (nitrogen and phosphorus), and (S)oil (PNS) loss indices.
- Model setting 2: Constraints on pesticide loss indices alone.
- Model setting 3: Constraints on nitrogen loss indices alone.
- Model setting 4: Constraints on phosphorus loss indices alone.
- Model setting 5: Constraints on soil loss indices alone.
- Model setting 6: Simultaneous constraints on all PNS indices.

Within each model setting, reductions in environmental loss indices are set at 10, 20, 30, and 40 percent, respectively. The maximum level of reduction of 40 percent is determined by complying with the Chesapeake Bay Program objective of 40-percent reduction of controllable nitrogen and phosphorus runoff to the Bay by the year 2000 relative to the 1985 level (Magnien et al)[13]. Within each model setting with a given PNS reduction level, risk aversion is parameterized from high to low to risk-neutral, deriving an efficient risk-frontier, which depicts the tradeoff between risk aversion and expected net income.

This chapter is divided into four major parts. In Section 4.1, presentation of the results focuses on optimal risk-neutral farm plans. In Section 4.2, effects of risk aversion on costs of reducing environmental losses based on a common baseline level of environmental losses for all levels of risk-aversion are discussed. In Section 4.3, further study is carried out when individual baselines are used for corresponding risk-aversion levels. Section 4.4 summarizes the results and discussion.

4.0. Simulation starting levels of PNS indices

To simulate the conditions that there are no constraints on PNS indices in Section 4.1 and Section 4.2, the actual accounting values of PNS indices from a risk-neutral, profit-maximizing farm plan are doubled and set to be the constraints for all levels of risk aversion. In the GAMS output these constraints are checked to make sure that they are really not binding. The risk neutral farm plan has baseline values for pollution indices as follows: pesticide index, 50,655; nitrogen index, 14,073; phosphorus index, 1,003; and soil index, 2,471. Thus, the no constraint on PNS losses is actually a condition in which the constraint on the pesticide index level is set at 101,310, that for the nitrogen index is 28,146, for the phosphorus index is 2,006, and for the soil index, is 4,942.

Justifications for using the expected PNS levels from a risk-neutral farmer's plan as the baseline in measuring required reductions in PNS levels for farmers of different risk-aversion levels in Section 4.2 are the following. First, as will be described later in the

[13] The study area does not lie in the Chesapeake Bay drainae area but rather in the Albemarle-Pamlico dreainage. The

chapter, when PNS indices are not constrained, the expected PNS levels for the unconstrained risk neutral and risk averse farm plans are quite close regardless of risk attitude, with loss indices of phosphorus and soil strictly higher in the risk-neutral plan, nitrogen index smaller in the risk-neutral plan, and pesticide index for the risk-neutral plan higher than moderate levels of risk aversion but smaller than high levels of risk aversion. Second, it is easier for a policy maker to set up a common level of allowable pollution (absolute allowable level) from farms of the same type (in physical characteristics) regardless of individual risk attitudes than to set up individual standards for individual farms of the same type according to individual risk attitudes.

However, a common allowable level of PNS loss in absolute values may overestimate or underestimate the real cost to the farmers of different risk-aversion levels if a reduction relative to that farmer's baseline pollution (for example, 30-percent reduction on nitrogen loss from that farmer's baseline level) is more relevant. So in Section 3, relative reductions in PNS losses with varying baseline levels of PNS losses are evaluated.

4.1 Results for risk-neutral farm plans

Several effects of reducing PNS losses on the representative farm are of interest: the costs of reducing PNS losses, the responsive behavior of the farmer in choosing rotations and crops, and the resultant PNS losses. The costs of reducing PNS losses are defined as the difference between expected net income from the current farm plan and those from the optimal plans under constraints on PNS reduction. Expected net income

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Chesapeake Bay objective is selected because it is a well-known pollution reduction objective.

(ENI) from the current unconstrained farm plan for the risk-neutral farmer is $175,954. Table 4-1 presents costs of reducing PNS losses for the risk-neutral case. Shadow prices of constraints on PNS losses, land by slope, and on peanut quota, as well as peanut production by poundage are also presented.

Table 4-1. Costs of reducing PNS losses, shadow prices, and peanut sales for a risk-neutral peanut-cotton farm

Pollutant Index	Percent reduction	Expected net return ($)	Cost of reduction to current level (in $)[a]	Cost of reduction to current level (in %)[b]	Shadow prices ($) Pesticide	N	P	Soil	Land (% slope) 1%	3%	5%	Peanut quota	Peanut sold(lb) as quota	as additional
Baseline[c]	0	175,954							189.80	187.80	179.20	0.009	589975	0
	10	175,771	183	0.1	0.036	0	0	0	189.00	187.00	172.00	0.007	589975	0
Pesticide	20	175,415	539	0.3	0.109	0	0	0	197.00	185.00	170.00	0.000	566699	0
only	30	174,243	1,711	1.0	0.239	0	0	0	185.50	181.00	163.50	0.000	432512	0
	40	173,035	2,919	1.7	0.239	0	0	0	186.00	181.00	164.00	0.000	293328	0
	10	165,464	10,490	6.0	0	8.38	0	0	82.00	3.40	-101.00	0.019	589975	0
Nitrogen	20	151,538	24,416	13.9	0	13.90	0	0	19.80	-108.00	-143.00	0.031	589975	0
only	30	131,754	44,200	25.1	0	14.60	0	0	20.10	-112.20	-148.70	0.003	589975	0
	40	111,196	64,758	36.8	0	14.60	0	0	20.00	-112.20	-148.70	0.031	589975	0
	10	173,057	2,897	1.6	0	0	40.80	0	165.30	134.80	80.70	0.000	295822	0
Phosphorus	20	164,905	11,049	6.3	0	0	129.30	0	121.20	28.70	-113.80	0.000	0	0
only	30	150,608	25,346	14.4	0	0	259.00	0	43.40	-139.80	-191.60	0.000	0	0
	40	123,670	52,284	29.7	0	0	280.00	0	52.50	-145.60	-201.60	0.000	0	0
	10	174,497	1,457	0.8	0	0	0	7.70	182.00	167.00	133.80	0.000	564010	0
Soil	20	172,245	3,709	2.1	0	0	0	14.20	180.00	158.00	108.00	0.000	353695	0
only	30	168,066	7,888	4.5	0	0	0	30.7	158.90	114.00	27.00	0.000	0	0
	40	157,286	18,668	10.6	0	0	0	50.30	143.00	74.00	-61.00	0.000	0	0
	10	164,903	11,051	6.3	0.146	7.72	0	0	97.00	14.00	-96.00	0.006	589975	0
All PNS	20	149,479	26,475	15.0	0.353	13.13	0	0	40.00	-105.00	-139.00	0.000	577956	0
losses	30	128,809	47,145	26.8	0.368	11.05	52.72	0	27.60	-116.00	-154.00	0.000	554865	0
	40	106,098	69,856	39.7	0.368	11.05	52.72	0	27.60	-115.70	-154.50	0.000	464381	0

a. It is calculated as $175,954 - expected net return.
b. It is calculated as [(175954 - expected net return)/175954]*100%.
c. It is expected profit maximizing farm plan.

Figure 4-1 further illustrates costs of reducing PNS losses for results presented in Table 4-1.

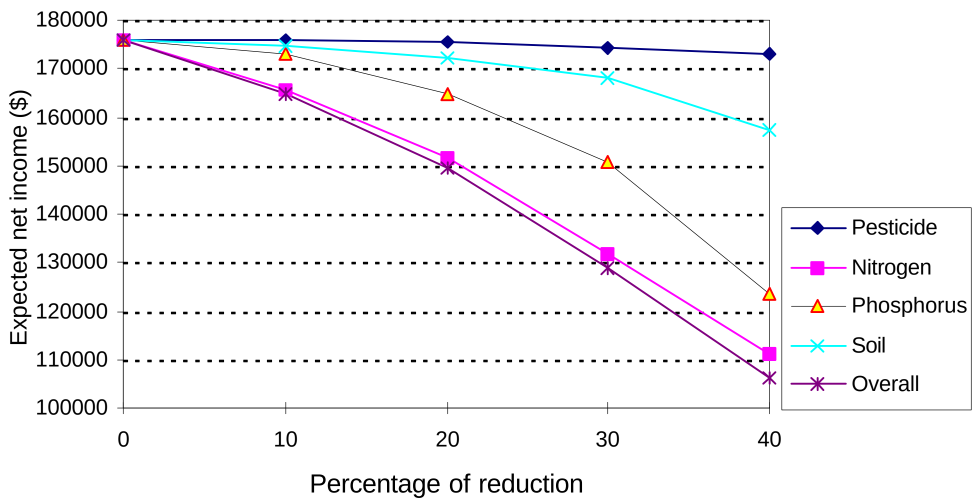

Figure 4-1. Income response to reducing PNS losses (risk-neutral)

As seen in Table 4-1 and Figure 4-1, the risk-neutral farmer suffers the least from constraints on pesticide alone. Even at 40-percent reduction level, ENI declines only 1.7 percent or $2,919 for the farmer. Similarly, ENI is not sensitive to constraints on soil loss alone (at 30-percent reduction level, ENI declines only 5 percent, and at the 40-percent reduction level, ENI declines slightly more than 10 percent). Reduction of phosphorus losses alone imposes a large penalty on ENI when reduction level is higher than 30 percent. At 30-percent reduction level, ENI is reduced by 14.4 percent, while at 40-percent reduction level, ENI is reduced by 29.7 percent. Costs of reducing nitrogen alone are very high as the reduction level passes 20 percent. At 30-percent reduction level, ENI is reduced by 25.1 percent, while at the 40-percent reduction level, ENI is reduced by 36.8 percent. The highest cost occurs when all PNS losses are reduced simultaneously, though this cost is only slightly higher than that of reducing nitrogen alone by the same percentage. The maximum difference between these two scenarios is at the 40-percent reduction level where ENI resulting from reducing all PNS losses is only $5,098 (or 2.9 percent of unconstrained ENI) lower than that from reducing nitrogen losses alone.

As can be seen from shadow prices in Table 4-1, constraints on single pollutant losses (pesticide, N, P, or soil) are always binding. However, when constraints are set to reduce all PNS losses simultaneously, the constraints for soil loss are never binding. Constraints on phosphorus are not binding at 20 percent or lower reduction level, while constraints on pesticide reduction and nitrogen reduction are always binding. This result indicates that soil erosion control is an important part of efforts to control nitrogen or phosphorus losses.

Shadow prices for land are all positive for the unconstrained farm plan. The lesser the slope, the higher the shadow price is. Land shadow prices with constraints on PNS losses are generally lower than those of the unconstrained case for any given slope. Shadow prices for one-percent slope are always positive regardless of constraints on PNS losses. When reducing only pesticide losses, shadow prices for land of any slope are all positive, indicating that all land remains in production. When constraints are imposed on soil alone, the shadow price for land of five-percent slope is negative at the 40-percent reduction level. Negative shadow prices for land indicate that the farmer has to idle land (rotation 13), which is a sure net income loss. It should be noted that in the table above, some shadow prices are more negative than the negative value of the direct cost of idling land ($40.12), because when one more acre of idle land is brought into the solution, some acreage of other profitable crops must be retired to satisfy the PNS constraints.

For other types of constraints (nitrogen alone, phosphorus alone, or all PNS losses), shadow prices for land of five-percent slope are generally negative, increasing in absolute value as the required reduction increases. The lowest (most negative) shadow prices are with constraints on phosphorus losses alone (for example, the shadow price is -$201.60 for five-percent slope when the reduction level is 40 percent). When reduction levels are 20 percent or less, the lowest (most negative) shadow prices are with constraints on nitrogen alone (for example, the shadow price is -$143 at 20-percent reduction level for five-percent slope). Although reducing nitrogen initially results in larger ENI losses, the rate of ENI loss for phosphorus is higher at higher constraint levels.

For a risk-neutral farmer, as expected, no additional peanut is produced since the return to additionals is negative and the only possible reason for a farmer to produce more than quota is to avoid a shortfall in filling the quota. Peanut production is maintained at quota poundage when nitrogen alone is constrained (all level of reduction) because quota peanut is profitable and peanut production has small nitrogen losses. As can be seen from Table 3-8, nitrogen losses from rotations involving conventional peanut are generally lower than rotations 5 and 6, which have no peanut in them. With all other constraints on PNS losses, peanut production is affected. When pesticide losses are constrained, only about half of the peanut quota is produced at the 40-percent constraint level. When phosphorus loss is constrained, peanut production is eliminated at constraint levels higher than 10 percent. For constraints on soil loss alone, no peanut is produced at constraint levels higher than 20 percent. However, peanut production is maintained at high levels when all PNS losses are constrained to be reduced. Even at 40-percent level of reduction on all PNS losses, 464,381 pounds of peanut are produced or 78.8 percent of the quota.

High peanut production shows the profitability of quota peanut and indicates that the farmer can reduce PNS losses yet maintain peanut production at a high level (relative to quota poundage). The latter can be seen in Table 4-2 and the discussion that follows.

Table 4-2. Crops and rotations with varying levels of PNS reduction for the risk-neutral farmer

Pollutant under constraint	Percentage of reduction	Rotations (1% slope)			Rotations (3% slope)			Rotations (5% slope)		
			Crops			Crops			Crops	
		No.	name	acreage	No.	name	acreage	No.	name	acreage
Baseline	0	1	peanut	119.7				1	peanut	37.5
			cotton	119.7					cotton	37.5
		5	cotton	30.3	5	cotton	187.5			
			wheat	30.3		wheat	187.5			
			soybean	30.3		soybean	187.5			
Pesticide only	10	1	peanut	140.0				1	peanut	17.5
			cotton	140.0					cotton	17.5
		5	cotton	10.3	5	cotton	187.5	5	cotton	20.1
			wheat	10.3		wheat	187.5		wheat	20.1
			soybean	10.3		soybean	187.5		soybean	20.1
	20	1	peanut	150.0						
			cotton	150.0						
					5	cotton	187.5	5	cotton	37.5
						wheat	187.5		wheat	37.5
						soybean	187.5		soybean	37.5
	30	1	peanut	115.1						
			cotton	115.1						
		5	cotton	35.0	5	cotton	187.5	5	cotton	37.5
			wheat	35.0		wheat	187.5		wheat	37.5
			soybean	35.0		soybean	187.5		soybean	37.5
	40	1	peanut	78.0						
			cotton	78.0						
		5	cotton	72.0	5	cotton	187.5	5	cotton	37.5
			wheat	72.0		wheat	187.5		wheat	37.5
			soybean	72.0		soybean	187.5		soybean	37.5
Nitrogen only	10	5	cotton	10.1	5	cotton	187.5			
			wheat	10.1		wheat	187.5			
			soybean	10.1		soybean	187.5			
		9	peanut	140.0				9	peanut	17.1
			cotton	140.0					cotton	17.1
			winter cover	280.0					winter cover	34.2
								13	cover only	40.8
	20	5	cotton	150.0	5	cotton	18.2			
			wheat	150.0		wheat	18.2			
			soybean	150.0		soybean	18.2			
					9	peanut	157.0			
						cotton	157.0			
						winter cover	315.0			
					13	cover only	23.8	13	cover only	75.0
	30	5	cotton	125.8						
			wheat	125.8						
			soybean	125.8						
		9	peanut	24.2	9	peanut	133.0			
			cotton	24.2		cotton	133.0			
			winter cover	48.3		winter cover	266.0			
					13	cover only	109.0	13	cover only	75.0
	40	5	cotton	83.0						
			wheat	83.0						
			soybean	83.0						
		9	peanut	67.0	9	peanut	67.0			
			cotton	67.0		cotton	67.0			
			winter cover	134.0		winter cover	134.0			
					13	cover only	195.0	13	cover only	75.0

Table 4-2. Crops and rotations with varying levels of PNS reduction for the risk-neutral farmer *(continued)*

Pollutant under constraint	Percentage of reduction	Rotations (1% slope)			Rotations (3% slope)			Rotations (5% slope)		
			Crops			Crops			Crops	
		No.	name	acreage	No.	name	acreage	No.	name	acreage
Phosphorus only	10	1	peanut	78.7						
			cotton	78.7						
		5	cotton	71.3	5	cotton	187.5	5	cotton	37.5
			wheat	71.3		wheat	187.5		wheat	37.5
			soybean	71.3		soybean	187.5		soybean	37.5
	20	5	cotton	150.0	5	cotton	187.5	5	cotton	26.5
			wheat	150.0		wheat	187.5		wheat	26.5
			soybean	150.0		soybean	187.5		soybean	26.5
								13	cover only	22.0
	30	5	cotton	150.0	5	cotton	181.8			
			wheat	150.0		wheat	181.8			
			soybean	150.0		soybean	181.8			
					13	cover only	11.3	13	cover only	75.0
	40	5	cotton	150.0	5	cotton	126.1			
			wheat	150.0		wheat	126.1			
			soybean	150.0		soybean	126.1			
					13	cover only	123.0	13	cover only	75.0
Soil only	10	1	peanut	88.5						
			cotton	85.5						
					5	cotton	187.5			
						wheat	187.5			
						soybean	187.5			
								6	cotton	37.5
									wheat	37.5
									soybean	37.5
									winter cover	37.5
		9	peanut	61.5						
			cotton	61.5						
			w-cover	123.0						
	20	5	cotton	56.0	5	cotton	187.5			
			wheat	56.0		wheat	187.5			
			soybean	56.0		soybean	187.5			
								6	cotton	37.5
									wheat	37.5
									soybean	37.5
									winter cover	37.5
		9	peanut	94.0						
			cotton	94.0						
			w-cover	188.0						
	30	5	cotton	150.0	5	cotton	187.5			
			wheat	150.0		wheat	187.5			
			soybean	150.0		soybean	187.5			
								6	cotton	37.5
									wheat	37.5
									soybean	37.5
									winter cover	37.5
	40	5	cotton	150						
			wheat	150						
			soybean	150						
					6	cotton	187.5	6	cotton	17.6
						wheat	187.5		wheat	17.6
						soybean	187.5		soybean	17.6
						winter cover	37.5		winter cover	17.6
								13	cover only	39.8

Table 4-2. Crops and rotations with varying levels of PNS reduction for the risk-neutral farmer *(concluded)*

Pollutant under constraint	Percentage of reduction	Rotations (1% slope)			Rotations (3% slope)			Rotations (5% slope)		
			Crops			Crops			Crops	
		No.	name	acreage	No.	name	acreage	No.	name	acreage
All PNS losses	10	1	peanut	40.9				1	peanut	6.9
			cotton	40.9					cotton	6.9
					5	cotton	187.5	5	cotton	7.8
						wheat	187.5		wheat	7.8
						soybean	187.5		soybean	7.8
		9	peanut	109.0						
			cotton	109.0						
			winter cover	218.0						
								13	cover only	46.0
	20	1	peanut	65.5	1	peanut	3.7			
			cotton	65.5		cotton	3.7			
					5	cotton	163.0			
						wheat	163.0			
						soybean	163.0			
		9	peanut	84.5						
			cotton	84.5						
			winter cover	169.0						
					13	cover only	41.6	13	cover only	75.0
	30	1	peanut	95.6						
			cotton	95.6						
		5	cotton	2.4	5	cotton	122.0			
			wheat	2.4		wheat	122.0			
			soybean	2.4		soybean	122.0			
		9	peanut	51.9						
			cotton	51.9						
			winter cover	103.8						
		13	cover only	1.0	13	cover only	131.0	13	cover only	75.0
	40	1	peanut	59.1						
			cotton	59.1						
		5	cotton	26.5	5	cotton	78.4			
			wheat	26.5		wheat	78.4			
			soybean	26.5		soybean	78.4			
		9	peanut	64.4						
			cotton	64.4						
			winter cover	129.0						
					13	cover only	218.0	13	cover only	75.0

In the baseline solution, only rotations 1 and 5 are adopted. Rotation 1 is on one-percent slope, while rotation 5 is on the remaining cropland. Rotation 5 is adopted because peanut acreage is constrained by the peanut quota while additional peanut is not profitable. When only pesticide losses are to be reduced, the farmer chooses only rotation 1 and rotation 5. Rotation 1 (conventional peanut - conventional cotton) is a very erosive practice with high levels of nitrogen, phosphorus, and pesticide losses while rotation 5 (wheat/soybean - conventional cotton) has smaller potential pesticide losses. After constraint levels are higher than 10 percent, all acreage of three-percent slope and five-percent slope is devoted solely to rotation 5, which is also low in soil loss and phosphorus loss, but high in nitrogen loss.

When nitrogen loss is constrained, rotation 5, rotation 9 (striptill cotton - conventional peanut with winter cover), and annual cover (rotation 13) are adopted at all levels of the constraint. As the constraint levels increase (greater than 10 percent), all land of five-percent slope and a large share of three-percent slope are devoted to annual cover (rotation 13), while rotation 5 is concentrated on one-percent slope. Acreage of rotation 9, which has smaller potential nitrogen loss than rotation 5, is constrained by the peanut quota. From Table 3-8, it can be seen that rotation 9 is lowest in potential nitrogen loss among all rotations with profitable conventional peanut in them, while rotation 5 has the smallest potential nitrogen loss among rotations with no peanut involved except rotation 13.

When phosphorus loss is constrained at a 10-percent reduction, only rotations 1 and 5 are chosen. Rotation 1 is planted only on one-percent slope and produces about half of the quota peanut (295,822 pounds). When phosphorus losses are constrained to 20 percent or more, peanut production is wiped out. Rotation 5 and rotation 13 are adopted with rotation 13 concentrated on three-percent slope and five-percent slope.

When soil loss is constrained, rotations 1, 5, 9, and 6 are chosen at the 10-percent reduction level. Rotation 1 is eliminated at the 20-percent level and 9 also at levels of reduction higher than 20 percent. Peanut production can be maintained at a relatively high level when soil losses are reduced by 10 percent because rotation 9 includes cover crops and is about 10 percent less erosive than rotation 1 (see Table 3-7). However, all rotations with peanut are generally erosive and peanut production is eliminated with 30 percent or more soil loss reduction. At a 40-percent level of soil loss reduction, annual cover has to be planted on part of five-percent slope, resulting in negative shadow prices for land.

When all PNS losses are constrained simultaneously, rotations 1, 5, 9, and 13 are adopted at all levels of constraints. Land of five-percent slope is idled at all constraint levels higher than 10 percent, and an increasingly larger share of three-percent slope is devoted to rotation 13 as well. As seen in Table 3-7 to Table 3-9, rotation 13 is much lower in all PNS losses as compared with any of the other 12 rotations. Peanut production is maintained at a high level for all constraint levels because of its profitability. This result can be explained by the fact that though rotations 1 and 9, which contain peanuts, are more erosive than rotation 5 and have higher soil, phosphorus, and pesticide loss potential, yet nitrogen loss in rotation 5 is higher. On the whole, rotation 13 (annual cover) is the key to reducing PNS losses. Acreage of annual cover increases from 0 on three and five-percent slopes when PNS losses are not constrained at all, to 218 acres on three-percent slope and all 75 acres on five-percent slope.

Resultant PNS losses from the optimal farm plans in response to various levels of constraints are listed in Table 4-3.

Table 4-3. Pesticide, nutrient and soil loses with varying constraints on pollutants for the risk-neutral representative farm

Pollutant under constraint	Percentage of reduction	Pesticide index		Nitrogen index		Phosphorus index		Soil index	
		Level	Ratio to current level	Level	Ratio to current level	Level	Ratio to current level	Level	Ratio to current level
Baseline	0	50655		14073		1003		2471	
Pesticide Only	10	45589	0.900	14098	1.002	983	0.980	2422	0.980
	20	40524	0.800	14151	1.006	961	0.958	2360	0.955
	30	35458	0.700	14271	1.014	932	0.929	2229	0.902
	40	30393	0.600	14404	1.024	902	0.899	2096	0.848
Nitrogen only	10	51903	1.025	12667	0.900	882	0.879	1994	0.807
	20	72429	1.430	11259	0.800	848	0.845	1824	0.738
	30	65809	1.299	9852	0.700	762	0.760	1605	0.650
	40	55786	1.101	8444	0.600	668	0.666	1372	0.555
Phosphorus only	10	33127	0.654	14753	1.048	903	0.900	2098	0.849
	20	18781	0.371	14102	1.002	803	0.800	1705	0.690
	30	16225	0.320	12507	0.889	702	0.700	1413	0.572
	40	13292	0.262	10634	0.756	602	0.600	1145	0.463
Soil only	10	45389	0.896	14017	0.996	955	0.952	2224	0.900
	20	39104	0.772	14147	1.005	904	0.901	1977	0.800
	30	25321	0.500	14813	1.053	847	0.844	1729	0.700
	40	27739	0.548	13972	0.993	775	0.773	1483	0.600
All PNS losses	10	45590	0.900	12667	0.900	873	0.870	2016	0.816
	20	40524	0.800	11259	0.800	783	0.781	1778	0.720
	30	35459	0.700	9852	0.700	702	0.700	1584	0.641
	40	30393	0.600	8444	0.600	601	0.600	1290	0.522

Large reductions in pesticide losses can be achieved with little impact on other pollutant losses. As seen in Table 4-3, which lists average PNS losses from farm plans, constraints on pesticides do not reduce nitrogen loss at all and at the 40-percent constraint level, nitrogen loss is actually increased by 2.4 percent. Phosphorus and soil losses decrease slightly as pesticide losses are reduced. For example, when pesticide losses are constrained to be reduced by 30 percent, soil loss and phosphorus loss decrease by less than 10 percent. When pesticide losses are constrained to be reduced by 40 percent, soil loss and phosphorus loss decrease slightly more than 10 percent. It can be seen in Table 4-2 that with the increase of constraints on pesticide losses, the farmer plants less rotation 1 and more rotation 5. Peanut in rotation 1 is pesticide intensive while rotation 5 is higher in potential nitrogen losses. Phosphorus losses and soil losses get smaller as some acreage of rotation 1 is shifted to rotation 5 because rotation 5 has small potential phosphorus loss and soil loss.

With constraints imposed on nitrogen alone, phosphorus loss and soil loss decrease by a similar degree as the constraint level (by percentage, phosphorus loss is reduced a little less than nitrogen loss, while soil loss decreases a little more than nitrogen loss). However, pesticide loss increases to 102.5 percent, 143 percent, 129.9 percent, and 110.1 percent of the current level, when nitrogen loss is reduced by 10 percent, 20 percent, 30 percent, and 40 percent, respectively. This result indicates constraints on nitrogen alone will encourage farmer to shift to farm plans that are less erosive but use more pesticides. As seen in Table 4-2, the farmer idles more land of three-percent slope and all land of five-percent slope, decreases acreage of rotation 5 (high in nitrogen losses) and shifts more acreage of rotation 9 from one-percent slope to three-percent slope (thus increasing pesticide losses from this rotation).

When phosphorus loss is constrained, pesticide losses from resultant farm plans decrease much more than the decrease of phosphorus. At 40-percent constraint level, pesticide loss is reduced 73.8 percent as compared to the current level. Phosphorus reduction causes a reduction in peanut production, which has high pesticide loss potential. In fact, as seen in Table 4-2, the previously large peanut production (at 10 percent phosphorus loss reduction, the acreage for rotation 1 is 157.4 acres on slope 1) is eliminated and only rotation 5 is grown. Rotation 5 has much smaller pesticide loss potential. Nitrogen loss is not reduced at all (actually there is a slight increase) when phosphorus losses are reduced 20 percent or less. When phosphorus losses are reduced more than 20 percent, nitrogen loss is reduced and at a 40-percent constraint level, nitrogen loss is reduced by 24.4 percent. This change indicates that nitrogen loss is sensitive to the level of phosphorus constraints. As seen in Table 4-2, at low constraint levels on phosphorus losses (10 to 20 percent), the primary shift is from rotation 1 to rotation 5, which increases nitrogen loss. With high constraints on phosphorus loss (20 percent or higher), the rotation shift is from 5 to 13, which greatly reduces nitrogen losses. Soil loss is reduced a little more than phosphorus loss because phosphorus loss is mainly attached to sediment.

When soil loss is constrained, pesticide loss is reduced more than soil loss and phosphorus loss is reduced a little less than soil loss, indicating that erosive practices contribute to high pesticide and phosphorus losses. Nitrogen loss remains nearly unchanged regardless of soil loss reduction, indicating increased soluble nitrogen runoff and leaching losses. As seen in Table 4-2, with the increased constraint on soil losses, peanut production (rotations 1 and 9) is eliminated while some acreage of rotation 5 shifts to rotation 6. Rotation 6 has lower potential soil loss but higher nitrogen and phosphorus loss.

Finally, when all PNS losses are constrained, it can be seen from Table 4-3 that constraints on pesticide losses and nitrogen losses are always binding, that constraints on soil losses are never binding, and that constraints on phosphorus losses are not binding at constraint levels less than 30 percent while binding at constraint levels of 30 percent and greater. Resultant phosphorus loss and soil loss are 10 to 15 percent below their constraint levels. Constraints on phosphorus loss and soil loss are redundant once the same levels of constraints have been imposed on nitrogen loss and pesticide loss.

4.2 Results for risk-averse farm plans (common baseline)

The effects of risk aversion on the costs of reducing PNS losses, the responsive behavior of the farmer in choosing rotations and crops, and the resultant PNS losses, will be discussed in this section. Required pollution reductions are based on a common baseline for all risk aversion levels, namely the baseline pollution level for the risk neutral farm. For example, the unconstrained level of pesticide index is 50,655, so 45,589 (= 50,655 - 5,066) is 10-percent reduction level for pesticides. The type one costs of reducing PNS losses now are defined as the difference between ENI from farm plans for no constraints on any PNS losses and ENI from farm plans with constraints on PNS losses for a given level of risk aversion. For example, at λ = \$8,000, ENI for no constraints on PNS losses is \$175,713, while for a 10-percent reduction of pesticide, ENI is \$175,599, thus the cost of a 10 percent reduction of pesticide losses is \$114. Type two cost occurs due to the increased risk. In this study, however, only type one costs are discussed explicitly. Although not done here, generalized stochastic dominance could be used to measure both type one and type two costs directly (Meyer). Table 4-4 lists the effects of varying risk aversion on costs of reducing PNS losses, shadow prices for several important constraints, and peanut production.

Table 4-4. Effects of varying risk aversion on costs of reducing PNS losses, shadow prices, and peanut sales

Pollutant Index	Level of reduction (%)	Expected shortfall allowed ($)	Expected net return ($)	Cost of reduction from baseline		Shadow prices ($)								Peanut sold(lb)	
				in $[a]	in %[b]	Pesti-cide	N	P	Soil	Land (% slope) 1%	3%	5%	Peanut quota	As quota	Additional
Baseline	0	7,500	174,427	0		0	0	0	0	208.50	203.10	195.70	0.003	589,975	0
		8,000	175,713	0		0	0	0	0	202.60	200.00	190.60	0.006	589,975	0
		8500 +[c]	175,954	0		0	0	0	0	189.80	187.80	179.20	0.009	589,975	0
pesticide only	10	7,500	174,171	256	0.1	0.04	0	0	0	212.80	204.70	195.00	0	513,517	0
		8,000	175,599	114	0.1	0.07	0	0	0	201.70	198.20	181.60	0.003	589,975	0
		8,500 +[c]	175,771	183	0.1	0.04	0	0	0	189.00	187.00	172.00	0.007	589,975	0
	20	7,500	173,764	663	0.4	0.10	0	0	0	206.00	200.00	182.00	0	460,983	0
		8,000	175,104	609	0.3	0.10	0	0	0	206.00	200.00	182.00	0	546,791	0
		8,500 +[c]	175,415	539	0.3	0.11	0	0	0	197.00	185.00	170.00	0	566,699	0
	30	7,500	173,256	1171	0.7	0.10	0	0	0	206.00	200.00	182.60	0	413,004	0
		8,000 +[c]	174,243	1470	0.8	0.24	0	0	0	185.50	181.00	163.50	0	432,512	0
	40	7,500	172,540	1887	1.1	0.15	0	0	0	201.00	196.00	179.00	0	288,467	0
		8,000 +[c]	173,035	2678	1.5	0.24	0	0	0	185.50	181.00	163.50	0	293,328	0
Nitrogen only	10	8,500	163,886	12068	7.4	0	12.63	0	0	116.50	-5.40	-177.00	0	505,732	0
		9,000 +[c]	165,464	10490	6.3	0	8.38	0	0	82.00	3.40	-101.00	0.019	589,975	0
	20	9,000	143,221	32733	22.9	0	43.50	0	0	-0.30	-415.00	-524.00	0	334,059	0
		9,500 +[c]	151,538	24416	16.1	0	13.90	0	0	19.80	-108.00	-143.00	0.031	589,975	0
	30	10,000	131,351	44603	34.0	0	18.20	0	0	21.10	-148.80	-194.40	0.029	589,975	0
		10,500 +[c]	131,754	44200	33.5	0	14.60	0	0	20.10	-112.20	-148.70	0.031	589,975	0
	40	11,000 +[c]	111,196	64758	58.2	0	14.60	0	0	20.00	-112.20	-148.70	0.031	589,975	0
Phosph-orus only	10	7,500	172,942	1485	0.9	0	0	37.20	0	170.60	142.40	91.40	0	361,127	0
		8,000 +[c]	173,057	2656	1.5	0	0	40.80	0	165.30	134.80	80.70	0	295,822	0
	20	8,000 +[c]	164,905	10808	6.6	0	0	129.30	0	121.20	28.70	-113.80	0	0	0
	30	8,500 +[c]	150,608	25346	16.8	0	0	259.00	0	43.40	-139.80	-191.60	0	0	0
	40	9,500 +[c]	123,670	52284	42.3	0	0	280.00	0	52.50	-145.60	-201.60	0	0	0
Soil only	10	7,500	173,784	643	0.4	0	0	0	6.20	191.00	178.00	147.00	0	462,925	0
		8,000	174,342	1371	0.8	0	0	0	8.10	183.00	169.00	134.00	0	509,456	0
		8,500 +[c]	174,497	1457	0.8	0	0	0	7.70	182.00	167.00	133.80	0	564,010	0
	20	7,500	171,800	2627	1.5	0	0	0	11.80	191.00	172.60	125.50	0	183,071	0
		8,000 +[c]	172,245	3468	2.0	0	0	0	14.20	180.00	158.00	108.00	0	353,695	0
	30	8,000 +[c]	168,066	7647	4.5	0	0	0	30.70	158.90	114.00	27.00	0	0	0
	40	8,000	155,583	20130	12.9	0	0	0	55.00	155.00	74.00	-75.00	0	0	0
		8,500 +[c]	157,286	18668	11.9	0	0	0	50.30	143.00	74.00	-61.00	0	0	0
All PNS losses	10	8,500	163,823	12131	7.4	0.05	11.48	0	0	115.30	4.10	-161.00	0	506,668	0
		9,000 +[c]	164,903	11051	6.7	0.15	7.72	0	0	97.00	14.00	-96.00	0.006	589,975	0
	20	9,000	143,221	32733	22.9	0	43.45	0	0	-0.30	-415.40	-524.00	0	334,059	0
		9,500 +[c]	149,479	26475	17.7	0.35	13.13	0	0	40.00	-105.00	-139.00	0	577,956	0
	30	10,000 +[c]	128,809	47145	36.6	0.37	11.05	52.72	0	27.60	-116.00	-154.00	0	554,865	0
	40	11,500 +[c]	106,098	69856	65.8	0.37	11.05	52.71	0	27.60	-115.70	-154.50	0	464,381	0

a. Calculated as ENI when constrained - ENI when not constrained, given level of risk aversion. Note, "not constrained" = "baseline".
b. Calculated as [(cost of reduction)/(ENI when not constrained)]*100, given level of risk aversion.
c. "+" means "and above". In the table, for each constraint level, for a given pollutant index, the first line is the MLR (minimum level of risk) for which a feasible solution can be found.

As can be seen from the baseline in Table 4-4, production on the representative farm is inherently risky as described by the Target MOTAD model, since even when there are no constraints on PNS losses, the farmer still needs to be able to take at least some risks ($\lambda \geq \$7,500$) of not being able to meet his preset income target. As λ gets larger (the farmer gets less risk averse), ENI increases, indicating that the less risk-averse farmer can achieve higher expected returns.

With the imposition of constraints on PNS indices, production gets riskier. This increased risk, referred to as type two cost, can be expressed by the increased minimum level of risk (MLR) which the farmer has to take in order to be able to find an optimal farm plan. For example, with no constraints on PNS indices, MLR is $\lambda = \$7,500$, and for 20-percent constraint on phosphorus index, MLR is $\lambda = \$8,000$[14]. Thus, the riskiness of imposing PNS constraints is illustrated by Figure 4-2:

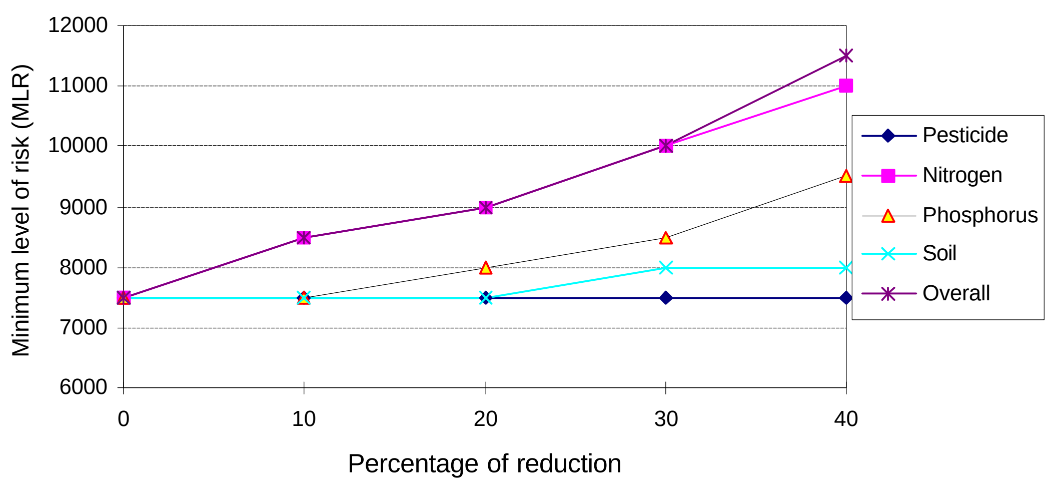

Figure 4-2. Risk of imposing PNS constraints

[14] In REPVAFARM, levels of expected shortfall are parameterized at a step length \$500, thus, numbers used to represent MLR and illustrated in Figure 4-2 are accurate only within ± \$500.

As seen in Table 4-4 and Figure 4-2, imposition of constraints on pesticide indices alone does not increase the minimum level of risk that can be achieved as compared with the base case where no constraints on PNS losses are imposed. Constraints on soil loss alone increase the MLR slightly when the constraint level is 30 percent or higher. Constraints on phosphorus increase risk for the farmer when the constraint level is higher than 10 percent and riskiness strictly increases with the increase of constraint level. At 40-percent level, the MLR increases 27 percent (up to λ = \$9,500). Constraints on nitrogen and on overall PNS indices strictly increase the MLR with the increase of constraint levels. Up to the 30-percent constraint level, the MLR for constraints on nitrogen and that for constraints for overall PNS losses are identical. At 40-percent constraint level, the increase of the MLR for nitrogen is smaller than that for the overall PNS constraint. As mentioned before, the increased riskiness of production can be interpreted as a qualitative cost for some risk averse farmers when they are forced to reduce PNS losses. These farmers must accept a higher than desired level of risk in order to achieve required reductions in PNS losses.

In addition to increased riskiness (type two cost), the risk-averse farmer also has to face the cost of reducing PNS losses as does the risk-neutral farmer (type one cost). For risk levels that can be achieved, by type of pollutant, the variation of the costs of reducing PNS losses for various levels of risk aversion are similar to that of the risk-neutral farmer. That is, costs for reduction of pesticide losses are the smallest, followed by soil, phosphorus, and nitrogen. As seen in Table 4-4, for phosphorus losses, the cost is very small at around 10-percent reduction then jumps up with higher reductions (from \$1,485 at 10-percent reduction (λ = \$7,500) to \$52,284 at 40-percent reduction for $\lambda \geq$ \$9,500).

Costs of reducing nitrogen losses are high. The cost rises from \$12,068 at 10-percent reduction (λ = \$8,500) to \$64,758 at 40-percent reduction level ($\lambda \geq$ \$11,000). The costs of reducing all PNS losses simultaneously are the highest. The cost increases from \$12,131 at 10-percent reduction (λ = \$8,500) to \$69,856 at a 40-percent reduction level ($\lambda \geq$ \$11,500).

Given a level of constraints on PNS losses, costs vary with risk aversion. At 10-percent to 20-percent constraint levels on pesticide loss, costs decrease as the farmer gets less risk averse, while at 30-percent to 40-percent reduction levels, the opposite is true, though the differences are very small for all levels of risk aversion. For nitrogen, costs strictly decrease as the farmer gets less risk averse. For phosphorus, the costs increase as farmer get less risk averse although there is only one constraint level for which different farm plans (and ENI) will be adopted for different risk aversion levels. For soil, the costs increase at 10 percent and 20-percent reduction level as farmer gets less risk averse, while costs decrease at the 40-percent reduction level. The largest differences of costs to reduce PNS losses among different levels of risk aversion are found in the case where all PNS losses are to be reduced simultaneously. Costs decrease with decreasing risk aversion at the 10 and 20-percent levels of the constraints. At 30 and higher percent reduction levels, only one risk level is feasible.

Combining the two types of cost (increasing MLR and reduced expected net income), the conclusion is that generally total costs increase somewhat with increasing risk aversion. However, the costs of reducing PNS losses do not vary greatly among different levels of risk aversion, indicating that for each constraint on PNS losses, the farmer's optimal plan and expected net return are quite insensitive to the decrease of risk aversion.

This insensitivity can be explained by the variation of historical yields. As can be seen in Table 3-6, an extremely bad year for all crops occurs in the same year, so income risk mainly comes from this extreme year. All rotational choices are affected to some extent by income risk in this year.

As shown by the shadow prices on pollutant indices in Table 4-4, all single constraints on PNS losses are binding regardless of risk attitude. Higher shadow prices on pollutant constraints indicate higher costs in terms of reduced ENIs of a pollutant reduction. The general pattern is that when the constraint on pollution is tightened, shadow prices of land generally decline. The implication of this observation is that as the constraint level is getting stricter (resulting in higher costs regardless of risk attitude), the profitability of each extra acre is decreasing. One exception is when the constraint on pesticide loss alone is increased from 10 percent to 20 percent for risk aversion levels of λ = \$8,000 on all slopes and λ = \$8,500 on one-percent slope, shadow prices actually increase slightly.

No additional peanut is ever produced regardless of constraints or risk attitude, indicating the low return from additionals. Just as in the risk-neutral case, constraints on pesticide alone do not greatly reduce peanut production until the constraint level is 40 percent. At 10-percent and 20-percent constraint levels, the more risk averse farmer produces less peanut than the less risk averse farmer and the differences are large. Constraints on nitrogen losses tend to reduce peanut production by less than pesticide constraints, with less risk averse farm plans producing the full peanut quota poundage. Constraints on phosphorus losses eliminate peanut production at constraint levels higher than 10 percent. Constraints on soil losses eliminate peanut production when constraint levels are higher than 20 percent. However, a high level of peanut production is maintained when constraints are imposed on all PNS losses simultaneously. The reader is reminded that the real price for peanut quota used here is lower than the fixed nominal price of $610 per ton (see Chapter 3). Thus, the result obtained here may change if the price of $610 per ton is used.

For each type of pollutant constraint, more risk averse farmers tend to produce less peanut. For example, when soil loss is reduced 10 percent, at λ = $7,500, only 462,925 pounds of peanut are produced, at λ = $8,000, production is 509,456 pounds, and at λ = $8,500, up to 564,010 pounds of peanut are produced. An exception to this trend is when phosphorus losses are constrained by 10 percent. This observation reveals that peanut production is risky as compared to other crops, though it yields higher expected net income.

Optimal cropping plans for risk-averse farmers are reported in Table 4-5.

Table 4-5. Crops and rotations with varying levels of PNS reduction and varying levels of risk aversion

Pollutant	Level of	Expected	Rotations									Total crop acres (all slopes and rotations)					
under	reduction	shortfall		1% slope			3% slope			5% slope		Corn	Peanut	Cotton	Soybean	Wheat	Cover
constraint	(%)	allowed ($)	#	crop	acres	#	name	acres	#	name	acres	(ac)	(ac)	(ac)	(ac)	(ac)	only(ac)
		7500	1	peanut	7.7								156.8	300.8	293.1	293.1	
	0			cotton	7.7												
Baseline			3	peanut	94.8	3	peanut	29.3	3	peanut	25.0						
				cotton	94.8		cotton	29.3		cotton	25.0						
				wheat	94.8		wheat	29.3		wheat	25.0						
				soybean	94.8		soybean	29.3		soybean	25.0						
						5	cotton	144.0									
							wheat	144.0									
							soybean	144.0									
		8000	1	peanut	121.8								157.3	358.1	236.1	236.1	
				cotton	121.8												
			3	peanut	10.3				3	peanut	25.0						
				cotton	10.3					cotton	25.0						
				wheat	10.3					wheat	25.0						
				soybean	10.3					soybean	25.0						
			5	cotton	12.8	5	cotton	187.5									
				wheat	12.8		wheat	187.5									
				soybean	12.8		soybean	187.5									
		8500+	1	peanut	119.7				1	peanut	37.5		157.5	375.8	218.3	218.3	
				cotton	119.7					cotton	37.5						
			5	cotton	30.3	5	cotton	187.5									
				wheat	30.3		wheat	187.5									
				soybean	30.3		soybean	187.5									
		7500	1	peanut	16.0								136.5	314.5	298.5	298.5	
Pesticide	10			cotton	16.0												
only			3	peanut	89.3	3	peanut	6.2	3	peanut	25.0						
				cotton	89.3		cotton	6.2		cotton	25.0						
				wheat	89.3		wheat	6.2		wheat	25.0						
				soybean	89.3		soybean	6.2		soybean	25.0						
						5	cotton	178.0									
							wheat	178.0									
							soybean	178.0									
		8000	1	peanut	122.3								157.0	358.2	235.8	235.9	
				cotton	122.3												
			3	peanut	16.4				3	peanut	18.3						
				cotton	16.4					cotton	18.3						
				wheat	16.4					wheat	18.3						
				soybean	16.4					soybean	18.3						
			5	cotton	3.2	5	cotton	188.0	5	cotton	10.0						
				wheat	3.2		wheat	188.0		wheat	10.0						
				soybean	3.2		soybean	188.0		soybean	10.0						
		8500+	1	peanut	140.0				1	peanut	17.4		157.4	375.3	217.9	217.9	
				cotton	140.0					cotton	17.4						
			5	cotton	10.3	5	cotton	187.5	5	cotton	20.1						
				wheat	10.3		wheat	187.5		wheat	20.1						
				soybean	10.3		soybean	187.5		soybean	20.1						

Table 4-5. Crops and rotations with varying levels of PNS reduction and varying levels of risk aversion *(continued)*

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations: 1% slope #	1% slope crop	1% slope acres	3% slope #	3% slope name	3% slope acres	5% slope #	5% slope name	5% slope acres	Total crop acres (all slopes and rotations): Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
		7500	1	peanut	21.6								123.4	324.9	303.3	303.3	
Pesticide	20			cotton	21.6												
(continue)			3	peanut	86.2				3	peanut	15.6						
				cotton	86.2					cotton	15.6						
				wheat	86.2					wheat	15.6						
				soybean	86.2					soybean	15.6						
						5	cotton	187.5	5	cotton	14.0						
							wheat	187.5		wheat	14.0						
							soybean	187.5		soybean	14.0						
		8000	1	peanut	125.6								145.4	365.0	239.4	239.4	
				cotton	125.6												
			3	peanut	16.2				3	peanut	3.6						
				cotton	16.2					cotton	3.6						
				wheat	16.2					wheat	3.6						
				soybean	16.2					soybean	3.6						
						5	cotton	187.5	5	cotton	32.1						
							wheat	187.5		wheat	32.1						
							soybean	187.5		soybean	32.1						
		8500+	1	peanut	150.0								151.0	374.8	241.0	241.0	
				cotton	150.0												
									3	peanut	1.0						
										cotton	1.0						
										wheat	1.0						
										soybean	1.0						
						5	cotton	187.5	5	cotton	36.3						
							wheat	187.5		wheat	36.3						
							soybean	187.5		soybean	36.3						
		7500	1	peanut	24.2								109.6	332.2	308.0	308.0	
	30			cotton	24.2												
			3	peanut	83.8				3	peanut	1.6						
				cotton	83.8					cotton	1.6						
				wheat	83.8					wheat	1.6						
				soybean	83.8					soybean	1.6						
						5	cotton	187.5	5	cotton	35.1						
							wheat	187.5		wheat	35.1						
							soybean	187.5		soybean	35.1						
		8000+	1	peanut	115.1								115.1	375.1	260.0	260.0	
				cotton	115.1												
			5	cotton	35.0	5	cotton	187.5	5	cotton	37.5						
				wheat	35.0		wheat	187.5		wheat	37.5						
				soybean	35.0		soybean	187.5		soybean	37.5						
		7500	1	peanut	31.0								76.6	352.1	321.1	321.1	
	40			cotton	31.0												
			3	peanut	45.6												
				cotton	45.6												
				wheat	45.6												
				soybean	45.6												
			5	cotton	50.5	5	cotton	187.5	5	cotton	37.5						
				wheat	50.5		wheat	187.5		wheat	37.5						
				soybean	50.5		soybean	187.5		soybean	37.5						
		8000+	1	peanut	78.0								78.0	375.0	297.0	297.0	
				cotton	78.0												
			5	cotton	72.0	5	cotton	187.5	5	cotton	37.5						
				wheat	72.0		wheat	187.5		wheat	37.5						
				soybean	72.0		soybean	187.5		soybean	37.5						

Table 4-5. Crops and rotations with varying levels of PNS reduction and varying levels of risk aversion *(continued)*

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations: 1% slope #	1% slope crop	1% slope acres	3% slope #	3% slope name	3% slope acres	5% slope #	5% slope name	5% slope acres	Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
		8500	5	cotton	30.0	5	cotton	187.5					134.6	352.1	217.5	217.5	45.0
Nitrogen	10			wheat	30.0		wheat	187.5									
only				soybean	30.0		soybean	187.5									
			9	peanut	120.0				9	peanut	14.6						
				cotton	120.0					cotton	14.6						
				winter cover	240.0					winter cover	29.2						
									13	cover only	45.0						
		9000+	5	cotton	10.1	5	cotton	187.5					157.1	354.7	197.6	197.6	40.8
				wheat	10.1		wheat	187.5									
				soybean	10.1		soybean	187.5									
			9	peanut	140.0				9	peanut	17.1						
				cotton	140.0					cotton	17.1						
				winter cover	280.0					winter cover	34.2						
									13	cover only	40.8						
		9000	5	cotton	61.2	5	cotton	160.0					88.8	310.0	212.2	212.2	130.0
	20			wheat	61.2		wheat	160.0									
				soybean	61.2		soybean	160.0									
			9	peanut	88.8												
				cotton	88.8												
				winter cover	177.6												
						13	cover only	55.0	13	cover only	75.0						
		9500+	5	cotton	150.0	5	cotton	18.2					157.0	325.2	168.2	168.2	98.8
				wheat	150.0		wheat	18.2									
				soybean	150.0		soybean	18.2									
						9	peanut	157.0									
							cotton	157.0									
							winter cover	315.0									
						13	cover only	23.8	13	cover only	75.0						
		10000	5	cotton	45.7	5	cotton	78.5					156.7	280.9	124.2	124.2	188.0
	30			wheat	45.7		wheat	78.5									
				soybean	45.7		soybean	78.5									
			9	peanut	104.0	9	peanut	52.7									
				cotton	104.0		cotton	52.7									
				winter cover	208.0		winter cover	105.0									
						13	cover only	113.0	13	cover only	75.0						
		10500+	5	cotton	125.8								157.2	283.0	126.0	126.0	184.0
				wheat	125.8												
				soybean	126.0												
			9	peanut	24.2	9	peanut	133.0									
				cotton	24.2		cotton	133.0									
				winter cover	48.3		winter cover	266.0									
						13	cover only	109.0	13	cover only	75.0						
		11000+	5	cotton	83.0								157.2	240.2	83.0	83.0	270.0
	40			wheat	83.0												
				soybean	83.0												
			9	peanut	67.0	9	peanut	90.2									
				cotton	67.0		cotton	90.2									
				winter cover	134.0		winter cover	180.4									
						13	cover only	195.0	13	cover only	75.0						

Table 4-5. Crops and rotations with varying levels of PNS reduction and varying levels of risk aversion *(continued)*

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations: 1% slope #	1% slope crop	1% slope acres	3% slope #	3% slope name	3% slope acres	5% slope #	5% slope name	5% slope acres	Total crop acres (all slopes and rotations): Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
		7500	1	peanut	27.1								95.9	340.6	313.5	313.5	
Phosphorus only	10			cotton	27.1												
			3	peanut	68.8												
				cotton	68.8												
				wheat	68.8												
				soybean	68.8												
			5	cotton	19.7	5	cotton	187.5	5	cotton	37.5						
				wheat	19.7		wheat	187.5		wheat	37.5						
				soybean	19.7		soybean	187.5		soybean	37.5						
		8000+	1	peanut	78.7								78.7	375.0	296.3	296.3	
				cotton	78.7												
			5	cotton	71.3	5	cotton	187.5	5	cotton	37.5						
				wheat	71.3		wheat	187.5		wheat	37.5						
				soybean	71.3		soybean	187.5		soybean	37.5						
		8000+	5	cotton	150.0	5	cotton	187.5	5	cotton	26.5			364.0	364.0	364.0	22.0
	20			wheat	150.0		wheat	187.5		wheat	26.5						
				soybean	150.0		soybean	187.5		soybean	26.5						
									13	cover only	22.0						
			5	cotton	150.0	5	cotton	181.8						331.8	331.8	331.8	86.3
	30	8500+		wheat	150.0		wheat	181.8									
				soybean	150.0		soybean	181.8									
						13	cover only	11.3	13	cover only	75.0						
			5	cotton	150.0	5	cotton	126.1						276.1	276.1	276.1	198.0
	40	9500+		wheat	150.0		wheat	126.1									
				soybean	150.0		soybean	126.1									
						13	cover only	123.0	13	cover only	75.0						
		7500	1	peanut	20.4								122.9	323.6	303.2	303.2	
soil	10			cotton	20.4												
only			3	peanut	86.3				3	peanut	16.2						
				cotton	86.3					cotton	16.2						
				wheat	86.3					wheat	16.2						
				soybean	86.3					soybean	16.2						
						5	cotton	187.5	5	cotton	13.2						
							wheat	187.5		wheat	13.2						
							soybean	187.5		soybean	13.2						
		8000	1	peanut	101.0								135.4	360.4	254.0	254.0	
				cotton	101.0												
			3	peanut	29.0												
				cotton	29.0												
				wheat	29.0												
				soybean	29.0												
						5	cotton	187.5									
							wheat	187.5									
							soybean	187.5									
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										winter cover	37.5						
			9	peanut	5.4												
				cotton	5.4												
				winter cover	10.8												

Table 4-5. Crops and rotations with varying levels of PNS reduction and varying levels of risk aversion *(continued)*

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations									Total crop acres (all slopes and rotations)					
			1% slope			3% slope			5% slope								
			#	crop	acres	#	name	acres	#	name	acres	Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
			1	peanut	88.5								150	375	225.0	225.0	
Soil only	10	8500+		cotton	88.5												
(continue)						5	cotton	187.5									
							wheat	187.5									
							soybean	187.5									
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										winter cover	37.5						
			9	peanut	61.5												
				cotton	61.5												
				winter cover	123.0												
		7500	1	peanut	33.8								48.6	367.5	333.7	333.7	
	20			cotton	33.8												
			3	peanut	14.8												
				cotton	14.8												
				wheat	14.8												
				soybean	14.8												
			5	cotton	93.9	5	cotton	187.5	5	cotton	37.5						
				wheat	93.9		wheat	187.5		wheat	37.5						
				soybean	93.9		soybean	187.5		soybean	37.5						
		8000+	5	cotton	56.0	5	187.5						94.0	375.0	281.0	281.0	
				wheat	56.0		187.5										
				soybean	56.0		187.5										
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										winter cover	37.5						
			9	peanut	94.0												
				cotton	94.0												
				winter cover	188.0												
		8000+	5	cotton	150.0	5	cotton	120.4						375.0	375.0	375.0	
	30			wheat	150.0		wheat	120.4									
				soybean	150.0		soybean	120.4									
						6	cotton	67.1	6	cotton	37.5						
							wheat	67.1		wheat	37.5						
							soybean	67.1		soybean	37.5						
							winter cover	67.1		winter cover	37.5						
		8000	5	cotton	150.0	5	cotton	163.4						344.0	344.0	344.0	62.0
	40			wheat	150.0		wheat	163.4									
				soybean	150.0		soybean	163.4									
						6	cotton	24.1	6	cotton	6.5						
							wheat	24.1		wheat	6.5						
							soybean	24.1		soybean	6.5						
							winter cover	24.1		winter cover	6.5						
									13	cover only	62.0						
		8500+	5	cotton	150.0									355.1	355.1	355.1	39.8
				wheat	150.0												
				soybean	150.0												
						6	cotton	187.5	6	cotton	17.6						
							wheat	187.5		wheat	17.6						
							soybean	187.5		soybean	17.6						
							winter cover	187.5		winter cover	17.6						
									13	cover only	39.8						

Table 4-5. Crops and rotations with varying levels of PNS reduction and varying levels of risk aversion *(concluded)*

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations									Total crop acres (all slopes and rotations)					
			1% slope			3% slope			5% slope								
			#	crop	acres	#	name	acres	#	name	acres	Cor- (ac)	Peanut (ac)	Cotton (ac)	Soybea- (ac)	Wheat (ac)	Cover only(ac)
		8500	5	cotton	26.1	5	cotton	187.5	5	cotton	3.6		134.9	352.1	217.2	217.2	46.0
All PNS	10			wheat	26.1		wheat	187.5		wheat	3.6						
				soybean	26.1		soybean	187.5		soybean	3.6						
			9	peanut	124.0				9	peanut	10.9						
				cotton	124.0					cotton	10.9						
				winter cover	248.0					winter cover	21.8						
									13	cover only	46.0						
		9000+	1	peanut	40.9				1	peanut	6.9		156.8	352.1	195.3	195.3	46.0
				cotton	40.9					cotton	6.9						
						5	cotton	187.5	5	cotton	7.8						
							wheat	187.5		wheat	7.8						
							soybean	187.5		soybean	7.8						
			9	peanut	109.0												
				cotton	109.0												
				winter cover	218.0												
									13	cover only	46.0						
		9000	5	cotton	61.2	5	cotton	160.0					88.8	310.0	221.2	221.2	130.0
	20			wheat	61.2		wheat	160.0									
				soybean	61.2		soybean	160.0									
			9	peanut	88.8												
				cotton	88.8												
				winter cover	177.6												
						13	cover only	55.0	13	cover only	75.0						
		9500+	1	peanut	65.5	1	peanut	3.7					153.7	316.7	163.0	163.0	115.4
				cotton	65.5		cotton	3.7									
						5	cotton	163.0									
							wheat	163.0									
							soybean	163.0									
			9	peanut	84.5												
				cotton	84.5												
				winter cover	169.0												
						13	cover only	41.4	13	cover only	75.0						
		10000+	1	peanut	95.6								147.5	271.9	124.4	124.4	206.0
	30			cotton	95.6												
			5	cotton	2.4	5	cotton	122.0									
				wheat	2.4		wheat	122.0									
				soybean	2.4		soybean	122.0									
			9	peanut	51.9												
				cotton	51.9												
				winter cover	103.8												
			13	cover only	1.0	13	cover only	131.0	13	cover only	75.0						
			1	peanut	59.1								123.5	228.4	104.9	104.9	293.0
	40	11500		cotton	59.1												
			5	cotton	26.5	5	cotton	78.4									
				wheat	26.5		wheat	78.4									
				soybean	26.5		soybean	78.4									
			9	peanut	64.4												
				cotton	64.4												
				winter cover	128.8												
						13	cover only	218.0	13	cover only	75.0						

The following discussion will focus on comparisons between the plan corresponding to the minimum level of risk (MLR) and the risk neutral (RN) farm plan for a given type and level of constraint. For example, the MLR plan has an expected shortfall of $8,500 when the nitrogen loss constraint is 10 percent and a shortfall of $11,000 when the constraint level is 40 percent. It should be noted that for a given type of constraint (e.g. constraint on nitrogen), the MLR's for different levels of a pollution constraint may be different. A jump in MLR indicates an addition of type two cost as discussed in the end of Chapter 2.

When no constraints are imposed on PNS losses (baseline), rotations 1, 3, and 5 (all currently typical practices) are adopted at the MLR (λ = $7,500). In the baseline solution, when the level of risk aversion decreases, the farmer reduces acreage for rotation 3, increases acreage of rotation 5, and increases rotation 1, indicating that rotation 1 is more profitable but also more risky than rotation 3. The total acreage devoted to peanut (conventional) is nearly fixed (around 157 acres) regardless of risk attitude. As the farmer gets less risk averse, he produces more cotton (300.8 acres when λ = $7,500 to 375 acres when λ = $8,500 or above) and less soybean/wheat (from 293.1 acres when λ = $7,500 to 218.3 acres when λ = $8,500 or above).

When only pesticide loss is constrained, rotations 1, 3, and 5 (all currently typical practices) are adopted at the MLR (λ = $7,500). Generally, total acreage devoted to rotation 1 and 3 declines and that for rotation 5 increases with the increase of constraint level regardless of risk attitude, indicating the pesticide intensive nature of peanut production. With the increase of the pesticide constraint level, the same farmer produces less peanut, more soybean/wheat, and slightly more cotton. For MLR (λ = $7,500), acreage for peanut, cotton, and wheat/soybean are 156.8, 300.8, and 293.1 acres, respectively, with no pesticide constraint and 76.6, 352.1, and 321.1 acres, respectively, at 40-percent constraint level, a decrease of 80.2 acres peanuts, an increase of 51.3 acres cotton, and an increase of 28.6 acres of wheat/soybean. By contrast, the risk neutral farmer reduces peanut by 79.5 acres, leaves cotton acres almost the same, and increases wheat/soybean by 78.7 acres when going from 0 to 40 percent pesticide constraint.

When constraints are imposed on nitrogen alone, rotation 9 and rotation 13, both containing conservation practices, are adopted. For the MLR plan with 40-percent reduction on nitrogen (λ = $11,000), peanut, cotton, wheat/soybean, and cover are 157.2, 240.2, 83, and 270 acres, respectively. Thus peanut acres remain constant, cotton declines by 60.6 acres, wheat/soybean declines by 210.1 acres and cover increases by 270 acres. By contrast, the risk-neutral farmer holds peanut acres constant, reduces cotton by 135.6 acres, reduces wheat/soybean by 135.3 acres, and increases cover by 270 acres. At a high level of nitrogen constraint, the MLR and risk-neutral farm plans converge.

When constraints are imposed on phosphorus alone, peanut production is eliminated when the constraint level is higher than 10 percent and only rotations 5 and 13 are adopted. For the MLR plan with 40-percent reduction on phosphorus (λ = $9,500), peanut, cotton, wheat/soybean, and cover acres are 0, 276.1, 276.1, and 198 acres, respectively. Thus peanuts decline by 156.8 acres, cotton declines by 24.7 acres, wheat/soybean declines by 17 acres and cover increases by 198.0 acres. By contrast, the risk-neutral farmer reduces peanut acres by 157.5 acres, reduces cotton by 99.7 acres, increases wheat/soybean by 57.8 acres, and increases cover by 198.0 acres. At a high level of the phosphorus constraint, the MLR and risk-neutral farm plans converge.

When soil loss is constrained, alternative rotations 6 and 13 are increasingly adopted as the constraint gets stricter and rotation 9 is also adopted when the constraint level is not higher than 20 percent. Rotation 9 as well as peanut production are eliminated when the constraint level is 30 percent or higher. For the MLR plan with 40-percent reduction on soil (λ = $8,000), peanut, cotton, wheat/soybean, and cover acres are 0, 344.0, 344.0, and 62 acres, respectively. Thus peanut acres decline by 156.8, cotton increases by 44 acres, wheat/soybean increases by 50.9 and cover increases by 62.0 acres. By contrast, the risk-neutral farmer reduces peanuts by 157.5 acres, reduces cotton by 20.7 acres, increases wheat/soybean by 136.8 acres, and increases cover by 39.8 acres.

When constraints are imposed on all PNS indices simultaneously, alternative practices 9 and 13 are adopted for all constraint levels regardless of risk attitudes. Rotations 1 and 5 are also grown. Peanut production is maintained at high levels throughout. For the MLR plan with 40-percent reduction on all PNS losses (λ = $11,500), peanut, cotton, wheat/soybean, and cover acres are 123.5, 228.4, 104.9, and 293.0 acres, respectively. Thus peanuts decline by 33.3, cotton declines by 72.4 acres, wheat/soybean declines by 188.2 and cover increases by 293 acres. By contrast, the risk-neutral farmer reduces peanut acres by 34 acres, reduces cotton by 147.4 acres, reduces wheat/soybean by 113.4 acres, and increases cover by 293 acres. At a high level of constraint, the MLR and risk-neutral farm plans converge.

Figure 4-3 shows the pattern of crop responses by the MLR farm to increased restrictions on all PNS losses. Generally cotton and wheat/soybean acres decline, idle land increases and peanut acres are about constant:

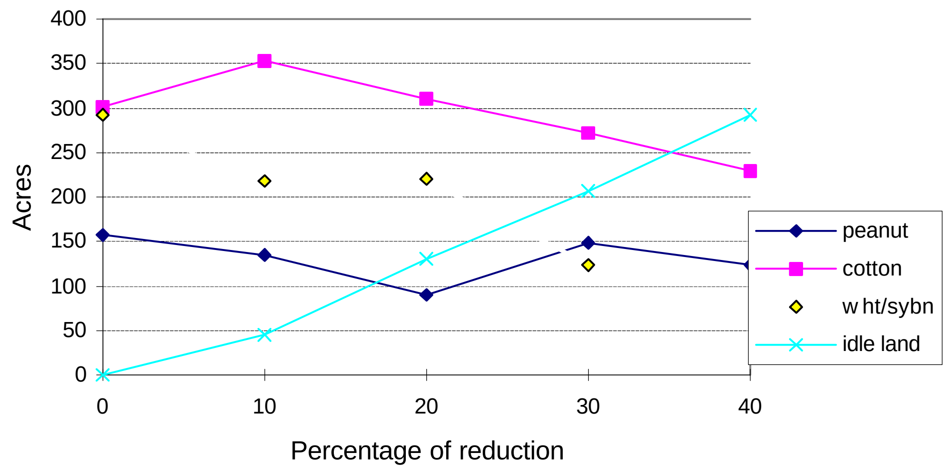

Figure 4-3. Crop acreage response for the MLR farm plans when all PNS are constrained

Cotton acreage is higher than the baseline level when constraint levels are 10 to 20 percent, and then falls below the baseline level at higher constraint levels. Peanut acreage decreases from the baseline with the increase (up to 20 percent) of constraint level, then jumps back (up) to nearly baseline level at 30-percent level, then decreases slightly at the 40-percent constraint level. The special response pattern for cotton and peanut come from the combined effects of constraints on pesticides and nitrogen because these constraints have non-zero shadow prices when all PNS are constrained simultaneously. The MLR plans have increasing cotton acreage when only pesticide is constrained and decreasing cotton acreage when only nitrogen is constrained. Clearly, the pesticide constraint has more effect at lower constraint levels (10 percent) and less effect at higher levels (20 percent or above) compared to the constraint on nitrogen.

Though constraints on the pesticide index alone at high levels reduce peanut production very much (at the 40-percent constraint level, peanut acres are reduced by more than 50 percent from the baseline), the combined effects of constraints on pesticide and nitrogen together maintain high peanut production (at the 30-percent constraint on all

PNS levels, peanut is reduced by only 5 percent while the at 40-percent constraint level, peanuts are reduced by only 20 percent compared to the baseline).

When nitrogen alone or soil alone is constrained, there is a modest tendency for less risk averse farmers to adopt alternative production practices, crop rotations or tillage to meet the constraints while more risk averse farmers to idle land. Rotation 13 (idle land) is increasingly adopted as λ gets smaller at the 20-percent constraint on all PNS indices.

Finally, the actual PNS losses with varying levels of reduction for the risk averse farm are presented in Table 4-6.

Table 4-6. Pesticide, nutrient, and soil losses with varying constraints on pollutants for risk-averse representative farm

Pollutant under constraint	Percentage of reduction	Expected shortfall allowed ($)	Pesticide index		N index		P index		Soil index	
			Level	Ratio to baseline	Level	Ratio to baseline	Level	Ratio to baseline	Level	Ratio to baseline
no constraints on PNS	0	7500	51870		15226		975		2362	
		8000	47133		14481		989		2439	
		8500+	50655		14073		1003		2471	
Pesticide only	10	7500	45589	0.9	15079	1.071	957	0.954	2293	0.928
		8000	45589	0.9	14438	1.026	980	0.977	2415	0.977
		8500+	45589	0.9	14098	1.002	983	0.980	2422	0.980
	20	7500	40524	0.8	14949	1.062	930	0.927	2220	0.898
		8000	40524	0.8	14301	1.016	956	0.953	2333	0.944
		8500+	40524	0.8	14154	1.006	961	0.958	2360	0.955
	30	7500	35458	0.7	14813	1.053	912	0.909	2138	0.865
		8000+	35458	0.7	14271	1.014	932	0.929	2229	0.902
	40	7500	30393	0.6	14683	1.043	892	0.889	2049	0.829
		8000+	30393	0.6	14404	1.024	902	0.899	2096	0.848
Nitrogen only	10	8500	46814	0.924	12666	0.9	857	0.855	1914	0.775
		9000+	51903	1.025	12667	0.9	882	0.879	1994	0.807
	20	9000	30972	0.611	11259	0.8	716	0.714	1503	0.608
		9500+	72429	1.430	11259	0.8	848	0.845	1824	0.738
	30	10000	51155	1.010	9852	0.7	726	0.724	1546	0.626
		10500+	65809	1.299	9852	0.7	762	0.760	1605	0.650
	40	11000	55786	1.101	8444	0.6	668	0.666	1372	0.555
Phosphorus only	10	7500	33127	0.654	14753	1.048	903	0.9	2098	0.849
		8000+	30484	0.602	14402	1.023	903	0.9	2098	0.849
	20	8000+	18781	0.371	14102	1.002	802	0.8	1705	0.690
	30	8500+	16225	0.320	12507	0.889	702	0.7	1413	0.572
	40	9500+	13292	0.262	10634	0.756	602	0.6	1145	0.463
Soil only	10	7500	40729	0.804	14954	1.063	937	0.934	2224	0.9
		8000	41156	0.812	14367	1.021	948	0.945	2223	0.9
		8500+	45389	0.896	14017	0.996	955	0.952	2224	0.9
	20	7500	26437	0.522	14598	1.037	878	0.875	1977	0.8
		8000+	39104	0.772	14147	1.005	904	0.901	1977	0.8
	30	8000+	25321	0.500	14813	1.053	847	0.844	1729	0.7
	40	8000	18614	0.367	13086	0.930	736	0.734	1482	0.6
		8500+	27739	0.548	13972	0.993	775	0.773	1483	0.6
All PNS losses	10	8500	45589	0.9	12667	0.9	853	0.850	1905	0.771
		9000+	45589	0.9	12666	0.9	873	0.870	2016	0.816
	20	9000	30972	0.8	11259	0.8	716	0.714	1503	0.608
		9500+	40524	0.8	11259	0.8	783	0.781	1778	0.720
	30	10000+	35459	0.7	9852	0.7	702	0.7	1584	0.641
	40	11500+	30393	0.6	8444	0.6	601	0.6	1290	0.522

With no constraints on PNS losses, less risk averse farmers adopt farm plans that result in lower nitrogen loss, higher phosphorus loss, and higher soil loss. Pesticide loss is lowest for the middle level of risk aversion (λ = $8,000) and highest for the most risk averse farmer (λ = $7,500).

When the constraint is on pesticide loss alone, as the farmer gets less risk averse (λ increases), nitrogen loss decreases, but phosphorus loss and soil loss increase, though the degrees of increase or decrease are rather small at all levels of constraints.

When the constraint is on nitrogen alone, as the farmer gets less risk averse, pesticide loss, phosphorus loss, and soil loss increase. The degree of increase for the pesticide index is dramatic. The index increases by 10 percent at the 10-percent constraint level, and more than doubles at the 20-percent constraint level. Phosphorus and soil loss increases are modest.

When the constraint is on phosphorus alone, at a 10-percent level of constraint, pesticide loss and nitrogen loss decrease as the farmer gets less risk averse. Soil loss remains at the same level because phosphorus loss is closely related to soil loss. At constraint levels higher than 10 percent, no comparison can be made in regard to level of risk aversion.

When soil loss alone is constrained by 10 percent and 20 percent, nitrogen loss decreases and phosphorus and pesticide losses increase as the farmer gets less risk averse. When the constraint is on all PNS indices simultaneously, phosphorus, soil, and pesticide losses increase at 10 percent and 20-percent constraint levels as the farmer gets less risk averse (nitrogen loss is the same at all risk aversion levels).

In this section, regardless of risk attitude, the estimated constraints on PNS losses are based on the baseline values of PNS losses for a risk-neutral farm plan. But a look at Table 4-6 reveals that when there is no constraint on any PNS indices, more risk averse farmers have larger nitrogen losses, smaller phosphorus losses and soil losses, and larger or smaller pesticide losses as compared to less risk averse or risk-neutral farmers. Thus, a constraint based on the risk-neutral baseline values will force the more risk averse farmers to reduce more nitrogen loss, less phosphorus loss and less soil loss, and more or less pesticide loss compared to a situation where the baseline is determined from the risk averter's unconstrained production level (referred to as individual baselines). The next section compares the farm plans and related ENIs (or costs) using individual baseline values to determine PNS loss constraints.

4.3 Results for risk-averse farm plans (individual baselines)

In this section, costs of complying with pollution restrictions are estimated based on percentage reductions in pollution from baseline levels of pollution that are specific to each level of risk aversion. For example, with a 10-percent constraint on nitrogen and λ =\$7,500, the allowable nitrogen index is 46,683 or 10 percent below the base value of 51,870. In the previous section when a common baseline was used to estimate allowable nitrogen pollution, this farm's 10-percent reduction corresponded to an allowable level of 45,589 (Table 4-6). The major interest is to find out how farmers' costs of reducing PNS loss compared with those estimated using the simpler approach of last section in which a common pollution baseline is used for all risk aversion levels.

It can be seen in Table 4-7 that only three levels of risk-aversion pertain here, namely, λ = \$7,500, \$8,000, and \$8,500, since when λ = \$8,500 or higher, baseline results are identical with those for the risk neutral farmer. Corresponding to Tables 4-4 and 4-6, Tables 4-7 and 4-8 list the results for costs of reducing PNS losses, and resultant levels of PNS losses when the level of risk aversion varies from λ = \$7,500 to \$8,500. Table G-1 in Appendix G shows the resultant cropping plans. The results for λ = \$7,500 and \$8,000 are different from those in the last section since now the baseline pollution values and resulting pollution reductions have changed. The results for λ = \$8,500 are the same as those listed in Table 4-4 to 4-6 because the baseline pollution values are the same as in the previous section.

Table 4-7. Effects of varying risk aversion on costs of reducing pollutant losses, shadow prices, and peanut sales (individual baselines)[a]

Pollutant Index	Level of reduction (%)	Expected shortfall allowed ($)	Expected net return ($)	Cost of reduction from baseline ($)		Shadow prices ($)								Peanut sold(lb)	
				now[b]	before[c]	Pesti-cide	N	P	Soil	Land (% slope) 1%	3%	5%	Peanut quota	as quota	addit-ional
Baseline	0	7,500	174,427	0	0	0	0	0	0	0	0	0	0	589,975	0
		8,000	175,713	0	0	0	0	0	0	0	0	0	0	589,975	0
		8,500+[d]	175,954	0	0	0	0	0	0	0	0	0	0	589,975	0
pesticide only	10	7,500	174,215	212	256	0.041	0	0	0	212.80	204.70	195.00	0	526,839	0
		8,000	175,294	419	114	0.100	0	0	0	206.00	200.10	182.60	0	564,754	0
		8,500 +	175,771	183	183	0.040	0	0	0	189.00	187.00	172.00	0.007	589,975	0
	20	7,500	173,861	566	663	0.100	0	0	0	206.00	200.10	182.60	0	470,196	0
		8,000	174,751	962	609	0.147	0	0	0	200.70	196.40	178.50	0	494,009	0
		8,500 +	175,415	539	539	0.100	0	0	0	206.00	200.00	182.00	0	546,791	0
	30	7,500	173,342	1,085	1,171	0.100	0	0	0	206.00	200.10	182.60	0	421,066	0
		8,000	173,656	2,057	1,470	0.239	0	0	0	185.50	181.00	163.50	0	235,279	0
		8,500+	174,243	1,470	1,470	0.240	0	0	0	185.50	181.00	163.50	0	432,512	0
	40	7,500	172,647	1,780	1,887	0.147	0	0	0	200.70	196.40	178.50	0	307,853	0
		8,000	172,531	3,182	2,678	0.239	0	0	0	185.50	181.00	163.50	0	235,279	0
		8,500+	173,035	2,678	2,678	0.240	0	0	0	185.50	181.00	163.50	0	293,328	0
Nitrogen only[e]	10	8,000	158,853	16,860	------	0	16.90	0	0	162.20	-2.40	-243.20	0	129,068	0
		8,500	163,886	12,068	12,068	0	12.63	0	0	116.50	-5.40	-177.00	0	505,732	0
Phosphoru s only[e]	10	7,500	171,929	2,498	1,485	0	0	52.90	0	175.00	135.60	68.50	0	198,403	0
		8,000	172,568	3,145	2,656	0	0	40.80	0	165.30	134.80	80.70	0	239,624	
		8,500+	173,057	2,656	2,656	0	0	40.80	0	165.30	134.80	80.70	0	295,822	0
	20	8,000	163,530	12,183	10,808	0	0	129.30	0	121.20	28.70	-113.80	0	0	0
		8,500+	164,905	10,808	10,808	0	0	129.30		121.20	28.70	-113.80	0	0	0
Soil only	10	7,500	173,180	1,247	643	0	0	0	7.01	187.50	174.40	140.70	0	406,658	0
		8,000	174,117	1,596	1,371	0	0	0	8.06	183.00	169.40	134.20	0	506,125	0
		8,500+	174,497	1,457	1,457	0	0	0	7.70	182.00	167.00	133.80	0	564,010	0
	20	7,500	170,771	3,656	2,627	0	0	0	12.04	189.40	170.20	122.50	0	93,676	0
		8,000	171,892	3,821	3,468	0	0	0	14.24	180.30	158.40	108.00	0	311,212	0
		8,500+	172,245	3,468	3,468	0	0	0	14.20	180.00	158.00	108.00	0	353,695	0
	30	8,000	166,611	9,102	7,647	0	1.987	0	36.63	125.50	54.20	-69.90	0	0	0
		8,500+	168,066	7,647	7,647	0	0	0	30.70	158.90	114.00	27.00	0	0	0
	40	8,000	154,558	21,155	20,130	0	0	0	55.03	154.80	74.40	-75.40	0	0	0
		8,500+	157,286	18,668	18,668	0	0	0	50.30	143.00	74.00	-61.00	0	0	0
All PNS[e]	10	8,000	158,853	16,860		0	16.90	0	0	162.20	-2.40	-243.20	0	129,068	0
		8,500+	163,823	12,131	12,131	0.050	11.48	0	0	115.30	4.10	-161.00	0	506,668	0

a. Individual baseline means the unconstrained PNS losses for each level of risk aversion are used to compute the required reduction in PNS losses for that level of risk aversion.
b. Calculated as ENI when constrained - ENI when not constrained, given level of risk aversion. Note, “not constrained” = “baseline”.
c. Copied from Table 4-4. Corresponds to common baseline of pollution used to compute required pollution reductions. Common baseline equals the unconstrained pollution level for the risk neutral farmer.
d. “+” means “and above”. In the table, for each constraint level, for a given pollutant index, the first line is the MLR (minimum level of risk) for which a feasible solution can be found.
e. Higher levels of constrain not listed here because the only feasible values of λ are equal to or greater than the baseline value of λ that corresponds to a risk neutral farmer. Consequently, the baseline value of the pollutant for the risk neutral is appropriate and the results are the same as in the previous section (common baseline).

Table 4-8. Pollutant losses with varying levels of reduction for the risk-averse representative farm (individual baselines)

Pollutant under constraint	Percentage of reduction	Expected shortfall allowed ($)	Pesticide index		N index		P index		Soil index	
			Level	Ratio to current level	Level	Ratio to current level	Level	Ratio to current level	Level	Ratio to current level
no constraint on PNS	0	7,500	51870		15226		975		2362	
		8,000	47133		14481		989		2439	
		8,500+	50655		14073		1003		2471	
Pesticide only	10	7,500	46684	0.90	15105	0.99	960	0.98	2305	0.976
		8,000	42421	0.90	14353	0.99	966	0.98	2364	0.969
		8500+	45589	0.90	14098	1.00	983	0.98	2422	0.980
	20	7,500	41497	0.80	14976	0.98	941	0.97	2236	0.947
		8,000	37707	0.80	14228	0.98	945	0.96	2286	0.937
		8500+	40524	0.80	14154	1.01	961	0.96	2360	0.955
	30	7,500	36309	0.70	14836	0.97	917	0.94	2153	0.912
		8,000	32993	0.70	14336	0.99	918	0.93	2164	0.887
		8,500+	35458	0.70	14271	1.01	932	0.93	2229	0.902
	40	7,500	31122	0.60	14701	0.97	895	0.92	2063	0.873
		8,000	28280	0.60	14460	1.00	890	0.90	2040	0.836
		8,500+	30393	0.60	14404	1.02	902	0.90	2096	0.848
Nitrogen only[b]	10	8,000	24219	0.51	13033	0.90	779	0.79	1674	0.686
		8,500+	46814	0.92	12666	0.90	857	0.85	1914	0.775
Phosphorus only[b]	10	7,500	27012	0.52	14609	1.04	878	0.90	1988	0.842
		8,000	28439	0.60	14456	1.00	891	0.90	2045	0.838
		8,500+	30484	0.60	14402	1.02	903	0.90	2098	0.849
	20	8,000	18514	0.39	13937	0.96	792	0.80	1674	0.686
		8,500+	18781	0.37	14102	1.00	802	0.80	1705	0.690
Soil only	10	7,500	34925	0.67	14801	0.97	910	0.93	2127	0.901
		8,000	41735	0.89	14345	0.99	945	0.96	2196	0.900
		8500+	45389	0.90	14017	1.00	955	0.95	2224	0.900
	20	7,500	23941	0.46	14598	0.96	862	0.88	1890	0.800
		8,000	37083	0.79	14213	0.98	897	0.91	1952	0.800
		8,500+	39104	0.77	14147	1.01	904	0.90	1977	0.800
	30	8,000	22885	0.49	14482	1.00	990	1.00	1708	0.700
		8,500+	25321	0.50	14813	1.05	847	0.84	1729	0.700
	40	8,000	17672	0.37	12914	0.89	726	0.73	1464	0.600
		8500+	27739	0.55	13972	0.99	775	0.77	1483	0.600
All PNS losses[b]	10	8,000	24219	0.51	13034	0.90	779	0.79	1674	0.686
		8,500+	45589	0.90	12666	0.90	853	0.85	1905	0.771

a. Individual baseline means the unconstrained PNS losses for each level of risk aversion are used to compute the required reduction in PNS losses for that level of risk aversion.
b. Higher levels of constrain not listed here because the only feasible values of λ are equal to or greater than the baseline value of λ that corresponds to a risk neutral farmer. Consequently, the baseline value of the pollutant for the risk neutral is appropriate and the results are the same as in the previous section (common baseline).

Comparing Table 4-4 to 4-6 with Table 4-7, 4-8, and G-1 major findings are (in the following discussion, the term "than before" refers to the results in Table 4-4 to 4-6 while the term "now" refers to corresponding results in Table 4-7, 4-8, and G-1):

1. Generally the minimum level of risk (MLR) that must be accepted (the lowest "expected shortfall allowed" shown in Table 4-7) is not greatly affected by using individual baseline values of pollutants. Exceptions are for the constraint on nitrogen at the 10-percent level and for the constraint on all PNS losses at the 10-percent level where MLR's both decline from $8,500 to $8,000. In these cases, the type two costs (costs to a risk averter of having to accept a higher MLR) are over-estimated when using common baseline values of the pollutant loadings.

2. Wherever the baseline pollution level for the risk averter is larger than that for risk neutral (as in the case of nitrogen for all levels of risk aversion and the case of pesticide for the risk aversion level of λ = $7,500), type one costs (reductions in ENI) of reducing that pollutant were over-estimated by using the risk neutral's baseline level of pollution. Thus, in the model before using common baseline values, the cost of reducing pesticide loss was over-estimated for λ = $7,500 and under-estimated for λ = $8,000. The costs for reducing soil loss and phosphorus loss were under-estimated when using common baseline values. As mentioned above, the costs for reducing nitrogen loss as well as for reducing all PNS losses at the 10-percent constraint level were also over-estimated. Costs were not affected for higher levels of the constraint because at higher constraint levels the feasible value of λ's are equal to or higher than $8,500, which equals the baseline for the risk neutral. Baseline pollution values are all the same as for the risk neutral farm meaning that costs are the same as in previous section. The largest over-estimated type one cost is $107 (for λ = $7,500 at 20 percent pesticide constraint level), while the largest under-estimated type one cost is $1,375 ($\lambda$ = $8,000 at the 20 percent phosphorus constraint level). In general, the estimated type one costs are not greatly

different for a common or the individual baselines of pollution. In only two cases are the MLR's slightly over-estimated by using a common pollution baseline. The conclusion is that the approach used in last section (common baseline values) is acceptable for measuring the cost of reducing pollution for this study.

3. Peanut production is generally less for the risk averter when individual pollution baselines are used compared to the common pollution baseline. A possible reason for lower peanut production is that baseline phosphorus loss and soil loss are smaller for more risk-averse farmers than those for less risk-averse farmers. Consequently the allowable phosphorus or soil losses are smaller than when the baseline for the risk neutral producer was used to compute pollution reductions. Peanut production is sensitive to constraints on soil and phosphorus loss.

4. Shadow prices of land follow similar patterns as when a common pollution baseline was used.

5. Crop rotations are not greatly affected by choice of the pollution baseline.

In summary, the use of individual baseline values for PNS losses results in higher allowable nitrogen losses and lower allowable phosphorus and soil losses, and both higher and lower allowable pesticide losses for more risk averse farmers compared to using a common baseline of pollution. However, the differences in reduced ENI are not large. Where the risk averse baseline pollution level was smaller than the risk neutral baseline, use of the individual baseline further reduced ENI as a result of a pollution constraint. When the risk averse baseline pollution was higher than the risk neutral baseline, use of the individual baseline increased ENI relative to use of the common baseline at each level of the constraint.

4.4. A summary of this chapter

In this chapter, output from the Target MOTAD as developed in Chapter 2 and Chapter 3 for the representative farm model, REPVAFARM, is presented and discussed. Major findings can be summarized as below:

First, for risk-neutral farmers, constraints on all PNS losses simultaneously are the most costly, followed by those on nitrogen losses, on phosphorus losses, on soil losses, and on pesticide losses. Peanut production is not affected by constraints on nitrogen losses, and is slightly reduced by constraints on all PNS losses, and by the constraint on pesticide losses when the reduction level is high (≥ 30 percent). Constraints on soil loss reduces peanut production greatly, while constraints on phosphorus losses eliminate peanut production. Strategies employed to reduce pesticide losses also reduce soil losses and phosphorus losses by a small degree, while having little effect on nitrogen losses. Strategies to reduce nitrogen losses have little effect on pesticide losses, while reducing soil losses and phosphorus losses by larger degrees. A combined reduction of nitrogen losses and pesticide losses can achieve a simultaneous reduction on all PNS losses.

Second, production on the representative peanut-cotton farm is inherently risky so in order to be able to operate the farm at all, the farmer has to take at least some risk as measured by expected shortfall from his target income. However, tradeoffs between increased risks measured by allowable shortfalls below the income target (λ) and expected net income are small. There is not a large difference in expected net income for risk neutral farmers and risk averse farmers. This limited tradeoff results because low yield years tend to affect all crops and rotations about the same. The result shows that most risk comes from one or two bad years, as is clearly seen from Table 3-5 (bad yields for all crops and rotations tend to fall in the same year, 1993 especially).

Third, generally, a more risk averse farmer would adopt production plans which result in higher nitrogen loss, but lower phosphorus loss, soil loss, and pesticide loss compared to the risk neutral farmer when PNS losses are not constrained.

Fourth, all constraints except those on pesticides alone (all levels) and those constraining soil loss by 20-percent or less increase riskiness of production for the farmer and generally restrict the risk-return tradeoff frontier even more. Thus both type one cost (all levels of risk aversion) and type two cost (for risk-averters only) of pollution constraints tend to increase with the increase of constraint levels. In this study, type two cost is dealt with only qualitatively by estimating the increased minimum level of risk (MLR) that can be attained with the constraint.

Fifth, the constraint on nitrogen reduces expected net income for the farmer the most of all individual pollution constraints regardless of his level of risk aversion. The constraint on phosphorus costs the second most, the constraint on soil loss the third most, and the constraint on pesticide loss reduces expected income the least regardless of the level of risk aversion. An overall constraint on all PNS indices reduces expected net income the most. The nitrogen and overall PNS constraints are costly at all constraint levels. The farmer’s expected net income is also greatly reduced where the constraint level on phosphorus alone exceeds 30 percent.

Sixth, constraining one pollutant results in production strategies that cause some other pollutants to fall while having little impact on other pollutants. Constraining pesticide loss alone also reduces soil loss and phosphorus loss by a smaller degree but has little effect on nitrogen loss. Reducing nitrogen loss has little impact on pesticide loss but soil loss and phosphorus loss are reduced by a similar degree. A combined constraint on nitrogen loss and pesticide loss together can achieve similar reductions in soil loss and phosphorus loss.

Seventh, risk-aversion is an obstacle to the adoption of conservation practices because risk averters suffer greater reductions in expected net income for a given constraint level and alternative practices tend to be less profitable and more risky. For example, with 10-percent and 20-percent constraint on soil loss, the less risk averse farmers tend to use more rotation 9 to maintain a higher level of peanut production than the more risk averse farmers. The risk averter tends to idle land (rotation 13) rather than adopt conservation alternatives when constraints on all PNS losses are binding. The risk averter tends to adopt more rotation 13 (annual cover) than the risk-neutral farmer because rotation 13 is less risky although more costly.

Chapter 5. Summary and Conclusions

This chapter consists of three parts. Part one reviews the problem statement, the objectives of the study, the theoretical framework for the study, the empirical model, and scenarios to analyse the empirical model. Part two recapitulates results of the empirical model and conclusions from the analysis. In part three, the limitations of this study are discussed, suggestions for further study are stated, and policy implications are discussed.

5.1. Review of the model in this thesis

There is increased concern about nonpoint sources pollution (NPSP) -- soil loss, nitrogen loss, phosphorus loss, and pesticide loss from agriculture to ground water and surface water. The study area for this research was Southeastern Virginia, part of the Albemarle-Pamlico Watershed. Peanut production in this area, where over 80 percent of peanut produced in Virginia is grown, is characterized as pesticide intensive, tillage intensive, erosive, management intensive, and highly profitable in peanut production. Reduced tillage reduces yield in peanut (Phipps, 1997). On the other hand, cotton is coming back rapidly in this area, replacing corn as the rotational crop with peanut. Profitable as it is, cotton performs well in reduced tillage also, but is pesticide intensive and subject to erosion particularly when grown using conventional tillage. Some of the methods to reduce NPSP from this type of peanut-cotton farm include choosing better rotational patterns, reducing tillage, and planting cover crops. The purposes of this study are: to evaluate the costs to a representative risk-neutral peanut-cotton farmer in Southeast Virginia of reducing pesticide, nitrogen, phosphorus, and sediment losses, and to evaluate the effects of varying levels of risk aversion on the costs of reducing pesticide, nitrogen, phosphorus, and sediment losses. Major crops, namely peanut, corn, cotton, winter wheat, and soybean, as well as major crop rotations in Southeastern Virginia are included in the study.

In Chapter 2, the theoretical framework to carry out economic analysis of farmers' choice under risk situation is developed. The von Neumann-Morgenstern type expected utility (EU) approach is adopted and described systematically. Farmers are described as seeking to maximize expected utility from their production activity. As is common in this type of study, utility generated from monetary income is assumed separable from utility generated from all other things. Thus, farmers' utility functions are thought of as functions of net income from production activities. Crop production is highly risky because of unpredictability of weather conditions and price conditions, in addition to other risky conditions. Farmers have limited methods to spread the risk they face. The study assumes that farmers are inclined to choose production practices which enable them to meet at least a pre-set income target, which may include the cost of living for their families, wages for full-time labor, property tax, interest cost on borrowed capital, and land rental. Within the EU paradigm, an efficient mathematical programming model, the Target MOTAD model by Tauer, is selected to describe farmers' choices in the face of income risk and technical constraints and NPSP loss reduction constraints.

In Chapter 3, a representative peanut-cotton farm is developed for the City of Suffolk in Southeastern Virginia based on a literature review, suggestions from experts, farm visits, and survey data. The farm is assumed to own 200 acres of land and rent another 550 acres. Slopes of land are one percent, three percent, and five percent, respectively, for 300 acres, 375 acres, and 75 acres, respectively, of the farm cropland. Land of the same slope is assumed to be equally productive for all crops. The soil type is Emporia. There is a peanut quota of 589,975 pounds allocated to the 750 acres of land, equally distributed among all acres, rented or not. The farmer has to pay rent of five cents for each pound of peanut attached to the rented land, in addition to $30 per acre for rented land when peanut quota is absent, so the resultant rental fee is $69.30 per acre. The farmer is assumed to take part 100 percent in government commodity program and gets a yearly total payment or $9,018.97 from the program.

The farmer is free to choose from 13 rotation patterns for his farm. Five of the rotations are currently popular in the study area, where the other eight rotations (called "alternative practices" or "conservation practices") are feasible alternatives which have potential to reduce some or all of the pollutants. The alternative practices differ from currently popular practices mainly in reduced tillage in cotton (strip-till or notill) and in peanut (strip-till), and in cover crops (no cover crops are planted in currently popular practices).

The farmer is assumed to maximize expected income subject to constraints on target income. This behavior is represented by a Target MOTAD model developed in Chapter 2. The target income is $145,458, which includes land debt payment, machinery debt payment, social security tax, family living expenses, income tax, payment for hired full-time labor, real estate tax, insurance for owned land, and annual land rental.

Two major sources of risk the farmer faces are yield variation and price variation. Based on historical price data from 1986-1995, ten states of nature are created, reflecting the variation of the same pattern but adjusted to the same expected average prices as projected by Food and Agricultural Policy Research Institute (FAPRI) for 1997-2002. Correspondingly, ten states of nature yields for each crop are established also, using EPIC simulation and historical rainfall and temperature data from Suffolk from 1986 to 1995. Both sets of states of nature for prices and yields use historical data of the same period. The outcomes on prices and yields are the states of nature as perceived by the farmer.

To evaluate the overall effects of pollutant losses from the farmland, especially for pesticides, environmental risk indices are developed based on the works done by others, notably by Warner, Alt, Cabe et al, and Kovach et al. Following a 1996 study by Teague, Mapp, and Bernardo, environmental indices for pesticides, nitrogen, and phosphorus are constructed. The soil loss index is simply tonnage of soil loss as estimated by the EPIC model. All indices are constructed for each rotation on each slope per acre, using average pollutant runoff and leaching values from EPIC simulations run with the actual historical weather data from 1976 to 1995.

In Chapter 4, results for six scenarios for the representative farmer are reported and analyzed. The six scenarios are: no constraints on PNS (pesticides, nutrients (nitrogen and phosphorus), and soil), constraints on pesticides only, constraints on nitrogen only, constraints on phosphorus only, constraints on sediment only, and simultaneous constraints on all pollutants. Constraints are parameterized from 10 percent reduction to 40 percent reduction on the PNS indices. Farmers' risk attitudes are parameterised from extremely risk averse to risk neutral in each scenario, 15 levels in all. Thus, the model solves 360 maximizing problems for this study.

5.2. Results and conclusions

Major findings in this study are:

- For any of the six scenarios, there is no production plan for the farmer which is 100 percent sure to meet farmer's income target meaning the farmer has to accept at least some risk to be able to operate. However, the tradeoff frontier between expected net income and expected shortfall below the income target is limited. This result occurs because yield risk for the farmer mainly comes from the dry years. Such a dry year has the same effects on all rotations the farmer may choose. However, it is evident that in all scenarios, risk aversion reduces expected net income for the farmer, and the more risk averse, the lower the expected net income.
- For a risk-neutral farmer, costs of reducing PNS losses come from the reduced expected net income. A reduction on all PNS losses at the same time is the most costly for the farmer, followed by the constraint on nitrogen loss, then phosphorus loss, then soil loss, and pesticide loss. The pesticide constraint is primarily met by shifting from peanut production (conventional) to cotton production (conventional). The nitrogen constraint is primarily met by planting rotation 13 (annual cover) on the steeper land. The phosphorus constraint is met mainly by shifting conventional peanut to conventional cotton and by planting more annual cover. The soil constraint is met mainly by shifting from conventional peanut to strip-till peanut, from conventional cotton to strip-till or notill

cotton, and by planting more annual cover. A constraint on all PNS losses simultaneously is met mainly by planting annual cover.

Peanut production remains high when constraints are imposed on all PNS losses at the same time. When nitrogen loss alone is constrained, peanut is always produced at full quota level regardless of the constraint level. When pesticide loss is constrained by 40 percent, peanut production is reduced by more than 50 percent. When high levels of constraint are imposed on soil loss or phosphorus loss, peanut production is eliminated altogether.

- Risk aversion is an obstacle to reducing pollution because the risk averter suffers additional costs compared to the risk neutral farmers in most cases. For a risk-averter, there are two costs of reducing PNS loss. One is referred to as type one cost and is the reduction of expected net income (ENI) just as in the risk-neutral case. The second is referred to as type two cost and is the increased minimum level of risk (MLR) that must be accepted to have a feasible farm plan. Imposing constraints on pesticide loss alone and on soil loss alone does not increase the MLR. The risk averter can find optimal plans to meet all his constraints and income target, just he does when there are no pesticide and soil loss constraints, though expected net income may suffer slightly or modestly. But constraints on nitrogen, on phosphorus, and on all PNS indices simultaneously not only increase the minimum level of risk, but also reduce expected income from moderately to severely. Type one cost (reduction in ENI) is higher for risk averters than risk neutral farmers when a constraint is imposed on all PNS losses at once, as well as when a nitrogen constraint is imposed. Type two costs are higher for risk neutrals when phosphorus and soil loss constraints are imposed. The pattern is mixed for pesticide constraints.

- When forced to reduce pollution, a farmer with higher levels of risk aversion would use more rotation 13 (idling land with cover), which is a sure but stable loss for him, while the risk neutral farmer tends to adopt rotation 6 (conventional cotton, minimum-till wheat, notill soybean, and winter cover) and rotation 9 (conventional peanut, strip-till cotton, and winter cover) which are more profitable though more risky than rotation 13.
- In general, policies which restrict the loss of one pollutant tend to reduce other pollutants as well with the exception of pesticides. For risk-neutrals, a constraint on nitrogen loss results in production strategies which tend to reduce phosphorus and soil loss by about the same amount. Strategies employed to reduce pesticide loss reduce soil loss and phosphorus slightly and may increase nitrogen loss slightly. Constraints on soil loss or phosphorus loss alone have little effect on nitrogen loss while reducing pesticide loss by larger degrees. A constraint on phosphorus loss alone brings down soil loss by a larger degree while a constraint on soil loss alone results in a smaller reduction of phosphorus loss. Reducing nitrogen loss and pesticide at the same time reduces soil loss and phosphorus loss by similar levels, thus soil loss and phosphorus loss constraints are redundant.

For risk-averters, a constraint on nitrogen loss tends to reduce phosphorus and soil loss by a larger degree as compared to the risk neutral farmer. A constraint on pesticide loss results in a larger reduction in soil loss and phosphorus loss for more risk averse farmers as compared with less risk averse ones while the effect of a pesticide constraint on nitrogen loss is small for both the risk averse and risk neutral farmer. A constraint on soil loss alone results in larger reductions in pesticide loss for more risk averse farmers as compared with less risk averse ones. For constraints on all PNS losses simultaneously, constraints for nitrogen and pesticide loss are always binding while more risk averse farmers would reduce phosphorus loss and soil loss by larger degrees than less risk averse farmers. Risk averters tend to achieve greater reductions in unconstrained pollutants, because they make more use of idling land in annual cover to achieve constraints in pollution. Idle land is low in all pollution levels.

Based on above findings, it is concluded that reductions of PNS losses are costly for farmers and are more costly for more risk averse farmers than for less risk averse or risk-neutral farmers. Because of the higher costs, risk aversion is a barrier to the adoption of conservation practices. The major practices employed to achieve reductions are reduced tillage cotton, cover crops, and annual cover on steeper slopes. A reduction of pesticide loss and a reduction of nitrogen loss can be achieved separately since reducing one has little effect on the other generally. A simultaneous reduction in nitrogen loss and pesticide loss brings about similar reductions in phosphorus loss and soil loss.

5.3. Limitations of the study and suggestions for further study

The pesticide index used in this study is somewhat arbitrary (for example, it does not consider toxicity to applicators and birds) and there is not a widely agreed upon standard for how to construct such an index. So a different way to construct the indices may yield different results. Future study may be needed to compare results for different ways to develop the pesticide index.

The second limitation of this study is that fixed machine costs (including principal and interest recovery, interest on salvage, insurance, taxes, and housing) are not included in the gross margins for the crop rotations in this study. This omission may change the relative profitability of the crop rotations since some combinations use more machines than others. Further study should evaluate the effects of fixed machine costs on the profitability of conservation practices.

Third, this study does not search for the entire income target-λ space where λ refers to the expected shortfall allowed from the income target (as is done by McCamley and Kliebenstein). With lower target incomes, the farmer would be able to bear larger deviations from the target (λ) and possibly reduce the cost in complying with restrictions on PNS loss.

Fourth, this study does not quantify type two costs, which are the increased minimum level of risk (MLR). Further analysis should amend this shortcoming using techniques like generalized stochastic dominance analysis to assess the costs (type one and type two combined) of reducing PNS losses in terms of reduced expected net income and higher minimum levels of risk (MLR).

Fifth, the farmer is assumed to make a farm plan for the next year, thus it is a one-year decision-making problem. In fact the farmer may plan for the next three to five years, especially when he is choosing among rotations of two to three years. Thus, a dynamic programming approach in which farmer is not only planning for one expected year, but also planning over the years should yield more realistic and informative results. Sixth, this study assumes the farmer bases his future plan solely on historical pattern, with a set of projected FAPRI prices as the expected prices. Once his plan is determined, he carries it out no matter what happens. Information is assumed to be costless. This assumption ignores the possibility that the farmer is also using other information sources such as the Leafspot Advisory Program (Phipps, 1989), extension advice, scouting reports, soil tests, and other information to make adjustments to nutrient or pesticide applications, tillage or cropping plans. For example, production operation and thus input costs and pollutant losses can change because of the real-time information of weather condition. Pest infestations can also change input costs and pollution levels. In this study, the more risk averse farmers are likely to comply with constraints on PNS losses by idling land (rotation 13). The Idle land was planted to annual wheat cover which is then burnt down chemically. However, in reality, when it is profitable, farmers would likely harvest wheat used for cover in the study area (Phipps). By allowing the harvest of annual wheat, rotation 13 need not be a sure loss for the farmer. Further studies could look at how additional information sources on weather, pests, and nutrient requirements affect risk-return tradeoffs and pollutant losses in the study area. Such information could help to develop a more sophisticated and realistic decision support system for nonpoint sources pollution control.

Seventh, the EPIC model cannot simulate the response of crop yield and quality to the timing or amount of applications of specific pesticides or field operations. Further study is needed to take into consideration the effects of specific pesticide or tillage operations on pests, yields, and crop quality. Also, the model should include more alternatives to reduce pesticide losses such as the integrated pest management (IPM) approach. Other best management practices (BMP) like contour planting, strip-cropping, and filter-strips to control soil loss and nutrient loss should also be considered.

Eighth, this study considers only long-term average levels of pollutants from each rotational pattern, but ignores the fact that each rotational pattern may perform differently under variable weather pattern such as high rainfall years. Research could be done to evaluate the effects of risk aversion with respects to pollution (Teague et al (1995)).

Ninth, researchers should look at how costs of reducing pollution vary spatially, that is, the regional impacts of reducing PNS losses. Costs of reducing pollution should be different spatially because of spatial differences in soil type, distance to water bodies, popular cultural practices, access to production information, and attributes of farmers. Identification of areas with low cost of pollution control would greatly assist in lowering overall pollution control cost.

5.4. Policy implications

Because costs of reducing pollutants vary and reductions in one pollutant do not necessarily reduce others by the same amount (if any), policy-makers need to identify and focus on the most limiting pollutant to water quality. It would be beneficial to generate an acceptable comprehensive “index” to measure the combined effects on the environment of NPSP from agricultural activities. Such an index could be used to assist in setting policy goals and target levels for pollutants. If an overall reduction in pollutants is desired by policy-makers, then resources should be devoted mainly to making sure that reduction of nitrogen loss and pesticide loss is achieved which will bring about a similar reduction for soil loss and phosphorus loss.

As can be seen in Chapter 3, on a per-acre bases, all PNS losses are quite sensitive to slopes. Pollutant losses on five percent slope are more than twice as much as those on one percent slope. Thus, conservation practices achieve greater pollutant reductions for a given cost on steeper slopes. Thus, policy for adopting or enforcing conservation practices should target farmland with higher slope rather than indiscriminately apply to all slopes.

Conservation alternative rotations involving minimum till wheat and notill soybean (double-cropping), winter cover, notill and striptill cotton, and annual cover were adopted with pollution constraints. Reduced-till peanut was not adopted. If future peanut quota prices increase (rather than remaining constant in nominal terms as assumed in this study), farmers may wish to keep peanut production at least at quota levels because of its high profitability. Policies to encourage the adoption of reduced-till cotton, and cover crops in rotations which include conventional-peanuts could be more effective than policies which encourage the adoption of reduced-till peanut in reducing NPSP from peanut-cotton farms in the study area. Including annual wheat in the rotation may also effective in reducing overall pollution.

Finally, when a farm plan is constrained by a peanut quota limit and/or pollution losses, farmers will produce cotton rotations on all the remaining land because cotton production has relatively high and stable profits. Because of its high profitability, cotton is replacing corn as rotational crop to peanut in study area. Cotton also has higher potential pollution losses than corn, therefore farmers should be encouraged to adopt reduced-till cotton and winter cover, which can reduce pesticide, nitrogen, phosphorus, and soil losses.

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Appendix A. Description of Cropping Systems

Introduction

The following tables describe farm operations in production of conventional till cotton, strip-till cotton, notill cotton, conventional till peanut, strip-till peanut, notill corn, minimum till wheat, notill soybean, and wheat (rye) winter cover crop on the representative farm. Each crop rather than each rotational pattern is described. For example, Table C-1 is about conventional cotton, Table C-4 is about conventional peanut, and Table C-9 is about wheat cover. Rotational patterns as used in this study are expressed by simple combinations of operations listed in this appendix.

Major information sources used in constructing these tables are:

1. 1995 Cotton Information (North Carolina Cooperative Extension Service);
2. 1996 Cotton Information (North Carolina Cooperative Extension Service);
3. 1997 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff) (as well as previous series);
4. Peanut Variety and Quality Evaluation Results (1990-1995), Tidewater Agricultural Experiment Station, VPI & SU;
5. Intensive Soft Red Winter Wheat Production: A Management Guide. Virginia Cooperative Extension. Pub. 424-803, 1993;
6. Corn Performance Trials, from Dr.Phipps, Tidewater Agricultural Experiment Station, VPI & SU, 1995;
7. Interviews with Azenegashe Abaye, Mark Alley, James Maitland, Pat Phipps, and Guy Sturt.

Table A-1. Conventional cotton: operation description[a]

Date[b]	Operation[c]	Dose/acre	Notes
3-15	tandem disk		Tractor: 110hp
3-15	Liming	0.33 ton/ac	incorporated.
3-30	tandem disk		Tractor: 110hp
4-5	field cultivator		Tractor: 110hp
4-5	P, K fertilizers	400 lb/ac 0-10-30	Incorporated
4-12	disk bedder + ripper		Tractor: 135hp
4-20	Treflan 4 EC	0.6 lb ai (product 1pt)	incorporated. For annual grass.
4-21	Cotoran 4L	1 lb ai (product 1qt)	broadcast. For annual grass + broadleaf
4-27	starter-fertilizer	120lb 10-34-0	incorporated
4-27	plant cotton	seed rate 10 lb/ac	row planted; tractor: 80hp
4-27	Ridomil PC 11G	1.1 lb ai (product 10 lb)	in-furrow fungicide.25% actual acreage[d]
4-27	Temik 15G	0.75 lb ai (product 5 lb)	in-furrow insecticide
5-20	cultivation		Tractor: 80hp
5-20	Orthene	0.1 lb ai (2 oz product)	banded. 50% acreage[d]
6-1	Fusilade	0.19 lb ai (12 oz product)	broadcast. 25% acerage[d]
6-10	cultivation		Tractor: 80hp
6-10	Cotoran 4L	0.3 lb ai (product 0.3 qt)	banded. For post-emergence weeds.
6-10	MSMA 6	0.66 lb ai (product 0.88 pt)	banded. For post-emergence weeds.
6-10	nitrogen	50 lb/ac	injected
6-20	Pix	4 oz/ac	sprayed[e]. Growth regulator. all acreage
7-1	Pix	8 oz/ac	sprayed[e]. Growth regulator.50% acerage[d]
8-10	Karate	0.03 lb/ac (3.2 oz product)	sprayed[e]
8-20	Karate	0.03 lb/ac (3.2 oz product)	sprayed[e]
9-19	Defoliants mix[f]	1 unit	sprayed[e]. A mix of Def, Pref and Dropp
10-5	harvest (picker)		
10-10	chop stalk		rotary mower; Tractor: 80hp
10-15	tandem disk		Tractor: 110hp

a. Major information sources: Cotton Information (1995,1996), North Carolina Cooperative Extension Service; 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff).

b. Operations done on the same day means that they are combined into one trip.

c. To kill winter cover, Roundup (glyphosate) 24 oz/ac will be sprayed 4 weeks before planting.

d. Actual dosage per acre in calculation of budget and EPIC data set will be adjusted by percentage of actual acreage indicated here. The formula is: actual dose/acre = dose/acre x percent of actual acreage.

e. All spray and field cultivation operations require 80hp tractor.

f. One unit of the mix consists of Def 1.5 pt (6 lb/gal ai), Prep 6 1.33pt (6 lb/gal ai), and Dropp 50 w.p. 0.1 lb.

Table A-2. Strip-till cotton: operation description[a]

Date[b]	Operation[c]	Dose/acre	Note
4-20	Gramoxone	0.47 lb/ac (product 1.5 pt)	sprayed[d].
4-20	Prowl	0.55 lb ai (product 1.33 pt)	sprayed[d].
4-27	Liming	0.33 ton/ac	incorporated.
4-27	P, K fertilizers	400 lb/ac 0-10-30	Incorporated
4-27	under-row ripping	4-10" wide, 10-16" deep, 36" between row	Tractor: 135hp (minimum)
4-27	starter-fertilizer	120 lb 10-34-0	Incorporated
4-27	Cotoran 4L	1 lb ai (product 1 qt)	broadcast. annual grass
4-27	plant cotton	seed rate: 10 lb	strip till and planting in one trip
4-27	Ridomil PC 11G	1.1 lb ai (product 10 lb)	in-furrow.fungicide. 75% actual acreage[e]
4-27	Temik 15G	0.75 lb ai (product 5 lb)	in-furrow. nematocide
5-15	Cotoran 4L	0.3 lb ai (product 0.3 qt)	banded. post-emergence
5-15	MSMA 6	0.66 lb ai (product 0.85 pt)	banded. post-emergence
5-20	Orthene	0.1 lb ai (2 oz product)	banded. 50% acreage[d]
6-20	Bladex	0.56 lb ai (product 1.12 pt)	24-inch banded. post-emergence
6-20	MSMA 6	1.5 lb ai (product 2 pt)	24-inch banded. post-emergence
6-20	nitrogen	50 lb/ac	broadcast
6-20	Pix	4 oz/ac	sprayed[d]. Growth regulator. all acreage
7-1	Pix	8 oz/ac	sprayed[d]. Growth regulator.50% acerage[e]
8-10	Karate	0.03 lb/ac (3.2 oz product)	sprayed[d]
8-20	Karate	0.03 lb/ac (3.2 oz product)	sprayed[d]
9-19	Defoliants mix[f]	1 unit	sprayed[d]. A mix of Def, Pref and Dropp
10-5	harvest (picker)		
10-10	chop stalk		Tractor: 110 hp. Rotary mower
10-10	disk bedder		Tractor: 110hp

a. Major information sources: Cotton Information (1995,1996), North Carolina Cooperative Extension Service; 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff).
b. Operations done on the same day means that they are combined into one trip.
c. To kill winter cover, Roundup (glyphosate) 1 quart/ac product (1 lb ai) will be sprayed on April 4th.
d. All spray and field cultivation operations require 80hp tractor.
e. Actual dosage per acre in calculation of budget and EPIC data set will be adjusted by percentage of actual acreage indicated here. The formula is: actual dose/acre = dose/acre x percent of actual acreage.
f. One unit of the mix consists of Def 1.5 pt (6 lb/gal ai), Prep 6 1.33pt (6 lb/gal ai), and Dropp 50 w.p. 0.1 lb.

Table A-3. Notill cotton: operation description[a]

Date[b]	Operation[c]	Dose/acre	Note
4-20	P, K fertilizers	400 lb/ac 0-10-30	Incorporated
4-20	Liming	0.33 ton/ac	incorporated.
4-20	Gramoxone	0.47 lb/ac (product 1.5 pt)	sprayed[d].
4-20	Prowl	0.55 lb ai (product 1.33 pt)	sprayed[d].
4-20	starter-fertilizer	120 lb 10-34-0	Injected.
4-27	Cotoran 4L	1 lb ai (product 1 qt)	incorporated. annual grass
4-27	plant cotton	seed rate:10 lb	Tractor: 80hp
4-27	Ridomil PC 11G	1.1 lb ai (product 10 lb)	in-furrow fungicide.100% actual acreage[e]
4-27	Temik 15G	0.75 lb ai (product 5 lb)	in-furrow nematodes
5-15	Cotoran 4L	0.3 lb ai (product 0.3 qt)	banded. post-emergence
5-15	MSMA 6	0.66 lb ai (product 0.85 pt)	banded. post-emergence
5-20	Orthene	0.1 lb ai (2 oz product)	banded. 50% acreage[e]
6-20	Bladex	0.56 lb ai (product 1.12 pt)	24-inch banded. post-emergence
6-20	MSMA 6	1.5 lb ai (product 2 pt)	24-inch banded. post-emergence
6-20	nitrogen	50 lb/ac	injected
6-20	Pix	4 oz/ac	sprayed[d]. Growth regulator. all acreage
7-1	Pix	8 oz/ac	sprayed[d]. Growth regulator.50% acerage[e]
8-10	Karate	0.03 lb/ac (3.2 oz product)	sprayed[d]
8-20	Karate	0.03 lb/ac (3.2 oz product)	sprayed[d]
9-19	Defoliants mix[f]	1 unit	sprayed[d]. A mix of Def, Pref and Dropp
10-10	harvest	Picker	
10-10	chop stalk		Tractor: 110hp (rotary mower)
10-10	disk		Tractor: 110hp

a. Major information sources: Cotton Information (1995,1996), North Carolina Cooperative Extension Service; 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff).
b. Operations done on the same day means that they are combined into one trip.
c. To kill winter cover, Roundup (glyphosate) 1 quart/ac product (1 lb ai) will be sprayed on April 4th.
d. All spray and field cultivation operations require 80hp tractor.
e. Actual dosage per acre in calculation of budget and EPIC data set will be adjusted by percentage of actual acreage indicated here. The formula is: actual dose/acre = dose/acre x percent of actual acreage.
f. One unit of the mix consists of Def 1.5 pt (6 lb/gal ai), Prep 6 1.33pt (6 lb/gal ai), and Dropp 50 w.p. 0.1 lb..

Table A-4. Conventional peanut: operation description[a]

Date[b]	Operation[c]	Dose/acre	Note
3-20	liming	0.33 ton/ac	Incorporated
3-20	moldboard plow		Tractor: 110hp
4-20	tandem disk		Tractor: 110hp
4-21	field cultivator		tractor: 80hp
4-21	Metam 42.3%	35.78 lb a.i.(product 7.5 gal)	fumigant.55%actual acreage[d]
4-21	Prowl	0.54 lb/ac ai (product 1.3 pt)	sprayed[e]
4-21	Dual 8E	1.5 lb/ac ai (product 1.5 pt)	incorporated. pre-emergence.
5-10	Temik 15G	1 lb ai (product 7 lb)	in-furrow. insect
5-10	plant peanut	seeding rate: 110 lb	
5-12	Dual 8E	1.5 lb/ac ai (product 1.5 pt)	sprayed. pre-emergence
5-12	Starfire	0.13 lb/ac ai (product 11 oz)	sprayed.
5-12	Basagran	0.5 lb/ac ai (product 1 pt)	sprayed. pre-emergence
6-12	Orthene 75S	0.75 lb/ac ai (product 1 lb)	sprayed. post-emergence
6-12	Basagran	0.75 lb/ac ai (product 1.5 pt)	sprayed. post-emergence
6-12	Surfactant	(product 1 qt)	sprayed. post-emergence
6-23	Bravo 720	1.12 lb ai (product 1.5 pt)	sprayed. disease
6-23	Manganese Sulfate	(product 3 lb)	sprayed. Fertilizer
6-28	cultivation		tractor: 80hp
6-28	Lorsban 15G	2 lb/ac ai (product 13 lb)	incorporated. rootworm
6-28	Land Plaster	900 lb/ac	incorporated. (granule)
7-15	Boron	product 3 pt (5%N, 3.3% B)	sprayed
7-15	Folicur 3.6F	0.13 lb/ac ai (product 4.5 oz)	sprayed. disease
8-3	Comite 6.55EC	1.64 lb/ac ai (product 2 pt)	sprayed. miticide. 50% actual acreage[d]
8-9	Nufilm 17	(product 8 oz)	sprayed. disease
8-9	Boron	product 3 lb/ac (10% B)	sprayed
8-15	Folicur 3.6F	0.13 lb/ac ai (product 4.5 oz)	sprayed. disease
8-15	Rovral 4F	0.5 lb/ac ai (product 0.5 qt)	sprayed. disease. 33% actual acreage[d]
8-31	Asana XL	0.025 lb ai (product 5 oz)	sprayed. worms
9-15	Rovral 4F	1 lb/ac ai (product 1 qt)	sprayed. disease. 33% actual acreage[d]
9-15	Bravo 720	0.76 lb ai (product 1.5 pt)	sprayed. disease
9-28	harvest (digger)		
9-30	tandem disk		Tractor: 110hp

a. Major information sources: 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff); Peanut Variety and Quality Evaluation Results (1990-1995), Tidewater Agricultural Experiment Station, VPI & SU.

b. Operations done on the same day means that they are combined into one trip.

c. To kill winter cover, Roundup (glyphosate) 24 oz/ac (0.75 lb ai) will be sprayed 4 weeks before planting.

d. Actual dosage per acre in calculation of budget and EPIC data set will be adjusted by percentage of actual acreage indicated here. The formula is: actual dose/acre = dose/acre x percent of actual acreage.

e. All spray and cultivation operations require 80hp tractor.

Table A-5. Strip-till peanut: operation description[a]

Date[b]	Operation[c]	Dose/acre	Note
4-20	Metam 42.3%	35.78 lb a.i.(product 7.5 gal)	knifed.Soil fumigant.55% actual acreage[d]
5-10	Temik 15G	1 lb ai (product 7 lb)	in-furrow. insecticide
5-10	plant peanut[e]	seeding rate: 110 lb; 12-14" deep, 10-12" wide, 36" between rows	Tractor: 80hp
5-12	Dual 8E	1.5 lb/ac ai (product 1.5 pt)	sprayed[f]. pre-emergence
5-12	Starfire	0.13 lb/ac ai (product 11 oz)	sprayed. pre-emergence
6-12	Orthene 75S	0.75 lb/ac ai (product 1 lb)	sprayed. post-emergence
6-12	Basagran	0.75 lb/ac ai (product 1.5 pt)	sprayed. post-emergence
6-12	Surfactant	(product 1 qt)	sprayed. post-emergence
6-23	Bravo 720	1.12 lb ai (product 1.5 pt)	sprayed. disease
6-23	Manganese Sulfate	product 3 lb	sprayed. Fertilizer
6-28	Lorsban 15G	2 lb ai (product 13 lb)	sprinckled on top. rootworm
6-28	Land Plaster	900 lb	spread on top. (granule)
7-15	Boron	product 3 pt (5%N, 3.3% B)	sprayed
7-15	Folicur 3.6F	0.13 lb/ac ai (product 4.5 oz)	sprayed. disease
8-3	Comite 6.55EC	1.64 lb/ac ai (product 2 pt)	sprayed. miticide. 50% actual acreage[d]
8-9	Nufilm 17	(product 8 oz)	sprayed. disease
8-9	Boron	product 3 lb/ac (10% B)	sprayed
8-15	Folicur 3.6F	0.13 lb/ac ai (product 4.5 oz)	sprayed. disease
8-15	Rovral 4F	0.5 lb/ac ai (product 0.5 qt)	sprayed. disease. 33% actual acreage[d]
8-31	Asana XL	0.025 lb ai (product 5 oz)	sprayed. worms
9-15	Rovral 4F	1 lb/ac ai (product 1 qt)	sprayed. disease. 33% actual acreage[d]
9-15	Bravo 720	0.76 lb ai (product 1.5 pt)	sprayed. disease
9-28	harvest (digger)		
9-30	tandem disk		Tractor: 110hp

a. Major information sources: 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff); Peanut Variety and Quality Evaluation Results (1990-1995), Tidewater Agricultural Experiment Station, VPI & SU.

b. Operations done on the same day means that they are combined into one trip.

c. To kill winter cover, Roundup (glyphosate) 24 oz/ac will be sprayed 4 weeks before planting.

d. Actual dosage per acre in calculation of budget and EPIC data set will be adjusted by percentage of actual acreage indicated here. The formula is: actual dose/acre = dose/acre x percent of actual acreage.

e. Strip till peanut on bed. Disk, rip, bedding, and seeding cover crop in previous fall after notill cotton.

f. All spray and cultivation operations require 80hp tractor.

Table A-6. Notill corn: operation description[a]

Date[b]	Operation[c]	Dose/acre	Note
4-15	fertilizer 5-10-30	300 lb	
4-19	plant corn	seed rate: 0.27 bag	drill plant. Tractor: 135hp
4-19	Counter	0.98 lb/ac ai (product 6.5 lb)	incorporated
4-20	BriceP 6L	Dual 1.21 lb ai, and Atrazine 1 lb ai (product 3 pt)	sprayed[d]
5-30	nitrogen N	90 lb/ac	injected
9-1	harvest		
9-5	chop stalks		Tractor: 85hp

a. Major information sources: Unpublished field experiment record from Dr.Phipps, Tiderwater Agricultural Experiment Station, VPI & SU, 1995; 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff).
b. Operations done on the same day means that they are combined into one trip.
c. To kill winter cover, Roundup (glyphosate) 24 oz/ac will be sprayed 4 weeks before planting.
d. All spray and cultivation operations require 80hp tractor.

Table A-7. Minimum-till wheat in double cropping: operation description[a]

Date[b]	Operation	Dose/acre	Note
10-20	offset disk		Tractor: 110hp
10-20	Liming	0.33 ton/ac	incorporated
10-21	fertilizer	N: 35lb; P_2O_5: 45 lb; K_2O: 50 lb.	incoporated
10-25	tandem disk		Tractor: 110hp
10-31	plant wheat	Tractor: 80hp	drill plant
2-1	nitrogen N	40 lb/ac	injected
3-21	Tilt 3.6 EC	(product 4 oz /ac)	tank mixed with N
3-21	nitrogen N	40 lb/ac	injected
6-1	harvest		small grain combine

a. Major information sources: Intensive Soft Red Winter Wheat Product uction: A management Guide. Virginia Cooperative Extension. Pub. 424-803, 1993; 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff).
b. Operations done on the same day means that they are combined into one trip.

Table A-8. Notill soybean in double cropping: operation description[a]

Date[b]	Operation	Dose/acre	Note
5-15[c]	Liming	0.2 ton/ac	broadcast
5-15[c]	P, K fertilizers	P_2O_5:30 lb; K_2O: 45 lb	broadcast
6-15	plant soybean	seed rate: 45 lb	drill plant
6-15	Bronco	Lasso 1.05 lb ai, Roundup 1.95 lb ai (product 3 qts)	sprayed [d]
8-30	Asana XL	0.04 lb ai (product 6 oz)	sprayed [d] (3.2 lb ai/gal). 60% acreage
11-5	harvest		

a. Major information sources: Information from farm visit.
b. Operations done on the same day means that they are combined into one trip.
c. Applications are done to wheat but charge soybean in budget calculation.
d. All spray and cultivation operations require 80hp tractor.

Table A-9. Cover crop (wheat[a]): operation description[b]

Date	Operation	Dose/acre	Note
11-1	offset disk		Tractor: 110hp
10-20[c]	plant wheat	seed rate: 2 bu[d]	drill plant
3-1[e]	Roundup	2 lb (product 2 pt)	burn down cover

a. For wheat-soybean double cropping, it is rye to be cover crop due to late date of seeding.
b. Major information sources: Intensive Soft Red Winter Wheat Product uction: A management Guide. Virginia Cooperative Extension. Pub. 424-803, 1993; 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff.
c. Planting date for rye is November 15.
d. For rye cover, seeding rate is 1.25 bushel.
e. For annual wheat cover, it is June 15.

Appendix B. Crop Budgets, Machinery Use, and Pesticide Use by Crop-rotation

Introduction

This appendix consists of three parts: part one is crop budgets for the nine crop-tillage combinations included in this study, namely, conventional till cotton, strip-till cotton, notill cotton, conventional till peanut, strip-till peanut, notill corn, minimum till wheat, notill soybean, and wheat cover crop (Table B-1 to Table B-9); part two decides machinery costs for each crop-tillage combination (Table B-10 to Table B-19); part three decides pesticide use and costs for each of these the cropping systems (Table B-20 to Table B-27).

The major information sources used in constructing these tables are:

1. "Appendix A: Description of Cropping Systems" of this thesis;
2. 1997 Crop Enterprise Cost Analysis for Eastern Virginia (Eastern District Farm Management Staff) (as well as previous series).

Table B-1. Conventional cotton crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Cotton	lb	1078.7	0.577	622.41
2.Operation/machine				
Production----				
Seed	lb	10.00	0.78	7.80
Nitrogen	lb	62.00	0.25	15.50
Phosphate P_2O_5	lb	40.00	0.21	8.40
Potash K_2O	lb	120.00	0.12	14.40
Lime, pro-rated	ton	0.33	28.00	9.24
Chem -Herbicides		1.00	21.37	21.37
Insecticides[b]		1.00	28.23	28.23
Fungicides		1.00	4.63	4.63
Other[c]		1.00	32.27	32.27
Machinery--production				
fuel, oil, repair, etc				54.05
Machinery--harvest				
repair, fuel, etc.				26.35
ginning (net) + marketing				32.50
Crop insurance				
Miscellaneous[d]				15.00
Interest		269.74	0.04	10.79
SUBTOTAL				280.53
3.Fixed cost[e]				
labor	Hours	6.65	6.00	39.90
Mach.-production				82.05
Mach.-harvest				38.25
SUBTOTAL				160.20
Total expense				440.74
Expense w/o labor				400.84
also w/o fixed mach-cost				280.53
assumed fixed machine-cost				120.30
Gross margin (no labor and fixed machine cost)				341.88

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Also include nematicides.
c Pix + defoliants mix.
d Insect-scouting, nematodes-sampling, etc
e Overhead or ownership cost.

Table B-2. Strip-till cotton crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Cotton	lb	1078.7	0.577	622.41
2.Operation/machine				
Production----				
Seed	lb	10.00	0.78	7.80
Nitrogen	lb	62.00	0.25	15.50
Phosphate	lb	40.00	0.21	8.40
Potash	lb	120.00	0.12	14.40
Lime,pro-rated	ton	0.40	28.00	11.20
Chem -Herbicides		1.00	33.00	33.00
Insecticides		1.00	28.23	28.23
Fungicides		1.00	13.88	13.88
Other[c]		1.00	32.27	32.27
Mach.-production				
Fuel, oil, repair, etc.				35.30
Mach.-harvest				
repair+fuel				26.35
ginning (net) + marketing				32.50
Crop insurance				
Miscellaneous[d]				15.00
Interest		273.83	0.04	10.95
SUBTOTAL				284.78
3.Fixed cost[e]				
labor	Hours	5.23	6.00	31.35
Mach.-production				51.52
Mach.-harvest				38.25
SUBTOTAL				121.12
Total expense				405.91
Expense w/o labor				374.56
also w/o fixed mach-cost				284.78
assumed fixed machine-cost				89.77
Gross margin (no labor and fixed machine cost)				337.63

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Also act as insecticides
c Pix + defoliants mix
d Insect-scouting, nematodes-sampling, etc
e Overhead or ownership cost.

Table B-3. No-till cotton crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Cotton	lb	1078.7	0.577	622.41
2.Operation/machine				
Production----				
Seed	lb	10.00	0.78	7.80
Nitrogen	lb	62.00	0.25	15.50
Phosphate	lb	40.00	0.21	8.40
Potash	lb	120.00	0.12	14.40
Lime, pro-rated	ton	0.40	28.00	11.20
Chem -Herbicides		1.00	33.00	33.00
Insecticides		1.00	28.23	28.23
Fungicides		1.00	18.50	18.50
Other[c]		1.00	32.27	32.27
Mach.-prod.				
Fuel, oil, repair				23.22
Mach.-harvest				
repair+fuel				26.35
ginning (net) + marketing				32.50
Crop insurance				
Miscellaneous[d]				15.00
Interest		266.37	0.04	10.65
SUBTOTAL				277.03
3.Fixed cost[e]				
labor	Hours	4.90	6.00	29.40
Mach.-production				41.26
Mach.-harvest				38.25
SUBTOTAL				108.91
Total expense				385.93
Expense w/o labor				356.53
also w/o fixed mach-cost				277.03
assumed fixed machine-cost				79.51
Gross margin (no labor and fixed machine cost)				345.38

a Based on operation descriptions in Appendix A and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Also act as insecticides
c Pix + defoliants mix
d Insect-scouting, nematodes-sampling, etc
e Overhead or ownership cost.

Table B-4. Conventional peanut crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Peanut	lb	3749.7	0.251	941.17
2.Operation/machine				
Production----				
Seed	lb	110.00	0.85	93.50
P_2O_5, pro-rated[b]	lb	50.00	0.21	10.50
K_2O, pro-rated[b]	lb	100.00	0.12	12.00
spread, pro-rated				3.00
Plaster	lb	900.00	0.03	24.43
Lime	ton	0.33	28.00	9.24
Chem -Herbicides		1.00	34.13	34.13
Insecticides		1.00	79.27	79.27
Fungicides		1.00	101.29	101.29
Other[c]		1.00	8.67	8.67
Mach.-production				
Fuel, oil				41.83
Mach.-harvest				
repair + fuel				73.15
Marketing				
Crop insurance				23.00
Miscellaneous[d]				20.00
Interest		534.01	0.04	21.36
SUBTOTAL				555.37
3.Fixed cost[e]				
labor	Hours	11.05	6.00	66.30
Mach.-production				65.15
Mach.-harvest				104.30
SUBTOTAL				235.75
Total expense				791.12
Expense w/o labor				724.82
also w/o fixed mach-cost				555.37
assumed fixed machine-cost				169.45
Gross margin (no labor and fixed machine cost)				385.80

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Can be applied to previous crops and charged here.
c Foliar nutrients and adjuvants.
d Insect-scouting, nematodes-sampling, etc
e Overhead or ownership cost.

Table B-5. Strip-till peanut crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Peanut	lb	3378.8	0.251	848.08
2.Operation/machine				
Production----				
Seed	lb	110.00	0.85	93.50
Nitrogen	lb	0.00	0.25	
P_2O_5, pro-rated	lb	50.00	0.21	10.50
K_2O, prorated	lb	100.00	0.12	12.00
spread, pro-rated				3.00
Plaster	lb	900.00	0.03	24.43
Lime	ton	0.33	28.00	9.24
Chem -Herbicides		1.00	50.27	50.27
Insecticides		1.00	79.27	79.27
Fungicides		1.00	83.00	83.00
Other[c]		1.00	10.19	10.19
Mach.-production				
Fuel, oil				29.88
Mach.-harvest				
repair + fuel				73.15
Marketing				
Crop insurance				23.00
Miscellaneous[d]				20.00
Interest		521.43	0.04	20.86
SUBTOTAL				542.29
3.Fixed cost[e]				
labor	Hours	10.03	6.00	60.15
Mach.-production				44.24
Mach.-harvest				104.30
SUBTOTAL				208.69
Total expense				750.97
Expense w/o labor				690.82
also w/o fixed mach-cost				542.29
assumed fixed machine-cost				148.54
Gross margin (no labor and fixed machine cost)				305.79

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Also act as insecticides
c Foliar nutrients + adjuvants.
d Insect-scouting, nematodes-sampling, etc
e Overhead or ownership cost.

Table B-6. Minimum till wheat crop budget (\$/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Wheat	bu	2.96	84.40	249.49
2.Operation/machine				
Production----				
Seed	lb	135.00	0.20	27.00
Nitrogen	lb	135.00	0.25	33.75
P_2O_5, pro-rated	lb	45.00	0.21	9.45
K_2O, pro-rated	lb	50.00	0.12	6.00
spread, pro-rated				3.00
Lime	ton	0.33	28.00	9.24
Chem -Herbicides		1.00	0.00	0.00
Mach.-production				
Fuel, oil				15.31
Mach.-harvest				
repair + fuel				11.45
Marketing				
Crop insurance				
Miscellaneous				2.00
Interest		117.20	0.04	4.69
SUBTOTAL				121.89
3.Fixed cost[b]				
labor	Hours	2.30	6.00	13.80
Mach.-production				21.92
Mach.-harvest				22.52
SUBTOTAL				58.24
Total expense				180.13
Expense w/o labor				166.33
also w/o fixed mach-cost				121.89
assumed fixed machine-cost				44.44
Gross margin (no labor and fixed machine cost)				127.60

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Overhead or ownership cost.

Table B-7. Notill soybean crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Soybean	bu	38.60	5.33	205.55
2.Operation/machine				
Production----				
Seed	lb	60.00	0.17	10.20
Nitrogen	lb	0.00	0.25	
P_2O_5, pro-rated	lb	30.00	0.21	6.30
K_2O, pro-rated	lb	45.00	0.12	5.40
spread, pro-rated				3.00
Plaster	lb		0.03	
Lime	ton	0.20	28.00	5.60
Chem -Herbicides		1.00	19.28	19.28
Insecticides		1.00	6.56	6.56
Other				
Mach.-production				
Fuel, oil				7.90
Mach.-harvest				
repair + fuel				9.54
Marketing				
Crop insurance				7.00
Miscellaneous				2.00
Interest		82.79	0.04	3.31
SUBTOTAL				86.10
3.Fixed cost[b]				
labor	Hours	1.70	6.00	10.20
Mach.-production				10.99
Mach.-harvest				18.77
SUBTOTAL				39.95
Total expense				126.05
Expense w/o labor				115.85
also w/o fixed mach-cost				86.10
assumed fixed machine-cost				29.75
Gross margin (no labor and fixed machine cost)				119.45

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Overhead or ownership cost.

Table B-8. Notill corn crop budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Gross receipts				
Corn	bu	102.00	2.35	239.60
2.Operation/machine				
Production----				
Seed	cwt	0.27	73.00	19.71
Nitrogen	lb	105.00	0.25	26.25
P_2O_5, pro-rated	lb	30.00	0.21	6.30
K_2O, pro-rated	lb	90.00	0.12	10.80
spread, pro-rated				3.00
Plaster	lb	0.00	0.03	
Lime	ton	0.60	28.00	16.80
Chem -Herbicides		1.00	16.43	16.43
Insecticides		1.00	12.03	12.03
Other				
Mach.-production				
Fuel, oil				12.22
Mach.-harvest				
repair+fuel+gas...				16.08
Marketing				
Crop insurance				11.00
Miscellaneous				6.00
Interest		156.63	0.04	6.27
SUBTOTAL				162.89
3.Fixed cost[b]				
labor	Hours	2.45	6.00	14.70
Mach.-production				15.68
Mach.-harvest				31.70
SUBTOTAL				62.08
Total expense				224.98
Expense w/o labor				210.28
also w/o fixed mach-cost				162.89
assumed fixed machine-cost				47.38
Gross margin (no labor and fixed machine cost)				76.71

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b Overhead or ownership cost.

Table B-9. Wheat cover budget ($/ac)[a]

Items	Unit	Quantity	Cost/unit	Value
1.Operation/machine				
Production----				
Seed	bu	1.25	6.00	7.50
Chem -Herbicides[b]				11.38
Mach.-prod.				
Fuel, oil				6.51
Interest		25.39	0.04	1.02
SUBTOTAL				26.41
2.Fixed cost[c]				
labor	Hours	0.65	6.00	3.90
Mach.-prod				
repair+fuel+gas...				9.81
SUBTOTAL				13.71
Total expense				40.12
Expense w/o labor				36.22
also w/o fixed mach-cost				26.41
assumed fixed machine-cost				9.81
Gross margin (no labor and fixed machine cost)				-40.12

a Based on operation descriptions in Appendix A, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia.
b For the burndown of rye cover about 4 weeks before planting next crop in spring.
c Overhead or ownership cost.

Table B-10. Conventional cotton machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Land preparation										
Disk (2X), 17'	0.40				0.40	0.30	9.60	2.88	12.13	3.64
Fld Cult(1x),15'	0.20				0.20	0.18	3.20	0.58	3.39	0.61
Tractor, 110HP						0.48	10.42	5.00	17.20	8.26
Dsk bed + ripper, 10"[c]	0.35				0.35	0.33	14.80	4.88	20.52	6.77
Tractor, 135HP						0.35	12.6	4.41	12.34	4.32
Planting & managing										
Planter, 4R	0.40				0.40	0.33	4.16	1.37	5.58	1.84
Tractor, 80HP						0.33	7.98	2.63	13.66	4.51
Sprayer (9x)	0.40	1.20	0.20		1.80	1.13	3.20	3.60	3.44	3.87
Cultivate (2x)	0.40	0.40			0.80	1.05	2.80	2.94	3.54	3.72
Tractor 80HP						2.18	7.98	17.36	13.66	29.71
Harvesting										
Picker			1.20		1.20	1.00	23.75	23.75	33.70	33.70
Hauling per acre[d]			0.20		0.20			2.60		4.55
Residue										
Rot mower			0.35		0.35	0.20	3.90	0.78	21.60	4.32
Tractor 80HP						0.20	7.98	1.60	13.66	2.73
Disk (1x), 12'			0.20		0.20	0.15	9.60	1.44	12.13	1.82
Tractor, 110HP						0.20	10.42	2.08	17.20	3.44
Misc (truck)	0.25	0.25	0.25		0.75			2.50		2.50
Seasonal labor	2.40	1.85	2.40	0.00						
Total:---------					6.65			80.40		120.30
Production: ----					5.25			54.05		82.05
Harvesting: ----					1.40			26.35		38.25

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c Cost for this is that of disk plus that of subsoiler.
d Yield (lint) is assumed 650 lb/ac here. It will not be adjusted to different yield levels.

Table B-11. Strip-till cotton machine cost estimate[a]

Operation and Machine	Man-hour used by season: spr	sum	fall	win	Total labor hour	Machine hours (hr/ac)	Variable cost ($/hr)	Variable cost ($/ac)	Fixed cost ($/hr)	Fixed cost ($/ac)[b]
Planting										
Under row ripping[c]	0.35				0.35	0.33	5.20	1.72	8.39	2.77
Sprayer (1x)	0.18				0.18	0.13	3.20	0.42	3.44	0.45
Planter, 4R	0.40				0.40	0.33	4.16	1.37	5.58	1.84
Tractor, 135HP						0.79	12.6	9.95	12.34	9.75
Managing										
Sprayer (8x)[d]	0.40	1.00	0.20		1.60	1.00	3.20	3.20	3.44	3.44
Tractor 80HP						1.00	7.36	7.36	13.66	13.66
Harvesting										
Picker			1.20		1.20	1.00	23.75	23.75	33.70	33.70
Hauling per acre[e]			0.20		0.20			2.60		4.55
Residue										
Rot mower			0.35		0.35	0.20	3.90	0.78	21.60	4.32
Tractor 80HP						0.30	7.98	2.39	13.66	4.10
Disk (1x), 17'			0.20		0.20	0.15	9.60	1.44	12.13	1.82
Tractor, 110HP						0.40	10.42	4.17	17.20	6.88
Misc (truck)	0.25	0.25	0.25		0.75			2.50		2.50
Seasonal labor	1.58	1.25	2.40	0.00						
Total:---------					5.23			61.65		89.77
Production: ----					3.83			35.30		51.52
Harvesting: ----					1.40			26.35		38.25

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c It is approximated by subsoiling operation.
d Ajusted by actual operation acreage. E.g. a 50% acreage operation counts only 0.5 spray.
e Yield (lint) is assumed 650 lb/ac here. It will not be adjusted to different yield levels.

Table B-12. No-till cotton machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Planting & managing										
Planter, 4R	0.40				0.40	0.33	4.16	1.37	8.18	2.70
Sprayer (9x)[c]	0.80	0.80	0.20		1.80	1.13	3.20	3.60	3.44	3.87
Tractor 80HP						1.46	7.36	10.71	13.66	19.88
Harvesting										
Picker			1.20		1.20	1.00	23.75	23.75	33.70	33.70
Hauling per acre[d]			0.20		0.20			2.60		4.55
Residue										
Rotary mower			0.35		0.35	0.20	3.90	0.78	21.60	4.32
Tractor 80HP						0.20	7.98	1.60	13.66	2.73
Disk (1x)			0.20		0.20	0.15	9.6	0.58	12.13	1.82
Tractor, 110HP						0.20	10.42	2.08	17.20	3.44
Misc (truck)	0.25	0.25	0.25		0.75			2.50		2.50
Seasonal labor	1.45	1.05	2.40	0.00						
Total:---------	4.90				4.90			49.57		79.51
Production: ----	2.95				3.50			23.22		41.26
Harvesting: ----	1.95				1.40			26.35		38.25

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c Ajusted by actual operation acreage. E.g. a 50% acreage operation counts only 0.5 spray.
d Yield (lint) is assumed 650 lb/ac here. It will not be adjusted to different yield levels.

Table B-13. Conventional peanut machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Land preparation										
Spreader (1x)	0.25				0.25	0.13	3.20	0.42	3.70	0.48
Tractor, 80HP						0.13	7.98	1.04	13.66	1.78
Flip Plow, 4B	0.45				0.45	0.40	4.58	1.83	11.55	4.62
Disk (1X), 17'	0.20				0.20	0.15	9.60	1.44	12.13	1.82
Fld Cult(1x),15'	0.20				0.20	0.18	3.20	0.58	3.39	0.61
Tractor, 110HP						0.73	10.42	7.61	17.20	12.56
Planting & managing										
Planter, 4R	0.80				0.80	0.50	4.16	2.08	5.58	2.79
Tractor, 110HP						0.50	10.42	5.21	17.20	8.60
Growing										
Cultivate, 4R		0.40			0.40	0.35	2.80	0.98	3.54	1.24
Sprayer (10.5x)[c]	0.40	1.30	0.40		2.10	1.31	3.20	4.20	3.44	4.52
Tractor 80HP						1.66	7.98	13.27	13.66	22.71
Harvesting										
Digger			1.00		1.00	0.75	6.00	4.50	8.51	6.38
Tractor, 110HP						0.75	10.42	7.82	17.20	12.90
Combine			1.75		1.75	1.33	12.5	16.63	25.00	33.25
Tractor, 80HP						1.33	7.98	10.61	13.66	18.17
Dryer[d]			0.70		0.70	per CWT	0.90	27.00		27.90
Hauling[d]			1.00		1.00	per CWT	0.22	6.60		5.70
Disk (1x)			0.20		0.20	0.15	9.6	0.58		0.61
Tractor, 110HP						0.15	10.42	1.56	17.20	2.58
Misc (truck)	0.70	0.65	0.65		2.00			2.50		2.50
Seasonal labor	3.00	2.35	5.70	0.00						
Total:---------	11.05				11.05			114.99		169.45
Production: ----	6.40				6.40			41.83		65.15
Harvesting: ----	4.65				4.65			73.15		104.30

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c Ajusted by actual operation acreage. E.g. a 50% acreage operation counts only 0.5 spray.
d Machine use for dryer and hauling is for yield of 3,000 lb/ac. It will not be ajusted to actual yield levels.

Table B-14. Strip-till peanut system machine cost estimate[a]

Operation and Machine	Man-hour used by season: spr	sum	fall	win	Total labor hour	Machine hours (hr/ac)	Variable cost ($/hr)	Variable cost ($/ac)	Fixed cost ($/hr)	Fixed cost ($/ac)[b]
Land preparation										
Spreader (1x)	0.25				0.25	0.13	3.20	0.42	3.70	0.48
Sprayer (1x)	0.20				0.20	0.13	3.20	0.40	3.44	0.43
Tractor 80HP						0.26	7.98	2.03	13.66	3.48
Disk (1X), 17'[c]	0.40				0.40	0.30	9.60	2.88	12.13	3.64
Tractor, 110HP						0.30	10.42	3.13	17.20	5.16
Planting & managing										
Planter, 4R	0.80				0.80	0.50	4.16	2.08	5.58	2.79
Tractor, 110HP						0.50	10.42	5.21	17.20	8.60
Growing										
Sprayer (11x)	0.35	1.23	0.35		1.93	1.26	3.20	4.03	3.44	4.33
Tractor 80HP						1.26	7.98	10.05	13.66	17.21
Harvesting										
Digger			1.00		1.00	0.75	6.00	4.50	8.51	6.38
Tractor, 110HP						0.75	10.42	7.82	17.20	12.90
Combine			1.75		1.75	1.33	12.5	16.63	25.00	33.25
Tractor, 80HP						1.33	7.98	10.61	13.66	18.17
Dryer[d]			0.70		0.70	per CWT	0.90	27.00		27.90
Hauling[e]			1.00		1.00	per CWT	0.22	6.60		5.70
Misc (truck)	0.70	0.65	0.65		2.00			2.50		2.50
Seasonal labor	2.70	1.88	5.45	0.00						
Total:---------					10.03			103.04		148.54
Production: ----					5.58			29.88		44.24
Harvesting: ----					4.45			73.15		104.30

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c Machine cost of knifing operation is approximated by field cultivation.
d Rot-shank operation at planting is approximated by tandem disk.
e Machine use for dryer and hauling is for yield of 3,000 lb/ac. It will not be ajusted to actual yield levels.

Table B-15. Minimum till wheat machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Land preparation										
Disk (1X)			0.20		0.20	0.15	9.60	1.44	12.13	1.82
Disk bedder,10"			0.20		0.20	0.15	9.60	1.44	12.13	1.82
Tractor, 110HP						0.30	10.42	3.13	17.20	5.16
Planting & managing										
Planter, 4R			0.40		0.40	0.33	4.16	1.37	5.58	1.84
Sprayer (2x)[c]	0.20			0.20	0.40	0.25	3.20	0.80	3.44	0.86
Tractor 80HP						0.58	7.98	4.63	13.66	7.92
Harvesting										
Combine		0.35			0.35	0.30	30.19	9.06	61.40	18.42
Tractor 80HP						0.30	7.98	2.39	13.66	4.10
Misc (truck)	0.15	0.20	0.20	0.20	0.75			2.50		2.50
Seasonal labor	0.35	0.55	1.00	0.40						
Total:---------					2.30			26.76		44.44
Production: ----					1.95			15.31		21.92
Harvesting: ----					0.35			11.45		22.52

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c These 2 sprayers are for nitrogen applications.

Table B-16. No till soybean (in double-cropping) machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Planting & managing										
Planter, 4R		0.40			0.40	0.33	4.16	1.37	5.58	1.84
Sprayer (1x)[c]		0.20			0.20	0.13	3.20	0.40	3.44	0.43
Tractor 80HP						0.46	7.98	3.63	13.66	6.22
Harvesting										
Combine[d]			0.35		0.35	0.25	30.19	7.55	61.40	15.35
Tractor 80HP						0.25	7.98	2.00	13.66	3.42
Misc (truck)	0.25	0.25	0.25		0.75			2.50		2.50
Seasonal labor	0.25	0.85	0.60	0.00						
Total:---------					1.70			17.45		29.75
Production: ----					1.35			7.90		10.99
Harvesting: ----					0.35			9.54		18.77

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c This does not include liming and P, K fertilizers applied to wheat but charged to soybean (otherwise, 4 sprays).
d Same as in the harvest of minimum till wheat.

Table B-17. No till corn machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Planting & managing										
Notill planter, 4R[c]	0.40				0.40	0.33	4.16	1.37	8.18	2.70
Tractor, 135HP						0.33	12.6	4.16	12.34	4.07
Sprayer (3x)	0.60				0.60	0.38	3.20	1.20	3.44	1.29
Tractor 80HP						0.38	7.98	2.99	13.66	5.12
Harvesting										
Combine			0.35		0.35	0.30	37.71	11.31	68.50	20.55
Rotary mower			0.35		0.35	0.20	3.90	0.78	21.60	4.32
Tractor 80HP						0.50	7.98	3.99	13.66	6.83
Misc (truck)	0.25	0.25	0.25		0.75			2.50		2.50
Seasonal labor	1.25	0.25	0.95	0.00						
Total:---------					2.45			28.31		47.38
Production: ----					1.75			12.22		15.68
Harvesting: ----					0.70			16.08		31.70

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c Actual operation is under-row drill plant, so need tractor of 135 hp.

Table B-18. Wheat (or rye) cover machine cost estimate[a]

Operation and Machine	Man-hour used by season				Total labor hour	Machine hours (hr/ac)	Variable cost		Fixed cost	
	spr	sum	fall	win			($/hr)	($/ac)	($/hr)	($/ac)[b]
Land preparation										
Disk[c]			0.20		0.20	0.15	9.60	1.44	12.13	1.82
Tractor, 110HP						0.15	10.42	1.56	17.20	2.58
Planting & managing										
Notill planter, 4R			0.25		0.25	0.15	6.08	0.91	8.18	1.23
Tractor 80HP						0.15	7.98	1.20	13.66	2.05
Harvesting[d]										
Sprayer (1x)[e]				0.20	0.20	0.13	3.20	0.40	3.44	0.43
Tractor 80HP						0.13	7.98	1.00	13.66	1.71
Seasonal labor	0.00	0.00	0.45	0.20						
Total:---------					0.65			6.51		9.81

a Based on operation descriptions in Appendix C, and 1995 Crop Enterprise Cost Analysis for Eastern Virginia (Sturt, 1995).
b. This number is based on implied hour-use in Sturt's budget (1995).
c This operation might be repetitive if it is also included in the production of previous crop.
d It is reasonable to deal with cover as if it a rotational crop.
e This operation is to burn down the cover. For winter cover, operation is in winter; for annual cover, summer.

Table B -19. Machinery performance and cost estimate (75% of new cost)[a]

Hours Use[b]	Item Name	Size	#	Approx. New cost	Hours /acre	Variable cost $/hr	Variable cost $/ac	Fixed cost[c] ($/ac)	Fixed cost[c] ($/hr)[d]
200	Flip Plow	4B	1	8,675	0.40	4.58	1.83	4.62	11.55
700	Disk	17'	2	12,000	0.15	9.60	1.44	1.82	12.13
700	Field Cult	15'	2	4,000	0.18	3.20	0.58	0.61	3.39
250	Subsoiler	4R	1	6,500	0.33	5.2	1.72	2.77	8.39
300	Cultivator	4R	2	3,500	0.35	2.80	0.98	1.24	3.54
300	Planter	4R	2	5,200	0.33	4.16	1.37	1.84	5.58
300	No-till	4R	1	7,600	0.33	6.08	2.01	2.70	8.18
1000	Sprayer	8R	2	4,000	0.13	3.20	0.40	0.43	3.44
500	Spreader		2	3,500	0.20	2.80	0.56	0.74	3.70
160	Rotary mower	14'	1	6,500	0.20	3.90	0.78	4.32	21.60
200	Drill	12'	1	8,300	0.20	6.64	1.33	4.42	22.10
200	Digger	4R	2	12,000	0.75	6.00	4.50	6.38	8.51
80	Peanut combine	2R	2	25,000	1.33	12.50	16.63	33.25	25.00
600	Combine			104,000					
300	Corn		1		0.30	37.71	11.31	20.55	68.50
300	Small grain		1		0.25	30.19	7.55	15.35	61.40
300	Cotton picker		1	95,000	1.00	6.64	23.75	33.70	33.70
	Tractors[e]								
300		80hp	1	38,500		7.98			13.66
300		110hp	1	48,500		10.42			17.20
500		135hp	1	58,500		12.60			12.34

a. Basic assumptions are (Guy Sturt, 1995):
1. Operating cost were based on 100% of new cost repair cost:
For tillage equipment -- 8 cents per $100 of new cost per hour
For planting, spraying -- 6 cents per $100 of new cost per hour
For harvesting --5 cents per $100 of new cost per hour
For tractors -- 1.25 cents per $100 of new cost per hour plus fuel cost per hour plus fac*(per horsepower)*(fuel cost) *(hour use)
where: fac is 0.07 for gasoline engines; 0.055 for diesel engine; and 0.065 for combines. Fuel cost is 0.72/gal.
2). Annual fixed cost estimates are based on 75% of new cost
Principal + interest recovery-10yr @9% = 0.15585 0.08767
Interest on salvage on 25% on 75% new cost @ 4% 0.00750
Insurance, taxes, and housing @ 1.5% on 75% 0.01125

b. Hours implied by corresponding cost parameters found in Machine Cost Estimate (Sturt, 1995)
c. Based on assumed hour-use.
d. Calculated as [(dollar per acre)/(hour per acre)]. For tractors, it is directly from Sturt (1995).
e. For tractors, per hour fixed cost come from Sturt (1995) based on hour-use.

Table B-20. Conventional cotton chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Prowl 3.3 EC	1.3 pt	26.25 / gal	4.27		
	Cotoran 4L	1 qt	36 / gal	11.70		
	Fusilade DX	12 oz	134 / gal	3.14		only to 25% acreage
	MSMA 6	0.88 pt	20.5 / gal	2.26	21.37	
Insecticides	Temik 15G	5 lb	3 / lb	15.00		
	Orthene 75S	2 oz	10 / lb	0.63		only to 50% acreage
	Karate	6.4 oz	252 / gal	12.60	28.23	
Fungicides	Ridomil PC 11G	10 lb	1.85 / lb	4.63	4.63	only to 25% acreage
Others	Pix	12 oz	102 /gal	9.57		
	Defoliants mix	1 unit	22.7 / unit	22.70		See table A-1 for detail
					32.27	
				Total chemicals:	86.50	

Table B-21. Strip-till cotton chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Gramoxone E	1.5 pt	32 / gal	6.00		
	Prowl 3EC	1.33 pt	26.25 /gal	4.36		
	Cotoran 4L	1.3 qt	36 / gal	11.70		
	Bladex 4L	1.12 pt	26 / gal	3.64		
	MSMA 6	2.85 pt	20.5 / gal	7.30	33.00	
Insecticides	Temik 15G	5 lb	3 / lb	15.00		
	Orthene 75S	2 oz	10 / lb	0.63		only to 50% acreage
	Karate	6.4 oz	252 / gal	12.60	28.23	
Fungicides	Ridomil PC 11G	10 lb	1.85 / lb	13.88	13.88	only to 75% acreage
Others	Pix	12 oz	102 /gal	9.57		
	Defoliants mix	1 unit	22.7 / unit	22.70	32.27	See table A-2 for detail
				Total chemicals:	107.38	

Table B-22. No-till cotton chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Gramoxone E	1.5 pt	32 / gal	6.00		
	Prowl 3EC	1.33 pt	26.25 /gal	4.36		
	Cotoran 4L	1.3 qt	36 / gal	11.70		
	Bladex 4L	1.12 pt	26 / gal	3.64		
	MSMA 6	2.85 pt	20.5 / gal	7.30	33.00	
Insecticides	Temik 15G	5 lb	3 / lb	15.00		
	Orthene 75S	2 oz	10 / lb	0.63		only to 50% acreage
	Karate	6.4 oz	252 / gal	12.60	28.23	
Fungicides	Ridomil PC 11G	10 lb	1.85 / lb	18.5	18.5	100% acreage
Others	Pix	12 oz	102 /gal	9.57		
	Defoliants mix	1 unit	22.7 / unit	22.70	32.27	See table A-3 for detail
				Total chemicals:	112.00	

Table B-23. Conventional peanut chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Prowl 3EC	1.3 pt	26.25 / gal	4.27		
	Dual 8E	3.0 pt	62.95 / gal	11.80		
	Starfire	11 oz	32.75 / gal	2.81		
	Storm 4 EC	1.5 pt	71.5 / gal	13.41		
	Butyrac	8 oz	29.4 /gal	1.84	34.13	
Insecticides	Temik 15G	7 lb	3 / lb	21.00		
	Orthene 75S	1 lb	10 / lb	10.00		
	Lorsban 15G	13 lb	1.85 /lb	24.05		
	Comite 6.55EC	2 pt	75 / gal	18.75		
	ASANA XL	5 oz	140 / gal	5.47	79.27	
Fungicides	Bravo 720	3 lb	51.75 /gal	19.41		
(diseases)	Metam 42.5%	7.7 gal	4.5 /gal	24.75		55% acreage
	Folicur 3.6F	14.4 oz	255 /gal	29.25		
	Rovral 4F	2 qt	169 /gal	27.88	101.29	33% acreage
Others	Nufilm 17	8 oz	27 /gal	1.69		
	MnS	3 lb	7.95 /gal	2.98		
	Solubor	5 lb	0.80 /lb	4.00	8.67	
				Total chemicals:	223.36	

Table B-24. Strip-till peanut chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Prowl 3EC	1.3 pt	26.25 / gal	4.27		
	Dual 8E	3.0 pt	62.95 / gal	11.80		
	Starfire	11 oz	32.75 / gal	7.11		
	Blazer	1.5 pt	58.8 / gal	11.03		
	Roundup	2.5 pt	45.5 / gal	14.22		
	Butyrac	8 oz	29.4 /gal	1.84	50.27	
Insecticides	Temik 15G	7 lb	3 / lb	21.00		
	Orthene 75S	1 lb	10 / lb	10.00		
	Lorsban 15G	13 lb	1.85 /lb	24.05		
	Comite 6.55EC	2 pt	75 / gal	18.75		
	ASANA XL	5 oz	140 / gal	5.47	79.27	
Fungicides (diseases)	Bravo 720	3 lb	51.75 /gal	19.41		
	Folicur 3.6F	9 oz	255 /gal	17.93		
	Metam 42.5%	7.7 gal	4.5 /gal	24.75		55% acreage
	Rovral 4F	1.5 qt	169 /gal	20.91	83	33% acreage
Others	Nufilm 17	8 oz	27 /gal	1.69		
	MnS	3 lb	7.95 /gal	2.98		
	Boron	6 lb	0.92 /gal	5.52	10.19	
				Total chemicals:	222.73	

Table B-25. Minimum-till wheat chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides						
Fungicides	Tilt 3.6 EC	4 oz	340 / gal	10.63	10.63	
				Total chemicals:	10.63	

Table B-26. No-till soybean chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Bronco	3 qt	25.7 /gal	19.28		
	(Lasso 1.05 lb ai, Roundup 1.95 lb ai)				19.28	
Insecticides	Asana XL	6.00	140 / gal	6.56	6.56	
				Total chemicals:	25.84	

Table B-27. No-till corn chemical input analysis ($/ac)

Type	Name of Input	Product per acre	Unit Price	Actual Cost	Sub-Total	Note
Herbicides	Bicep 6L	2 qts	32.85 /gal	16.43	16.43	
Insecticides	Counter 15G	6.5 lb	1.85 /lb	12.03	12.03	
				Total chemicals:	28.46	

Appendix C. Crop Prices and Program Payment Rates

Table C-1. Historical southeastern and national cotton prices in United States (1986-1996)[a]

Cotton Year[b]	Grade 41-34 (leaf 4)[c] Southeat (in nominal dollars)	Grade 41-34 (leaf 4)[c] National (in nominal dollars)	Grade 41-34 (leaf 4)[c] Southeast (in 1995 dollars)[d]	Grade 41-34 (leaf 4)[c] National (in 1995 dollars)[d]	Grade 31-34 (leaf 4)[e] Southeat (in nominal dollars)	Grade 31-34 (leaf 4)[e] National (in nominal dollars)	Grade 31-34 (leaf 4)[e] Southeast (in 1995 dollars)[d]	Grade 31-34 (leaf 4)[e] National (in 1995 dollars)[d]	GDP deflator	Average Regional (in 1995 dollars)[d]	Average National (in 1995 dollars)[d]	Ratio[f]
85-86	60.52	60.01	82.79	82.09	61.33	61.12	83.90	83.61	73.1	83.34	82.85	1.01
86-87	51.66	53.16	68.79	70.79	52.41	54.89	69.79	73.09	75.1	69.29	71.94	0.96
87-88	63.37	63.13	81.87	81.56	64.33	65.04	83.11	84.03	77.4	82.49	82.80	1.00
88-89	57.26	57.67	71.40	71.91	58.37	59.51	72.78	74.20	80.2	72.09	73.05	0.99
89-90	70.64	69.78	84.50	83.47	71.43	71.21	85.44	85.18	83.6	84.97	84.32	1.01
90-91	75.90	74.80	87.04	85.78	76.40	76.08	87.61	87.25	87.2	87.33	86.51	1.01
91-92	57.70	56.68	63.62	62.49	58.00	57.63	63.95	63.54	90.7	63.78	63.02	1.01
92-93	56.73	54.10	60.87	58.05	56.98	55.12	61.14	59.14	93.2	61.00	58.59	1.04
93-94	67.46	66.12	70.56	69.16	67.71	66.89	70.83	69.97	95.6	70.70	69.57	1.02
94-95	87.17	88.14	89.04	90.03	87.37	89.47	89.24	91.39	97.9	89.14	90.71	0.98
95-96[g]	84.09	86.00	84.09	86.00	84.41	86.25	84.41	86.25	100	84.25	86.13	0.98
										Average ratio:		1.00

a. Data from "Cotton Price Statistics (1985-1996)", USDA, Agricultural Marketing Service, Cotton Division, Memphis, Tennessee. All prices are in cents per pound.
b. A cotton year is from August 1 of the first year to July 31 of the second year.
c. Roughly 50 percent of the cotton yield belongs to this category in southeast United States.
d. Deflator used is GDP deflator.
e. Roughly 50 percent of the cotton yield belongs to this category in southeast United States.
f. Ratio = (regional average)/(national average).
g. Simple average of only 10 months' data available for this cotton year

Table C-2. Historical prices of corn, cotton, peanut, soybean, and winter wheat for Virginia and the U.S. (1986-1995)[a]

		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average Ratio[b]
Corn ($/bu)	Nominal Price[c]	1.70	2.05	2.90	2.60	2.51	2.60	2.25	2.65	2.35	2.57	
		1.50	1.94	2.54	2.36	2.28	2.37	2.07	2.50	2.25	2.57	
	In 1995 dollars[c]	2.26	2.65	3.62	3.11	2.88	2.87	2.41	2.77	2.40	2.57	
		2.00	2.51	3.17	2.82	2.61	2.61	2.22	2.62	2.30	2.57	
	Ratio[d]	1.13	1.06	1.14	1.10	1.10	1.10	1.09	1.06	1.04	1.00	1.08
Peanut ($/lb)	Nominal Price[c]	0.311	0.278	0.277	0.303	0.331	0.283	0.318	0.304	0.275	0.29	
		0.292	0.280	0.279	0.280	0.347	0.283	0.300	0.304	0.290	0.29	
	In 1995 dollars[c]	0.41	0.36	0.35	0.36	0.38	0.31	0.34	0.32	0.28	0.29	
		0.39	0.36	0.35	0.33	0.40	0.31	0.32	0.32	0.30	0.29	
	Ratio[d]	1.07	0.99	0.99	1.08	0.95	1.00	1.06	1.00	0.95	1.00	1.01
Soybean ($/bu)	Nominal Price[c]	4.90	6.05	7.40	5.70	5.55	5.50	5.50	6.45	5.30	5.83	
		4.78	5.88	7.42	5.69	5.74	5.58	5.56	6.40	5.45	5.83	
	In 1995 dollars[c]	6.52	7.82	9.23	6.82	6.36	6.06	5.90	6.75	5.41	5.83	
		6.36	7.60	9.25	6.81	6.58	6.15	5.97	6.69	5.57	5.83	
	Ratio[d]	1.03	1.03	1.00	1.00	0.97	0.99	0.99	1.01	0.97	1.00	1.00
W-Wheat ($/bu)	Nominal Price[c]	2.55	2.55	3.45	3.45	2.95	2.70	3.10	2.72	2.85	4.04	
		2.33	2.49	3.65	3.78	2.62	2.92	3.24	3.03	3.37	4.04	
	In 1995 dollars[c]	3.40	3.29	4.30	4.13	3.38	2.98	3.33	2.85	2.91	4.04	
		3.10	3.22	4.55	4.52	3.00	3.22	3.48	3.17	3.44	4.04	
	Ratio[d]	1.09	1.02	0.95	0.91	1.13	0.92	0.96	0.90	0.85	1.00	0.97

a. From "Agricultural Prices (1985-1996 Summary)", USDA, NASS, Agricultural Statistics Board, DC. 1987-1996.
b. Simple average
c. First row is for Virginia, second row is for national average.
d. Virginia/(national average)

Table C-3. Estimated contract commodity payment rates[a]

Year	Fapri GNP deflator	Denom.[b]	Wheat USDA[c]	Wheat Deflated[d]	Corn USDA[c]	Corn Deflated[d]	Cotton USDA[c]	Cotton Deflated[d]
1996	1.9	0.981	62.00	60.84	24.00	23.55	7.85	7.70
1997	2.3	0.959	61.00	58.52	33.00	31.66	7.40	7.10
1998	2.1	0.94	65.00	61.07	36.00	33.82	7.87	7.39
1999	2.3	0.918	63.00	57.86	35.00	32.15	7.60	6.98
2000	2.3	0.898	57.00	51.17	32.00	28.73	6.96	6.25
2001	2.5	0.876	46.00	40.29	26.00	22.77	5.64	4.94
2002	2.5	0.855	45.00	38.45	25.00	21.36	5.46	4.67
			Average	52.60		27.72		6.43

a. All payment rates are in cents per unit. Units are bushel for wheat and corn, and pound for cotton
b. It is 1/[(1+deflator_1/100)*...*(1+deflator_t/100)].
c. Payment rates as estimated by USDA.
d. It is USDA/denom.

Table C-4. FAPRI U.S. crop prices forecast (1996-2002)[a]

	FAPRI GNP	Adjustment	Peanut[c]		Wheat		Corn		Cotton		Soybean	
Year	deflator	Denominator[b]	Forcast	Deflated[d]	Forcast	Deflated[d]	Forcast	Deflated[d]	Forcast	Deflated[d]	Forcast	Deflated[d]
1996	1.9	0.981	27.69	27.18	3.78	3.71	2.75	2.70	0.66	0.65	6.5	6.38
1997	2.3	0.959	27.69	26.57	3.37	3.23	2.46	2.36	0.64	0.62	6.26	6.01
1998	2.1	0.940	27.69	26.02	3.43	3.22	2.31	2.17	0.64	0.60	5.74	5.39
1999	2.3	0.918	27.69	25.44	3.43	3.15	2.23	2.05	0.64	0.59	5.57	5.12
2000	2.3	0.898	27.69	24.86	3.45	3.10	2.29	2.06	0.64	0.57	5.54	4.97
2001	2.5	0.876	27.69	24.26	3.24	2.84	2.33	2.04	0.64	0.56	5.68	4.98
2002	2.5	0.855	27.69	23.67	3.21	2.74	2.43	2.08	0.64	0.55	5.86	5.01
2003	2.6	0.833	27.69	23.07	3.24	2.70	2.45	2.04	0.65	0.54	6.03	5.02
2004	2.5	0.813	27.69	22.50	3.36	2.73	2.57	2.09	0.65	0.53	6.22	5.05
			Average:	24.839		3.047		2.175		0.578		5.325
			Adjusted to Virginia Price[e]:	25.088		2.956		2.349		0.577		5.325

a. All payment rates are in dollars per unit. Units are bushel for wheat, corn, and soybean, and pound for cotton and peanut. All forecast prices are "farm prices".
b. It is 1/[(1+deflator_1/100)*...*(1+deflator_t/100)].
c. Peanut price are fixed at $610/mt, or 27cents per pound throughout.
d. It is forecast/denominator.
e. It is the average values in this table times the corresponding ratios in Table C-1.

Appendix D. Environmental Pesticide, Nitrogen, Phosphorus, and Soil Indices

Introduction

The following tables in this appendix give the data and steps used to construct the environmental indices for pesticides used on the representative farm. The major information sources are:

- "Drinking Water Regulations and Health Advisories." by Office of Water, EPA, May 1995.
- "The Agro-chemicals Handbook (3rd edition)." by Royal Society of Chemistry, Information Service, 1991.
- "Pesticides and Aquatic Animals: a Guide to Reducing Impacts on Aquatic Systems." by Virginia Cooperative Extension, VPI & SU, 1996. Pub.420-013.
- "Drinking Water Health Advisory. Pesticides." by Office of Drinking Water Health Advisories, EPA, 1991.

Table D-0. All pesticides used in all study rotations[a]

	Common	Generic			Lifetime	HA	Fish 96-hr LC_{50}(mg/l)			LC
Type	Trade	Nameb	Formulation	Practices[b]	HAL(mmg/l)	value	Trout	Bluegill	Average	value[c]
H	Basagran	Bentazon	4 lb/gal WSG	CP; SP;	20.0	3	109.0	116.0	>10.0	1
H	Bicep 6L	Atrazine/Metolachlor	3.7 lb/gal + 3.25 lb/gal	NCn						
		Atrazine			3.0	5	8.80	16.0	>10.0	2
		Metolachlor			100.0	3	2.0	15.0	8.500	2
H	Bladex	Cyanazine	50,80% G; 4 lb/gal F;	SCt; NCt;	1.0	5	10[d]	18[e]	>10.0	2
H	Bronco	Alachlor/Glyphosate	2.5 + 1.5 lb/gal	NSb;						
		Alachlor (Lasso)			B2	5	1.80	2.80	2.300	3
		Glyphosate			700.0	1	86.0	120.0	>10.0	1
H	Command 4EC	Clomazone	4 lb /gal;	NCt;SCt			19.0	34.0	>10.0	1
H	Cotoran 4L	Fluometron	4 lb/gal	CCt; SCt; NCt	90.0	3	47.0	96.0	>10.0	1
H	Dual	Metolachlor	8 lb/gal EC; 25% G; 500, 720 g/l EC	CP; SP;	100.0	3	2.0	15.0	8.500	2
H	Fusilade	Fluazifop-p-butyl	1,2,4 lb/gal EC	CCt;	7.0[f]	5	1.37	0.53	0.950	4
H	Gramoxone	Paraquat	2 lb/gal AS	SCt; NCt;	30.0	3	15.0	13.0	>10.0	1
H	Harmony	Thifensulfuron-methyl		MWt			>100	>100	>10.0	1
H	MSMA	Modosodium		CCt; SCt; NCt;	7.0[f]	5		1000.0	>10.0	1
H	Prowl	Pendimethalin	4 lb/gal EC; 75% WP	SCt; NCt; Cp;	90.0(C)[f]	5	0.10	0.20	0.150	5
H	Reflex	Fomesofen	2 lb/gal EC	NSb;	1.80(C)[f]	5	680.0	6030.0	>10.0	1
H	Roundup	Glyphosate	4 lb/gal S	Cover	700.0	1	86.0	120.0	>10.0	1
H	Starfire 1.5L	Paraquat	1.5 lb/gal	CP; SP;	30.0	3	15.0	13.0	>10.0	1
H	Treflan	Trifluralin	5% G; 4, 5 lb/gal EC	CCt,	5.0	5	0.01	0.02	0.015	5
I	ASANA XL	Esfenvalerate		CP; SP;	20.0[f]	3	< 0.01	< 0.01	0.09	5
I	Comite	Propargite	6 lb/gal EC; 30% WP; $% D	CP; SP;	0.28[f]	5	0.12	0.10	0.110	5
I	Counter	Terbufos	15% G	NCn	0.90	5	0.01	<0.01	0.09	5
I	Karate	Lambdacyhalothrin		CCt; SCt; NCt;	7.0[f]	5	<0.01	<0.01	0.09	5
I	Lorsban	Chlorpyrifos	2.4 lb/gal EC; 15% G; 30% F; 25% WP	CP; SP;	20.0	3	< 0.01	0.01	0.09	5
I	Orthene	Acephate	75% WP; 50% WP; 2% D	CCt;SCt;NCt;CP;SP;	3.0[f]	5	> 1000	2050.0	>10.0	1
I	Temik	Aldicarb	10, 15% G;	CCt;SCt;NCt;CP;SP;	7.0	5	0.90	1.50	1.200	4
F	Bravo	Chlorothalonil	75% WP; 4.17 lb/gal F; 20% P	CP; SP;	B2	5	0.25	0.39	0.320	5
F	Folicur 3.6F	Tebuconazole		CP; SP;	20.0(C)[f]	5	6.40	8.70	7.550	3
F	Rovral	Iprodione	50% WP	CP; SP;	1.0[f]	5	6.70	2.25	4.475	3
F	Vapam	Metam-sodium	32.7% WSS	CP; SP;	2.0(B2)[f]	5	0.08	0.39	0.235	5
F	Ridomil	Metalaxyl	2 lb/gal EC; 2.67 lb/ga F; 25% WP; 5% G	CCt; SCt; NCt;	500.0[f]	1	> 100	> 100	>10.0	1
Def	Dropp	Thidiazuron		CCt; SCt; NCt;		1	>1000	>1000	>10.0	1
Def	Def	s,s,s-tributyl		CCt; SCt; NCt;		5	<0.50	1.0	0.700	4
R	Pix	Mepiquat Chloride		CCt; SCt; NCt;	4000.0[f]	1	4300.0		>10.0	1

a. All chemicals used in all practices which are considered toxic to the environment. Not only includes "explicit" pesticides.
b. CP -- conventional peanut; SP -- strip-till peanut; CCt -- conventional cotton; SCt -- strip-till cotton; NCt – notill cotton NCn -- no-till corn; NSb -- notill soybean; MWt – minimum till wheat
c. LC here is the average value. E.g. if LC for rainbow trout is 3, and for bluegill sunfish is 4, then LC for "fish" is 3.5.
d. This value is actually for Harlequin, not rainbow trout.
e. It is actually for sheephead minnow, not bluegill sunfish.
f. Official EPA HAL value was not available for this chemical. The indicated value was selected in consultation with Dr.Amal Mahafouz, Senior Toxicologist, Office of Water, EPA, Washington, D.C. and based on preliminary data. This value may change based on additinoal information that may become available Ion toxicity of these chemicals.

Table D-1. Pesticide environmental indices for rotation 1 (conventional cotton + conventional peanut, w/o cover)

	Pesticide	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
	(type, name)	(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Dual 8E	1596	1.42	13.01	11.01	9.01	1.40	1.54	3.84	35.07	22.06	8.06	2.0	1.0	1.0	15.01	12.01	10.01	3	36.47	23.60	11.90	2	58.99	41.62	26.92	23.87	16.84	10.89
	Paraquat(Starfire)	71	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.08	0.08	4.0	2.0	1.0	4.0	2.0	1.0	3	0.08	0.08	0.08	1	6.04	3.04	1.54	2.45	1.23	0.62
	Storm (Basagran	214	0.19	2.61	1.61	1.50	0.0	0.0	0.01	4.01	2.01	1.01	0.0	0.0	0.0	2.61	1.61	1.50	3	4.01	2.01	1.02	1	5.92	3.42	2.76	2.40	1.38	1.12
	+ Blazer)	133	0.12	1.58	1.56	1.50	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.58	1.56	1.50	5	1.0	1.0	0.0	1	4.45	4.40	3.75	1.80	1.78	1.52
	Butyrac	67	0.06	1.22	0.21	0.19	0.0	0.0	0.0	0.10	0.09	0.08	0.0	0.0	0.0	1.22	0.21	0.19	3	0.10	0.09	0.08	3	1.98	0.45	0.41	0.80	0.18	0.16
	Prowl 3.3 EC	637	0.57	4.0	3.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0	14.0	8.0	3.0	18.0	11.0	5.0	5	1.0	1.0	0.0	5	47.50	30.0	12.50	19.22	12.14	5.06
	Cotoran 4L	694	0.62	18.01	11.01	8.0	2.91	3.0	6.0	20.04	13.04	5.04	0.0	0.0	0.0	18.01	11.01	8.0	3	22.95	16.04	11.04	1	38.49	24.54	17.52	15.58	9.93	7.09
	Fusilade DX	24	0.02	0.02	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	0.02	5	0.0	0.0	0.0	4	0.06	0.05	0.05	0.02	0.02	0.02
	MSMA 6	352	0.31	0.0	0.0	0.0	0.0	0.0	0.0	0.97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	0.97	0.0	0.0	1	0.49	0.0	0.0	0.20	0.0	0.0
I[j]	Lorsban 15G	1064	0.95	0.01	0.01	0.01	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	3	1.0	1.0	0.0	5	2.52	2.52	0.02	1.02	1.02	0.01
	Comite 6.55EC	437	0.39	3.0	2.92	1.79	0.0	0.0	0.0	0.41	0.37	0.34	3.0	2.0	1.0	6.0	4.92	2.79	5	0.41	0.37	0.34	5	16.03	13.23	7.83	6.49	5.35	3.17
	ASANA XL	14	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	3	0.01	0.01	0.01	5	0.04	0.04	0.04	0.02	0.02	0.02
	Temik 15G	850	0.76	2.65	1.54	1.42	1.36	1.48	3.76	22.04	15.04	5.04	0.0	0.0	0.0	2.65	1.54	1.42	5	23.40	16.52	8.80	4	53.43	36.89	21.15	21.62	14.93	8.56
	Orthene 75S	427	0.38	1.41	1.38	0.25	0.82	0.0	0.01	3.01	2.01	1.01	0.0	0.0	0.0	1.41	1.38	0.25	5	3.83	2.01	1.02	1	5.44	4.46	1.14	2.20	1.80	0.46
	Karate	28	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.08	0.07	0.0	0.0	0.0	0.0	0.0	0.0	5	0.09	0.08	0.07	5	0.23	0.20	0.18	0.09	0.08	0.07
F[j]	Bravo 720	1002	0.89	8.0	6.0	4.0	0.0	0.0	0.0	2.0	1.0	0.0	5.0	2.0	1.0	13.0	8.0	5.0	5	2.0	1.0	0.0	5	37.50	22.50	12.50	15.18	9.11	5.06
	Vapam	9310	8.30	0.0	0.0	0.0	0.22	1.21	3.87	104.20	73.21	29.22	0.0	0.0	0.0	0.0	0.0	0.0	5	104.42	74.42	33.09	5	261.06	186.05	82.73	105.65	75.29	33.48
	Folicur 3.6F	209	0.19	6.0	5.0	3.0	0.0	0.0	0.0	3.01	1.0	1.0	1.0	0.0	0.0	7.0	5.0	3.0	5	3.01	1.0	1.0	3	22.02	14.0	9.0	8.91	5.67	3.64
	Rovral 4F	352	0.31	3.0	2.0	2.98	0.0	0.0	0.0	0.53	0.45	0.41	1.0	0.0	0.0	4.0	2.0	2.98	5	0.53	0.45	0.41	3	10.80	5.68	8.07	4.37	2.30	3.26
	Ridomil PC 11G	147	0.13	1.33	1.27	0.21	1.37	1.47	2.62	5.01	3.01	1.01	0.0	0.0	0.0	1.33	1.27	0.21	1	6.38	4.48	3.63	1	3.86	2.88	1.92	1.56	1.16	0.78
O[J]	Pix	314	0.28	0.03	0.03	0.03	0.0	0.0	0.0	0.02	0.02	0.02	36.0	19.0	8.0	36.03	19.03	8.03	1	0.02	0.02	0.02	1	18.03	9.53	4.03	7.29	3.85	1.63
																				Index of rotation							240.72	164.08	86.61

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide

Table D-2. Pesticide environmental indices for rotation 2 (notill corn + conventional peanut, w/o cover)

Pesticide		Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
(type, name)				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
		(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Paraquat	71	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.37	0.32	0.28	0.0	2.0	1.0	0.0	2.0	1.0	3	0.37	0.32	0.28	1	0.19	3.16	1.64	0.07	1.28	0.66
	Dual 8E	2461	2.19	26.01	21.01	14.01	1.46	2.62	4.0	48.09	30.09	10.08	3.0	2.0	1.0	29.01	23.01	15.01	3	49.55	32.71	14.08	2	93.07	67.23	36.60	37.66	27.21	14.81
	Prowl 3EC	290	0.26	3.0	2.0	2.92	0.0	0.0	0.0	0.34	0.29	0.25	13.0	7.0	3.0	16.0	9.0	5.92	5	0.34	0.29	0.25	5	40.85	23.23	15.43	16.53	9.40	6.24
	Storm (Blazer	133	0.12	2.75	2.69	1.63	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	2.75	2.69	2.63	5	1.0	0.0	0.0	1	7.38	6.73	6.58	2.98	2.72	2.66
	+ Basagran)	266	0.24	4.0	2.92	2.86	0.0	0.01	0.02	5.01	3.01	1.01	0.0	0.0	0.0	4.0	2.92	2.86	3	5.01	3.02	1.03	1	8.51	5.89	4.81	3.44	2.38	1.94
	Butyrac	67	0.06	1.26	1.23	0.21	0.0	0.0	0.0	0.06	0.05	0.05	0.0	0.0	0.0	1.26	1.23	0.21	3	0.06	0.05	0.05	3	1.98	1.92	0.39	0.80	0.78	0.16
	Aatrex	978	0.87	13.01	10.0	7.0	1.32	1.47	3.74	23.04	14.04	5.04	0.0	0.0	0.0	13.01	10.0	7.0	5	24.36	15.51	8.78	2	56.89	40.51	26.28	23.02	16.39	10.64
I[j]	Temik 15G	532	0.47	0.01	0.01	0.01	1.22	1.29	2.45	13.02	9.03	3.03	0.0	0.0	0.0	0.01	0.01	0.01	5	14.24	10.32	5.48	4	28.51	20.67	10.99	11.54	8.36	4.45
	Orthene 75S	399	0.36	1.49	1.44	1.41	0.74	0.0	0.01	2.01	2.0	1.0	0.0	0.0	0.0	1.49	1.44	1.41	5	2.75	2.0	1.01	1	5.10	4.60	4.03	2.06	1.86	1.63
	Lorsban 15G	1064	0.95	0.04	0.06	0.04	0.0	0.0	0.0	0.55	0.56	0.49	0.0	0.0	0.0	0.04	0.06	0.04	3	0.55	0.56	0.49	5	1.44	1.49	1.29	0.58	0.60	0.52
	Comite 6.55EC	437	0.39	2.83	2.81	1.67	0.0	0.0	0.0	0.17	0.14	0.13	3.0	2.0	1.0	5.83	4.81	2.67	5	0.17	0.14	0.13	5	15.0	12.38	7.0	6.07	5.01	2.83
	ASANA XL	52	0.05	0.02	0.02	0.02	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.02	0.02	0.02	3	0.01	0.01	0.01	5	0.06	0.06	0.06	0.02	0.02	0.02
	Counter 15G	523	0.47	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	1.0	0.0	0.0	5	2.50	0.0	0.0	1.01	0.0	0.0
F[j]	Bravo 720	1002	0.89	7.0	6.0	4.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	3.0	1.0	12.0	9.0	5.0	5	1.0	0.0	0.0	5	32.50	22.50	12.50	13.15	9.11	5.06
	Vapam	9310	8.30	0.0	0.0	0.0	0.09	1.21	3.74	104.20	74.21	26.20	0.0	0.0	0.0	0.0	0.0	0.0	5	104.29	75.42	29.94	5	260.73	188.55	74.85	105.51	76.30	30.29
	Folicur 3.6F	209	0.19	5.0	5.0	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	6.0	5.0	3.0	5	2.0	1.0	0.0	3	18.0	14.0	7.50	7.28	5.67	3.04
	Rovral 4F	352	0.31	3.0	2.0	2.87	0.0	0.0	0.0	0.30	0.24	0.21	1.0	0.0	0.0	4.0	2.0	2.87	5	0.30	0.24	0.21	3	10.45	5.36	7.49	4.23	2.17	3.03
																				Index of rotation							235.98	169.26	87.98

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-3. Pesticide environmental indices for rotation 3 (conventional peanut + wheat/soybean + conventional cotton, w/o cover)

	Pesticide	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
	(type, name)	(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Dual 8E	1064	0.95	8.0	6.0	4.0	0.25	1.35	2.53	22.04	14.04	5.04	1.0	1.0	0.0	9.0	7.0	4.0	3	22.29	15.39	7.57	2	35.79	25.89	13.57	14.48	10.48	5.49
	Paraquat	48	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.07	0.07	2.0	1.0	0.0	2.0	1.0	0.0	3	0.07	0.07	0.07	1	3.04	1.54	0.04	1.23	0.62	0.01
	Basagran	142	0.13	1.40	1.36	1.34	0.0	0.0	0.01	3.01	2.01	1.0	0.0	0.0	0.0	1.40	1.36	1.34	3	3.01	2.01	1.01	1	3.61	3.05	2.52	1.46	1.23	1.02
	Blazer	89	0.08	1.41	1.38	1.34	0.0	0.0	0.0	1.0	0.94	0.86	0.0	0.0	0.0	1.41	1.38	1.34	5	1.0	0.94	0.86	1	4.03	3.92	3.78	1.63	1.59	1.53
	Lasso	374	0.33	2.74	2.68	1.56	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	2.74	2.68	1.56	5	2.0	1.0	0.0	1	7.85	7.20	3.90	3.18	2.91	1.58
	Roundup	694	0.62	2.60	1.50	1.40	0.0	0.0	0.0	0.09	0.06	0.05	6.0	3.0	1.0	8.60	4.50	2.40	1	0.09	0.06	0.05	1	4.35	2.28	1.23	1.76	0.92	0.50
	Reflex	142	0.13	1.25	1.25	0.22	2.0	3.0	5.0	7.01	4.01	1.01	0.0	0.0	0.0	1.25	1.25	0.22	5	9.01	7.01	6.01	1	7.63	6.63	3.56	3.09	2.68	1.44
	Butyrac	44	0.04	0.15	0.13	0.12	0.0	0.0	0.0	0.07	0.06	0.05	0.0	0.0	0.0	0.15	0.13	0.12	3	0.07	0.06	0.05	3	0.33	0.29	0.26	0.13	0.12	0.10
	Prowl 3.3 EC	424	0.38	2.86	2.78	1.65	0.0	0.0	0.0	0.73	0.62	0.59	17.0	13.0	10.0	19.86	15.78	11.65	5	0.73	0.62	0.59	5	51.48	41.0	30.60	20.83	16.59	12.38
	Cotoran 4L	462	0.41	15.01	10.01	5.0	1.57	2.79	3.0	13.03	8.02	3.02	0.0	0.0	0.0	15.01	10.01	5.0	3	14.60	10.81	6.02	1	29.82	20.42	10.51	12.07	8.26	4.25
	Fusilade DX	16	0.01	0.01	0.01	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.10	5	0.0	0.0	0.0	4	0.03	0.03	0.25	0.01	0.01	0.10
	MSMA 6	234	0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.62	0.64	0.66	0.0	0.0	0.0	0.0	0.0	0.0	5	0.62	0.64	0.66	1	0.31	0.32	0.33	0.13	0.13	0.13
I[j]	Lorsban 15G	709	0.63	0.01	0.01	0.01	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	3	1.0	0.0	0.0	5	2.52	0.02	0.02	1.02	0.01	0.01
	Comite 6.55EC	291	0.26	2.64	1.56	1.49	0.0	0.0	0.0	0.66	0.62	0.59	2.0	1.0	0.0	4.64	2.56	1.49	5	0.66	0.62	0.59	5	13.25	7.95	5.20	5.36	3.22	2.10
	ASANA XL	9	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	3	0.01	0.01	0.01	5	0.04	0.04	0.04	0.02	0.02	0.02
	Temik 15G	567	0.51	0.01	0.02	0.02	0.23	1.31	1.47	13.03	9.03	3.03	0.0	0.0	0.0	0.01	0.02	0.02	5	13.26	10.34	4.50	4	26.55	20.73	9.05	10.74	8.39	3.66
	Orthene 75S	285	0.25	0.19	0.15	0.21	0.72	0.0	0.01	2.0	1.0	0.0	0.0	0.0	0.0	0.19	0.15	0.21	5	2.72	1.0	0.01	1	1.84	0.88	0.53	0.74	0.35	0.21
	Karate	19	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.11	0.09	0.08	0.0	0.0	0.0	0.0	0.0	0.0	5	0.11	0.09	0.08	5	0.28	0.23	0.20	0.11	0.09	0.08
F[j]	Bravo 720	668	0.60	5.0	4.0	3.0	0.0	0.0	0.0	1.0	1.0	0.0	4.0	2.0	1.0	9.0	6.0	4.0	5	1.0	1.0	0.0	5	25.0	17.50	10.0	10.12	7.08	4.05
	Vapam	6702	5.97	0.58	0.74	0.0	0.08	0.12	2.60	65.13	48.14	18.14	0.0	0.0	0.0	0.58	0.74	0.0	5	65.21	48.26	20.74	5	164.48	122.50	51.85	66.56	49.57	20.98
	Folicur 3.6F	139	0.12	4.0	3.0	2.0	0.79	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	5.0	3.0	2.0	5	2.79	1.0	0.0	3	16.69	9.0	5.0	6.75	3.64	2.02
	Rovral 4F	234	0.21	2.83	2.67	1.61	0.0	0.0	0.0	0.42	0.36	0.34	0.0	0.0	0.0	2.83	2.67	1.61	5	0.42	0.36	0.34	3	7.71	7.22	4.54	3.12	2.92	1.84
	Ridomil PC 11G	98	0.09	0.01	0.01	0.01	1.28	1.35	1.44	3.01	2.01	1.01	0.0	0.0	0.0	0.01	0.01	0.01	1	4.29	3.36	2.45	1	2.15	1.69	1.23	0.87	0.68	0.50
O[J]	Pix	209	0.19	0.02	0.02	0.02	0.0	0.0	0.0	0.02	0.01	0.01	26.0	14.0	6.0	26.02	14.02	6.02	1	0.02	0.01	0.01	1	13.02	7.02	3.02	5.27	2.84	1.22
																					Index of rotation						170.67	124.36	65.23

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-4. Pesticide environmental indices for rotation 4 (conventional peanut + wheat/soybean + notill corn, w/o cover)

	Pesticide	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
	(type, name)	(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Paraquat	48.0	0.04	0.0	0.0	0.83	0.0	0.0	0.0	0.07	0.07	0.07	2.0	1.0	0.0	2.0	1.0	0.83	3	0.07	0.07	0.07	1	3.04	1.54	1.28	1.23	0.62	0.52
	Dual 8E	1640.0	1.46	21.01	12.01	9.01	1.32	1.46	2.71	32.06	19.06	7.05	2.0	1.0	1.0	23.01	13.01	10.01	3	33.38	20.52	9.76	2	67.90	40.04	24.78	27.48	16.20	10.03
	Prowl 3EC	193.0	0.17	2.73	1.66	1.45	0.0	0.0	0.0	0.32	0.23	0.21	16.0	12.0	10.0	18.73	13.66	11.45	5	0.32	0.23	0.21	5	47.63	34.73	29.15	19.27	14.05	11.80
	Storm (Blazer	89.0	0.08	1.44	1.39	1.37	0.0	0.0	0.0	1.0	0.85	0.78	0.0	0.0	0.0	1.44	1.39	1.37	5	1.0	0.85	0.78	1	4.10	3.90	3.82	1.66	1.58	1.54
	+ Basagran)	142.0	0.13	1.44	1.41	1.42	0.0	0.0	0.01	2.01	1.0	1.0	0.0	0.0	0.0	1.44	1.41	1.42	3	2.01	1.0	1.01	1	3.17	2.62	2.64	1.28	1.06	1.07
	Butyrac	44.0	0.04	0.14	0.12	0.11	0.0	0.0	0.0	0.06	0.05	0.05	0.0	0.0	0.0	0.14	0.12	0.11	3	0.06	0.05	0.05	3	0.30	0.26	0.24	0.12	0.10	0.10
	Lasso	374.0	0.33	2.72	1.64	1.58	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	2.72	1.64	1.58	5	2.0	1.0	0.0	3	9.80	5.60	3.95	3.97	2.27	1.60
	Roundup	694.0	0.62	1.55	1.44	1.38	0.0	0.0	0.0	0.07	0.06	0.05	6.0	3.0	1.0	7.55	4.44	2.38	1	0.07	0.06	0.05	1	3.81	2.25	1.22	1.54	0.91	0.49
	Reflex	142.0	0.13	1.25	1.25	0.22	2.0	3.0	5.0	6.01	4.01	1.01	0.0	0.0	0.0	1.25	1.25	0.22	5	8.01	7.01	6.01	1	7.13	6.63	3.56	2.89	2.68	1.44
	Aatrex	652.0	0.58	12.01	6.0	4.0	0.21	1.31	1.46	14.03	8.02	3.0	0.0	0.0	0.0	12.01	6.0	4.0	5	14.24	9.33	4.46	2	44.27	24.33	14.46	17.91	9.85	5.85
I[j]	Temik 15G	355.0	0.32	0.01	0.01	0.01	0.15	0.19	1.31	8.02	6.02	2.02	0.0	0.0	0.0	0.01	0.01	0.01	5	8.17	6.21	3.33	4	16.37	12.45	6.69	6.62	5.04	2.71
	Orthene 75S	266.0	0.24	1.20	1.24	0.23	0.67	0.0	0.01	2.0	1.0	0.0	0.0	0.0	0.0	1.20	1.24	0.23	5	2.67	1.0	0.01	1	4.34	3.60	0.58	1.75	1.46	0.23
	Lorsban 15G	709.0	0.63	0.01	0.01	0.01	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	3	1.0	0.0	0.0	5	2.52	0.02	0.02	1.02	0.01	0.01
	Comite 6.55EC	291.0	0.26	1.57	1.50	1.40	0.0	0.0	0.0	0.64	0.60	0.58	2.0	1.0	0.0	3.57	2.50	1.40	5	0.64	0.60	0.58	5	10.53	7.75	4.95	4.26	3.14	2.0
	ASANA XL	9.0	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	3	0.01	0.01	0.01	5	0.04	0.04	0.04	0.02	0.02	0.02
	Counter 15G	348.0	0.31	0.03	0.01	0.01	0.0	0.0	0.0	0.29	0.32	0.28	0.0	0.0	0.0	0.03	0.01	0.01	5	0.29	0.32	0.28	5	0.80	0.83	0.73	0.32	0.33	0.29
F[j]	Bravo 720	668.0	0.60	5.0	4.0	3.0	0.0	0.0	0.0	1.0	0.0	0.0	4.0	2.0	1.0	9.0	6.0	4.0	5	1.0	0.0	0.0	5	25.0	15.0	10.0	10.12	6.07	4.05
	Vapam	6207.0	5.53	0.76	0.0	0.0	0.07	0.11	3.94	66.13	46.14	19.15	0.0	0.0	0.0	0.76	0.0	0.0	5	66.20	46.25	23.09	5	167.40	115.63	57.73	67.74	46.79	23.36
	Folicur 3.6F	139.0	0.12	4.0	3.0	2.0	0.75	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	5.0	3.0	2.0	5	2.75	1.0	0.0	3	16.63	9.0	5.0	6.73	3.64	2.02
	Rovral 4F	234.0	0.21	2.87	2.72	1.60	0.0	0.0	0.0	0.35	0.31	0.29	0.0	0.0	0.0	2.87	2.72	1.60	5	0.35	0.31	0.29	3	7.70	7.27	4.44	3.12	2.94	1.79
																								Index of rotation			179.05	118.75	70.91

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-5. Pesticide environmental indices for rotation 5 (wheat/soybean + conventional. cotton, w/o cover)

	Pesticide (type, name)	Dosage(ai)[a] (g/ha)	Dosage(ai)[a] (lb/ac)	Annual average loss (g/ha) PSRO[b] 5%	PSRO 3%	PSRO 1%	PLCH[c] 5%	PLCH 3%	PLCH 1%	PSSF[d] 5%	PSSF 3%	PSSF 1%	PSED[e] 5%	PSED 3%	PSED 1%	To surface water[f] g/ha 5%	g/ha 3%	g/ha 1%	HA	To ground water[g] g/ha 5%	g/ha 3%	g/ha 1%	LC	Index /ha[h] 5%	/ha 3%	/ha 1%	/ac[i] 5%	/ac 3%	/ac 1%
H[j]	Prowl 3EC	347.0	0.31	0.09	0.09	0.08	0.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	1.09	0.09	0.08	5	1.0	1.0	0.0	5	5.23	2.73	0.20	2.11	1.10	0.08
	Cotoran 4L	694.0	0.62	21.01	12.01	9.01	1.58	2.83	4.0	20.04	13.04	4.04	1.0	0.0	0.0	22.01	12.01	9.01	3	21.62	15.87	8.04	1	43.83	25.95	17.54	17.74	10.50	7.10
	Fusilade	24.0	0.02	0.02	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.02	0.01	0.01	5	0.01	0.01	0.01	4	0.07	0.05	0.05	0.03	0.02	0.02
	MSMA 6	352.0	0.31	0.01	0.0	0.0	0.0	0.0	0.0	0.83	0.78	0.72	3.0	2.0	1.0	3.01	2.0	1.0	5	0.83	0.78	0.72	1	7.94	5.39	2.86	3.21	2.18	1.16
	Lasso	560.0	0.50	2.85	1.68	1.68	0.0	0.0	0.0	2.01	1.0	0.0	0.0	0.0	0.0	2.85	1.68	1.68	5	2.01	1.0	0.0	3	10.14	5.70	4.20	4.10	2.31	1.70
	Roundup	1040.0	0.93	2.79	2.75	1.66	0.0	0.0	0.0	0.11	0.09	0.08	8.0	4.0	2.0	10.79	6.75	3.66	1	0.11	0.09	0.08	1	5.45	3.42	1.87	2.21	1.38	0.76
	Reflex	214.0	0.19	1.29	0.22	0.22	3.0	4.0	7.0	10.02	6.02	2.02	0.0	0.0	0.0	1.29	0.22	0.22	5	13.02	10.02	9.02	1	9.74	5.56	5.06	3.94	2.25	2.05
I[j]	Temik 15G	318.0	0.28	0.02	0.02	0.01	0.09	0.14	1.25	8.02	5.02	2.02	0.0	0.0	0.0	0.02	0.02	0.01	5	8.11	5.16	3.27	4	16.27	10.37	6.57	6.58	4.20	2.66
	Orthene 75S	28.0	0.02	0.0	0.0	0.0	0.0	0.04	0.60	0.53	0.53	0.51	0.0	0.0	0.0	0.0	0.0	0.0	5	0.53	0.57	1.11	1	0.27	0.29	0.56	0.11	0.12	0.22
	Karate	28.0	0.02	0.0	0.90	0.73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.90	0.73	5	0.0	0.0	0.0	5	0.0	2.25	1.83	0.0	0.91	0.74
F[j]	Ridomil11G	147.0	0.13	0.01	0.01	0.01	0.29	1.39	2.57	5.01	3.01	1.01	0.0	0.0	0.0	0.01	0.01	0.01	1	5.30	4.40	3.58	1	2.66	2.21	1.80	1.07	0.89	0.73
O[J]	Pix	314.0	0.28	0.03	0.02	0.02	0.0	0.0	0.0	1.0	0.0	0.0	26.0	14.0	5.0	26.03	14.02	5.02	1	1.0	0.0	0.0	1	13.52	7.01	2.51	5.47	2.84	1.02
																								Index of rotation			46.58	28.70	18.22

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-6. Pesticide environmental indices for rotation 6
(Notill cotton + wheat/soybean. w/ rye cover)

	Pesticide	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
	(type, name)	(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Paraquat	532	0.47	0.02	0.01	0.01	0.0	0.0	0.0	0.50	0.50	0.49	25.0	12.0	5.0	25.02	12.01	5.01	3	0.50	0.50	0.49	1	37.78	18.27	7.76	15.29	7.39	3.14
	Prowl 3EC	347	0.31	0.40	3.0	2.96	0.0	0.0	0.0	1.0	0.0	0.0	12.0	6.0	2.0	12.40	9.0	4.96	5	1.0	0.0	0.0	5	33.50	22.50	12.40	13.56	9.11	5.02
	Cotoran 4L	694	0.62	2.72	1.67	1.53	1.16	2.85	3.0	19.04	12.04	4.04	0.0	0.0	0.0	2.72	1.67	1.53	3	20.20	14.89	7.04	1	14.18	9.95	5.82	5.74	4.03	2.35
	Bladex 4L	299	0.27	3.0	2.0	1.78	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	3.0	2.0	1.78	5	1.0	1.0	0.0	2	8.50	6.0	4.45	3.44	2.43	1.80
	Reflex	214	0.19	1.34	1.30	1.29	2.0	4.0	7.0	9.02	6.02	2.02	0.0	0.0	0.0	1.34	1.30	1.29	5	11.02	10.02	9.02	1	8.86	8.26	7.74	3.59	3.34	3.13
	Lasso	560	0.50	2.92	2.78	1.74	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	2.92	2.78	1.74	5	2.0	1.0	0.0	3	10.30	8.45	4.35	4.17	3.42	1.76
	Roundup	2104	1.88	4.0	3.0	2.0	0.0	0.0	0.0	0.76	0.73	0.70	49.0	25.0	10.0	53.0	28.0	12.0	1	0.76	0.73	0.70	1	26.88	14.37	6.35	10.88	5.81	2.57
	MSMA 6	352	0.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	2.0	1.0	0.0	5	0.0	0.0	0.0	1	5.0	2.50	0.0	2.02	1.01	0.0
I[j]	Temik 15G	480	0.43	0.29	0.35	0.34	0.14	0.21	1.37	12.02	8.02	3.02	0.0	0.0	0.0	0.29	0.35	0.34	5	12.16	8.23	4.39	4	25.05	17.34	9.63	10.14	7.02	3.90
	Orthene 75S	28	0.02	0.06	0.05	0.04	0.0	0.0	0.64	0.55	0.52	0.51	0.0	0.0	0.0	0.06	0.05	0.04	5	0.55	0.52	1.15	1	0.43	0.39	0.68	0.17	0.16	0.27
	Karate	28	0.02	0.96	0.78	0.65	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.96	0.78	0.65	5	0.0	0.0	0.0	5	2.40	1.95	1.63	0.97	0.79	0.66
F[j]	Ridomil PC 11G	703	0.63	0.0	0.02	0.0	2.0	4.0	7.0	23.05	15.05	5.04	0.0	0.0	0.0	0.0	0.02	0.0	1	25.05	19.05	12.04	1	12.53	9.54	6.02	5.07	3.86	2.44
O[J]	Pix	314	0.28	0.02	0.02	0.02	0.0	0.0	0.0	1.0	0.0	1.0	27.0	15.0	6.0	27.02	15.02	6.02	1	1.0	0.0	1.0	1	14.01	7.51	3.51	5.67	3.04	1.42
																					Index of rotation						80.70	51.40	28.46

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-7. Pesticide environmental indices for rotation 7 (conventional peanut + conventional cotton, w/ wheat cover)

Pesticide (type, name)		Dosage(ai)[a] (g/ha)	Dosage(ai)[a] (lb/ac)	Annual average loss (g/ha) PSRO[b] 5%	PSRO 3%	PSRO 1%	PLCH[c] 5%	PLCH 3%	PLCH 1%	PSSF[d] 5%	PSSF 3%	PSSF 1%	PSED[e] 5%	PSED 3%	PSED 1%	To surface water[f] g/ha 5%	g/ha 3%	g/ha 1%	HA	To ground water[g] g/ha 5%	g/ha 3%	g/ha 1%	LC	Index /ha[h] 5%	/ha 3%	/ha 1%	/ac[i] 5%	/ac 3%	/ac 1%
H[j]	Dual 8E	1596.0	1.42	11.0	9.0	6.0	1.25	1.33	2.54	30.06	19.06	7.05	2.0	1.0	1.0	13.0	10.0	7.0	3	31.31	20.39	9.59	2	50.81	35.39	20.09	20.56	14.32	8.13
	Paraquat(Starfire)	71.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.41	0.36	0.32	4.0	2.0	1.0	4.0	2.0	1.0	3	0.41	0.36	0.32	1	6.21	3.18	1.66	2.51	1.29	0.67
	Storm (Basagran	214.0	0.19	2.83	2.74	1.76	0.0	0.0	0.01	4.01	2.01	1.01	0.0	0.0	0.0	2.83	2.74	1.76	3	4.01	2.01	1.02	1	6.25	5.12	3.15	2.53	2.07	1.27
	+ Blazer)	133.0	0.12	2.75	2.68	1.67	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.75	2.68	1.67	5	1.0	0.0	0.0	1	7.38	6.70	4.18	2.98	2.71	1.69
	Butyrac	67.0	0.06	1.26	1.24	0.23	0.0	0.0	0.0	0.08	0.06	0.05	0.0	0.0	0.0	1.26	1.24	0.23	3	0.08	0.06	0.05	3	2.01	1.95	0.42	0.81	0.79	0.17
	Prowl 3.3 EC	637.0	0.57	3.0	3.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0	15.0	8.0	4.0	18.0	11.0	6.0	5	1.0	1.0	0.0	5	47.50	30.0	15.0	19.22	12.14	6.07
	Cotoran 4L	694.0	0.62	17.01	13.01	10.01	2.84	3.0	5.0	22.04	13.04	5.04	0.0	0.0	0.0	17.01	13.01	10.01	3	24.88	16.04	10.04	1	37.96	27.54	20.04	15.36	11.14	8.11
	Fusilade DX	24.0	0.02	0.02	0.02	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.02	0.02	0.01	5	0.01	0.01	0.01	4	0.07	0.07	0.05	0.03	0.03	0.02
	Roundup	2128.0	1.90	4.0	3.0	2.86	0.0	0.0	0.0	2.0	1.0	0.0	43.0	24.0	10.0	47.0	27.0	12.86	1	2.0	1.0	0.0	1	24.50	14.0	6.43	9.91	5.67	2.60
	MSMA 6	352.0	0.31	0.01	0.0	0.0	0.0	0.0	0.0	0.83	0.78	0.73	3.0	2.0	1.0	3.01	2.0	1.0	5	0.83	0.78	0.73	1	7.94	5.39	2.87	3.21	2.18	1.16
I[j]	Lorsban 15G	1064.0	0.95	0.01	0.01	0.01	0.0	0.0	0.0	0.53	0.59	0.52	0.0	0.0	0.0	0.01	0.01	0.01	3	0.53	0.59	0.52	5	1.34	1.49	1.32	0.54	0.60	0.53
	Comite 6.55EC	437.0	0.39	2.92	2.89	1.71	0.0	0.0	0.0	0.19	0.16	0.14	3.0	2.0	1.0	5.92	4.89	2.71	5	0.19	0.16	0.14	5	15.28	12.63	7.13	6.18	5.11	2.88
	ASANA XL	14.0	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.01	0.01	0.01	3	0.0	0.02	0.0	5	0.02	0.07	0.02	0.01	0.03	0.01
	Temik 15G	850.0	0.76	0.02	0.03	0.02	1.33	1.44	2.68	20.04	14.40	5.04	0.0	0.0	0.0	0.02	0.03	0.02	5	21.37	15.84	7.72	4	42.79	31.76	15.49	17.32	12.85	6.27
	Orthene 75S	427.0	0.38	2.68	1.60	1.57	0.81	0.0	0.01	3.01	2.01	1.01	0.0	0.0	0.0	2.68	1.60	1.57	5	3.82	2.01	1.02	1	8.61	5.01	4.44	3.48	2.03	1.79
	Karate	28.0	0.02	0.0	0.0	0.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.91	5	0.0	0.0	0.0	5	0.0	0.0	2.28	0.0	0.0	0.92
F[j]	Bravo 720	1002.0	0.89	8.0	6.0	5.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	3.0	1.0	13.0	9.0	6.0	5	1.0	0.0	0.0	5	35.0	22.50	15.0	14.16	9.11	6.07
	Vapam	9310.0	8.30	0.0	0.0	0.0	0.10	1.22	3.80	101.19	74.22	27.21	0.0	0.0	0.0	0.0	0.0	0.0	5	101.29	75.44	31.01	5	253.23	188.60	77.53	102.48	76.32	31.37
	Folicur 3.6F	209.0	0.19	6.0	5.0	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	7.0	5.0	3.0	5	2.0	1.0	0.0	3	20.50	14.0	7.50	8.30	5.67	3.04
	Rovral 4F	352.0	0.31	3.0	3.0	2.90	0.0	0.0	0.0	0.34	0.26	0.23	1.0	0.0	0.0	4.0	3.0	2.90	5	0.34	0.26	0.23	3	10.51	7.89	7.60	4.25	3.19	3.07
	Ridomil PC 11G	147.0	0.13	0.01	0.01	0.01	1.37	1.46	2.63	5.01	3.01	1.01	0.0	0.0	0.0	0.01	0.01	0.01	1	6.38	4.47	3.64	1	3.20	2.24	1.83	1.29	0.91	0.74
O[J]	Pix	314.0	0.28	0.03	0.03	0.03	0.0	0.0	0.0	0.53	0.53	0.53	34.0	18.0	7.0	34.03	18.03	7.03	1	0.53	0.53	0.53	1	17.28	9.28	3.78	6.99	3.76	1.53
																								Index of rotation			242.15	171.90	88.12

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-8. Pesticide environmental indices for rotation 8 (conventional peanut + notill cotton, w/ wheat cover)

Pesticide		Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
(type, name)		(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Dual 8E	1596	1.42	11.0	9.0	6.0	0.24	1.32	2.53	29.06	18.05	6.05	2.0	1.0	1.0	13.0	10.0	7.0	3	29.30	19.37	8.58	2	48.80	34.37	19.08	19.75	13.91	7.72
	Paraquat(Starfire)	603	0.54	0.02	0.02	0.02	0.0	0.0	0.0	0.33	0.32	0.31	32.0	16.0	6.0	32.02	16.02	6.02	3	0.33	0.32	0.31	1	48.20	24.19	9.19	19.50	9.79	3.72
	Storm (Basagran	214	0.19	2.94	2.76	1.78	0.0	0.0	0.01	4.01	2.01	1.01	0.0	0.0	0.0	2.94	2.76	1.78	3	4.01	2.01	1.02	1	6.42	5.15	3.18	2.60	2.08	1.29
	+ Blazer)	133	0.12	2.82	2.69	1.68	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.82	2.69	1.68	5	1.0	0.0	0.0	1	7.55	6.73	4.20	3.06	2.72	1.70
	Butyrac	67	0.06	1.28	1.24	0.23	0.0	0.0	0.0	0.07	0.05	0.05	0.0	0.0	0.0	1.28	1.24	0.23	3	0.07	0.05	0.05	3	2.03	1.94	0.42	0.82	0.78	0.17
	Prowl 3.3 EC	584	0.52	7.0	5.0	4.0	0.0	0.0	0.0	1.0	0.0	0.0	24.0	13.0	6.0	31.0	18.0	10.0	5	1.0	0.0	0.0	5	80.0	45.0	25.0	32.38	18.21	10.12
	Cotoran 4L	694	0.62	0.01	0.01	0.01	2.96	3.0	5.0	19.04	13.04	5.04	0.0	0.0	0.0	0.01	0.01	0.01	3	22.0	16.04	10.04	1	11.02	8.04	5.04	4.46	3.25	2.04
	Bladex	299	0.27	4.0	2.0	1.79	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	4.0	2.0	1.79	5	1.0	1.0	0.0	4	12.0	7.0	4.48	4.86	2.83	1.81
	Roundup	2128	1.90	5.0	3.0	2.0	0.0	0.0	0.0	0.77	0.73	0.70	60.0	32.0	14.0	65.0	35.0	16.0	1	0.77	0.73	0.70	1	32.89	17.87	8.35	13.31	7.23	3.38
	MSMA 6	1150	1.03	0.01	0.01	0.01	0.0	0.0	0.0	0.96	0.96	0.95	5.0	2.0	1.0	5.01	2.01	1.01	5	0.96	0.96	0.95	1	13.01	5.51	3.0	5.26	2.23	1.21
I[j]	Lorsban 15G	1064	0.95	0.01	0.01	0.01	0.0	0.0	0.0	0.52	0.56	0.48	0.0	0.0	0.0	0.01	0.01	0.01	3	0.52	0.56	0.48	5	1.32	1.42	1.22	0.53	0.57	0.49
	Comite 6.55EC	437	0.39	2.85	2.84	1.66	0.0	0.0	0.0	0.17	0.15	0.13	3.0	2.0	1.0	5.85	4.84	2.66	5	0.17	0.15	0.13	5	15.05	12.48	6.98	6.09	5.05	2.82
	ASANA XL	14	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	3	0.0	0.0	0.0	5	0.02	0.02	0.02	0.01	0.01	0.01
	Temik 15G	1012	0.90	0.01	0.01	0.01	1.37	1.50	3.79	23.05	17.05	6.06	0.0	0.0	0.0	0.01	0.01	0.01	5	24.42	18.55	9.85	4	48.87	37.13	19.73	19.78	15.02	7.98
	Orthene 75S	427	0.38	2.69	1.55	1.54	0.77	0.0	0.01	3.01	2.01	1.01	0.0	0.0	0.0	2.69	1.55	1.54	5	3.78	2.01	1.02	1	8.62	4.88	4.36	3.49	1.97	1.76
	Karate	28	0.02	0.0	0.0	0.86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.86	5	0.0	0.0	0.0	5	0.0	0.0	2.15	0.0	0.0	0.87
F[j]	Bravo 720	1002	0.89	7.0	6.0	5.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	3.0	1.0	12.0	9.0	6.0	5	1.0	0.0	0.0	5	32.50	22.50	15.0	13.15	9.11	6.07
	Vapam	9310	8.30	0.0	0.0	0.0	0.10	1.21	3.79	100.19	72.21	26.20	0.0	0.0	0.0	0.0	0.0	0.0	5	100.29	73.42	29.99	5	250.73	183.55	74.98	101.47	74.28	30.34
	Folicur 3.6F	209	0.19	6.0	5.0	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	7.0	5.0	3.0	5	2.0	1.0	0.0	3	20.50	14.0	7.50	8.30	5.67	3.04
	Rovral 4F	352	0.31	3.0	3.0	2.87	0.0	0.0	0.0	0.31	0.24	0.21	1.0	0.0	0.0	4.0	3.0	2.87	5	0.31	0.24	0.21	3	10.47	7.86	7.49	4.24	3.18	3.03
	Ridomil PC 11G	703	0.63	0.96	0.0	0.0	4.0	6.0	10.0	23.04	16.05	6.04	0.0	1.0	0.0	0.96	1.0	0.0	1	27.04	22.05	16.04	1	14.0	11.53	8.02	5.67	4.66	3.25
O[J]	Pix	314	0.28	0.03	0.03	0.03	0.0	0.0	0.0	0.53	0.53	0.52	34.0	18.0	8.0	34.03	18.03	8.03	1	0.53	0.53	0.52	1	17.28	9.28	4.28	6.99	3.76	1.73
																				Index of rotation							275.68	186.32	94.55

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-9. Pesticide environmental indices for rotation 9 (conventional peanut + striptill cotton, w/ wheat cover)

	Pesticide	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
	(type, name)	(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Dual 8E	1596	1.42	34.01	28.01	19.01	0.20	1.31	2.51	32.06	18.05	6.05	5.0	3.0	2.0	39.01	31.01	21.01	3	32.26	19.36	8.56	2	90.78	65.88	40.08	36.74	26.66	16.22
	Paraquat(Starfire)	603	0.54	0.02	0.02	0.01	0.0	0.0	0.0	0.67	0.64	0.61	26.0	13.0	5.0	26.02	13.02	5.01	3	0.67	0.64	0.61	1	39.37	19.85	7.82	15.93	8.03	3.16
	Storm (Basagran	214	0.19	2.84	2.75	1.76	0.0	0.0	0.01	4.01	2.01	1.01	0.0	1.0	0.0	2.84	3.75	1.76	3	4.01	2.01	1.02	1	6.27	6.63	3.15	2.54	2.68	1.27
	+ Blazer)	133	0.12	2.75	2.69	1.68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.75	2.69	1.68	5	0.0	0.0	0.0	1	6.88	6.73	4.20	2.78	2.72	1.70
	Butyrac	67	0.06	1.26	1.24	0.23	0.0	0.0	0.0	0.07	0.06	0.05	0.0	0.0	0.0	1.26	1.24	0.23	3	0.07	0.06	0.05	3	2.0	1.95	0.42	0.81	0.79	0.17
	Prowl 3.3 EC	584	0.52	6.0	5.0	4.0	0.0	0.0	0.0	1.0	0.0	0.0	23.0	12.0	5.0	29.0	17.0	9.0	5	1.0	0.0	0.0	5	75.0	42.50	22.50	30.35	17.20	9.11
	Cotoran 4L	694	0.62	4.0	3.0	2.0	2.86	3.0	5.0	21.04	13.04	5.04	0.0	0.0	0.0	4.0	3.0	2.0	3	23.90	16.04	10.04	1	17.95	12.52	8.02	7.26	5.07	3.25
	Bladex	299	0.27	3.0	2.0	1.79	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	3.0	2.0	1.79	5	1.0	1.0	0.0	4	9.50	7.0	4.48	3.84	2.83	1.81
	Roundup	2128	1.90	5.0	3.0	2.0	0.0	0.0	0.0	1.98	0.93	0.90	58.0	32.0	14.0	63.0	35.0	16.0	1	1.98	0.93	0.90	1	32.49	17.97	8.45	13.15	7.27	3.42
	MSMA 6	1150	1.03	0.01	0.01	0.01	0.0	0.0	0.0	0.95	0.95	0.94	5.0	2.0	1.0	5.01	2.01	1.01	5	0.95	0.95	0.94	1	13.0	5.50	3.0	5.26	2.23	1.21
I[j]	Lorsban 15G	1064	0.95	5.0	4.0	3.0	0.0	0.0	0.0	0.28	0.23	0.20	17.0	9.0	3.0	22.0	13.0	6.0	3	0.28	0.23	0.20	5	33.70	20.08	9.50	13.64	8.12	3.84
	Comite 6.55EC	437	0.39	2.91	2.88	1.70	0.0	0.0	0.0	0.18	0.15	0.14	3.0	2.0	1.0	5.91	4.88	2.70	5	0.18	0.15	0.14	5	15.23	12.58	7.10	6.16	5.09	2.87
	ASANA XL	14	0.01	0.10	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.01	0.01	3	0.0	0.0	0.0	5	0.15	0.02	0.02	0.06	0.01	0.01
	Temik 15G	1012	0.90	3.0	2.89	1.71	1.35	1.51	3.80	27.05	17.05	6.05	0.0	0.0	0.0	3.0	2.89	1.71	5	28.40	18.56	9.85	4	64.30	44.35	23.98	26.02	17.95	9.70
	Orthene 75S	427	0.38	2.62	1.55	1.54	0.80	0.0	0.01	3.01	2.01	1.01	0.0	0.0	0.0	2.62	1.55	1.54	5	3.81	2.01	1.02	1	8.46	4.88	4.36	3.42	1.97	1.76
	Karate	28	0.02	0.0	0.0	0.86	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.86	5	0.0	0.0	0.0	5	0.0	0.0	2.15	0.0	0.0	0.87
F[j]	Bravo 720	1002	0.89	7.0	6.0	5.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	3.0	1.0	12.0	9.0	6.0	5	1.0	0.0	0.0	5	32.50	22.50	15.0	13.15	9.11	6.07
	Vapam	9310	8.30	0.0	0.0	0.0	0.10	1.21	3.79	101.20	73.21	27.21	0.0	0.0	0.0	0.0	0.0	0.0	5	101.30	74.42	31.0	5	253.25	186.05	77.50	102.49	75.29	31.36
	Folicur 3.6F	209	0.19	6.0	5.0	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	7.0	5.0	3.0	5	2.0	1.0	0.0	3	20.50	14.0	7.50	8.30	5.67	3.04
	Rovral 4F	352	0.31	3.0	3.0	2.90	0.0	0.0	0.0	0.32	0.26	0.23	1.0	0.0	0.0	4.0	3.0	2.90	5	0.32	0.26	0.23	3	10.48	7.89	7.60	4.24	3.19	3.07
	Ridomil PC 11G	532	0.47	0.85	0.0	0.97	3.0	4.0	7.0	17.03	12.04	4.03	0.0	0.0	0.0	0.85	0.0	0.97	1	20.03	16.04	11.03	1	10.44	8.02	6.0	4.22	3.25	2.43
O[J]	Pix	314	0.28	0.03	0.03	0.02	0.0	0.0	0.0	0.77	0.77	0.76	29.0	15.0	6.0	29.03	15.03	6.02	1	0.77	0.77	0.76	1	14.90	7.90	3.39	6.03	3.20	1.37
																					Index of rotation						306.40	208.32	107.72

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-10. Pesticide environmental indices for rotation 10 (striptill peanut + notill cotton, w/ wheat cover)

Pesticide (type, name)		Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
		(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Dual 8E	798	0.71	13.01	11.01	8.01	0.14	1.22	1.36	17.03	10.03	4.03	1.0	1.0	0.0	14.01	12.01	8.01	3	17.17	11.25	5.39	2	38.19	29.27	17.41	15.45	11.84	7.04
	Paraquat(Starfire)	603	0.54	0.02	0.02	0.02	0.0	0.0	0.0	0.06	0.06	0.06	32.0	17.0	7.0	32.02	17.02	7.02	3	0.06	0.06	0.06	1	48.06	25.56	10.56	19.45	10.34	4.27
	Blazer	199	0.18	2.87	2.76	1.79	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	2.87	2.76	1.79	5	1.0	1.0	0.0	1	7.68	7.40	4.48	3.11	2.99	1.81
	Butyrac	67	0.06	1.21	0.17	0.18	0.0	0.0	0.0	0.09	0.08	0.07	0.0	0.0	0.0	1.21	0.17	0.18	3	0.09	0.08	0.07	3	1.95	0.38	0.38	0.79	0.15	0.15
	Prowl 3.3 EC	295	0.26	3.0	3.0	2.0	0.0	0.0	0.0	0.34	0.29	0.26	10.0	6.0	2.0	13.0	9.0	4.0	5	0.34	0.29	0.26	5	33.35	23.23	10.65	13.50	9.40	4.31
	Cotoran 4L	694	0.62	0.01	0.01	0.01	2.85	3.0	5.0	18.03	12.04	4.03	0.0	0.0	0.0	0.01	0.01	0.01	3	20.88	15.04	9.03	1	10.46	7.54	4.53	4.23	3.05	1.83
	Bladex	299	0.27	4.0	3.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	4.0	3.0	2.0	5	1.0	1.0	0.0	4	12.0	9.50	5.0	4.86	3.84	2.02
	Roundup	3192	2.85	8.0	6.0	4.0	0.0	0.0	0.0	1.0	1.0	0.0	106.0	56.0	26.0	114.0	62.0	30.0	1	1.0	1.0	0.0	1	57.50	31.50	15.0	23.27	12.75	6.07
	MSMA 6	1150	1.03	0.01	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	6.0	3.0	1.0	6.01	3.01	1.01	5	0.0	0.0	0.0	1	15.03	7.53	2.53	6.08	3.05	1.02
I[j]	Lorsban 15G	1064	0.95	5.0	4.0	3.0	0.0	0.0	0.0	0.79	0.73	0.69	15.0	8.0	3.0	20.0	12.0	6.0	3	0.79	0.73	0.69	5	31.98	19.83	10.73	12.94	8.02	4.34
	Comite 6.55EC	437	0.39	2.83	2.76	1.64	0.0	0.0	0.0	0.39	0.36	0.34	3.0	2.0	1.0	5.83	4.76	2.64	5	0.39	0.36	0.34	5	15.55	12.80	7.45	6.29	5.18	3.01
	ASANA XL	14	0.01	0.01	0.10	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.10	0.01	3	0.01	0.01	0.01	5	0.04	0.18	0.04	0.02	0.07	0.02
	Temik 15G	1012	0.90	3.0	2.98	1.77	1.35	1.50	3.83	26.05	17.05	6.05	0.0	0.0	0.0	3.0	2.98	1.77	5	27.40	18.55	9.88	4	62.30	44.55	24.19	25.21	18.03	9.79
	Orthene 75S	427	0.38	1.40	1.35	1.28	0.94	0.01	0.02	3.01	2.01	1.01	0.0	0.0	0.0	1.40	1.35	1.28	5	3.95	2.02	1.03	1	5.48	4.39	3.72	2.22	1.77	1.50
	Karate	28	0.02	0.0	0.0	0.92	0.0	0.0	0.0	0.09	0.07	0.06	0.0	0.0	0.0	0.0	0.0	0.92	5	0.09	0.07	0.06	5	0.23	0.18	2.45	0.09	0.07	0.99
F[j]	Bravo 720	1002	0.89	8.0	7.0	5.0	0.0	0.0	0.0	1.0	1.0	0.0	6.0	3.0	1.0	14.0	10.0	6.0	5	1.0	1.0	0.0	5	37.50	27.50	15.0	15.18	11.13	6.07
	Folicur 3.6F	209	0.19	5.0	4.0	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	6.0	4.0	3.0	5	2.0	1.0	0.0	3	18.0	11.50	7.50	7.28	4.65	3.04
	Rovral 4F	261	0.23	2.60	1.55	1.49	0.0	0.0	0.0	0.36	0.32	0.29	0.0	0.0	0.0	2.60	1.55	1.49	5	0.36	0.32	0.29	3	7.04	4.36	4.16	2.85	1.76	1.68
	Ridomil PC 11G	703	0.63	0.47	0.72	0.89	3.0	5.0	9.0	22.04	15.04	5.04	0.0	0.0	0.0	0.47	0.72	0.89	1	25.04	20.04	14.04	1	12.76	10.38	7.47	5.16	4.20	3.02
O[J]	Pix	314	0.28	0.04	0.04	0.03	0.0	0.0	0.0	0.02	0.02	0.02	40.0	22.0	9.0	40.04	22.04	9.03	1	0.02	0.02	0.02	1	20.03	11.03	4.53	8.11	4.46	1.83
																								Index of rotation			176.08	116.78	63.83

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-11. Pesticide environmental indices for rotation 11 (notill corn + conventional peanut, w/ wheat cover)

Pesticide		Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
(type, name)		(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Paraquat	71	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.37	0.32	0.29	4.0	2.0	1.0	4.0	2.0	1.0	3	0.37	0.32	0.29	1	6.19	3.16	1.65	2.50	1.28	0.67
	Dual 8E	2461	2.19	26.01	22.0	15.01	1.38	1.55	3.90	46.09	28.08	10.08	4.0	2.0	1.0	30.01	24.0	16.01	3	47.47	29.63	13.98	1	68.75	50.82	31.01	27.82	20.56	12.55
	Roundup	2128	1.90	4.0	3.0	2.0	0.0	0.0	0.0	1.0	0.0	1.0	49.0	26.0	11.0	53.0	29.0	13.0	1	1.0	0.0	1.0	1	27.0	14.50	7.0	10.93	5.87	2.83
	Prowl 3EC	290	0.26	3.0	2.0	2.93	0.0	0.0	0.0	0.33	0.28	0.25	13.0	8.0	3.0	16.0	10.0	5.93	5	0.33	0.28	0.25	2	40.33	25.28	15.08	16.32	10.23	6.10
	Storm (Blazer	133	0.12	2.73	2.70	1.64	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.73	2.70	1.64	5	1.0	0.0	0.0	3	8.33	6.75	4.10	3.37	2.73	1.66
	+ Basagran)	266	0.24	3.0	2.98	2.90	0.0	0.01	0.02	4.01	3.01	1.01	0.0	0.0	0.0	3.0	2.98	2.90	5	4.01	3.02	1.03	1	9.51	8.96	7.77	3.85	3.63	3.14
	Butyrac	67	0.06	1.25	1.24	0.21	0.0	0.0	0.0	0.06	0.05	0.05	0.0	0.0	0.0	1.25	1.24	0.21	3	0.06	0.05	0.05	3	1.97	1.94	0.39	0.80	0.78	0.16
	Aatrex	978	0.87	13.01	10.01	7.0	1.29	1.42	2.66	22.04	13.04	5.04	0.0	0.0	0.0	13.01	10.01	7.0	5	23.33	14.46	7.70	2	55.86	39.49	25.20	22.60	15.98	10.20
I[j]	Temik 15G	532	0.47	0.01	0.01	0.01	0.19	1.27	1.42	13.03	9.03	3.02	0.0	0.0	0.0	0.01	0.01	0.01	5	13.22	10.30	4.44	4	26.47	20.63	8.91	10.71	8.35	3.60
	Orthene 75S	399	0.36	2.61	1.57	1.51	0.82	0.0	0.01	2.01	2.0	1.0	0.0	0.0	0.0	2.61	1.57	1.51	5	2.83	2.0	1.01	1	7.94	4.93	4.28	3.21	1.99	1.73
	Lorsban 15G	1064	0.95	0.05	0.05	0.04	0.0	0.0	0.0	0.53	0.53	0.46	0.0	0.0	0.0	0.05	0.05	0.04	3	0.53	0.53	0.46	5	1.40	1.40	1.21	0.57	0.57	0.49
	Comite 6.55EC	437	0.39	2.86	2.74	1.64	0.0	0.0	0.0	0.16	0.14	0.13	3.0	2.0	1.0	5.86	4.74	2.64	5	0.16	0.14	0.13	5	15.05	12.20	6.93	6.09	4.94	2.80
	ASANA XL	52	0.05	0.02	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.02	0.01	0.01	3	0.01	0.01	0.01	5	0.06	0.04	0.04	0.02	0.02	0.02
	Counter 15G	523	0.47	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	1.0	0.0	0.0	5	2.50	0.0	0.0	1.01	0.0	0.0
F[j]	Bravo 720	1002	0.89	7.0	6.0	4.0	0.0	0.0	0.0	1.0	0.0	0.98	5.0	3.0	1.0	12.0	9.0	5.0	5	1.0	0.0	0.98	5	32.50	22.50	14.95	13.15	9.11	6.05
	Vapam	9310	8.30	0.0	0.0	0.0	0.09	1.20	3.77	105.20	7.21	26.20	0.0	0.0	0.0	0.0	0.0	0.0	5	105.29	8.41	29.97	5	263.23	21.03	74.93	106.52	8.51	30.32
	Folicur 3.6F	209	0.19	6.0	4.0	3.0	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	7.0	4.0	3.0	5	2.0	1.0	0.0	3	20.50	11.50	7.50	8.30	4.65	3.04
	Rovral 4F	352	0.31	3.0	2.0	2.85	0.0	0.0	0.0	0.28	0.23	0.20	1.0	0.0	0.0	4.0	2.0	2.85	5	0.28	0.23	0.20	3	10.42	5.35	7.43	4.22	2.16	3.0
																								Index of rotation			241.99	101.35	88.36

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-12. Pesticide environmental indices for rotation 12 (striptill peanut + wwht/sb + notill cotton, w/ cover)

	Pesticide (type, name)	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
				PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
		(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j]	Dual 8E	532	0.47	8.0	5.0	4.0	0.09	0.15	1.24	12.02	7.02	2.02	1.0	1.0	0.0	9.0	6.0	4.0	3	12.11	7.17	3.26	2	25.61	16.17	9.26	10.36	6.54	3.75
	Paraquat	48	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.04	0.04	2.0	1.0	0.0	2.0	1.0	0.0	3	0.04	0.04	0.04	1	3.02	1.52	0.02	1.22	0.62	0.01
	Blazer	133	0.12	1.56	1.48	1.46	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.56	1.48	1.46	5	1.0	0.0	0.0	1	4.40	3.70	3.65	1.78	1.50	1.48
	Lasso	374	0.33	2.79	1.58	1.55	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	2.79	1.58	1.55	5	2.0	1.0	0.0	1	7.98	4.45	3.88	3.23	1.80	1.57
	Roundup	2822	2.52	6.0	4.0	3.0	0.0	0.0	0.0	0.89	0.76	0.59	103.0	69.0	51.0	109.0	73.0	54.0	1	0.89	0.76	0.59	1	54.95	36.88	27.30	22.24	14.92	11.05
	Reflex	142	0.13	1.26	0.21	0.22	2.99	3.0	5.0	7.01	4.01	1.01	0.0	0.0	0.0	1.26	0.21	0.22	5	10.0	7.01	6.01	1	8.15	4.03	3.56	3.30	1.63	1.44
	Butyrac	44	0.04	0.14	0.12	0.11	0.0	0.0	0.0	0.06	0.05	0.05	0.0	0.0	0.0	0.14	0.12	0.11	3	0.06	0.05	0.05	3	0.30	0.26	0.24	0.12	0.10	0.10
	Prowl 3.3 EC	231	0.21	2.93	2.85	1.71	0.0	0.0	0.0	0.32	0.24	0.20	10.0	5.0	2.0	12.93	7.85	3.71	5	0.32	0.24	0.20	5	33.13	20.23	9.78	13.41	8.18	3.96
	Cotoran 4L	462	0.41	1.55	1.51	1.46	1.62	2.81	3.0	12.02	8.02	3.02	0.0	0.0	0.0	1.55	1.51	1.46	3	13.64	10.83	6.02	1	9.15	7.68	5.20	3.70	3.11	2.10
	Bladex	200	0.18	4.0	2.74	1.55	0.0	0.0	0.0	1.0	0.0	0.98	0.0	0.0	0.0	4.0	2.74	1.55	5	1.0	0.0	0.98	2	11.0	6.85	4.86	4.45	2.77	1.96
	MSMA 6	234	0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.21	0.18	0.16	2.0	1.0	0.0	2.0	1.0	0.0	5	0.21	0.18	0.16	1	5.11	2.59	0.08	2.07	1.05	0.03
I[j]	Lorsban 15G	709	0.63	0.01	0.01	0.01	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	3	1.0	0.0	0.0	5	2.52	0.02	0.02	1.02	0.01	0.01
	Comite 6.55EC	291	0.26	2.66	1.53	1.46	0.0	0.0	0.0	0.64	0.62	0.59	2.0	1.0	0.0	4.66	2.53	1.46	5	0.64	0.62	0.59	5	13.25	7.87	5.13	5.36	3.18	2.07
	ASANA XL	9	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.0	0.0	0.01	0.01	0.01	3	0.01	0.01	0.01	5	0.04	0.04	0.04	0.02	0.02	0.02
	Temik 15G	567	0.51	0.0	0.01	0.01	0.22	1.31	1.47	13.03	9.03	3.03	0.0	0.0	0.0	0.0	0.01	0.01	5	13.25	10.34	4.50	4	26.50	20.71	9.03	10.72	8.38	3.65
	Orthene 75S	285	0.25	1.24	0.15	0.14	0.0	0.0	0.02	2.0	1.0	0.0	0.0	0.0	0.0	1.24	0.15	0.14	5	2.0	1.0	0.02	1	4.10	0.88	0.36	1.66	0.35	0.15
	Karate	19	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.10	0.09	0.0	0.0	0.0	0.0	0.0	0.0	5	0.12	0.10	0.09	5	0.30	0.25	0.23	0.12	0.10	0.09
F[j]	Bravo 720	668	0.60	6.0	4.0	3.0	0.0	0.0	0.0	1.0	0.0	0.0	4.0	2.0	1.0	10.0	6.0	4.0	5	1.0	0.0	0.0	5	27.50	15.0	10.0	11.13	6.07	4.05
	Folicur 3.6F	139	0.12	4.0	3.0	2.0	0.76	0.0	0.0	2.0	1.0	0.0	1.0	0.0	0.0	5.0	3.0	2.0	5	2.76	1.0	0.0	3	16.64	9.0	5.0	6.73	3.64	2.02
	Rovral 4F	174	0.16	1.53	1.41	1.37	0.0	0.0	0.0	0.24	0.21	0.20	0.0	0.0	0.0	1.53	1.41	1.37	5	0.24	0.21	0.20	3	4.19	3.84	3.73	1.69	1.55	1.51
	Ridomil PC 11G	98	0.09	0.0	0.0	0.0	1.27	1.34	1.42	3.01	2.01	1.01	0.0	0.0	0.0	0.0	0.0	0.0	1	4.28	3.35	2.43	1	2.14	1.68	1.22	0.87	0.68	0.49
O[J]	Pix	209	0.19	0.02	0.02	0.02	0.0	0.0	0.0	0.02	0.01	0.01	24.0	13.0	5.0	24.02	13.02	5.02	1	0.02	0.01	0.01	1	12.02	6.52	2.52	4.86	2.64	1.02
																								Index of rotation			110.06	68.85	42.51

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-13. Pesticide environmental indices for rotation 13 (annual wheat cover)

Pesticide	Dosage(ai)[a]		Annual average loss (g/ha)												To surface water[f]				To ground water[g]				Index					
			PSRO[b]			PLCH[c]			PSSF[d]			PSED[e]			g/ha			HA	g/ha			LC	/ha[h]			/ac[i]		
(type, name)	(g/ha)	(lb/ac)	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%	5%	3%	1%		5%	3%	1%		5%	3%	1%	5%	3%	1%
H[j] Roundup	2128	1.90	6.0	4.0	3.0	0.0	0.0	0.0	1.0	1.0	0.0	13.0	7.0	3.0	19.0	11.0	6.0	1	1.0	1.0	0.0	1	10.0	6.0	3.0	4.05	2.43	1.21
																				Index of rotation						**4.05**	**2.43**	**1.21**

a. Dosage: pesticide applied (adjusted to machine efficiency) (g/ha, lb/a). It is an average value for the whole rotational cycle.
b. PSRO: pesticide in runoff (g/ha)
c. PLCH: pesticide leached below the soil profile (g/ha)
d. PSSF: pesticide in subsurface flow (g/ha)
e. PSED: pesticide in the sediment (g/ha)
f. Sum of PSRO and PSED.
g. Sum of PLCH and PSSF.
h. Formula is 0.5*HA*(PSRO+PSED)+0.5*LC*(PLCH+PSSF)
i. Index per hectare divided by 2.47104.
j. H = herbicide, I = insecticide, F = fungicide, and O = growth regulators. Classification is not strict. E.g. Temik and Vapam act as nematicide also.

Table D-14. Estimated yearly soil loss for rotation 1 (slope: 5%) (conventional cotton - conventional peanut, w/o cover)

	Peanut (tons/ha)			Cotton (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	12.72	21.07	33.78	2.37	18.07	20.44				7.54	19.57	27.11	12.18
1977	1.86	18.20	20.05	1.94	14.37	16.31				1.90	16.28	18.18	8.17
1978	2.44	26.85	29.28	5.81	17.95	23.76				4.12	22.40	26.52	11.92
1979	5.22	18.93	24.15	0.57	14.12	14.68				2.89	16.52	19.42	8.73
1980	1.90	12.89	14.79	1.26	8.42	9.68				1.58	10.65	12.23	5.50
1981	10.55	10.75	21.31	2.38	8.59	10.98				6.47	9.67	16.14	7.25
1982	1.38	17.72	19.10	1.18	13.53	14.71				1.28	15.62	16.90	7.60
1983	1.65	19.62	21.27	0.42	14.10	14.52				1.04	16.86	17.89	8.04
1984	4.17	21.68	25.85	2.69	14.32	17.01				3.43	18.0	21.43	9.63
1985	1.83	13.50	15.33	1.40	13.07	14.48				1.62	13.29	14.90	6.70
1986	2.60	10.02	12.62	3.14	7.21	10.35				2.87	8.61	11.48	5.16
1987	2.36	20.14	22.50	3.03	13.92	16.95				2.70	17.03	19.72	8.86
1988	2.77	10.91	13.68	1.32	7.44	8.76				2.04	9.18	11.22	5.04
1989	41.73	26.30	68.03	4.33	18.80	23.13				23.03	22.55	45.58	20.48
1990	4.88	10.30	15.19	1.82	6.91	8.73				3.35	8.61	11.96	5.37
1991	3.46	15.08	18.53	2.75	13.03	15.78				3.11	14.05	17.16	7.71
1992	5.52	16.25	21.77	2.53	12.81	15.34				4.02	14.53	18.56	8.34
1993	4.15	10.59	14.75	2.42	7.62	10.04				3.29	9.10	12.39	5.57
1994	5.08	25.19	30.26	0.48	12.96	13.43				2.78	19.07	21.85	9.82
Max	41.73	26.85	68.03	5.81	18.80	23.76				23.03	22.55	45.58	20.48
Min	1.38	10.02	12.62	0.42	6.91	8.73				1.04	8.61	11.22	5.04
Ave.	6.12	17.16	23.28	2.20	12.49	14.69				4.16	14.82	18.98	8.53

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-15. Estimated yearly soil loss for rotation 1 (slope: 3%) (conventional cotton - conventional peanut, w/o cover)

	Peanut (tons/ha)			Cotton (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	14.51	9.29	23.80	2.33	7.92	10.25				8.42	8.61	17.03	7.65
1977	2.09	7.54	9.63	1.46	5.58	7.04				1.78	6.56	8.34	3.75
1978	1.61	11.86	13.47	6.18	7.85	14.03				3.89	9.86	13.75	6.18
1979	5.35	8.01	13.36	1.17	5.35	6.52				3.26	6.68	9.94	4.47
1980	6.08	4.98	11.06	1.27	3.42	4.69				3.67	4.20	7.87	3.54
1981	9.53	4.44	13.97	1.39	4.26	5.65				5.46	4.35	9.81	4.41
1982	3.45	7.15	10.59	1.11	5.68	6.79				2.28	6.41	8.69	3.91
1983	1.64	7.96	9.60	0.79	5.76	6.56				1.22	6.86	8.08	3.63
1984	5.71	7.76	13.47	2.06	5.44	7.49				3.88	6.60	10.48	4.71
1985	4.84	5.73	10.57	7.23	5.15	12.38				6.04	5.44	11.48	5.16
1986	1.21	4.25	5.46	2.73	3.15	5.88				1.97	3.70	5.67	2.55
1987	2.51	8.36	10.87	2.98	5.95	8.94				2.75	7.16	9.90	4.45
1988	3.25	4.12	7.37	1.99	2.66	4.65				2.62	3.39	6.01	2.70
1989	44.49	11.76	56.25	2.87	7.55	10.42				23.68	9.65	33.33	14.98
1990	5.51	3.83	9.34	0.89	2.84	3.73				3.20	3.33	6.53	2.94
1991	4.11	6.90	11.01	6.25	5.38	11.63				5.18	6.14	11.32	5.09
1992	6.26	6.82	13.08	1.12	5.47	6.59				3.69	6.15	9.83	4.42
1993	2.89	3.90	6.78	0.83	3.35	4.18				1.86	3.63	5.48	2.46
1994	5.28	9.75	15.03	0.89	4.99	5.88				3.09	7.37	10.45	4.70
Max	44.49	11.86	56.25	7.23	7.92	14.03				23.68	9.86	33.33	14.98
Min	1.21	3.83	5.46	0.79	2.66	3.73				1.22	3.33	5.48	2.46
Ave.	6.86	7.07	13.93	2.40	5.14	7.54				4.63	6.11	10.74	4.83

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-16. Estimated yearly soil loss for rotation 1 (slope: 1%) (conventional cotton - conventional peanut, w/o cover)

	Peanut (tons/ha)			Cotton (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	14.80	2.74	17.54	2.29	2.41	4.70				8.55	2.57	11.12	5.0
1977	2.47	2.02	4.48	1.62	1.58	3.20				2.04	1.80	3.84	1.73
1978	2.29	3.22	5.51	5.86	2.29	8.15				4.07	2.75	6.83	3.07
1979	5.40	2.24	7.64	1.11	1.64	2.75				3.25	1.94	5.19	2.33
1980	10.27	1.34	11.61	0.85	0.94	1.79				5.56	1.14	6.70	3.01
1981	10.29	1.22	11.50	1.56	1.28	2.84				5.93	1.25	7.17	3.22
1982	5.72	2.12	7.85	1.13	1.69	2.82				3.43	1.91	5.33	2.40
1983	1.69	2.16	3.86	1.09	1.65	2.73				1.39	1.91	3.29	1.48
1984	2.39	1.95	4.33	2.06	1.53	3.58				2.22	1.74	3.96	1.78
1985	5.19	1.58	6.77	8.18	1.44	9.63				6.69	1.51	8.20	3.68
1986	2.80	1.12	3.91	2.80	0.89	3.69				2.80	1.01	3.80	1.71
1987	2.59	2.37	4.96	4.40	1.64	6.04				3.49	2.01	5.50	2.47
1988	4.87	1.09	5.96	2.15	0.67	2.83				3.51	0.88	4.39	1.97
1989	44.69	3.23	47.92	6.02	2.30	8.32				25.36	2.76	28.12	12.64
1990	9.10	0.92	10.02	0.97	0.77	1.73				5.04	0.84	5.88	2.64
1991	3.88	1.92	5.80	4.76	1.53	6.28				4.32	1.72	6.04	2.72
1992	10.05	1.99	12.04	1.10	1.60	2.70				5.57	1.80	7.37	3.31
1993	2.87	1.02	3.90	1.42	0.93	2.35				2.14	0.98	3.12	1.40
1994	6.41	2.90	9.31	0.92	1.36	2.28				3.67	2.13	5.80	2.60
Max	44.69	3.23	47.92	8.18	2.41	9.63				25.36	2.76	28.12	12.64
Min	1.69	0.92	3.86	0.85	0.67	1.73				1.39	0.84	3.12	1.40
Ave.	7.78	1.95	9.73	2.65	1.48	4.13				5.21	1.72	6.93	3.11

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-17. Estimated yearly soil loss for rotation 2 (slope: 5%) (conventional peanut – conventional corn w/o cover)

	Corn (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	0.87	10.41	11.28	4.76	18.35	23.11				2.81	14.38	17.20	7.73
1977	0.31	10.41	10.72	3.31	17.44	20.75				1.81	13.92	15.74	7.07
1978	0.08	11.44	11.53	8.62	20.60	29.22				4.35	16.02	20.37	9.15
1979	0.58	11.05	11.63	1.34	16.75	18.09				0.96	13.90	14.86	6.68
1980	0.69	5.55	6.24	1.97	10.68	12.65				1.33	8.12	9.44	4.24
1981	0.82	5.87	6.69	2.25	11.77	14.02				1.54	8.82	10.36	4.65
1982	0.11	11.45	11.56	1.98	13.02	15.0				1.04	12.24	13.28	5.97
1983	0.07	8.80	8.87	0.70	16.75	17.46				0.39	12.78	13.16	5.91
1984	0.99	10.42	11.42	6.81	17.37	24.18				3.90	13.90	17.80	8.0
1985	0.16	9.54	9.71	1.80	12.39	14.19				0.98	10.97	11.95	5.37
1986	0.46	7.60	8.06	6.22	7.68	13.90				3.34	7.64	10.98	4.93
1987	0.62	10.06	10.68	5.48	14.81	20.29				3.05	12.44	15.48	6.96
1988	0.33	5.31	5.64	2.13	8.59	10.72				1.23	6.95	8.18	3.68
1989	2.73	14.54	17.28	5.97	24.52	30.49				4.35	19.53	23.88	10.73
1990	0.40	5.57	5.98	5.68	8.90	14.58				3.04	7.24	10.28	4.62
1991	0.30	8.58	8.88	4.45	15.45	19.90				2.37	12.01	14.39	6.47
1992	0.62	12.34	12.96	8.33	13.67	22.01				4.48	13.01	17.48	7.86
1993	0.23	4.65	4.88	5.73	9.62	15.35				2.98	7.13	10.12	4.55
1994	1.24	12.72	13.96	1.31	15.10	16.41				1.27	13.91	15.19	6.82
Max	2.73	14.54	17.28	8.62	24.52	30.49				4.48	19.53	23.88	10.73
Min	0.07	4.65	4.88	0.70	7.68	10.72				0.39	6.95	8.18	3.68
Ave.	0.61	9.28	9.89	4.15	14.39	18.54				2.38	11.84	14.22	6.39

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-18. Estimated yearly soil loss for rotation 2 (slope: 3%) (conventional peanut - conventional corn w/o cover)

	Corn (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	0.92	4.68	5.60	4.56	8.07	12.63				2.74	6.38	9.11	4.10
1977	0.34	4.47	4.81	2.59	7.49	10.08				1.46	5.98	7.44	3.35
1978	0.08	4.82	4.89	9.15	9.03	18.18				4.61	6.92	11.54	5.18
1979	0.62	4.80	5.41	1.89	6.57	8.46				1.25	5.68	6.94	3.12
1980	1.01	2.33	3.34	1.93	4.40	6.32				1.47	3.36	4.83	2.17
1981	0.74	2.52	3.26	2.71	5.09	7.81				1.73	3.81	5.53	2.49
1982	0.19	4.94	5.12	1.88	5.48	7.35				1.03	5.21	6.24	2.80
1983	0.07	3.72	3.79	2.47	6.90	9.38				1.27	5.31	6.58	2.96
1984	0.74	3.97	4.71	4.79	6.42	11.21				2.77	5.20	7.96	3.58
1985	0.43	4.01	4.44	12.48	5.11	17.59				6.46	4.56	11.02	4.95
1986	0.24	3.19	3.43	5.77	3.31	9.08				3.0	3.25	6.25	2.81
1987	0.37	4.13	4.51	7.52	7.18	14.70				3.95	5.66	9.60	4.32
1988	0.56	2.20	2.76	3.41	3.07	6.48				1.99	2.64	4.62	2.08
1989	2.72	6.70	9.43	7.88	10.84	18.71				5.30	8.77	14.07	6.32
1990	0.58	2.19	2.76	2.11	3.70	5.81				1.34	2.94	4.29	1.93
1991	0.40	3.84	4.24	13.53	6.57	20.10				6.97	5.20	12.17	5.47
1992	0.52	5.45	5.97	5.06	5.57	10.63				2.79	5.51	8.30	3.73
1993	0.24	1.78	2.01	4.39	3.98	8.37				2.31	2.88	5.19	2.33
1994	1.23	5.17	6.39	0.74	5.61	6.35				0.98	5.39	6.37	2.86
Max	2.72	6.70	9.43	13.53	10.84	20.10				6.97	8.77	14.07	6.32
Min	0.07	1.78	2.01	0.74	3.07	5.81				0.98	2.64	4.29	1.93
Ave.	0.63	3.94	4.57	4.99	6.02	11.01				2.81	4.98	7.79	3.50

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-19. Estimated yearly soil loss for rotation 2 (slope: 1%) (conventional peanut - conventional corn w/o cover)

	Corn (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	0.92	1.38	2.30	4.40	2.44	6.85				2.66	1.91	4.57	2.05
1977	0.39	1.27	1.66	2.95	2.31	5.26				1.67	1.79	3.46	1.56
1978	0.11	1.38	1.49	8.72	2.62	11.34				4.42	2.0	6.41	2.88
1979	0.65	1.40	2.05	2.01	1.83	3.85				1.33	1.62	2.95	1.33
1980	1.72	0.53	2.25	1.19	1.22	2.41				1.46	0.87	2.33	1.05
1981	0.83	0.73	1.56	2.98	1.23	4.22				1.91	0.98	2.89	1.30
1982	0.35	1.53	1.88	1.90	1.63	3.53				1.12	1.58	2.70	1.22
1983	0.08	1.03	1.10	2.17	2.03	4.20				1.13	1.53	2.65	1.19
1984	0.80	1.08	1.87	4.82	1.96	6.78				2.81	1.52	4.33	1.94
1985	0.47	1.22	1.69	5.10	1.47	6.58				2.79	1.35	4.13	1.86
1986	0.22	0.87	1.10	5.95	0.90	6.85				3.09	0.88	3.97	1.79
1987	0.36	1.20	1.56	8.39	1.79	10.18				4.37	1.49	5.87	2.64
1988	0.66	0.57	1.23	3.39	0.80	4.19				2.02	0.68	2.71	1.22
1989	2.74	1.99	4.73	8.21	3.04	11.25				5.47	2.52	7.99	3.59
1990	1.16	0.66	1.82	2.32	0.94	3.26				1.74	0.80	2.54	1.14
1991	0.39	1.12	1.51	14.89	2.07	16.96				7.64	1.60	9.24	4.15
1992	1.0	1.54	2.54	4.63	1.67	6.30				2.82	1.60	4.42	1.99
1993	0.21	0.44	0.65	2.67	1.05	3.72				1.44	0.74	2.19	0.98
1994	0.54	1.49	2.02	0.80	1.44	2.23				0.67	1.46	2.13	0.96
Max	2.74		4.73	14.89	3.04	16.96				7.64	2.52	9.24	4.15
Min	0.08	0.44	0.65	0.80	0.80	2.23				0.67	0.68	2.13	0.96
Ave.	0.72	1.13	1.84	4.61	1.71	6.31				2.66	1.42	4.08	1.83

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-20. Estimated yearly soil loss for rotation 3 (slope: 5%)
(conventional peanut - wheat/soybean - conventional cotton, w/o cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Cotton (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.48	22.05	24.53	0.03	7.62	7.64	1.20	18.31	19.51	1.24	15.99	17.23	7.74
1977	16.93	19.47	36.40	0.21	13.25	13.46	2.77	13.67	16.44	6.64	15.46	22.10	9.93
1978	3.08	34.32	37.40	0.08	10.78	10.85	0.34	19.11	19.45	1.16	21.40	22.57	10.14
1979	7.19	22.54	29.73	1.41	16.68	18.08	1.62	13.34	14.96	3.41	17.52	20.92	9.40
1980	6.38	9.85	16.23	3.22	8.15	11.37	0.84	8.39	9.23	3.48	8.80	12.28	5.52
1981	20.44	11.25	31.69	0.90	5.28	6.18	0.44	9.12	9.57	7.26	8.55	15.81	7.11
1982	0.86	16.10	16.96	3.82	19.40	23.22	0.61	12.96	13.56	1.76	16.15	17.91	8.05
1983	8.73	20.27	29.0	2.60	11.20	13.80	1.98	14.60	16.57	4.44	15.35	19.79	8.89
1984	4.77	23.96	28.73	1.39	13.81	15.20	6.21	15.45	21.66	4.12	17.74	21.86	9.83
1985	1.85	18.61	20.47	0.81	11.54	12.35	2.18	11.31	13.49	1.61	13.82	15.44	6.94
1986	2.40	9.37	11.77	4.83	5.61	10.44	13.04	9.98	23.03	6.76	8.32	15.08	6.78
1987	2.75	22.83	25.58	0.03	9.30	9.33	1.85	14.49	16.34	1.54	15.54	17.08	7.68
1988	8.86	10.69	19.55	0.02	2.81	2.83	6.75	6.97	13.72	5.21	6.82	12.03	5.41
1989	2.76	29.48	32.24	0.0	6.31	6.31	3.25	20.89	24.14	2.0	18.89	20.90	9.39
1990	16.32	10.25	26.58	0.04	2.80	2.84	6.08	6.99	13.07	7.48	6.68	14.16	6.36
1991	3.04	17.74	20.78	0.0	3.68	3.68	1.70	13.95	15.65	1.58	11.79	13.37	6.01
1992	3.93	15.56	19.48	0.08	4.26	4.34	2.24	14.75	16.99	2.08	11.52	13.61	6.11
1993	16.60	14.42	31.02	0.0	1.96	1.96	1.11	7.04	8.15	5.90	7.81	13.71	6.16
Max	20.44	34.32	37.40	4.83	19.40	23.22	13.04	20.89	24.14	7.48	21.40	22.57	10.14
Min	0.86	9.37	11.77	0.0	1.96	1.96	0.34	6.97	8.15	1.16	6.68	12.03	5.41
Ave.	7.19	18.26	25.45	1.08	8.58	9.66	3.01	12.85	15.86	3.76	13.23	16.99	7.64

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-21. Estimated yearly soil loss for rotation 3 (slope: 3%)
(conventional peanut - wheat/soybean - conventional cotton, w/o cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Cotton (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.50	9.61	12.11	0.03	3.04	3.06	0.86	8.07	8.93	1.13	6.91	8.04	3.61
1977	16.88	8.15	25.03	0.22	5.85	6.07	2.0	5.29	7.30	6.37	6.43	12.80	5.75
1978	1.63	14.05	15.68	0.09	4.79	4.88	0.28	8.46	8.74	0.67	9.10	9.77	4.39
1979	7.45	8.42	15.87	0.09	7.03	7.12	1.24	5.60	6.84	2.93	7.01	9.94	4.47
1980	6.25	3.80	10.05	8.54	3.31	11.85	1.98	3.40	5.38	5.59	3.50	9.09	4.09
1981	11.68	5.65	17.32	0.93	2.38	3.32	0.41	3.39	3.79	4.34	3.81	8.14	3.66
1982	0.71	7.59	8.30	2.19	8.11	10.30	0.61	5.60	6.21	1.17	7.10	8.27	3.72
1983	8.80	8.27	17.07	2.60	5.04	7.64	1.19	5.40	6.60	4.20	6.24	10.44	4.69
1984	4.33	8.54	12.87	1.38	6.07	7.44	5.77	5.41	11.19	3.83	6.67	10.50	4.72
1985	1.86	7.28	9.14	0.60	4.96	5.56	1.42	4.59	6.01	1.29	5.61	6.90	3.10
1986	2.42	4.01	6.43	3.84	2.66	6.50	8.04	3.70	11.74	4.77	3.46	8.22	3.69
1987	3.63	8.92	12.54	0.02	3.88	3.91	1.72	5.65	7.37	1.79	6.15	7.94	3.57
1988	8.48	4.02	12.50	0.0	1.31	1.31	6.0	2.69	8.69	4.83	2.67	7.50	3.37
1989	3.36	12.19	15.55	0.0	2.37	2.37	0.55	8.19	8.74	1.30	7.58	8.89	3.99
1990	13.17	3.80	16.97	0.04	1.14	1.18	2.05	3.03	5.08	5.09	2.66	7.74	3.48
1991	4.09	8.03	12.12	0.0	1.26	1.26	1.99	6.02	8.0	2.03	5.10	7.13	3.20
1992	3.93	6.74	10.67	0.08	2.07	2.15	2.97	5.57	8.54	2.32	4.80	7.12	3.20
1993	19.24	4.30	23.54	0.0	0.77	0.77	1.02	2.98	4.0	6.75	2.68	9.44	4.24
Max	19.24	14.05	25.03	8.54	8.11	11.85	8.04	8.46	11.74	6.75	9.10	12.80	5.75
Min	0.71	3.80	6.43	0.0	0.77	0.77	0.28	2.69	3.79	0.67	2.66	6.90	3.10
Ave.	6.69	7.41	14.10	1.15	3.67	4.82	2.23	5.17	7.40	3.35	5.42	8.77	3.94

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-22. Estimated yearly soil loss for rotation 3 (slope: 1%) (conventional peanut - wheat/soybean - conventional cotton, w/o cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Cotton (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	7.23	2.83	10.06	0.04	0.84	0.88	0.93	2.42	3.34	2.73	2.03	4.76	2.14
1977	17.06	2.20	19.26	1.01	1.72	2.73	3.06	1.44	4.50	7.04	1.79	8.83	3.97
1978	3.09	3.70	6.79	0.19	1.39	1.59	0.72	2.15	2.87	1.33	2.42	3.75	1.69
1979	8.26	2.56	10.81	1.13	2.23	3.36	0.81	1.55	2.37	3.40	2.11	5.51	2.48
1980	6.04	0.95	6.99	4.60	1.01	5.61	1.27	0.75	2.02	3.97	0.90	4.87	2.19
1981	10.54	1.67	12.21	0.91	0.75	1.66	0.82	1.08	1.90	4.09	1.16	5.26	2.36
1982	1.48	2.26	3.75	0.99	2.54	3.53	0.61	1.68	2.29	1.03	2.16	3.19	1.43
1983	8.86	2.22	11.08	1.90	1.28	3.19	1.81	1.66	3.47	4.19	1.72	5.91	2.66
1984	4.46	2.53	6.99	1.37	1.53	2.89	12.35	1.62	13.96	6.06	1.89	7.95	3.57
1985	2.73	2.24	4.97	0.55	1.74	2.28	3.06	1.32	4.38	2.11	1.77	3.88	1.74
1986	3.96	1.21	5.17	2.98	0.71	3.69	6.22	1.01	7.23	4.39	0.98	5.36	2.41
1987	3.31	2.39	5.70	0.06	0.94	1.0	1.54	1.59	3.14	1.63	1.64	3.28	1.47
1988	10.10	0.92	11.03	0.02	0.34	0.36	4.55	0.67	5.22	4.89	0.65	5.53	2.49
1989	3.01	3.25	6.26	0.0	0.69	0.69	1.09	2.44	3.52	1.36	2.13	3.49	1.57
1990	7.87	0.88	8.75	0.01	0.33	0.34	7.46	0.77	8.23	5.11	0.66	5.77	2.59
1991	2.65	2.56	5.20	0.0	0.42	0.42	2.88	1.35	4.23	1.84	1.44	3.29	1.48
1992	6.07	1.82	7.88	0.04	0.52	0.56	2.99	1.64	4.63	3.03	1.33	4.36	1.96
1993	5.17	1.41	6.58	0.0	0.18	0.18	3.0	0.79	3.79	2.73	0.79	3.52	1.58
Max	17.06	3.70	19.26	4.60	2.54	5.61	12.35	2.44	13.96	7.04	2.42	8.83	3.97
Min	1.48	0.88	3.75	0.0	0.18	0.18	0.61	0.67	1.90	1.03	0.65	3.19	1.43
Ave.	6.22	2.09	8.30	0.88	1.06	1.94	3.06	1.44	4.51	3.39	1.53	4.92	2.21

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-23. Estimated yearly soil loss for rotation 4 (slope: 5%) (conventional peanut – wheat/soybean - notill corn, w/o cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Corn (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.46	19.67	22.13	0.03	7.60	7.63	0.35	11.67	12.01	0.94	12.98	13.93	6.26
1977	16.47	18.17	34.65	0.21	13.18	13.39	0.32	11.27	11.59	5.67	14.21	19.88	8.93
1978	0.53	25.15	25.67	0.07	10.50	10.58	0.04	11.66	11.70	0.21	15.77	15.98	7.18
1979	7.10	18.37	25.47	1.38	16.20	17.58	0.43	10.95	11.39	2.97	15.18	18.14	8.15
1980	4.03	8.48	12.51	3.21	8.11	11.31	0.63	5.02	5.66	2.62	7.21	9.83	4.42
1981	18.23	9.42	27.65	0.89	5.25	6.14	0.13	6.86	6.99	6.42	7.18	13.59	6.11
1982	0.61	12.97	13.58	4.0	17.59	21.59	0.10	11.16	11.26	1.57	13.91	15.47	6.95
1983	4.16	17.65	21.81	2.57	11.11	13.68	0.45	10.10	10.54	2.39	12.95	15.35	6.90
1984	5.57	20.36	25.93	1.36	14.64	16.0	1.68	10.89	12.56	2.87	15.30	18.17	8.16
1985	1.79	15.86	17.65	2.25	11.10	13.35	0.67	9.46	10.13	1.57	12.14	13.71	6.16
1986	2.29	8.69	10.98	4.78	5.64	10.42	3.28	8.81	12.09	3.45	7.71	11.16	5.02
1987	2.20	17.69	19.88	0.03	9.29	9.32	0.67	10.82	11.49	0.96	12.60	13.56	6.09
1988	5.32	8.57	13.88	0.0	2.71	2.72	4.36	5.60	9.96	3.23	5.63	8.85	3.98
1989	2.49	24.41	26.89	0.0	6.35	6.35	1.68	16.27	17.94	1.39	15.67	17.06	7.67
1990	9.77	8.45	18.22	0.04	2.81	2.84	1.40	5.28	6.68	3.74	5.51	9.25	4.16
1991	1.65	15.41	17.06	0.0	3.54	3.54	0.80	10.63	11.42	0.82	9.86	10.67	4.80
1992	1.68	13.73	15.41	0.08	4.28	4.36	1.12	12.80	13.92	0.96	10.27	11.23	5.05
1993	12.32	10.18	22.50	0.0	1.97	1.97	0.30	5.46	5.76	4.21	5.87	10.07	4.53
Max	18.23	25.15	34.65	4.78	17.59	21.59	4.36	16.27	17.94	6.42	15.77	19.88	8.93
Min	0.53	8.45	10.98	0.0	1.97	1.97	0.04	5.02	5.66	0.21	5.51	8.85	3.98
Ave.	5.48	15.18	20.66	1.16	8.44	9.60	1.02	9.71	10.73	2.55	11.11	13.66	6.14

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-24. Estimated yearly soil loss for rotation 4 (slope: 3%)
(conventional peanut - wheat/soybean - notill corn, w/o cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Corn (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	7.07	8.33	15.40	0.04	2.94	2.98	0.23	5.13	5.36	2.44	5.47	7.91	3.56
1977	16.42	7.60	24.02	1.0	5.70	6.70	0.30	4.45	4.75	5.91	5.92	11.82	5.31
1978	2.76	10.18	12.94	0.09	4.67	4.75	0.07	4.55	4.62	0.97	6.47	7.44	3.34
1979	9.17	7.23	16.41	1.13	7.11	8.24	0.19	4.70	4.90	3.50	6.35	9.85	4.43
1980	4.06	3.24	7.30	3.78	3.43	7.21	0.56	2.07	2.63	2.80	2.91	5.71	2.57
1981	16.98	5.27	22.24	0.92	2.37	3.29	0.19	2.85	3.03	6.03	3.50	9.52	4.28
1982	0.83	6.05	6.88	1.42	7.67	9.09	0.10	4.94	5.04	0.78	6.22	7.01	3.15
1983	4.16	7.11	11.27	1.90	4.41	6.30	0.62	4.13	4.74	2.22	5.21	7.44	3.34
1984	2.17	7.99	10.16	1.34	5.19	6.53	2.87	4.24	7.11	2.12	5.81	7.93	3.56
1985	1.42	6.45	7.87	0.54	5.34	5.88	0.33	4.0	4.33	0.77	5.26	6.03	2.71
1986	3.03	3.88	6.91	3.15	2.42	5.57	2.09	3.42	5.52	2.76	3.24	6.0	2.70
1987	3.05	6.47	9.52	0.08	3.58	3.67	0.48	4.30	4.78	1.21	4.78	5.99	2.69
1988	5.61	2.92	8.53	0.01	1.39	1.40	3.71	2.18	5.89	3.11	2.16	5.27	2.37
1989	2.79	9.47	12.26	0.0	2.39	2.39	0.60	6.42	7.02	1.13	6.09	7.22	3.25
1990	9.32	3.20	12.52	0.01	1.21	1.22	1.22	2.19	3.41	3.52	2.20	5.72	2.57
1991	2.25	7.79	10.04	0.0	1.38	1.38	1.44	3.85	5.29	1.23	4.34	5.57	2.50
1992	1.66	5.47	7.12	0.04	1.75	1.79	1.26	4.88	6.14	0.99	4.03	5.02	2.26
1993	4.81	3.34	8.15	0.0	0.70	0.70	0.76	2.0	2.76	1.86	2.01	3.87	1.74
Max	16.98	10.18	24.02	3.78	7.67	9.09	3.71	6.42	7.11	6.03	6.47	11.82	5.31
Min	0.83	2.92	6.88	0.0	0.70	0.70	0.07	2.0	2.63	0.77	2.01	3.87	1.74
Ave.	5.42	6.22	11.64	0.86	3.54	4.39	0.95	3.91	4.85	2.41	4.55	6.96	3.13

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-25. Estimated yearly soil loss for rotation 4 (slope: 1%)
(conventional peanut - wheat/soybean – notill corn, w/o cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Corn (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	7.08	2.43	9.51	0.02	0.91	0.93	0.22	1.53	1.75	2.44	1.62	4.06	1.83
1977	16.57	2.04	18.60	1.0	1.70	2.70	0.50	1.23	1.73	6.02	1.66	7.68	3.45
1978	1.01	2.30	3.31	0.19	1.36	1.54	0.07	1.29	1.36	0.42	1.65	2.07	0.93
1979	8.22	1.97	10.20	0.09	1.99	2.08	0.16	1.35	1.51	2.82	1.77	4.60	2.07
1980	3.91	0.79	4.70	4.57	1.0	5.57	0.15	0.53	0.69	2.88	0.77	3.65	1.64
1981	14.15	1.35	15.50	0.90	0.74	1.64	0.21	0.83	1.04	5.09	0.97	6.06	2.72
1982	1.36	1.77	3.13	1.11	2.72	3.83	0.10	1.53	1.63	0.86	2.01	2.87	1.29
1983	4.18	1.88	6.06	1.89	1.28	3.16	0.23	1.08	1.32	2.10	1.41	3.51	1.58
1984	5.83	1.98	7.82	1.34	1.50	2.84	1.58	1.10	2.69	2.92	1.53	4.45	2.0
1985	2.13	1.74	3.87	0.64	1.61	2.25	0.75	1.18	1.93	1.18	1.51	2.68	1.21
1986	3.03	1.10	4.13	0.73	0.82	1.55	3.57	0.98	4.55	2.44	0.97	3.41	1.53
1987	1.97	1.87	3.84	0.06	1.04	1.09	0.46	1.22	1.67	0.83	1.37	2.20	0.99
1988	3.16	0.75	3.91	0.02	0.43	0.45	3.59	0.56	4.16	2.26	0.58	2.84	1.28
1989	2.40	2.55	4.95	0.01	0.71	0.72	0.66	1.96	2.62	1.02	1.74	2.76	1.24
1990	6.44	0.85	7.29	0.01	0.33	0.34	2.10	0.59	2.69	2.85	0.59	3.44	1.54
1991	3.28	1.73	5.01	0.0	0.41	0.41	1.38	1.11	2.49	1.55	1.08	2.64	1.18
1992	1.70	1.57	3.26	0.07	0.63	0.70	1.26	1.53	2.79	1.01	1.24	2.25	1.01
1993	16.21	0.80	17.01	0.0	0.18	0.18	0.92	0.61	1.53	5.71	0.53	6.24	2.80
Max	16.57	2.55	18.60	4.57	2.72	5.57	3.59	1.96	4.55	6.02	2.01	7.68	3.45
Min	1.01	0.75	3.13	0.0	0.18	0.18	0.07	0.53	0.69	0.42	0.53	2.07	0.93
Ave.	5.70	1.64	7.34	0.70	1.08	1.78	1.0	1.12	2.12	2.47	1.28	3.74	1.68

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-26. Estimated yearly soil loss for rotation 5 (slope: 5%) (conventional cotton - wheat/soybean, w/o cover)

	Cotton (tons/ha)			Wht/sybn (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	4.76	18.48	23.24	0.95	8.89	9.85				2.86	13.69	16.54	7.43
1977	0.62	14.60	15.22	1.33	12.44	13.77				0.98	13.52	14.49	6.51
1978	0.69	18.73	19.42	2.05	10.95	12.99				1.37	14.84	16.20	7.28
1979	3.05	14.40	17.45	0.08	17.09	17.17				1.57	15.74	17.31	7.78
1980	1.35	8.11	9.45	0.98	8.33	9.31				1.16	8.22	9.38	4.22
1981	4.21	9.06	13.28	0.53	6.87	7.41				2.37	7.97	10.34	4.65
1982	0.33	14.09	14.43	0.52	18.01	18.53				0.43	16.05	16.48	7.40
1983	0.28	14.46	14.73	0.08	14.48	14.56				0.18	14.47	14.65	6.58
1984	3.38	14.44	17.83	11.29	16.03	27.32				7.33	15.24	22.57	10.14
1985	0.82	12.79	13.61	0.96	11.07	12.04				0.89	11.93	12.83	5.76
1986	1.36	6.97	8.33	1.71	5.91	7.62				1.53	6.44	7.97	3.58
1987	2.99	13.93	16.92	0.01	3.80	3.81				1.50	8.87	10.37	4.66
1988	0.92	7.75	8.67	0.0	1.74	1.74				0.46	4.75	5.21	2.34
1989	5.63	22.45	28.08	0.01	5.42	5.42				2.82	13.93	16.75	7.53
1990	1.91	8.20	10.11	0.02	2.84	2.86				0.97	5.52	6.48	2.91
1991	1.50	12.08	13.58	0.0	3.15	3.15				0.75	7.62	8.37	3.76
1992	2.02	15.29	17.31	0.0	2.90	2.90				1.01	9.09	10.10	4.54
1993	1.31	6.34	7.65	0.02	1.17	1.18				0.66	3.75	4.41	1.98
1994	3.76	13.42	17.18	0.33	6.87	7.20				2.05	10.14	12.19	5.48
Max	5.63	22.45	28.08	11.29	18.01	27.32				7.33	16.05	22.57	10.14
Min	0.28	6.34	7.65	0.0	1.17	1.18				0.18	3.75	4.41	1.98
Ave.	2.15	12.93	15.08	1.10	8.31	9.41				1.63	10.62	12.24	5.50

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-27. Estimated yearly soil loss for rotation 5 (slope: 3%) (conventional cotton - wheat/soybean, w/o cover)

	Cotton (tons/ha)			Wht/sybn (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	5.12	7.71	12.83	0.89	3.93	4.82				3.01	5.82	8.82	3.97
1977	0.62	6.10	6.72	1.05	5.47	6.52				0.84	5.78	6.62	2.97
1978	0.38	7.67	8.05	2.06	4.84	6.90				1.22	6.25	7.47	3.36
1979	3.07	5.97	9.04	0.26	7.34	7.60				1.67	6.65	8.32	3.74
1980	1.50	2.98	4.48	0.99	3.59	4.57				1.25	3.28	4.53	2.04
1981	3.47	3.83	7.30	0.84	2.41	3.24				2.15	3.12	5.27	2.37
1982	0.55	5.90	6.46	0.99	8.35	9.34				0.77	7.13	7.90	3.55
1983	0.37	5.86	6.23	0.36	4.86	5.22				0.37	5.36	5.72	2.57
1984	3.32	5.92	9.24	6.70	6.83	13.53				5.01	6.37	11.39	5.12
1985	1.62	5.50	7.12	1.87	5.38	7.25				1.74	5.44	7.19	3.23
1986	0.86	2.43	3.30	2.03	2.49	4.52				1.45	2.46	3.91	1.76
1987	2.03	6.20	8.24	0.04	1.57	1.61				1.03	3.89	4.92	2.21
1988	1.68	2.97	4.65	0.0	0.72	0.72				0.84	1.84	2.69	1.21
1989	4.99	9.11	14.10	0.01	2.36	2.37				2.50	5.73	8.23	3.70
1990	4.41	2.75	7.16	0.02	1.33	1.35				2.22	2.04	4.25	1.91
1991	2.19	5.03	7.22	0.0	1.41	1.41				1.09	3.22	4.31	1.94
1992	1.85	6.07	7.92	0.0	1.31	1.31				0.93	3.69	4.62	2.08
1993	0.83	2.18	3.01	0.04	0.42	0.47				0.43	1.30	1.74	0.78
1994	4.62	5.67	10.29	0.04	2.94	2.98				2.33	4.30	6.63	2.98
Max	5.12	9.11	14.10	6.70	8.35	13.53				5.01	7.13	11.39	5.12
Min	0.37	2.18	3.01	0.0	0.42	0.47				0.37	1.30	1.74	0.78
Ave.	2.29	5.26	7.55	0.96	3.55	4.51				1.62	4.40	6.03	2.71

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-28. Estimated yearly soil loss for rotation 5 (slope: 1%) (conventional cotton - wheat/soybean, w/o cover)

	Cotton (tons/ha)			Wht/sybn (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	5.19	2.30	7.49	0.83	1.16	1.99				3.01	1.73	4.74	2.13
1977	0.61	1.60	2.21	1.25	1.75	3.0				0.93	1.68	2.61	1.17
1978	0.75	2.24	2.99	2.07	1.39	3.46				1.41	1.81	3.22	1.45
1979	3.08	1.65	4.74	0.13	2.19	2.33				1.61	1.92	3.53	1.59
1980	3.27	0.65	3.91	0.69	1.05	1.74				1.98	0.85	2.82	1.27
1981	4.50	1.09	5.58	0.84	0.77	1.61				2.67	0.93	3.60	1.62
1982	0.64	1.74	2.38	0.99	2.74	3.73				0.82	2.24	3.06	1.37
1983	0.67	1.50	2.16	0.36	1.48	1.83				0.51	1.49	2.0	0.90
1984	2.96	1.31	4.26	7.25	1.87	9.12				5.10	1.59	6.69	3.01
1985	1.64	1.78	3.42	1.64	1.45	3.09				1.64	1.62	3.25	1.46
1986	0.66	0.76	1.42	2.04	0.76	2.80				1.35	0.76	2.11	0.95
1987	2.04	1.60	3.64	0.06	0.38	0.43				1.05	0.99	2.04	0.92
1988	1.92	0.67	2.58	0.0	0.24	0.24				0.96	0.45	1.41	0.63
1989	5.12	2.51	7.63	0.0	0.71	0.72				2.56	1.61	4.17	1.88
1990	8.06	0.78	8.83	0.02	0.37	0.39				4.04	0.57	4.61	2.07
1991	2.17	1.40	3.57	0.0	0.40	0.40				1.09	0.90	1.98	0.89
1992	2.49	1.89	4.38	0.0	0.41	0.41				1.24	1.15	2.39	1.08
1993	0.88	0.53	1.41	0.01	0.10	0.11				0.45	0.32	0.76	0.34
1994	1.62	1.40	3.02	0.04	0.81	0.85				0.83	1.11	1.93	0.87
Max	8.06	2.51	8.83	7.25	2.74	9.12				5.10	2.24	6.69	3.01
Min	0.61	0.53	1.41	0.0	0.10	0.11				0.45	0.32	0.76	0.34
Ave.	2.54	1.44	3.98	0.96	1.05	2.01				1.75	1.25	3.0	1.35

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-29. Estimated yearly soil loss for rotation 6 (slope: 5%) (notill cotton - wheat/soybean, w/o cover)

	Cotton (tons/ha)			wht/sybn (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	3.11	13.10	16.20	0.94	8.83	9.77				2.03	10.96	12.99	5.84
1977	0.20	12.91	13.10	1.55	13.07	14.61				0.87	12.99	13.86	6.23
1978	0.16	13.34	13.50	2.05	10.89	12.94				1.10	12.12	13.22	5.94
1979	2.06	13.53	15.59	0.27	17.41	17.67				1.16	15.47	16.63	7.47
1980	0.58	5.99	6.57	0.98	8.29	9.27				0.78	7.14	7.92	3.56
1981	2.57	7.43	10.0	0.85	6.57	7.42				1.71	7.0	8.71	3.91
1982	0.09	12.51	12.60	0.54	17.93	18.47				0.32	15.22	15.54	6.98
1983	0.34	11.90	12.24	0.24	13.87	14.11				0.29	12.88	13.17	5.92
1984	1.96	12.31	14.26	6.73	15.35	22.08				4.34	13.83	18.17	8.17
1985	0.72	12.49	13.21	0.33	12.08	12.41				0.52	12.28	12.81	5.76
1986	0.48	9.02	9.50	2.04	5.20	7.24				1.26	7.11	8.37	3.76
1987	1.72	11.89	13.61	0.02	3.81	3.83				0.87	7.85	8.72	3.92
1988	1.63	6.53	8.15	0.0	1.91	1.91				0.81	4.22	5.03	2.26
1989	6.76	20.66	27.42	0.0	5.62	5.63				3.38	13.14	16.52	7.43
1990	0.75	6.0	6.75	0.02	3.19	3.21				0.39	4.59	4.98	2.24
1991	1.08	8.88	9.95	0.0	3.24	3.24				0.54	6.06	6.60	2.97
1992	1.18	13.53	14.72	0.0	2.99	2.99				0.59	8.26	8.86	3.98
1993	0.63	5.16	5.79	0.01	1.0	1.01				0.32	3.08	3.40	1.53
1994	3.07	13.37	16.44	0.04	6.08	6.12				1.55	9.73	11.28	5.07
Max	6.76	20.66	27.42	6.73	17.93	22.08				4.34	15.47	18.17	8.17
Min	0.09	5.16	5.79	0.0	1.0	1.01				0.29	3.08	3.40	1.53
Ave.	1.53	11.08	12.61	0.87	8.28	9.16				1.20	9.68	10.88	4.89

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-30. Estimated yearly soil loss for rotation 6 (slope: 3%) (notill cotton - wheat/soybean, w/o cover)

Year	Cotton (tons/ha)			wht/sybn (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	3.06	5.61	8.67	0.89	3.90	4.79				1.97	4.76	6.73	3.02
1977	0.21	5.43	5.64	1.01	5.92	6.93				0.61	5.68	6.29	2.83
1978	0.18	5.42	5.59	2.05	4.80	6.85				1.11	5.11	6.22	2.80
1979	1.97	5.67	7.64	0.27	7.32	7.59				1.12	6.49	7.61	3.42
1980	0.95	2.57	3.52	0.99	3.56	4.55				0.97	3.07	4.04	1.81
1981	2.19	3.17	5.37	0.85	2.76	3.60				1.52	2.96	4.48	2.02
1982	0.33	5.39	5.72	0.99	8.29	9.28				0.66	6.84	7.50	3.37
1983	0.39	4.74	5.13	0.36	5.82	6.18				0.38	5.28	5.66	2.54
1984	1.96	4.57	6.53	7.32	6.19	13.51				4.64	5.38	10.02	4.50
1985	0.73	5.79	6.52	1.93	4.92	6.85				1.33	5.36	6.68	3.0
1986	0.47	3.85	4.32	2.06	2.34	4.40				1.26	3.09	4.36	1.96
1987	1.71	4.83	6.55	0.04	1.50	1.54				0.87	3.17	4.04	1.82
1988	1.43	2.34	3.77	0.0	0.85	0.85				0.72	1.60	2.31	1.04
1989	6.86	8.49	15.35	0.01	2.28	2.29				3.43	5.39	8.82	3.96
1990	1.51	2.26	3.77	0.02	1.23	1.25				0.77	1.74	2.51	1.13
1991	1.14	3.86	4.99	0.0	1.58	1.58				0.57	2.72	3.29	1.48
1992	1.16	5.84	7.0	0.0	1.14	1.14				0.58	3.49	4.07	1.83
1993	0.54	2.09	2.63	0.04	0.38	0.42				0.29	1.23	1.52	0.68
1994	4.56	5.30	9.85	0.04	2.73	2.77				2.30	4.01	6.31	2.84
Max	6.86	8.49	15.35	7.32	8.29	13.51				4.64	6.84	10.02	4.50
Min	0.18	2.09	2.63	0.0	0.38	0.42				0.29	1.23	1.52	0.68
Ave.	1.65	4.59	6.24	0.99	3.55	4.55				1.32	4.07	5.39	2.42

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-31. Estimated yearly soil loss for rotation 6 (slope: 1%) (notill cotton - wheat/soybean, w/o cover)

Year	Cotton (tons/ha)			wht/sybn (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.94	1.63	4.58	0.83	1.15	1.98				1.89	1.39	3.28	1.47
1977	0.22	1.47	1.69	1.23	1.77	3.0				0.72	1.62	2.35	1.05
1978	0.23	1.42	1.65	2.06	1.37	3.43				1.15	1.40	2.54	1.14
1979	1.90	1.61	3.52	0.13	2.21	2.34				1.02	1.91	2.93	1.32
1980	1.80	0.65	2.45	0.69	1.04	1.73				1.25	0.85	2.09	0.94
1981	2.36	0.92	3.28	0.84	0.85	1.68				1.60	0.88	2.48	1.12
1982	0.62	1.63	2.25	0.99	2.72	3.71				0.81	2.17	2.98	1.34
1983	0.65	1.25	1.91	0.36	1.63	1.99				0.51	1.44	1.95	0.88
1984	1.89	1.15	3.04	7.31	1.86	9.17				4.60	1.51	6.11	2.75
1985	0.77	1.70	2.46	1.70	1.49	3.18				1.23	1.59	2.82	1.27
1986	0.47	1.13	1.60	2.06	0.69	2.75				1.27	0.91	2.17	0.98
1987	1.75	1.34	3.09	0.06	0.44	0.50				0.90	0.89	1.79	0.81
1988	1.53	0.64	2.17	0.0	0.25	0.25				0.76	0.44	1.21	0.54
1989	6.82	2.39	9.20	0.01	0.64	0.65				3.41	1.52	4.93	2.21
1990	3.24	0.62	3.87	0.02	0.35	0.37				1.63	0.48	2.12	0.95
1991	1.12	1.08	2.20	0.0	0.40	0.40				0.56	0.74	1.30	0.59
1992	1.98	1.66	3.63	0.0	0.33	0.33				0.99	1.0	1.98	0.89
1993	0.43	0.51	0.95	0.01	0.11	0.12				0.22	0.31	0.53	0.24
1994	1.10	1.21	2.30	0.04	0.76	0.81				0.57	0.98	1.55	0.70
Max	6.82	2.39	9.20	7.31	2.72	9.17				4.60	2.17	6.11	2.75
Min	0.22	0.51	0.95	0.0	0.11	0.12				0.22	0.31	0.53	0.24
Ave.	1.67	1.26	2.94	0.97	1.06	2.02				1.32	1.16	2.48	1.11

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-32. Estimated yearly soil loss for rotation 7 (slope: 5%) (conventional cotton - conventional peanut, w/ cover)

Year	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	4.90	17.50	22.40	5.29	20.83	26.12				5.10	19.16	24.26	10.90
1977	1.44	15.67	17.11	4.30	20.15	24.45				2.87	17.91	20.78	9.34
1978	0.93	24.78	25.71	8.95	25.70	34.65				4.94	25.24	30.18	13.56
1979	3.30	15.96	19.26	1.40	19.72	21.12				2.35	17.84	20.19	9.07
1980	2.41	9.69	12.09	2.36	12.04	14.39				2.38	10.86	13.24	5.95
1981	6.32	9.07	15.39	2.42	12.70	15.12				4.37	10.89	15.26	6.86
1982	0.62	16.61	17.23	2.13	15.85	17.98				1.37	16.23	17.60	7.91
1983	1.15	15.64	16.79	0.74	19.17	19.91				0.94	17.40	18.35	8.25
1984	3.47	16.93	20.41	10.90	18.23	29.13				7.19	17.58	24.77	11.13
1985	1.26	12.56	13.82	2.66	14.86	17.52				1.96	13.71	15.67	7.04
1986	1.97	8.52	10.49	8.03	8.45	16.48				5.0	8.49	13.48	6.06
1987	2.47	14.88	17.35	5.14	18.06	23.19				3.80	16.47	20.27	9.11
1988	0.83	7.20	8.03	2.11	8.89	10.99				1.47	8.04	9.51	4.28
1989	9.43	17.56	27.0	5.46	26.98	32.44				7.45	22.27	29.72	13.35
1990	2.09	7.29	9.38	4.80	10.41	15.20				3.44	8.85	12.29	5.52
1991	1.33	11.03	12.36	4.26	16.02	20.28				2.79	13.53	16.32	7.33
1992	1.81	12.97	14.78	5.57	14.47	20.04				3.69	13.72	17.41	7.82
1993	1.30	6.42	7.72	3.91	10.45	14.36				2.61	8.43	11.04	4.96
1994	3.94	15.23	19.17	1.03	15.63	16.66				2.48	15.43	17.92	8.05
Max	9.43	24.78	27.0	10.90	26.98	34.65				7.45	25.24	30.18	13.56
Min	0.62	6.42	7.72	0.74	8.45	10.99				0.94	8.04	9.51	4.28
Ave.	2.68	13.45	16.13	4.29	16.24	20.53				3.48	14.85	18.33	8.24

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-33. Estimated yearly soil loss for rotation 7 (slope: 3%) (conventional cotton - conventional peanut, w/ cover)

Year	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	5.40	7.13	12.53	5.08	9.15	14.24				5.24	8.14	13.38	6.01
1977	1.60	6.56	8.16	2.84	8.26	11.10				2.22	7.41	9.63	4.33
1978	0.93	10.53	11.45	9.52	11.32	20.84				5.22	10.92	16.15	7.26
1979	3.33	6.70	10.03	2.12	7.82	9.94				2.73	7.26	9.99	4.49
1980	3.63	4.16	7.79	2.34	4.99	7.32				2.98	4.57	7.55	3.40
1981	5.45	3.76	9.22	2.82	5.26	8.08				4.14	4.51	8.65	3.89
1982	2.71	6.71	9.42	2.26	6.79	9.05				2.49	6.75	9.24	4.15
1983	0.99	6.34	7.33	2.31	7.20	9.51				1.65	6.77	8.42	3.78
1984	2.0	6.70	8.70	7.17	8.56	15.72				4.58	7.63	12.21	5.49
1985	2.89	5.16	8.05	9.92	6.48	16.39				6.40	5.82	12.22	5.49
1986	1.98	3.22	5.20	7.63	3.51	11.14				4.80	3.36	8.17	3.67
1987	1.65	5.90	7.55	7.84	7.67	15.52				4.75	6.78	11.53	5.18
1988	1.78	2.72	4.50	3.29	3.05	6.33				2.53	2.88	5.41	2.43
1989	9.03	7.39	16.43	6.98	10.37	17.35				8.01	8.88	16.89	7.59
1990	3.06	3.14	6.20	1.60	3.30	4.90				2.33	3.22	5.55	2.49
1991	1.79	4.94	6.73	6.99	6.78	13.78				4.39	5.86	10.25	4.61
1992	2.39	5.11	7.50	1.55	6.24	7.80				1.97	5.68	7.65	3.44
1993	0.90	2.59	3.49	2.86	4.99	7.85				1.88	3.79	5.67	2.55
1994	4.98	5.83	10.81	0.78	6.51	7.29				2.88	6.17	9.05	4.07
Max	9.03	10.53	16.43	9.92	11.32	20.84				8.01	10.92	16.89	7.59
Min	0.90	2.59	3.49	0.78	3.05	4.90				1.65	2.88	5.41	2.43
Ave.	2.97	5.50	8.48	4.52	6.75	11.27				3.75	6.13	9.87	4.44

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-34. Estimated yearly soil loss for rotation 7 (slope: 1%) (conventional cotton - conventional peanut, w/ cover)

	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	5.48	2.19	7.68	4.92	2.77	7.68				5.20	2.48	7.68	3.45
1977	1.85	1.73	3.57	3.05	2.34	5.39				2.45	2.03	4.48	2.01
1978	1.35	2.71	4.07	9.11	3.31	12.42				5.23	3.01	8.24	3.70
1979	3.39	1.88	5.27	2.15	2.19	4.34				2.77	2.03	4.80	2.16
1980	6.26	1.04	7.30	1.57	1.39	2.96				3.91	1.21	5.13	2.30
1981	6.34	1.04	7.38	3.16	1.61	4.76				4.75	1.32	6.07	2.73
1982	3.07	1.98	5.05	2.29	2.04	4.33				2.68	2.01	4.69	2.11
1983	1.06	1.66	2.73	2.22	1.97	4.19				1.64	1.82	3.46	1.56
1984	3.84	1.75	5.60	7.46	2.57	10.04				5.65	2.16	7.82	3.51
1985	2.93	1.49	4.42	11.68	1.66	13.33				7.30	1.57	8.88	3.99
1986	1.01	0.84	1.85	7.82	1.01	8.83				4.42	0.92	5.34	2.40
1987	1.65	1.67	3.32	6.89	2.14	9.03				4.27	1.90	6.17	2.77
1988	1.45	0.65	2.10	3.27	0.90	4.17				2.36	0.78	3.13	1.41
1989	9.08	1.93	11.01	5.87	3.04	8.92				7.48	2.49	9.97	4.48
1990	7.55	0.72	8.27	1.77	0.89	2.66				4.66	0.81	5.46	2.46
1991	1.79	1.54	3.33	13.02	1.99	15.01				7.40	1.76	9.17	4.12
1992	1.56	1.42	2.98	1.51	1.71	3.22				1.53	1.57	3.10	1.39
1993	0.91	0.72	1.64	2.07	1.20	3.27				1.49	0.96	2.45	1.10
1994	4.38	1.50	5.89	0.83	1.77	2.60				2.61	1.64	4.24	1.91
Max	9.08	2.71	11.01	13.02	3.31	15.01				7.48	3.01	9.97	4.48
Min	0.91	0.65	1.64	0.83	0.89	2.60				1.49	0.78	2.45	1.10
Ave.	3.42	1.50	4.92	4.77	1.92	6.69				4.09	1.71	5.80	2.61

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-35. Estimated yearly soil loss for rotation 8 (slope: 5%) (notill contton - conventional peanut, w/ cover)

	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.59	12.03	13.63	5.29	20.79	26.08				3.44	16.41	19.85	8.92
1977	1.23	13.31	14.54	4.29	20.21	24.50				2.76	16.76	19.52	8.77
1978	0.70	17.88	18.58	8.97	25.83	34.81				4.84	21.86	26.70	12.0
1979	3.01	14.92	17.93	1.38	19.80	21.18				2.20	17.36	19.56	8.79
1980	2.26	8.39	10.65	2.36	12.09	14.45				2.31	10.24	12.55	5.64
1981	5.79	7.72	13.51	2.48	12.89	15.37				4.14	10.31	14.44	6.49
1982	0.46	15.41	15.88	2.14	15.88	18.02				1.30	15.65	16.95	7.62
1983	1.18	12.69	13.87	0.75	19.56	20.31				0.97	16.12	17.09	7.68
1984	3.52	15.24	18.76	10.96	18.29	29.25				7.24	16.77	24.01	10.79
1985	1.08	11.69	12.77	2.44	14.29	16.73				1.76	12.99	14.75	6.63
1986	2.08	8.47	10.55	8.12	8.50	16.62				5.10	8.48	13.58	6.10
1987	1.98	11.18	13.15	5.15	16.92	22.06				3.56	14.05	17.61	7.91
1988	0.51	5.85	6.36	2.12	8.91	11.03				1.32	7.38	8.70	3.91
1989	7.59	14.92	22.51	5.55	26.04	31.59				6.57	20.48	27.05	12.16
1990	0.92	5.96	6.89	4.79	10.45	15.24				2.86	8.21	11.06	4.97
1991	0.52	7.44	7.96	4.34	16.98	21.32				2.43	12.21	14.64	6.58
1992	1.05	11.30	12.35	5.63	14.50	20.13				3.34	12.90	16.24	7.30
1993	0.49	5.12	5.61	3.58	10.35	13.93				2.03	7.74	9.77	4.39
1994	2.78	14.42	17.20	1.04	15.71	16.75				1.91	15.07	16.98	7.63
Max	7.59	17.88	22.51	10.96	26.04	34.81				7.24	21.86	27.05	12.16
Min	0.46	5.12	5.61	0.75	8.50	11.03				0.97	7.38	8.70	3.91
Ave.	2.04	11.26	13.30	4.28	16.21	20.49				3.16	13.74	16.90	7.59

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-36. Estimated yearly soil loss for rotation 8 (slope: 3%) (notill contton - conventional peanut, w/ cover)

Year	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.83	4.79	6.62	5.08	9.14	14.22				3.45	6.97	10.42	4.68
1977	1.39	5.58	6.96	2.84	8.25	11.09				2.11	6.91	9.03	4.06
1978	0.80	7.25	8.05	9.53	11.35	20.88				5.16	9.30	14.46	6.50
1979	2.97	6.32	9.30	2.16	7.73	9.89				2.57	7.03	9.59	4.31
1980	3.42	3.59	7.01	2.34	5.0	7.34				2.88	4.29	7.17	3.22
1981	5.05	3.23	8.28	2.81	5.14	7.95				3.93	4.18	8.11	3.65
1982	2.41	6.50	8.91	2.27	6.79	9.07				2.34	6.65	8.99	4.04
1983	1.01	5.17	6.18	2.36	7.36	9.72				1.69	6.26	7.95	3.57
1984	2.07	5.62	7.69	7.20	8.57	15.77				4.64	7.09	11.73	5.27
1985	2.66	4.98	7.64	10.18	6.60	16.78				6.42	5.79	12.21	5.49
1986	1.91	3.22	5.13	7.71	3.52	11.24				4.81	3.37	8.18	3.68
1987	1.21	3.73	4.93	7.95	7.80	15.76				4.58	5.77	10.35	4.65
1988	1.04	2.12	3.15	3.31	3.04	6.34				2.17	2.58	4.75	2.13
1989	7.72	6.31	14.02	7.01	10.46	17.47				7.36	8.38	15.75	7.08
1990	1.11	2.42	3.53	1.61	3.29	4.90				1.36	2.86	4.22	1.89
1991	0.78	3.38	4.16	7.08	6.87	13.95				3.93	5.12	9.05	4.07
1992	0.98	4.72	5.70	1.56	6.23	7.79				1.27	5.47	6.74	3.03
1993	0.53	2.10	2.63	2.81	5.08	7.89				1.67	3.59	5.26	2.36
1994	3.49	5.45	8.94	0.78	6.52	7.30				2.14	5.98	8.12	3.65
Max	7.72	7.25	14.02	10.18	11.35	20.88				7.36	9.30	15.75	7.08
Min	0.53	2.10	2.63	0.78	3.04	4.90				1.27	2.58	4.22	1.89
Ave.	2.23	4.55	6.78	4.56	6.78	11.33				3.39	5.66	9.06	4.07

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-37. Estimated yearly soil loss for rotation 8 (slope: 1%) (notill contton - conventional peanut, w/ cover)

Year	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.82	1.46	3.28	4.92	2.76	7.68				3.37	2.11	5.48	2.46
1977	1.63	1.53	3.16	3.06	2.32	5.39				2.35	1.93	4.27	1.92
1978	1.02	1.87	2.89	9.10	3.31	12.42				5.06	2.59	7.66	3.44
1979	2.96	1.81	4.77	2.18	2.21	4.39				2.57	2.01	4.58	2.06
1980	6.01	0.89	6.90	1.57	1.39	2.96				3.79	1.14	4.93	2.22
1981	5.55	0.91	6.45	3.09	1.62	4.71				4.32	1.26	5.58	2.51
1982	2.89	1.92	4.81	2.30	2.04	4.34				2.60	1.98	4.58	2.06
1983	1.09	1.33	2.42	2.27	2.0	4.27				1.68	1.66	3.35	1.50
1984	2.40	1.46	3.87	7.50	2.57	10.07				4.95	2.02	6.97	3.13
1985	2.75	1.45	4.20	10.55	1.68	12.22				6.65	1.57	8.21	3.69
1986	1.82	0.84	2.67	7.90	1.01	8.91				4.86	0.93	5.79	2.60
1987	1.17	1.25	2.42	8.56	2.12	10.68				4.86	1.69	6.55	2.94
1988	1.04	0.50	1.54	3.28	0.90	4.18				2.16	0.70	2.86	1.28
1989	7.63	1.71	9.34	7.42	3.05	10.47				7.53	2.38	9.90	4.45
1990	1.85	0.58	2.43	1.78	0.89	2.66				1.81	0.73	2.55	1.15
1991	0.77	1.04	1.81	8.33	1.99	10.32				4.55	1.52	6.06	2.73
1992	1.22	1.33	2.55	1.52	1.66	3.17				1.37	1.49	2.86	1.29
1993	0.45	0.58	1.02	3.03	1.21	4.24				1.74	0.89	2.63	1.18
1994	3.01	1.46	4.47	0.84	1.76	2.60				1.93	1.61	3.54	1.59
Max	7.63	1.92	9.34	10.55	3.31	12.42				7.53	2.59	9.90	4.45
Min	0.45	0.50	1.02	0.84	0.89	2.60				1.37	0.70	2.55	1.15
Ave.	2.48	1.26	3.74	4.69	1.92	6.62				3.59	1.59	5.18	2.33

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-38. Estimated yearly soil loss for rotation 9 (slope: 5%) (striptill cotton - conventional peanut, w/ cover)

Year	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.77	12.75	14.52	5.52	21.23	26.75				3.65	16.99	20.64	9.28
1977	1.25	13.78	15.03	4.48	20.34	24.82				2.87	17.06	19.93	8.95
1978	0.71	18.11	18.83	9.0	26.51	35.51				4.85	22.31	27.17	12.21
1979	3.36	15.23	18.59	1.42	20.95	22.37				2.39	18.09	20.48	9.20
1980	2.29	8.33	10.62	2.49	12.66	15.15				2.39	10.50	12.89	5.79
1981	5.69	8.10	13.79	2.53	12.99	15.51				4.11	10.54	14.65	6.58
1982	0.49	15.55	16.04	2.17	17.35	19.52				1.33	16.45	17.78	7.99
1983	1.19	13.02	14.21	0.74	19.80	20.54				0.97	16.41	17.37	7.81
1984	4.0	15.36	19.36	12.13	19.15	31.28				8.06	17.26	25.32	11.38
1985	1.10	12.11	13.21	2.64	14.86	17.49				1.87	13.48	15.35	6.90
1986	2.08	8.47	10.55	8.49	8.65	17.14				5.29	8.56	13.85	6.22
1987	2.57	11.27	13.84	5.07	13.30	18.38				3.82	12.29	16.11	7.24
1988	0.57	6.08	6.65	2.11	8.93	11.05				1.34	7.51	8.85	3.98
1989	7.59	15.30	22.89	5.49	24.20	29.69				6.54	19.75	26.29	11.82
1990	1.10	6.10	7.21	5.04	10.42	15.46				3.07	8.26	11.33	5.09
1991	0.53	7.52	8.06	4.35	16.85	21.20				2.44	12.19	14.63	6.58
1992	1.19	11.63	12.82	5.57	11.98	17.56				3.38	11.81	15.19	6.83
1993	0.56	4.88	5.45	3.68	9.89	13.58				2.12	7.39	9.51	4.27
1994	3.16	14.51	17.67	1.05	15.33	16.38				2.10	14.92	17.03	7.65
Max	7.59	18.11	22.89	12.13	26.51	35.51				8.06	22.31	27.17	12.21
Min	0.49	4.88	5.45	0.74	8.65	11.05				0.97	7.39	8.85	3.98
Ave.	2.17	11.48	13.65	4.42	16.07	20.49				3.29	13.78	17.07	7.67

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-39. Estimated yearly soil loss for rotation 9 (slope: 3%) (striptill cotton - conventional peanut, w/ cover)

Year	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.01	5.09	7.10	5.31	9.34	14.65				3.66	7.22	10.88	4.89
1977	1.41	5.77	7.18	2.94	8.39	11.33				2.17	7.08	9.25	4.16
1978	0.81	7.32	8.14	9.56	11.68	21.23				5.19	9.50	14.68	6.60
1979	3.33	6.45	9.77	2.17	8.49	10.66				2.75	7.47	10.22	4.59
1980	3.61	3.57	7.18	2.48	5.26	7.74				3.05	4.41	7.46	3.35
1981	4.93	3.40	8.33	2.86	5.17	8.03				3.89	4.28	8.18	3.67
1982	2.53	6.54	9.06	2.39	7.50	9.89				2.46	7.02	9.48	4.26
1983	1.05	5.32	6.37	2.42	7.54	9.96				1.73	6.43	8.16	3.67
1984	2.48	5.64	8.12	7.88	8.97	16.84				5.18	7.30	12.48	5.61
1985	2.72	5.13	7.86	10.58	6.88	17.46				6.65	6.01	12.66	5.69
1986	1.85	3.22	5.08	8.18	3.62	11.79				5.01	3.42	8.43	3.79
1987	1.56	4.55	6.11	7.86	6.10	13.96				4.71	5.33	10.04	4.51
1988	1.06	2.18	3.23	3.30	3.06	6.36				2.18	2.62	4.80	2.16
1989	7.67	6.47	14.14	7.09	9.44	16.53				7.38	7.95	15.33	6.89
1990	1.34	2.46	3.80	1.64	3.28	4.92				1.49	2.87	4.36	1.96
1991	0.88	3.43	4.31	7.13	6.75	13.88				4.0	5.09	9.10	4.09
1992	1.02	4.78	5.80	1.56	5.33	6.89				1.29	5.06	6.35	2.85
1993	0.63	2.0	2.63	2.90	4.72	7.62				1.77	3.36	5.13	2.30
1994	3.80	5.40	9.20	0.78	6.59	7.38				2.29	6.0	8.29	3.72
Max	7.67	7.32	14.14	10.58	11.68	21.23				7.38	9.50	15.33	6.89
Min	0.63	2.0	2.63	0.78	3.06	4.92				1.29	2.62	4.36	1.96
Ave.	2.35	4.67	7.02	4.69	6.74	11.43				3.52	5.71	9.22	4.15

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-40. Estimated yearly soil loss for rotation 9 (slope: 1%) (striptill cotton - conventional peanut, w/ cover)

	Cotton (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.01	1.55	3.55	5.15	2.82	7.97				3.58	2.18	5.76	2.59
1977	1.65	1.57	3.22	3.08	2.39	5.47				2.37	1.98	4.35	1.95
1978	1.07	1.89	2.96	9.14	3.41	12.56				5.11	2.65	7.76	3.49
1979	3.33	1.84	5.17	2.17	2.37	4.54				2.75	2.11	4.85	2.18
1980	6.10	0.89	6.99	1.71	1.47	3.17				3.90	1.18	5.08	2.28
1981	5.41	0.96	6.36	3.19	1.64	4.83				4.30	1.30	5.60	2.52
1982	2.85	1.93	4.78	2.42	2.28	4.70				2.63	2.11	4.74	2.13
1983	1.19	1.37	2.56	2.33	2.07	4.40				1.76	1.72	3.48	1.56
1984	2.81	1.47	4.28	8.26	2.68	10.94				5.54	2.07	7.61	3.42
1985	2.85	1.50	4.34	10.87	1.78	12.66				6.86	1.64	8.50	3.82
1986	1.77	0.85	2.62	8.35	1.03	9.38				5.06	0.94	6.0	2.70
1987	1.53	1.26	2.80	8.39	1.69	10.07				4.96	1.47	6.43	2.89
1988	1.05	0.52	1.57	3.28	0.91	4.19				2.17	0.71	2.88	1.30
1989	7.59	1.76	9.35	7.44	2.72	10.16				7.51	2.24	9.75	4.38
1990	1.97	0.59	2.56	1.79	0.89	2.69				1.88	0.74	2.62	1.18
1991	0.87	1.06	1.93	8.32	1.98	10.30				4.60	1.52	6.11	2.75
1992	1.31	1.35	2.65	1.53	1.38	2.91				1.42	1.36	2.78	1.25
1993	0.52	0.57	1.09	3.14	1.09	4.23				1.83	0.83	2.66	1.20
1994	3.29	1.44	4.73	0.85	1.80	2.65				2.07	1.62	3.69	1.66
Max	7.59	1.93	9.35	10.87	3.41	12.66				7.51	2.65	9.75	4.38
Min	0.52	0.52	1.09	0.85	0.89	2.65				1.42	0.71	2.62	1.18
Ave.	2.59	1.28	3.87	4.81	1.92	6.73				3.70	1.60	5.30	2.38

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-41. Estimated yearly soil loss for rotation 10(slope: 5%) (notill cotton - striptill peanut, w/ cover)

	Peanut (tons/ha)			Cotton (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	4.55	13.75	18.30	3.85	16.99	20.84				4.20	15.37	19.57	8.79
1977	1.25	12.18	13.42	3.47	14.27	17.74				2.36	13.22	15.58	7.0
1978	1.07	16.87	17.95	5.15	15.44	20.59				3.11	16.15	19.27	8.66
1979	5.27	15.91	21.18	0.78	15.65	16.43				3.03	15.78	18.80	8.45
1980	2.66	8.0	10.65	1.75	9.27	11.02				2.20	8.64	10.84	4.87
1981	8.25	8.33	16.58	1.75	9.38	11.13				5.0	8.85	13.86	6.23
1982	0.66	14.0	14.66	1.03	15.39	16.41				0.84	14.69	15.54	6.98
1983	1.82	12.61	14.43	0.41	13.13	13.53				1.12	12.87	13.98	6.28
1984	3.96	14.03	17.99	6.87	13.81	20.68				5.41	13.92	19.34	8.69
1985	1.52	12.30	13.82	1.48	12.04	13.52				1.50	12.17	13.67	6.14
1986	2.42	9.63	12.05	6.63	7.02	13.64				4.52	8.32	12.85	5.77
1987	1.06	11.96	13.02	1.38	8.81	10.19				1.22	10.39	11.61	5.22
1988	0.64	5.83	6.47	0.72	5.12	5.83				0.68	5.48	6.15	2.76
1989	3.36	18.37	21.73	3.56	14.45	18.01				3.46	16.41	19.87	8.93
1990	1.51	6.24	7.76	1.93	5.37	7.30				1.72	5.81	7.53	3.38
1991	1.02	7.55	8.57	0.90	8.62	9.52				0.96	8.08	9.04	4.06
1992	1.57	13.18	14.75	1.21	11.26	12.47				1.39	12.22	13.61	6.12
1993	0.78	5.41	6.19	1.02	6.55	7.57				0.90	5.98	6.88	3.09
1994	3.42	9.49	12.90	0.60	12.84	13.44				2.01	11.16	13.17	5.92
Max	8.25	18.37	21.73	6.87	16.99	20.84				5.41	16.41	19.87	8.93
Min	0.64	5.41	6.19	0.41	5.12	5.83				0.68	5.48	6.15	2.76
Ave.	2.46	11.35	13.81	2.34	11.34	13.68				2.40	11.34	13.74	6.18

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-42. Estimated yearly soil loss for rotation 10 (slope: 3%) (notill cotton - striptill peanut, w/ cover)

	Peanut (tons/ha)			Cotton (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	5.13	5.65	10.78	3.69	7.40	11.09				4.41	6.52	10.94	4.91
1977	1.36	5.09	6.45	1.95	5.81	7.76				1.66	5.45	7.10	3.19
1978	1.20	6.54	7.74	5.37	6.74	12.11				3.28	6.64	9.92	4.46
1979	5.39	6.79	12.18	1.14	6.22	7.36				3.27	6.50	9.77	4.39
1980	4.11	3.55	7.67	1.82	3.79	5.61				2.97	3.67	6.64	2.98
1981	7.47	3.49	10.96	1.75	3.85	5.60				4.61	3.67	8.28	3.72
1982	1.30	5.85	7.16	1.09	6.77	7.86				1.20	6.31	7.51	3.37
1983	1.42	5.11	6.53	1.76	5.40	7.15				1.59	5.25	6.84	3.08
1984	4.18	5.07	9.25	4.39	6.37	10.76				4.28	5.72	10.0	4.50
1985	4.06	5.22	9.28	8.48	5.24	13.72				6.27	5.23	11.50	5.17
1986	1.09	3.82	4.91	5.97	2.86	8.84				3.53	3.34	6.87	3.09
1987	0.65	4.57	5.22	1.59	3.48	5.07				1.12	4.03	5.15	2.31
1988	1.28	2.0	3.29	1.01	2.35	3.35				1.14	2.17	3.32	1.49
1989	2.50	7.21	9.70	3.49	5.71	9.20				2.99	6.46	9.45	4.25
1990	3.08	2.38	5.45	0.59	2.32	2.91				1.83	2.35	4.18	1.88
1991	1.25	3.44	4.69	2.45	3.34	5.79				1.85	3.39	5.24	2.35
1992	0.70	5.48	6.18	0.34	4.84	5.18				0.52	5.16	5.68	2.55
1993	0.97	2.59	3.55	0.71	2.70	3.40				0.84	2.64	3.48	1.56
1994	4.56	3.89	8.45	0.38	5.10	5.49				2.47	4.50	6.97	3.13
Max	7.47	7.21	12.18	8.48	7.40	13.72				6.27	6.64	11.50	5.17
Min	0.65	2.0	3.29	0.34	2.32	2.91				0.52	2.17	3.32	1.49
Ave.	2.72	4.62	7.34	2.53	4.75	7.28				2.62	4.68	7.31	3.28

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-43. Estimated yearly soil loss for rotation 10 (slope: 1%) (notill cotton - striptill peanut, w/ cover)

	Peanut (tons/ha)			Cotton (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	4.95	1.62	6.58	3.55	2.21	5.76				4.25	1.92	6.17	2.77
1977	1.55	1.39	2.93	2.14	1.79	3.93				1.84	1.59	3.43	1.54
1978	1.73	1.84	3.57	5.07	1.94	7.01				3.40	1.89	5.29	2.38
1979	5.39	1.93	7.32	1.09	1.79	2.88				3.24	1.86	5.10	2.29
1980	6.86	0.76	7.63	1.38	1.06	2.44				4.12	0.91	5.04	2.26
1981	8.25	0.99	9.24	1.93	0.99	2.92				5.09	0.99	6.08	2.73
1982	4.03	1.80	5.83	1.10	2.0	3.10				2.56	1.90	4.46	2.01
1983	1.36	1.31	2.67	1.53	1.52	3.06				1.45	1.41	2.86	1.29
1984	4.16	1.32	5.49	4.57	1.81	6.38				4.37	1.57	5.93	2.67
1985	4.26	1.52	5.78	3.81	1.59	5.40				4.04	1.55	5.59	2.51
1986	1.02	1.10	2.12	6.09	0.81	6.90				3.55	0.95	4.51	2.03
1987	0.62	1.01	1.64	1.60	0.94	2.54				1.11	0.98	2.09	0.94
1988	1.23	0.54	1.78	1.0	0.57	1.58				1.12	0.56	1.68	0.75
1989	2.58	2.06	4.64	5.08	1.80	6.88				3.83	1.93	5.76	2.59
1990	5.51	0.57	6.08	0.61	0.61	1.22				3.06	0.59	3.65	1.64
1991	1.22	0.95	2.17	2.52	1.07	3.59				1.87	1.01	2.88	1.30
1992	1.73	1.61	3.33	0.32	1.45	1.78				1.03	1.53	2.56	1.15
1993	0.91	0.56	1.48	0.59	0.71	1.30				0.75	0.64	1.39	0.62
1994	1.0	0.96	1.95	0.39	1.49	1.89				0.70	1.22	1.92	0.86
Max	8.25	2.06	9.24	6.09	2.21	7.01				5.09	1.93	6.17	2.77
Min	0.62	0.54	1.48	0.32	0.57	1.22				0.70	0.56	1.39	0.62
Ave.	3.07	1.25	4.33	2.34	1.38	3.71				2.70	1.32	4.02	1.81

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-44. Estimated yearly soil loss for rotation 11 (slope: 5%) (notill corn - conventional peanut, w/ cover)

	Corn (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.08	10.21	11.29	4.79	18.48	23.27				2.93	14.35	17.28	7.77
1977	0.71	11.29	11.99	2.91	17.52	20.43				1.81	14.40	16.21	7.29
1978	0.25	13.01	13.26	8.68	20.82	29.49				4.46	16.91	21.38	9.61
1979	1.67	12.14	13.81	1.70	16.42	18.12				1.68	14.28	15.97	7.18
1980	1.60	7.07	8.67	2.04	10.76	12.80				1.82	8.91	10.73	4.82
1981	3.07	6.65	9.73	2.52	11.39	13.91				2.80	9.02	11.82	5.31
1982	0.20	12.33	12.54	1.99	13.44	15.43				1.10	12.89	13.98	6.28
1983	0.44	10.11	10.56	1.18	18.20	19.37				0.81	14.16	14.97	6.73
1984	2.12	12.35	14.48	5.13	17.86	22.99				3.63	15.10	18.73	8.42
1985	1.40	10.28	11.69	8.23	13.83	22.06				4.82	12.05	16.87	7.58
1986	0.57	7.53	8.09	5.64	7.94	13.58				3.10	7.73	10.83	4.87
1987	0.53	9.89	10.42	6.72	16.88	23.61				3.63	13.39	17.01	7.65
1988	0.57	5.72	6.29	3.21	8.75	11.96				1.89	7.24	9.13	4.10
1989	0.77	15.46	16.22	4.53	25.80	30.33				2.65	20.63	23.27	10.46
1990	0.29	5.39	5.68	0.91	9.91	10.82				0.60	7.65	8.25	3.71
1991	0.40	9.13	9.53	10.50	15.54	26.04				5.45	12.33	17.78	7.99
1992	0.26	12.63	12.89	2.44	13.95	16.40				1.35	13.29	14.64	6.58
1993	0.40	5.51	5.91	3.64	9.47	13.11				2.02	7.49	9.51	4.27
1994	0.41	12.56	12.97	0.67	14.13	14.80				0.54	13.35	13.88	6.24
Max	3.07	15.46	16.22	10.50	25.80	30.33				5.45	20.63	23.27	10.46
Min	0.20	5.39	5.68	0.67	7.94	10.82				0.54	7.24	8.25	3.71
Ave.	0.88	9.96	10.84	4.07	14.79	18.87				2.48	12.38	14.86	6.68

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-45. Estimated yearly soil loss for rotation 11 (slope: 3%) (notill corn – conventional peanut, w/ cover)

	Corn (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.05	4.30	5.34	4.58	8.13	12.72				2.81	6.22	9.03	4.06
1977	0.76	4.76	5.52	2.52	8.26	10.78				1.64	6.51	8.15	3.66
1978	0.39	5.66	6.05	9.20	9.12	18.32				4.80	7.39	12.19	5.48
1979	1.78	5.23	7.01	2.06	6.53	8.58				1.92	5.88	7.80	3.50
1980	2.38	2.45	4.83	2.0	4.44	6.44				2.19	3.44	5.63	2.53
1981	2.79	2.81	5.60	2.74	4.23	6.97				2.77	3.52	6.28	2.82
1982	0.49	5.57	6.06	1.93	5.74	7.68				1.21	5.66	6.87	3.09
1983	0.35	4.17	4.52	2.30	7.04	9.34				1.32	5.61	6.93	3.11
1984	2.05	4.35	6.40	5.25	7.94	13.19				3.65	6.14	9.79	4.40
1985	1.46	4.32	5.79	10.62	5.38	16.0				6.04	4.85	10.89	4.90
1986	0.55	3.28	3.83	5.81	3.37	9.18				3.18	3.33	6.51	2.92
1987	0.51	4.65	5.15	6.93	6.45	13.38				3.72	5.55	9.27	4.16
1988	0.46	2.18	2.64	3.12	3.37	6.49				1.79	2.77	4.56	2.05
1989	0.73	6.64	7.38	3.46	10.41	13.88				2.10	8.53	10.63	4.78
1990	0.54	2.13	2.67	1.38	3.58	4.96				0.96	2.85	3.81	1.71
1991	0.40	3.81	4.21	12.59	6.58	19.18				6.50	5.20	11.69	5.26
1992	0.28	5.26	5.53	1.46	6.0	7.46				0.87	5.63	6.50	2.92
1993	0.36	1.88	2.24	2.09	4.15	6.24				1.22	3.02	4.24	1.91
1994	1.31	5.43	6.74	0.64	5.91	6.54				0.97	5.67	6.64	2.98
Max	2.79	6.64	7.38	12.59	10.41	19.18				6.50	8.53	12.19	5.48
Min	0.28	1.88	2.24	0.64	3.37	4.96				0.87	2.77	3.81	1.71
Ave.	0.98	4.15	5.13	4.25	6.14	10.39				2.61	5.14	7.76	3.49

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-46. Estimated yearly soil loss for rotation 11 (slope: 1%) (notill corn - conventional peanut, w/ cover)

	Corn (tons/ha)			Peanut (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	1.03	1.28	2.30	4.43	2.46	6.89				2.73	1.87	4.60	2.07
1977	0.84	1.31	2.15	2.96	2.37	5.33				1.90	1.84	3.74	1.68
1978	0.53	1.57	2.10	8.78	2.65	11.43				4.66	2.11	6.77	3.04
1979	1.89	1.51	3.40	2.03	1.83	3.86				1.96	1.67	3.63	1.63
1980	4.32	0.61	4.93	1.26	1.23	2.49				2.79	0.92	3.71	1.67
1981	3.17	0.80	3.96	2.99	1.18	4.18				3.08	0.99	4.07	1.83
1982	1.20	1.67	2.87	1.96	1.73	3.68				1.58	1.70	3.28	1.47
1983	0.34	1.09	1.43	2.17	1.96	4.13				1.25	1.53	2.78	1.25
1984	2.10	1.16	3.26	5.20	2.29	7.48				3.65	1.73	5.37	2.41
1985	1.57	1.27	2.84	5.26	1.61	6.87				3.41	1.44	4.86	2.18
1986	0.53	0.92	1.44	5.90	0.94	6.84				3.21	0.93	4.14	1.86
1987	0.49	1.29	1.78	7.59	1.81	9.40				4.04	1.55	5.59	2.51
1988	0.53	0.58	1.10	3.12	0.90	4.01				1.82	0.74	2.56	1.15
1989	0.73	1.86	2.59	4.72	3.0	7.72				2.72	2.43	5.15	2.32
1990	1.11	0.56	1.67	1.44	0.96	2.40				1.28	0.76	2.04	0.91
1991	0.39	1.11	1.50	14.73	2.05	16.77				7.56	1.58	9.14	4.11
1992	0.52	1.60	2.13	1.47	1.73	3.21				1.0	1.67	2.67	1.20
1993	0.30	0.47	0.77	2.14	1.15	3.29				1.22	0.81	2.03	0.91
1994	0.53	1.36	1.88	0.70	1.60	2.30				0.61	1.48	2.09	0.94
Max	4.32	1.86	4.93	14.73	3.0	16.77				7.56	2.43	9.14	4.11
Min	0.30	0.47	0.77	0.70	0.90	2.30				0.61	0.74	2.03	0.91
Ave.	1.16	1.16	2.32	4.15	1.76	5.91				2.66	1.46	4.12	1.85

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-47. Estimated yearly soil loss for rotation 12 (slope: 5%) (striptill peanut – wheat/soybean - notill cotton, w/ cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Cotton (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	2.57	18.95	21.52	0.03	7.30	7.33	1.46	18.58	20.04	1.35	14.94	16.30	7.32
1977	14.54	14.69	29.23	0.21	13.40	13.61	3.02	13.83	16.86	5.92	13.97	19.90	8.94
1978	0.79	22.94	23.73	0.08	10.88	10.95	0.37	19.63	20.0	0.41	17.81	18.23	8.19
1979	6.26	20.43	26.70	1.39	16.88	18.27	1.93	13.21	15.14	3.19	16.84	20.03	9.0
1980	6.09	8.0	14.08	3.21	7.92	11.13	1.45	8.68	10.13	3.58	8.20	11.78	5.29
1981	16.39	9.40	25.78	0.90	5.71	6.61	0.58	9.33	9.91	5.95	8.15	14.10	6.34
1982	0.79	17.16	17.95	4.12	18.35	22.47	0.72	13.67	14.39	1.88	16.39	18.27	8.21
1983	7.82	16.73	24.55	2.58	11.06	13.64	1.41	15.50	16.91	3.93	14.43	18.36	8.25
1984	5.66	18.99	24.65	1.39	12.59	13.98	6.66	15.04	21.70	4.57	15.54	20.11	9.04
1985	1.81	15.98	17.79	2.29	12.39	14.68	2.83	11.78	14.60	2.31	13.38	15.69	7.05
1986	2.31	9.48	11.79	4.75	5.71	10.46	12.10	9.74	21.84	6.38	8.31	14.70	6.60
1987	2.32	17.88	20.21	0.03	8.04	8.07	2.12	14.64	16.76	1.49	13.52	15.01	6.75
1988	5.65	8.07	13.72	0.0	2.80	2.81	5.25	7.85	13.09	3.63	6.24	9.87	4.44
1989	1.88	22.28	24.16	0.0	5.79	5.79	4.36	23.05	27.41	2.08	17.04	19.12	8.59
1990	7.57	7.30	14.87	0.04	2.47	2.51	5.77	7.06	12.83	4.46	5.61	10.07	4.53
1991	1.13	10.16	11.30	0.0	3.49	3.49	1.35	12.43	13.78	0.83	8.69	9.52	4.28
1992	1.05	13.78	14.83	0.08	4.36	4.44	1.46	14.57	16.03	0.86	10.90	11.77	5.29
1993	8.63	8.06	16.69	0.0	1.67	1.67	1.06	7.74	8.80	3.23	5.82	9.05	4.07
Max	16.39	22.94	29.23	4.75	18.35	22.47	12.10	23.05	27.41	6.38	17.81	20.11	9.04
Min	0.79	7.30	11.30	0.0	1.67	1.67	0.37	7.06	8.80	0.41	5.61	9.05	4.07
Ave.	5.18	14.46	19.64	1.17	8.38	9.55	2.99	13.13	16.12	3.12	11.99	15.11	6.79

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-48. Estimated yearly soil loss for rotation 12 (slope: 3%) (striptill peanut - wheat/soybean - notill cotton, w/ cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Cotton (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	7.45	8.32	15.78	0.04	2.63	2.67	1.04	8.20	9.24	2.84	6.38	9.23	4.15
1977	14.50	6.26	20.76	1.01	5.32	6.33	3.26	5.56	8.83	6.26	5.72	11.97	5.38
1978	2.98	9.26	12.24	0.09	4.81	4.90	0.94	8.03	8.97	1.34	7.37	8.70	3.91
1979	8.18	8.32	16.50	1.13	6.55	7.68	1.43	5.55	6.98	3.58	6.81	10.39	4.67
1980	6.15	3.02	9.17	3.73	3.30	7.03	1.88	2.95	4.84	3.92	3.09	7.01	3.15
1981	15.03	5.20	20.23	0.93	2.59	3.52	0.89	3.76	4.65	5.62	3.85	9.47	4.25
1982	0.78	7.41	8.19	1.42	7.74	9.16	0.73	5.90	6.63	0.98	7.02	7.99	3.59
1983	7.92	6.85	14.77	1.90	4.51	6.41	1.01	6.32	7.33	3.61	5.89	9.50	4.27
1984	2.0	7.81	9.81	1.35	5.52	6.87	12.88	6.39	19.27	5.41	6.57	11.98	5.39
1985	1.46	6.64	8.09	0.86	4.81	5.67	1.47	4.85	6.32	1.26	5.43	6.70	3.01
1986	3.64	4.29	7.93	3.09	2.41	5.50	6.69	3.86	10.55	4.48	3.52	7.99	3.59
1987	3.0	7.53	10.53	0.08	3.47	3.56	1.79	5.77	7.56	1.63	5.59	7.21	3.24
1988	6.80	3.26	10.05	0.01	1.27	1.28	3.04	3.03	6.07	3.28	2.52	5.80	2.61
1989	2.58	8.92	11.50	0.0	2.54	2.54	1.18	8.78	9.96	1.25	6.75	8.0	3.60
1990	8.47	2.33	10.80	0.01	1.05	1.05	2.76	2.88	5.64	3.75	2.09	5.83	2.62
1991	0.67	4.77	5.45	0.01	1.47	1.48	2.26	4.93	7.19	0.98	3.72	4.70	2.11
1992	1.30	5.72	7.02	0.04	2.06	2.10	1.21	5.65	6.85	0.85	4.48	5.32	2.39
1993	9.21	3.15	12.36	0.0	0.55	0.55	3.28	3.09	6.37	4.17	2.26	6.43	2.89
Max	15.03	9.26	20.76	3.73	7.74	9.16	12.88	8.78	19.27	6.26	7.37	11.98	5.39
Min	0.67	2.33	5.45	0.0	0.55	0.55	0.73	2.88	4.65	0.85	2.09	4.70	2.11
Ave.	5.67	6.06	11.73	0.87	3.48	4.35	2.65	5.30	7.96	3.07	4.95	8.01	3.60

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-49. Estimated yearly soil loss for rotation 12 (slope: 1%) (striptill peanut - wheat/soybean - notill cotton, w/ cover)

	Peanut (tons/ha)			Wht/sybn (tons/ha)			Cotton (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1976	7.45	2.47	9.92	0.02	0.87	0.89	1.12	2.46	3.58	2.86	1.93	4.80	2.16
1977	14.67	1.75	16.42	1.01	1.57	2.58	5.81	1.71	7.52	7.16	1.68	8.84	3.97
1978	3.10	2.42	5.52	0.19	1.40	1.60	0.94	2.30	3.24	1.41	2.04	3.45	1.55
1979	7.29	2.40	9.69	0.10	1.92	2.02	0.99	1.60	2.59	2.79	1.97	4.77	2.14
1980	5.95	0.78	6.73	4.51	0.96	5.47	0.50	0.71	1.21	3.66	0.81	4.47	2.01
1981	12.11	1.39	13.50	0.91	0.81	1.73	1.01	1.04	2.05	4.68	1.08	5.76	2.59
1982	1.28	2.28	3.56	1.18	2.54	3.72	0.74	1.72	2.46	1.06	2.18	3.25	1.46
1983	7.97	1.81	9.78	1.89	1.34	3.23	0.84	1.55	2.39	3.57	1.57	5.13	2.31
1984	7.48	1.86	9.33	1.37	1.64	3.01	7.39	1.76	9.15	5.41	1.75	7.16	3.22
1985	2.18	1.98	4.16	0.63	1.47	2.10	3.65	1.42	5.07	2.15	1.62	3.77	1.70
1986	3.64	1.26	4.90	0.72	0.77	1.49	12.08	0.96	13.05	5.48	1.0	6.48	2.91
1987	2.24	2.12	4.36	0.06	1.03	1.08	1.70	1.84	3.54	1.33	1.66	3.0	1.35
1988	2.69	0.94	3.63	0.02	0.36	0.38	3.06	0.79	3.84	1.92	0.70	2.62	1.18
1989	2.18	2.51	4.69	0.01	0.72	0.73	2.07	2.49	4.57	1.42	1.91	3.33	1.50
1990	5.07	0.54	5.61	0.01	0.28	0.29	7.26	0.73	7.99	4.11	0.52	4.63	2.08
1991	1.63	1.22	2.84	0.0	0.41	0.41	2.23	1.44	3.67	1.29	1.02	2.31	1.04
1992	1.34	1.67	3.01	0.07	0.63	0.70	2.98	1.66	4.64	1.46	1.32	2.78	1.25
1993	10.96	0.74	11.70	0.0	0.13	0.13	3.51	0.74	4.25	4.83	0.53	5.36	2.41
Max	14.67	2.51	16.42	4.51	2.54	5.47	12.08	2.49	13.05	7.16	2.18	8.84	3.97
Min	1.28	0.54	2.84	0.0	0.13	0.13	0.50	0.71	1.21	1.06	0.52	2.31	1.04
Ave.	5.51	1.67	7.19	0.71	1.05	1.75	3.22	1.50	4.71	3.14	1.41	4.55	2.05

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-50. Estimated yearly soil loss for rotation 13 (slope: 5%) (annual wheat cover)

Year	Wheat (tons/ha)			Crop 2 (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1977	0.74	6.20	6.94							0.74	6.20	6.94	3.12
1978	0.12	0.97	1.10							0.12	0.97	1.10	0.49
1979	0.30	1.23	1.52							0.30	1.23	1.52	0.68
1980	0.12	0.70	0.82							0.12	0.70	0.82	0.37
1981	0.09	0.67	0.76							0.09	0.67	0.76	0.34
1982	0.20	1.26	1.46							0.20	1.26	1.46	0.66
1983	0.16	1.28	1.44							0.16	1.28	1.44	0.65
1984	0.47	1.64	2.11							0.47	1.64	2.11	0.95
1985	0.13	1.09	1.21							0.13	1.09	1.21	0.54
1986	0.53	0.42	0.94							0.53	0.42	0.47	0.21
1987	0.02	0.61	0.63							0.02	0.61	0.63	0.28
1988	0.07	0.28	0.35							0.07	0.28	0.35	0.16
1989	0.07	0.81	0.89							0.07	0.81	0.89	0.40
1990	0.01	0.22	0.24							0.01	0.22	0.24	0.11
1991	0.01	0.36	0.37							0.01	0.36	0.37	0.17
1992	0.0	0.49	0.50							0.0	0.49	0.50	0.22
1993	0.0	0.30	0.30							0.0	0.30	0.30	0.14
1994	0.01	0.62	0.63							0.01	0.62	0.63	0.28
1995	0.03	0.29	0.32							0.03	0.29	0.32	0.14
Max	0.74	6.20	6.94							0.74	6.20	6.94	3.12
Min	0.0	0.22	0.24							0.0	0.22	0.24	0.11
Ave.	0.16	1.02	1.19							0.16	1.02	1.16	0.52

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-51. Estimated yearly soil loss for rotation 13 (slope: 3%) (annual wheat cover)

Year	Wheat (tons/ha)			Crop 2 (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1977	1.28	2.86	4.15							1.28	2.86	4.15	1.86
1978	0.17	0.47	0.64							0.17	0.47	0.64	0.29
1979	0.31	0.57	0.88							0.31	0.57	0.88	0.39
1980	0.12	0.30	0.42							0.12	0.30	0.42	0.19
1981	0.08	0.29	0.37							0.08	0.29	0.37	0.16
1982	0.74	0.55	1.29							0.74	0.55	1.29	0.58
1983	0.18	0.53	0.70							0.18	0.53	0.70	0.32
1984	0.45	0.70	1.15							0.45	0.70	1.15	0.51
1985	0.08	0.49	0.57							0.08	0.49	0.57	0.26
1986	0.53	0.18	0.71							0.53	0.18	0.35	0.16
1987	0.02	0.25	0.27							0.02	0.25	0.27	0.12
1988	0.06	0.11	0.17							0.06	0.11	0.17	0.08
1989	0.0	0.33	0.33							0.0	0.33	0.33	0.15
1990	0.01	0.09	0.10							0.01	0.09	0.10	0.04
1991	0.01	0.15	0.16							0.01	0.15	0.16	0.07
1992	0.0	0.20	0.21							0.0	0.20	0.21	0.09
1993	0.0	0.12	0.12							0.0	0.12	0.12	0.05
1994	0.01	0.25	0.26							0.01	0.25	0.26	0.12
1995	0.03	0.11	0.14							0.03	0.11	0.14	0.06
Max	1.28	2.86	4.15							1.28	2.86	4.15	1.86
Min	0.0	0.09	0.10							0.0	0.09	0.10	0.04
Ave.	0.21	0.45	0.66							0.21	0.45	0.65	0.29

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-52. Estimated yearly soil loss for rotation 13 (slope: 1%) (annual wheat cover)

	Wheat (tons/ha)			Crop 2 (tons/ha)			Crop 3 (tons/ha)			Rotational total[a]			
Year	wind	water	total	wind	water	total	wind	water	total	wind	water	sum(m)	sum(e)
1977	1.32	0.93	2.25							1.32	0.93	2.25	1.01
1978	0.24	0.15	0.39							0.24	0.15	0.39	0.18
1979	0.34	0.19	0.52							0.34	0.19	0.52	0.23
1980	0.09	0.09	0.18							0.09	0.09	0.18	0.08
1981	0.09	0.09	0.18							0.09	0.09	0.18	0.08
1982	0.73	0.17	0.90							0.73	0.17	0.90	0.40
1983	0.17	0.15	0.32							0.17	0.15	0.32	0.14
1984	0.47	0.21	0.68							0.47	0.21	0.68	0.30
1985	0.06	0.16	0.22							0.06	0.16	0.22	0.10
1986	0.50	0.05	0.55							0.50	0.05	0.28	0.12
1987	0.01	0.07	0.09							0.01	0.07	0.09	0.04
1988	0.06	0.03	0.09							0.06	0.03	0.09	0.04
1989	0.0	0.09	0.09							0.0	0.09	0.09	0.04
1990	0.01	0.02	0.03							0.01	0.02	0.03	0.01
1991	0.01	0.04	0.05							0.01	0.04	0.05	0.02
1992	0.0	0.05	0.06							0.0	0.05	0.06	0.03
1993	0.0	0.03	0.03							0.0	0.03	0.03	0.01
1994	0.0	0.07	0.07							0.0	0.07	0.07	0.03
1995	0.03	0.03	0.06							0.03	0.03	0.06	0.03
Max	1.32	0.93	2.25							1.32	0.93	2.25	1.01
Min	0.0	0.02	0.03							0.0	0.02	0.03	0.01
Ave.	0.22	0.14	0.36							0.22	0.14	0.42	0.19

a. Rotational total = average of crop totals; sum is the sum of wind and water. m is t/ha, and e is t/ac.

Table D-53. Indices for nitrogen, and phosphorus[a]

Rotation		Nitrogen									Phosphorus						
		YNO3[b]		SSFN[c]		YON[d]		PRKN[e]		N	YP[f]		PRKP[g]		YAP[h]		P
#	slope	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	Index[i]	kg/ha	lb/ac	kg/ha	lb/ac	kg/ha	lb/ac	Index[j]
1	5 %	6.16	5.50	6.11	5.46	29.49	26.33	5.10	4.55	31.80	17.70	15.80	0.06	0.06	0.42	0.38	3.25
	3 %	5.26	4.69	3.86	3.44	17.53	15.65	7.29	6.50	19.72	10.04	8.96	0.08	0.07	0.25	0.22	1.85
	1 %	4.05	3.62	1.45	1.29	9.69	8.65	10.61	9.47	11.11	5.38	4.80	0.10	0.08	0.20	0.17	1.01
2	5 %	6.85	6.11	6.06	5.41	26.15	23.35	4.70	4.20	29.11	13.15	11.74	0.07	0.06	0.20	0.17	2.40
	3 %	5.57	4.97	3.86	3.44	15.74	14.05	6.55	5.85	18.26	7.53	6.72	0.08	0.07	0.20	0.17	1.39
	1 %	4.39	3.92	1.37	1.22	7.89	7.05	9.61	8.58	9.62	3.67	3.28	0.10	0.09	0.14	0.13	0.70
3	5 %	15.04	13.43	8.75	7.81	29.57	26.39	6.07	5.42	37.01	15.97	14.25	0.05	0.05	0.44	0.39	2.94
	3 %	12.45	11.11	5.64	5.04	17.27	15.42	8.68	7.75	23.49	8.72	7.78	0.07	0.06	0.28	0.25	1.62
	1 %	10.90	9.73	2.03	1.82	8.86	7.91	13.14	11.73	13.69	4.34	3.88	0.09	0.08	0.20	0.18	0.83
4	5 %	15.65	13.97	8.64	7.72	27.91	24.92	4.89	4.37	35.76	12.45	11.12	0.06	0.05	0.28	0.25	2.28
	3 %	12.72	11.35	5.61	5.01	16.46	14.70	7.06	6.30	22.88	6.81	6.08	0.07	0.06	0.19	0.17	1.26
	1 %	11.21	10.01	2.02	1.80	8.20	7.32	10.61	9.47	13.23	3.26	2.91	0.09	0.08	0.16	0.14	0.63
5	5 %	20.24	18.07	9.40	8.39	23.44	20.92	4.80	4.29	34.15	12.36	11.03	0.05	0.04	0.34	0.31	2.28
	3 %	16.73	14.93	6.15	5.49	13.23	11.81	7.36	6.57	22.02	6.65	5.94	0.06	0.05	0.32	0.29	1.25
	1 %	13.88	12.39	2.35	2.10	6.31	5.63	11.79	10.53	12.87	3.09	2.76	0.08	0.07	0.22	0.19	0.60
6	5 %	19.62	17.52	8.79	7.84	24.19	21.59	4.61	4.11	34.27	12.77	11.40	0.05	0.04	0.47	0.42	2.37
	3 %	17.24	15.39	5.71	5.10	14.22	12.69	7.10	6.33	22.93	6.99	6.24	0.06	0.05	0.42	0.38	1.33
	1 %	14.29	12.76	2.20	1.96	6.73	6.01	11.10	9.91	13.37	3.10	2.77	0.08	0.07	0.30	0.27	0.62
7	5 %	4.95	4.42	5.24	4.68	30.20	26.96	2.79	2.49	31.51	17.58	15.69	0.06	0.05	0.37	0.33	3.21
	3 %	4.18	3.73	3.42	3.05	17.70	15.80	3.92	3.50	19.20	9.83	8.77	0.07	0.06	0.22	0.20	1.81
	1 %	3.24	2.89	1.27	1.13	9.21	8.22	5.79	5.17	10.24	5.0	4.46	0.09	0.08	0.22	0.20	0.95
8	5 %	6.16	5.50	4.93	4.40	29.76	26.57	2.55	2.28	31.52	18.34	16.37	0.06	0.05	0.71	0.63	3.41
	3 %	5.0	4.46	3.24	2.89	17.70	15.80	3.81	3.40	19.48	10.24	9.14	0.07	0.06	0.48	0.43	1.93
	1 %	3.76	3.36	1.27	1.13	9.25	8.26	5.76	5.14	10.50	5.11	4.56	0.09	0.08	0.30	0.27	0.98
9	5 %	5.72	5.11	4.91	4.38	28.85	25.76	2.63	2.35	30.50	17.05	15.22	0.06	0.05	0.46	0.41	3.14
	3 %	4.79	4.28	3.21	2.87	16.93	15.11	3.95	3.52	18.69	9.53	8.51	0.07	0.06	0.31	0.27	1.77
	1 %	3.58	3.20	1.27	1.13	8.76	7.82	5.90	5.26	9.98	4.79	4.28	0.09	0.08	0.23	0.21	0.91
#	5 %	6.36	5.68	4.75	4.24	25.54	22.80	2.59	2.31	27.76	17.99	16.06	0.06	0.05	0.89	0.79	3.38
	3 %	5.28	4.72	3.06	2.73	14.97	13.36	3.72	3.32	17.09	10.14	9.05	0.07	0.06	0.71	0.63	1.95
	1 %	3.90	3.48	1.19	1.06	7.58	6.76	5.69	5.08	9.03	5.04	4.50	0.09	0.08	0.43	0.38	0.99
#	5 %	5.39	4.81	4.88	4.36	28.37	25.33	2.16	1.92	29.91	13.47	12.03	0.06	0.05	0.22	0.19	2.45
	3 %	4.46	3.98	3.11	2.78	16.63	14.84	3.03	2.70	18.22	7.49	6.69	0.07	0.06	0.19	0.17	1.38
	1 %	3.48	3.11	1.14	1.02	8.19	7.31	4.71	4.20	9.37	3.57	3.19	0.09	0.08	0.14	0.13	0.68
#	5 %	13.02	11.63	8.19	7.31	28.01	25.0	5.70	5.09	34.47	16.18	14.44	0.06	0.05	0.55	0.49	3.0
	3 %	11.55	10.31	5.29	4.72	16.46	14.70	7.90	7.06	22.21	9.06	8.09	0.07	0.06	0.41	0.37	1.70
	1 %	10.02	8.95	1.85	1.65	8.35	7.45	11.80	10.54	12.75	4.60	4.10	0.09	0.08	0.24	0.22	0.88
#	5 %	3.44	3.07	2.15	1.92	5.79	5.17	5.51	4.92	7.66	2.90	2.59	0.08	0.07	0.11	0.10	0.55
	3 %	3.12	2.79	1.30	1.16	3.64	3.25	6.89	6.15	5.22	1.86	1.66	0.10	0.09	0.11	0.10	0.37
	1 %	2.34	2.09	0.60	0.54	2.16	1.93	8.82	7.87	3.24	1.16	1.03	0.12	0.11	0.11	0.10	0.25

a. From EPIC simulation for 20 years using actual rainfall and temperature data from 1976-1995 in Suffolk, Virginia, while long-term average wind data come from EPIC data set for Matthew, Virginia, which is close to the study area.
b. YNO3 is NO3 loss in surface runoff (lb/ac, kg/ha)
c. SSFN is mineral nitrogen loss in subsurface flow (lb/ac, kg/ha)
d. YON is organic nitrogen loss with sediment (lb/ac, kg/ha).
e. PKRN is mineral nitrogen loss in percolate (lb/ac, kg/ha)
f. YP is phosphorus loss with sediment (lb/ac, kg/ha).
g. PRKP is mineral phosphorus loss in percolate (lb/ac, kg/ha).
h. YAP is soluble phosphorus loss in runoff (lb/1000ac, g/ha)
i. Formula is (YNO3+PKRN)*0.5+(SSFN+YON)*0.5
j. Formula is (YP+YAP)*0.5+PRKP*0.5

Appendix E. Calibration of EPIC model

Table E-1. Field data simulation results: peanut[a]

Year	Description[b]	Yield (lb/ac) Field report[c]	Yield (lb/ac) Simulated[d]	Ratio[e]	Note
1991	Suffolk, VA. Dig I. Variety: VNC851 (VAC92R)	3600	3439	1.05	
1992	Suffolk, VA. Dig II. Soil: Eunola loamy fine sand. pH 6.4. History: 1991 corn.	3746	3507	1.07	
1993	Suffolk, VA. Dig II. Soil: Eunola loamy fine sand. pH 6.1. History: 1992 corn.	3517	3533	1.0	
1994	Suffolk, VA. Dig II. Soil: Eunola loamy fine sand. pH: 6.1 History: 1993 corn.	3650	3896	0.94	
1995	Page 24. Treatment #5. Soil: Kenansvill loamy sand. pH 6.2. History: corn 1994; peanut 1993; cotton 1992.	4527	3144	1.44	
	Total =	19040	17519	1.10	
		(ratio of total: 1.09)		(average)	

a. Field experiment data come from P.M.Phipps: Applied Research on Field Crop Disease Control 1995. VPI&SU. Information Series No.368. For 1991-1994, R.W.Mozingo: Peanut Variety and Quality Evaluation Results (1991-1994). VPI&SU. Information Series No.313, 328, 351,
b. Field yield data are of variety VAC92R.
c. Reported yields are based on moisture content of 7%.
d. Special setting in EPIC: Harvest Index (HI) is 0.40 (0.40); Potential Heat Unit (PHU) is 1300; FPP is 60. Leaf decline stage is 95 (75).
e. Ratio = (Field yield) / (simulated yield

Table E-2. Field data simulation results: cotton[a]

Year	Description[b]	Yield (lb/ac) Field report[c]	Yield (lb/ac) Simulated[d]	Ratio[e]	Note
1991	Page 8. Treatment #16. Soil: Nansemond. pH 5.7 History 1989-1990 peanut; 1988 corn	1146.6	1248.1	0.92	Hand picked[f]
1992	page 9. Treatment #13. Soil: Kenansville loamy sand. pH: 5.6 History:peanut 1991; corn 1990	980.13	923.52	1.06	Hand picked[f]
1993	Page12. Treatment #4. Soil: Kenansville loamy sand. pH: 6.27 History: peanut 1992; cotton 1991; peanut 1990.	416.25	463.27	0.90	Hand picked[f]
1994	Page 7. Treatment #5. Soil: Suffolk loamy snad. pH: 6.0 History: 1993 peanut	1253.36	1212.02	1.03	Hand picked[f]
1995	Page 17. Treatment #1. Soil: Kenansville loamy sand. pH: 6.8 History: peanut 1994	994.93	936.35	1.06	Cotton picker[f]
	Total =	4791	4783 (ratio of total: 1.0)	1.0 (average)	

a. Field experiment data come from P.M.Phipps: Applied Research on Field Crop Disease Control (1991-1995). VPI&SU. Information Series No.297, 316, 333, 354, 368.
b. Field yield data are for variety Deltapine 50.
c. Reported yields are in lint+seed. Lint yield (which is simulated) is 37% of reported lint+seed yields.
d. Special setting in EPIC: Harvest Index (HI) is 0.53 (0.40); Potential Heat Unit (PHU) is 1800; FPP is 14.
e. Ratio = (Field yield) / (simulated yield)
f. Yield data from hand-picking and cotton picker might be different (up to 20 percent

Table E-3. Field data simulation results: corn[a]

Year	Description[b]	Yield (bu/ac) Field report[c]	Yield (bu/ac) Simulated[d]	Ratio[e]	Note
1991	Soil series: Nansenmond fine sandy loam	103.30	129.30	0.80	
1992	Soil series:	107.60	139.81	0.77	
1993	Soil series:	60.20	46.51	1.29	
1994	Soil series: Nansenmond fine sandy loam	120.90	128.70	0.94	
1995	Soil series: Nansenmond fine sandy loam	141.60	129.80	1.09	
	Total =	534	574	0.98	
		(ratio of total: 0.93)		(average)	

a. Field experiment data come from D.W. Ball.et al. Virginia Corn Performance Trials in 1990-95. Virginia Cooperative Exension Service, VPI&SU. Pub.424-031 (1991-1995).
b. Field yield data are averages of mid-full maturity varieties in Holland Station.
c. Reported yields are based on moisture content of 15.5%.
d. Special setting in EPIC:Potential Heat Unit (PHU) is 2000; FPP is 8.
e. Ratio = (Field yield) / (simulated yield

Table E-4. Field data simulation results: winter-wheat[a]

Year	Description[b]	Yield (bu/ac) Field report[c]	Yield (bu/ac) Simulated[d]	Ratio[e]	Note
1991	Page 4. Treatment #1. Soil: Goldsboro fine sandy loam. pH 6.3. History: 1990 soybean; 1989 wheat/soybean.	73.90	60.02	1.23	
1992	page 4. Treatment #7. Soil: Goldsboro fine sandy loam. pH 6.1. History: 1991 soybean; 1990 wheat/soybean.	70.40	74.74	0.94	
1993	Page 5. Treatment #1. Soil: Goldsboro fine sandy loam. pH 6.21. History: 1990-1992 wheat/soybean.	64.40	71.16	0.91	
1994	Page 5. Treatment #1. Soil: Suffolk loamy snad. pH: 5.6 History: 1993 peanut	72.40	71.86	1.01	
1995	Page 5. Treatment #2. Soil: Goldsboro fine sandy loam. pH 6.2. History: peanut 1994; soybean 1993.	94.30	76.62	1.23	
	Total =	375	354	1.06	
		(ratio of total: 1.06)		(average)	

a. Field experiment data come from P.M.Phipps: Applied Research on Field Crop Disease Control (1991-1995). VPI&SU. Information Series No.297, 316, 333, 354, 368.
b. Field yield data are of variety Florida 302 for 1991-1993, Coker 916 for 1994, and Wakefield for 1995.
c. Reported yields are based on moisture content of 13.5% and one bushel equals 60 lbs.
d. Special setting in EPIC:Potential Heat Unit (PHU) is 1800; FPP is 120 (100); Leaf decline stage is 0.70(0.60).
e. Ratio = (Field yield) / (simulated yield)

Table E-5. Field data simulation results: soybean[a]

Year	Description[b]	Yield (bu/ac) Field report[c]	Simulated[d]	Ratio[e]	Note
1991	Page 61. Treatment #20. Soil: Kenansville loamy fine sand. pH 6.2. History: 1990 wheat/soybean; 1989 soybean.	47.60	39.22	1.21	Variety not known
1992	page 69. Treatment #2. Soil: Goldsboro fine sandy loam. pH 6.1. History: 1991 soybean/wheat; 1990 soybean.	38.30	42.93	0.89	Variety not known
1993	Page 68. Treatment #6. Soil: Goldsboro fine sandy loam. pH 6.1. History: 1992 & 1990 wheat/soybean. 1991 soybean.	18.30	25.90	0.71	Variety not known
1994	Page 74. Treatment #1. Soil: Goldsboro fine sandy loam. pH 6.2. History: 1993 & 1991 wheat/soybean. 1992 soybean.	42.0	44.41	0.95	Hutcheson
1995[f]					
	Total =	146	152	0.94	
		(ratio of total: 0.96)		(average)	

a. Field experiment data come from P.M.Phipps: Applied Research on Field Crop Disease Control (1991-1995). VPI&SU. Information Series No.297, 316, 333, 354.
b. Field yield data are of variety Hutcheson 1994.
c. Reported yields are based on moisture content of 11% and one bushel equals 60 lbs.
d. Special setting in EPIC: Harvest Index (HI) is 0.24(0.30); Potential Heat Unit (PHU) is 1350; FPP is 60(50.7).
e. Ratio = (Field yield) / (simulated yield)
f. Not simulated for lack of data

Appendix F. Target MOTAD Model in GAMS Program

The following program is the actually used for this study. Three points need to be mentioned here:

1. Data about accounting of hours of machine-used are not further used in the model. So table like TMACH is actually not used here.
2. By changing line 720-721 to only one point instead of 15, then compress line 745-760 to one line of expected shortfall of $300,000, a risk neutral output can be obtained.
3. The command “DISPLAY” in the program is not an efficient way to get the specific results needed. “PUT” statement should be used to communicate with spreadsheets.

```
  1  *
  2  * Risk analysis on Virginia Peanut-Cotton Farm
  3  * GAMS program (Target MOTAD)
  4  *
  5  * Part 2. This part has income risk
  6
  7  SET
  8    I crop types (7 in all)
  9      /PNUT    peanut
 10       CTTN    cotton
 11       CORN    corn
 12       WHT     wheat in double-cropping
 13       SYBN    soybean in double cropping
 14       WCVR    winter wheat cover
 15       ACVR    annual wheat cover/
 16    I2 /CTTN,CORN,WHT,SYBN,WCVR,ACVR/
 17    I3 /PNUT/
 18    J  rotations /ROT1*ROT13/
 19    K  slopes /SLP1*SLP3/
 20    S  states of nature /STATE1*STATE10/
 21    M  seasons /SEASON1*SEASON4/
 22    T  all machinery items used for "fixed machine cost"
 23      /FLPLW    1 flip plow
 24       DISK     2 disk
 25       FLDCLT   2 field cultivator
 26       SUBSIL   1 subsoiler
 27       RWCLT    2 row cultivator
 28       PLANT    2 regular planter
 29       NPLANT   1 notill planter
 30       SPRAYER  2 sprayer
 31       SPREAD   2
 32       ROTMOW   1 rotary mower
 33       DIGGER   2 peanut digger
 34       PNTCOM   2 combine for peanut
 35       COMBINE  1 combine for corn and small grain
 36       PICKER   1 cotton picker
 37       TRA80    1 tractor of 80 hp
 38       TRA110   1 tractor of 110 hp
 39       TRA135   1 tractor of 135 hp/
 40    B  environmental factors
 41      /PESTCD   pesticide index
 42       NITROGEN nitrogen index
 43       PHOSPHOR phosphorus index
 44       SOIL     soil loss /;
 45  SCALAR
 46      PRICELAB parttime labor wage /6.0/
 47      QUOPRICE price of quota peanut /0.251/
 48      ADDPRICE price of addtional peanut /0.055/
 49      TARGET   income target /145458/
 50      QUOTA    peanut quota allocated to the farm /589975/
 51      PROGPAY  payment from crop programs /9018.97/
 52      FIXMACH0 total fixed machine cost(calulated from assumption)
 53      REALFIX0 total fixed mach cost (calculated from optimal plan)
 54      EXPSHORT expected shortfall from target;
 55  PARAMETERS
 56      PRICEA(I) expected crop prices (no peanut here)
 57         /CTTN       0.577
 58          CORN       2.349
 59          WHT        2.956
 60          SYBN       5.325/
 61      RHLAND(K) land by slope constraints RHS
 62         /SLP1       300
```

```
         SLP2       375
         SLP3        75/
     NDXINI(B) initial envir index level (big now for no control)
        /PESTCD        1000000
         NITROGEN      1000000
         PHOSPHOR      1000000
         SOIL          3296.25/
*soil level is 4.395*750 where 4.395 is tolerance level as
*calculated by McSweeny
     RHINDEX(B) environ index control level conventional constraints
     FIXMACH(I,J) per acre fixed machine cost for (I J) (from plan)
     RHLABOR(M) fulltime labor seasonal RHS
         /SEASON1       1250
          SEASON2       1000
          SEASON3       1250
          SEASON4       1000/
     PROB(S) probability of state of nature
         /STATE1  0.1
          STATE2  0.1
          STATE3  0.1
          STATE4  0.1
          STATE5  0.1
          STATE6  0.1
          STATE7  0.1
          STATE8  0.1
          STATE9  0.1
          STATE10 0.1/
     YIELDA(I,J,K)  average crop yield (per acre);

* file LAND.PRN contains table ROTAC(J,I,K) about all
* land and rotational constraints.
INCLUDE    C:\PENG\GAMS\THESIS\LAND.PRN
* note: the table ROTAC(j,i,k) is used to constrain rotational requirement
* note: the subscripts is (j,i,k), not (i,j,k)
TABLE ROTAC(J,I,K) rotational acreage factor for crop i in rotation j
               slp1  slp2  slp3
    Rot1.pnut  0.500 0.500 0.500
    Rot1.cttn  0.500 0.500 0.500
    Rot2.pnut  0.500 0.500 0.500
    Rot2.corn  0.500 0.500 0.500
    Rot3.pnut  0.333 0.333 0.333
    Rot3.cttn  0.333 0.333 0.333
     Rot3.wht  0.333 0.333 0.333
    Rot3.sybn  0.333 0.333 0.333
    Rot4.pnut  0.333 0.333 0.333
    Rot4.corn  0.333 0.333 0.333
     Rot4.wht  0.333 0.333 0.333
    Rot4.sybn  0.333 0.333 0.333
    Rot5.cttn  0.500 0.500 0.500
     Rot5.wht  0.500 0.500 0.500
    Rot5.sybn  0.500 0.500 0.500
    Rot6.cttn  0.500 0.500 0.500
     Rot6.wht  0.500 0.500 0.500
    Rot6.sybn  0.500 0.500 0.500
    Rot6.wcvr  0.500 0.500 0.500
    Rot7.pnut  0.500 0.500 0.500
    Rot7.cttn  0.500 0.500 0.500
    Rot7.wcvr  1.00 1.00 1.00
    Rot8.pnut  0.500 0.500 0.500
    Rot8.cttn  0.500 0.500 0.500
    Rot8.wcvr  1.00 1.00 1.00
    Rot9.pnut  0.500 0.500 0.500
    Rot9.cttn  0.500 0.500 0.500
    Rot9.wcvr  1.00 1.00 1.00
   Rot10.pnut  0.500 0.500 0.500
   Rot10.cttn  0.500 0.500 0.500
   Rot10.wcvr  1.00 1.00 1.00
   Rot11.pnut  0.500 0.500 0.500
   Rot11.corn  0.500 0.500 0.500
   Rot11.wcvr  1.00 1.00 1.00
   Rot12.pnut  0.333 0.333 0.333
   Rot12.cttn  0.333 0.333 0.333
    Rot12.wht  0.333 0.333 0.333
   Rot12.sybn  0.333 0.333 0.333
   Rot12.wcvr  0.667 0.667 0.667
   Rot13.acvr  1.00 1.00 1.00

* file YIELD.prn contains table YIELDS(I,J,K,S)
INCLUDE    C:\PENG\GAMS\THESIS\YIELD.PRN
* In the following table, data for additional peanut is not given (same).
TABLE YIELDS(I,J,K,S)  crop yield (per acre)
                   State1 State2 State3 State4 State5
  Pnut.rot1.slp1    3877   3611   3743   4031   4126
  Pnut.rot1.slp2    3878   3591   3741   4025   4107
  Pnut.rot1.slp3    3878   3573   3740   4016   4072
  Pnut.rot2.slp1    3877   3612   3742   4032   4126
  Pnut.rot2.slp2    3878   3592   3741   4025   4108
  Pnut.rot2.slp3    3878   3575   3739   4017   4073
  Pnut.rot3.slp1    3865   3607   3743   4006   4122
  Pnut.rot3.slp2    3866   3585   3743   3999   4094
  Pnut.rot3.slp3    3866   3560   3741   3994   4056
  Pnut.rot4.slp1    3865   3607   3744   4005   4125
  Pnut.rot4.slp2    3865   3585   3742   3998   4095
```

156	Pnut.rot4.slp3	3865	3560	3741	3994	4056
157	Pnut.rot7.slp1	3877	3609	3745	4037	4122
158	Pnut.rot7.slp2	3878	3588	3742	4034	4092
159	Pnut.rot7.slp3	3879	3563	3741	4025	4054
160	Pnut.rot8.slp1	3877	3609	3745	4037	4122
161	Pnut.rot8.slp2	3878	3588	3742	4034	4092
162	Pnut.rot8.slp3	3879	3563	3741	4025	4054
163	Pnut.rot9.slp1	3877	3609	3745	4037	4121
164	Pnut.rot9.slp2	3878	3588	3742	4034	4092
165	Pnut.rot9.slp3	3879	3563	3741	4025	4054
166	Pnut.rot10.slp1	3489	3248	3371	3634	3709
167	Pnut.rot10.slp2	3490	3230	3368	3631	3683
168	Pnut.rot10.slp3	3491	3207	3367	3623	3650
169	Pnut.rot11.slp1	3877	3610	3744	4037	4122
170	Pnut.rot11.slp2	3878	3588	3742	4034	4092
171	Pnut.rot11.slp3	3878	3563	3741	4025	4055
172	Pnut.rot12.slp1	3479	3250	3369	3604	3704
173	Pnut.rot12.slp2	3480	3237	3369	3598	3667
174	Pnut.rot12.slp3	3480	3218	3368	3593	3627
175	Cttn.rot1.slp1	1247	926	1151	1192	1154
176	Cttn.rot1.slp2	1241	917	1125	1185	1132
177	Cttn.rot1.slp3	1240	903	1096	1178	1110
178	Cttn.rot3.slp1	1247	917	1185	1216	1133
179	Cttn.rot3.slp2	1243	917	1168	1207	1133
180	Cttn.rot3.slp3	1239	904	1150	1198	1113
181	Cttn.rot5.slp1	1180	884	1126	1173	1126
182	Cttn.rot5.slp2	1180	879	1126	1188	1126
183	Cttn.rot5.slp3	1152	871	1076	1185	1072
184	Cttn.rot6.slp1	1180	883	1126	1173	1126
185	Cttn.rot6.slp2	1165	879	1103	1188	1100
186	Cttn.rot6.slp3	1152	871	1076	1185	1072
187	Cttn.rot7.slp1	1245	925	1156	1206	1149
188	Cttn.rot7.slp2	1238	916	1136	1194	1125
189	Cttn.rot7.slp3	1237	898	1114	1183	1101
190	Cttn.rot8.slp1	1245	925	1156	1206	1149
191	Cttn.rot8.slp2	1238	916	1136	1194	1125
192	Cttn.rot8.slp3	1237	898	1114	1183	1101
193	Cttn.rot9.slp1	1245	925	1156	1206	1149
194	Cttn.rot9.slp2	1238	916	1136	1194	1125
195	Cttn.rot9.slp3	1237	898	1114	1183	1101
196	Cttn.rot10.slp1	1245	927	1156	1207	1150
197	Cttn.rot10.slp2	1238	918	1137	1195	1126
198	Cttn.rot10.slp3	1237	899	1115	1184	1102
199	Cttn.rot12.slp1	1247	922	1186	1227	1116
200	Cttn.rot12.slp2	1243	922	1169	1216	1116
201	Cttn.rot12.slp3	1239	909	1157	1209	1085
202	Corn.rot2.slp1	108.8	92.1	102.3	101.4	107.0
203	Corn.rot2.slp2	107.9	92.1	101.4	102.3	106.0
204	Corn.rot2.slp3	107.9	91.1	100.4	101.4	106.0
205	Corn.rot4.slp1	112.5	94.9	112.5	110.7	117.2
206	Corn.rot4.slp2	111.6	94.9	111.6	110.7	117.2
207	Corn.rot4.slp3	110.7	93.9	109.7	110.7	115.3
208	Corn.rot11.slp1	107.9	90.2	101.4	104.2	107.0
209	Corn.rot11.slp2	107.9	90.2	100.4	103.2	107.0
210	Corn.rot11.slp3	107.0	89.3	99.5	102.3	106.0
211	Wht.rot3.slp1	77.4	75.3	92.2	86.9	75.3
212	Wht.rot3.slp2	77.4	74.2	91.2	86.9	74.2
213	Wht.rot3.slp3	76.3	74.2	91.2	86.9	73.1
214	Wht.rot4.slp1	77.4	75.3	92.2	86.9	74.2
215	Wht.rot4.slp2	77.4	74.2	91.2	86.9	73.1
216	Wht.rot4.slp3	77.4	74.2	91.2	86.9	73.1
217	Wht.rot5.slp1	88.0	71.0	73.1	85.9	99.6
218	Wht.rot5.slp2	86.9	71.0	73.1	85.9	99.6
219	Wht.rot5.slp3	86.9	70.0	73.1	84.8	98.6
220	Wht.rot6.slp1	72.1	71.0	88.0	85.9	73.1
221	Wht.rot6.slp2	72.1	71.0	86.9	85.9	73.1
222	Wht.rot6.slp3	71.0	70.0	85.9	84.8	73.1
223	Wht.rot12.slp1	77.4	75.3	92.2	86.9	74.2
224	Wht.rot12.slp2	77.4	74.2	92.2	86.9	74.2
225	Wht.rot12.slp3	77.4	74.2	92.2	86.9	74.2
226	Sybn.rot3.slp1	41.3	40.3	40.3	41.3	44.2
227	Sybn.rot3.slp2	41.3	39.4	40.3	41.3	44.2
228	Sybn.rot3.slp3	41.3	36.5	40.3	41.3	44.2
229	Sybn.rot4.slp1	42.2	40.3	40.3	41.3	44.2
230	Sybn.rot4.slp2	41.3	39.4	40.3	41.3	44.2
231	Sybn.rot4.slp3	41.3	38.4	40.3	41.3	44.2
232	Sybn.rot5.slp1	42.2	38.4	44.2	41.3	44.2
233	Sybn.rot5.slp2	42.2	38.4	44.2	41.3	44.2
234	Sybn.rot5.slp3	41.3	36.5	44.2	41.3	44.2
235	Sybn.rot6.slp1	41.3	38.4	42.2	41.3	44.2
236	Sybn.rot6.slp2	41.3	37.4	42.2	41.3	44.2
237	Sybn.rot6.slp3	41.3	36.5	44.2	41.3	44.2
238	Sybn.rot12.slp1	41.3	40.3	40.3	41.3	44.2
239	Sybn.rot12.slp2	41.3	39.4	40.3	41.3	44.2
240	Sybn.rot12.slp3	41.3	38.4	40.3	41.3	44.2
241	+	State6	State7	State8	State9	State10
242	Pnut.rot1.slp1	3877	3870	2700	4224	3529
243	Pnut.rot1.slp2	3877	3868	2649	4205	3505
244	Pnut.rot1.slp3	3878	3868	2616	4190	3477
245	Pnut.rot2.slp1	3876	3868	2700	4224	3529
246	Pnut.rot2.slp2	3876	3868	2650	4205	3505
247	Pnut.rot2.slp3	3877	3868	2617	4189	3477
248	Pnut.rot3.slp1	3878	3850	2700	4206	3738

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   Pnut.rot3.slp2    3878   3850   2649   4206   3720
   Pnut.rot3.slp3    3878   3850   2616   4191   3696
   Pnut.rot4.slp1    3876   3849   2699   4224   3738
   Pnut.rot4.slp2    3876   3850   2649   4205   3720
   Pnut.rot4.slp3    3877   3849   2616   4190   3697
   Pnut.rot7.slp1    3877   3870   2731   4228   3529
   Pnut.rot7.slp2    3878   3870   2681   4226   3503
   Pnut.rot7.slp3    3879   3870   2652   4193   3476
   Pnut.rot8.slp1    3877   3870   2729   4228   3529
   Pnut.rot8.slp2    3878   3870   2681   4226   3503
   Pnut.rot8.slp3    3878   3870   2652   4193   3476
   Pnut.rot9.slp1    3877   3868   2731   4227   3527
   Pnut.rot9.slp2    3877   3868   2681   4225   3501
   Pnut.rot9.slp3    3878   3868   2651   4197   3474
  Pnut.rot10.slp1    3488   3482   2457   3804   3175
  Pnut.rot10.slp2    3488   3482   2414   3802   3152
  Pnut.rot10.slp3    3489   3482   2389   3776   3127
  Pnut.rot11.slp1    3875   3868   2729   4226   3527
  Pnut.rot11.slp2    3876   3868   2681   4224   3501
  Pnut.rot11.slp3    3877   3868   2619   4191   3479
  Pnut.rot12.slp1    3489   3464   2436   3803   3365
  Pnut.rot12.slp2    3489   3464   2392   3803   3349
  Pnut.rot12.slp3    3490   3464   2363   3784   3329
   Cttn.rot1.slp1    1234   1266    580   1265    955
   Cttn.rot1.slp2    1226   1262    566   1251    941
   Cttn.rot1.slp3    1218   1255    557   1234    928
   Cttn.rot3.slp1    1231   1281    567   1218    956
   Cttn.rot3.slp2    1224   1280    567   1196    942
   Cttn.rot3.slp3    1215   1276    558   1178    932
   Cttn.rot5.slp1    1194   1229    573   1171   1016
   Cttn.rot5.slp2    1177   1229    561   1171   1005
   Cttn.rot5.slp3    1158   1157    553   1125    992
   Cttn.rot6.slp1    1194   1129    573   1171   1016
   Cttn.rot6.slp2    1177   1196    561   1152   1005
   Cttn.rot6.slp3    1158   1157    553   1125    992
   Cttn.rot7.slp1    1228   1261    587   1278    955
   Cttn.rot7.slp2    1221   1255    573   1260    941
   Cttn.rot7.slp3    1215   1248    558   1247    930
   Cttn.rot8.slp1    1238   1261    587   1278    955
   Cttn.rot8.slp2    1221   1355    573   1260    941
   Cttn.rot8.slp3    1215   1248    558   1247    930
   Cttn.rot9.slp1    1228   1262    587   1279    955
   Cttn.rot9.slp2    1222   1255    574   1260    941
   Cttn.rot9.slp3    1215   1249    566   1248    929
  Cttn.rot10.slp1    1229   1262    588   1279    956
  Cttn.rot10.slp2    1222   1255    574   1261    943
  Cttn.rot10.slp3    1215   1248    567   1249    932
  Cttn.rot12.slp1    1226   1277    568   1216    958
  Cttn.rot12.slp2    1219   1273    568   1196    947
  Cttn.rot12.slp3    1210   1265    560   1175    937
   Corn.rot2.slp1   106.0  105.1   72.5  105.1  104.2
   Corn.rot2.slp2   105.1  103.2   70.7  105.1  104.2
   Corn.rot2.slp3   104.2  101.4   69.8  104.2  103.2
   Corn.rot4.slp1   112.5  116.3   73.5  112.5  112.5
   Corn.rot4.slp2   111.6  114.4   72.5  112.5  111.6
   Corn.rot4.slp3   111.6  111.6   71.6  111.6  109.7
  Corn.rot11.slp1   106.0  105.1   73.5  105.1  104.2
  Corn.rot11.slp2   105.1  103.2   71.6  105.1  104.2
  Corn.rot11.slp3   105.1  102.3   68.8  104.2  103.2
    Wht.rot3.slp1    85.9   99.6   92.2   78.4   93.3
    Wht.rot3.slp2    85.9   99.6   92.2   78.4   93.3
    Wht.rot3.slp3    84.8   99.6   91.2   78.4   92.2
    Wht.rot4.slp1    85.9  100.7   92.2   78.4   94.3
    Wht.rot4.slp2    85.9  100.7   92.2   78.4   93.3
    Wht.rot4.slp3    84.8   99.6   91.2   78.4   93.3
    Wht.rot5.slp1    81.6   80.6   89.0   79.5   88.0
    Wht.rot5.slp2    81.6   80.6   89.0   78.4   88.0
    Wht.rot5.slp3    83.7   80.6   88.0   78.4   86.9
    Wht.rot6.slp1    81.6   99.6   89.0   80.6   88.0
    Wht.rot6.slp2    81.6   99.6   89.0   80.6   86.9
    Wht.rot6.slp3    80.6   98.6   88.0   79.5   86.9
   Wht.rot12.slp1    85.9  100.7   92.2   78.4   93.3
   Wht.rot12.slp2    85.9  100.7   92.2   78.4   93.3
   Wht.rot12.slp3    85.9   99.6   92.2   78.4   93.3
   Sybn.rot3.slp1    39.4   45.1   20.2   45.1   33.6
   Sybn.rot3.slp2    36.5   45.1   19.2   44.2   33.6
   Sybn.rot3.slp3    35.5   45.1   18.2   42.2   31.7
   Sybn.rot4.slp1    39.4   45.1   20.2   45.1   35.5
   Sybn.rot4.slp2    37.4   45.1   19.2   44.2   33.6
   Sybn.rot4.slp3    35.5   45.1   18.2   42.2   31.7
   Sybn.rot5.slp1    39.4   44.2   22.1   41.3   35.5
   Sybn.rot5.slp2    39.4   43.2   22.1   39.4   35.5
   Sybn.rot5.slp3    35.5   41.3   20.2   37.4   32.6
   Sybn.rot6.slp1    39.4   44.2   22.1   44.2   35.5
   Sybn.rot6.slp2    37.4   44.2   21.1   43.2   34.6
   Sybn.rot6.slp3    35.5   41.3   20.2   37.4   32.6
  Sybn.rot12.slp1    40.3   45.1   20.2   46.1   33.6
  Sybn.rot12.slp2    38.4   45.1   19.2   45.1   33.6
  Sybn.rot12.slp3    36.5   45.1   18.2   44.2   31.7;

 * file PRICE.PRN contains table PRICES(I2,S) (no peanut prices)
INCLUDE    C:\PENG\GAMS\THESIS\PRICE.PRN
 TABLE PRICES(I,S)  state of nature crop prices
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              State1  State2  State3  State4  State5
         Cttn  0.550   0.655   0.572   0.674   0.693
         Corn  2.037   2.389   3.264   2.804   2.596
          Wht  3.154   3.052   3.989   3.831   3.136
         Sybn  5.385   6.459   7.623   5.633   5.253
         Wcvr
         Acvr
           +  State6  State7  State8  State9 State10
         Cttn  0.506   0.484   0.561   0.707   0.668
         Corn  2.587   2.173   2.497   2.164   2.317
          Wht  2.764   3.089   2.644   2.700   3.748
         Sybn  5.05   4.873   5.575   4.468   4.815
         Wcvr
         Acvr    ;

* file BUDGET.PRN contains the following tables and parameters:
* -- TMACH(I,J,T) hours need of machine T for (I,J) production
* -- MASSHR(T) originally assumed total machine use in hours
* -- MASSFX(T) originally assumed per hour fixed cost
* -- MACHNUM(T) number of each machine type
* -- LABOR(I,J,M), crop seasonal labore hour requirements
* -- VINPUT(I,J), input cost without labor and fixed machine cost
INCLUDE    C:\PENG\GAMS\THESIS\BUDGET.PRN
TABLE LABOR(I,J,M)  crop seasonal labor use (hours per acre)
                Season1  Season2 Season3  Season4
    Pnut.rot1     3.0    2.35    5.70    0.0
    Pnut.rot2     3.0    2.35    5.70    0.0
    Pnut.rot3     3.0    2.35    5.70    0.0
    Pnut.rot4     3.0    2.35    5.70    0.0
    Pnut.rot7     3.0    2.35    5.70    0.0
    Pnut.rot8     3.0    2.35    5.70    0.0
    Pnut.rot9     3.0    2.35    5.70    0.0
   Pnut.rot10     2.70    1.88    5.45    0.0
   Pnut.rot11     3.0    2.35    5.70    0.0
   Pnut.rot12     2.70    1.88    5.45    0.0
    Cttn.rot1     2.40    1.85    2.40    0.0
    Cttn.rot3     2.40    1.85    2.40    0.0
    Cttn.rot5     2.40    1.85    2.40    0.0
    Cttn.rot6     1.45    1.05    2.40    0.0
    Cttn.rot7     1.45    1.05    2.40    0.0
    Cttn.rot8     1.45    1.05    2.40    0.0
    Cttn.rot9     1.58    1.25    2.40    0.0
   Cttn.rot10     1.45    1.05    2.40    0.0
   Cttn.rot12     1.45    1.05    2.40    0.0
    Corn.rot2     1.25    0.25    0.95    0.0
    Corn.rot4     1.25    0.25    0.95    0.0
   Corn.rot11     1.25    0.25    0.95    0.0
     Wht.rot3     0.35    0.55    1.0    0.40
     Wht.rot4     0.35    0.55    1.0    0.40
     Wht.rot5     0.35    0.55    1.0    0.40
     Wht.rot6     0.35    0.55    1.0    0.40
    Wht.rot12     0.35    0.55    1.0    0.40
    Sybn.rot3     0.25    0.85    0.60    0.0
    Sybn.rot4     0.25    0.85    0.60    0.0
    Sybn.rot5     0.25    0.85    0.60    0.0
    Sybn.rot6     0.25    0.85    0.60    0.0
   Sybn.rot12     0.25    0.85    0.60    0.0
    Wcvr.rot6     0.0    0.0    0.45    0.20
    Wcvr.rot7     0.0    0.0    0.45    0.20
    Wcvr.rot8     0.0    0.0    0.45    0.20
    Wcvr.rot9     0.0    0.0    0.45    0.20
   Wcvr.rot10     0.0    0.0    0.45    0.20
   Wcvr.rot11     0.0    0.0    0.45    0.20
   Wcvr.rot12     0.0    0.0    0.45    0.20
   Acvr.rot13     0.0    0.0    0.45    0.20      ;

TABLE VINPUT(I,J)  per acre crop input with out labor and fixed machine
                 rot1    rot2    rot3    rot4    rot5    rot6    rot7
        Pnut   555.37  555.37  555.37  555.37    0       0     555.37
        Cttn   277.41    0     277.41    0     277.41  283.99  277.41
        Corn     0     162.89    0     162.89    0       0       0
         Wht     0       0     128.31  128.31  128.31  128.31    0
        Sybn     0       0      93.41   93.41   93.41   93.41    0
        Wcvr     0       0       0       0       0      26.41   26.41
        Acvr     0       0       0       0       0       0       0
           +    rot8    rot9   rot10   rot11   rot12   rot13
        Pnut   555.37  512.08  555.37  555.37  512.08    0
        Cttn   283.99  290.78  283.99    0     283.99    0
        Corn     0       0       0     162.89    0       0
         Wht     0       0       0       0     128.31    0
        Sybn     0       0       0       0      93.41    0
        Wcvr    26.41   26.41   26.41   26.41   26.41    0
        Acvr     0       0       0       0       0      26.41     ;

TABLE TMACH(I,J,T) hour need of machine T in (I J) (per acre)
                FLPLW    DISK  FLDCLT  SUBSIL   RWCLT   PLANT  NPLANT
    Pnut.rot1     0.40    0.30    0.18    0.0    0.35    0.50    0.0
    Pnut.rot2     0.40    0.30    0.18    0.0    0.35    0.50    0.0
    Pnut.rot3     0.40    0.30    0.18    0.0    0.35    0.50    0.0
    Pnut.rot4     0.40    0.30    0.18    0.0    0.35    0.50    0.0
    Pnut.rot7     0.40    0.30    0.18    0.0    0.35    0.50    0.0
    Pnut.rot8     0.40    0.30    0.18    0.0    0.35    0.50    0.0
    Pnut.rot9     0.40    0.30    0.18    0.0    0.35    0.50    0.0
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 Pnut.rot10     0.0    0.30    0.0    0.0    0.0    0.0    0.50
 Pnut.rot11     0.40    0.30    0.18    0.0    0.35    0.50    0.0
 Pnut.rot12     0.0    0.30    0.0    0.0    0.0    0.0    0.50
  Cttn.rot1     0.0    0.78    0.18    0.33    1.05    0.33    0.0
  Cttn.rot3     0.0    0.78    0.18    0.33    1.05    0.33    0.0
  Cttn.rot5     0.0    0.78    0.18    0.33    1.05    0.33    0.0
  Cttn.rot6     0.0    0.15    0.0    0.0    0.0    0.0    0.33
  Cttn.rot7     0.0    0.78    0.18    0.33    1.05    0.33    0.0
  Cttn.rot8     0.0    0.15    0.0    0.0    0.0    0.0    0.33
  Cttn.rot9     0.0    0.15    0.0    0.33    0.0    0.33    0.0
 Cttn.rot10     0.0    0.15    0.0    0.33    0.0    0.33    0.0
 Cttn.rot12     0.0    0.15    0.0    0.0    0.0    0.0    0.33
  Corn.rot2     0.0    0.0    0.0    0.0    0.0    0.0    0.33
  Corn.rot4     0.0    0.0    0.0    0.0    0.0    0.0    0.33
 Corn.rot11     0.0    0.0    0.0    0.0    0.0    0.0    0.33
   Wht.rot3     0.0    0.30    0.0    0.0    0.0    0.33    0.0
   Wht.rot4     0.0    0.30    0.0    0.0    0.0    0.33    0.0
   Wht.rot5     0.0    0.30    0.0    0.0    0.0    0.33    0.0
   Wht.rot6     0.0    0.30    0.0    0.0    0.0    0.33    0.0
  Wht.rot12     0.0    0.30    0.0    0.0    0.0    0.33    0.0
  Sybn.rot3     0.0    0.0    0.0    0.0    0.0    0.0    0.0
  Sybn.rot4     0.0    0.0    0.0    0.0    0.0    0.0    0.0
  Sybn.rot5     0.0    0.0    0.0    0.0    0.0    0.0    0.0
  Sybn.rot6     0.0    0.0    0.0    0.0    0.0    0.0    0.0
 Sybn.rot12     0.0    0.0    0.0    0.0    0.0    0.0    0.0
  Wcvr.rot6     0.0    0.15    0.0    0.0    0.0    0.0    0.15
  Wcvr.rot7     0.0    0.15    0.0    0.0    0.0    0.0    0.15
  Wcvr.rot8     0.0    0.15    0.0    0.0    0.0    0.0    0.15
  Wcvr.rot9     0.0    0.15    0.0    0.0    0.0    0.0    0.15
 Wcvr.rot10     0.0    0.15    0.0    0.0    0.0    0.0    0.15
 Wcvr.rot11     0.0    0.15    0.0    0.0    0.0    0.0    0.15
 Wcvr.rot12     0.0    0.15    0.0    0.0    0.0    0.0    0.15
 Acvr.rot13     0.0    0.15    0.0    0.0    0.0    0.0    0.15
     +        SPRAYER  SPREAD  ROTMOW  DIGGER  PNTCOM COMBINE
  Pnut.rot1     1.31    0.13    0.0    0.75    1.33    0.0
  Pnut.rot2     1.31    0.13    0.0    0.75    1.33    0.0
  Pnut.rot3     1.31    0.13    0.0    0.75    1.33    0.0
  Pnut.rot4     1.31    0.13    0.0    0.75    1.33    0.0
  Pnut.rot7     1.31    0.13    0.0    0.75    1.33    0.0
  Pnut.rot8     1.31    0.13    0.0    0.75    1.33    0.0
  Pnut.rot9     1.31    0.13    0.0    0.75    1.33    0.0
 Pnut.rot10     1.39    0.13    0.0    0.75    1.33    0.0
 Pnut.rot11     1.31    0.13    0.0    0.75    1.33    0.0
 Pnut.rot12     1.39    0.13    0.0    0.75    1.33    0.0
  Cttn.rot1     1.13    0.0    0.20    0.0    0.0    0.0
  Cttn.rot3     1.13    0.0    0.20    0.0    0.0    0.0
  Cttn.rot5     1.13    0.0    0.20    0.0    0.0    0.0
  Cttn.rot6     1.13    0.0    0.20    0.0    0.0    0.0
  Cttn.rot7     1.13    0.0    0.20    0.0    0.0    0.0
  Cttn.rot8     1.13    0.0    0.20    0.0    0.0    0.0
  Cttn.rot9     1.13    0.0    0.20    0.0    0.0    0.0
 Cttn.rot10     1.13    0.0    0.20    0.0    0.0    0.0
 Cttn.rot12     1.13    0.0    0.20    0.0    0.0    0.0
  Corn.rot2     0.38    0.0    0.20    0.0    0.0    0.30
  Corn.rot4     0.38    0.0    0.20    0.0    0.0    0.30
 Corn.rot11     0.38    0.0    0.20    0.0    0.0    0.30
   Wht.rot3     0.25    0.0    0.0    0.0    0.0    0.30
   Wht.rot4     0.25    0.0    0.0    0.0    0.0    0.30
   Wht.rot5     0.25    0.0    0.0    0.0    0.0    0.30
   Wht.rot6     0.25    0.0    0.0    0.0    0.0    0.30
  Wht.rot12     0.25    0.0    0.0    0.0    0.0    0.30
  Sybn.rot3     0.13    0.0    0.0    0.0    0.0    0.25
  Sybn.rot4     0.13    0.0    0.0    0.0    0.0    0.25
  Sybn.rot5     0.13    0.0    0.0    0.0    0.0    0.25
  Sybn.rot6     0.13    0.0    0.0    0.0    0.0    0.25
 Sybn.rot12     0.13    0.0    0.0    0.0    0.0    0.25
  Wcvr.rot6     0.13    0.0    0.0    0.0    0.0    0.0
  Wcvr.rot7     0.13    0.0    0.0    0.0    0.0    0.0
  Wcvr.rot8     0.13    0.0    0.0    0.0    0.0    0.0
  Wcvr.rot9     0.13    0.0    0.0    0.0    0.0    0.0
 Wcvr.rot10     0.13    0.0    0.0    0.0    0.0    0.0
 Wcvr.rot11     0.13    0.0    0.0    0.0    0.0    0.0
 Wcvr.rot12     0.13    0.0    0.0    0.0    0.0    0.0
 Acvr.rot13     0.13    0.0    0.0    0.0    0.0    0.0
     +         PICKER   TRA80  TRA110  TRA135
  Pnut.rot1     0.0    3.12    2.13    0.0
  Pnut.rot2     0.0    3.12    2.13    0.0
  Pnut.rot3     0.0    3.12    2.13    0.0
  Pnut.rot4     0.0    3.12    2.13    0.0
  Pnut.rot7     0.0    3.12    2.13    0.0
  Pnut.rot8     0.0    3.12    2.13    0.0
  Pnut.rot9     0.0    3.12    2.13    0.0
 Pnut.rot10     0.0    2.85    1.55    0.0
 Pnut.rot11     0.0    3.12    2.13    0.0
 Pnut.rot12     0.0    2.85    1.55    0.0
  Cttn.rot1     1.0    2.71    0.68    0.35
  Cttn.rot3     1.0    2.71    0.68    0.35
  Cttn.rot5     1.0    2.71    0.68    0.35
  Cttn.rot6     1.0    1.66    0.20    0.0
  Cttn.rot7     1.0    2.71    0.68    0.35
  Cttn.rot8     1.0    1.66    0.20    0.0
  Cttn.rot9     1.0    1.30    0.40    0.79
 Cttn.rot10     1.0    1.66    0.20    0.0
```

```
     Cttn.rot12     1.0    1.66    0.20    0.0
      Corn.rot2     0.0    0.88    0.0    0.33
      Corn.rot4     0.0    0.88    0.0    0.33
     Corn.rot11     0.0    0.88    0.0    0.33
       Wht.rot3     0.0    0.88    0.30    0.0
       Wht.rot4     0.0    0.88    0.30    0.0
       Wht.rot5     0.0    0.88    0.30    0.0
       Wht.rot6     0.0    0.88    0.30    0.0
      Wht.rot12     0.0    0.88    0.30    0.0
      Sybn.rot3     0.0    0.71    0.0    0.0
      Sybn.rot4     0.0    0.71    0.0    0.0
      Sybn.rot5     0.0    0.71    0.0    0.0
      Sybn.rot6     0.0    0.71    0.0    0.0
     Sybn.rot12     0.0    0.71    0.0    0.0
      Wcvr.rot6     0.0    0.28    0.15    0.0
      Wcvr.rot7     0.0    0.28    0.15    0.0
      Wcvr.rot8     0.0    0.28    0.15    0.0
      Wcvr.rot9     0.0    0.28    0.15    0.0
     Wcvr.rot10     0.0    0.28    0.15    0.0
     Wcvr.rot11     0.0    0.28    0.15    0.0
     Wcvr.rot12     0.0    0.28    0.15    0.0
     Acvr.rot13     0.0    0.28    0.15    0.0;

  PARAMETER
     MASSHR(T) original assumed total machine use in hours
               /FLPLW     200.0
                DISK      700.0
                FLDCLT    700.0
                SUBSIL    250.0
                RWCLT     300.0
                PLANT     300.0
                NPLANT    300.0
                SPRAYER  1000.0
                SPREAD    500.0
                ROTMOW    160.0
                DIGGER    200.0
                PNTCOM     80.0
                COMBINE   600.0
                PICKER    300.0
                TRA80     300.0
                TRA110    300.0
                TRA135    500.0/
    MASSFX(T) originally assumed per acre fixed cost for each piece
               /FLPLW       4.62
                DISK        1.82
                FLDCLT      0.61
                SUBSIL      2.77
                RWCLT       1.24
                PLANT       1.84
                NPLANT      2.70
                SPRAYER     0.43
                SPREAD      0.74
                ROTMOW      4.32
                DIGGER      6.38
                PNTCOM     33.25
                COMBINE    20.55
                PICKER     33.70
                TRA80      13.66
                TRA110     17.20
                TRA135     12.34/
    MACHNUM(T) number of each type of machines on the farm
               /FLPLW         1
                DISK          2
                FLDCLT        2
                SUBSIL        1
                RWCLT         2
                PLANT         2
                NPLANT        1
                SPRAYER       2
                SPREAD        2
                ROTMOW        1
                DIGGER        2
                PNTCOM        2
                COMBINE       1
                PICKER        1
                TRA80         1
                TRA110        1
                TRA135        1 /;
  * note: actual_fixed_cost/ac = massfx(t)*actualhour/(assumed hour)
  *

  * file INDEX.PRN constains table PNSINDEX(J,K,B), that's all environ indices
INCLUDE    C:\PENG\GAMS\THESIS\INDEX.PRN
  TABLE PNSINDEX(J,K,B) this table contains all envirn indices
                    PESTCD  NITROGEN  PHOSPHOR   SOIL
      ROT1.SLP1      86.6     11.1      1.0      3.1
      ROT1.SLP2     164.1     19.7      1.9      4.8
      ROT1.SLP3     240.7     31.8      3.2      8.5
      ROT2.SLP1      88.0      9.6      0.7      1.8
      ROT2.SLP2     169.3     18.3      1.4      3.5
      ROT2.SLP3     236.0     29.1      2.4      7.0
      ROT3.SLP1      65.2     13.7      0.8      2.2
      ROT3.SLP2     124.4     23.5      1.6      3.9
```

```
    ROT3.SLP3     170.7     37.0      2.9      7.6
    ROT4.SLP1      70.9     13.2      0.6      1.7
    ROT4.SLP2     118.8     22.9      1.3      3.1
    ROT4.SLP3     179.0     35.8      2.3      6.1
    ROT5.SLP1      18.2     12.9      0.6      1.3
    ROT5.SLP2      28.7     22.0      1.3      2.7
    ROT5.SLP3      46.6     34.2      2.3      5.5
    ROT6.SLP1      28.5     13.4      0.6      1.1
    ROT6.SLP2      51.4     22.9      1.3      2.4
    ROT6.SLP3      80.7     34.3      2.4      4.9
    ROT7.SLP1      88.1     10.2      0.9      2.6
    ROT7.SLP2     171.9     19.2      1.8      4.4
    ROT7.SLP3     242.1     31.5      3.2      8.2
    ROT8.SLP1      94.5     10.5      1.0      2.3
    ROT8.SLP2     186.3     19.5      1.9      4.1
    ROT8.SLP3     275.7     31.5      3.4      7.6
    ROT9.SLP1     107.7     10.0      0.9      2.4
    ROT9.SLP2     208.3     18.7      1.8      4.1
    ROT9.SLP3     306.4     30.5      3.1      7.7
   ROT10.SLP1      63.8      9.0      1.0      1.8
   ROT10.SLP2     116.8     17.1      1.9      3.3
   ROT10.SLP3     176.1     27.8      3.4      6.2
   ROT11.SLP1      88.4      9.4      0.7      1.8
   ROT11.SLP2     101.4     18.2      1.4      3.5
   ROT11.SLP3     242.0     29.9      2.5      6.7
   ROT12.SLP1      42.5     12.8      0.9      2.0
   ROT12.SLP2      68.8     22.2      1.7      3.6
   ROT12.SLP3     110.1     34.5      3.0      6.8
   ROT13.SLP1       1.2      3.2      0.2      0.2
   ROT13.SLP2       2.4      5.2      0.4      0.3
   ROT13.SLP3       4.0      7.7      0.6      0.5       ;

* Now calculate the average yield (expeceted)
  YIELDA(I,J,K)=SUM((S),YIELDS(I,J,K,S))/CARD(S);

* now calculate total fixed mach cost from assumption:
  FIXMACH0=SUM((T),MASSHR(T)*MASSFX(T));
  FIXMACH(I,J)=SUM((T),MASSFX(T)*TMACH(I,J,T));

VARIABLES
      INC        expected total income
      PTQ        # of expected quota peanut sold
      PTA        # of expected addit peanut sold
      LAB(M)     seasonal parttime labor hours
      X(I,J,K)   acres devoted to crops of (ijk)
      RT(J,K)    acrea of kth slope devoted to jth rotation
*      MACHH(T)   hour use of machine T
      NDXACC(B)  environ index accounting
      Z(S)       annual negative target deviation ($)
      PQ(S)      # of quota peanut sold for state s
      PA(S)      # of addit peanut sold for state s;

POSITIVE VARIABLES PTQ,PTA,LAB,X,RT,MACHH,NDXACC,Z,PQ,PA;
* (Note: INC cannot be set to be positive here)

EQUATION
       INCOME        objective function

       PEANUT1       decomposition of peanut sale for plan year
       PEANUT2       peanut quota constraint for plan year
       LAND1(I,J,K)  x(ijk) definition constriants
       LAND2(K)      total acreage by slope constraint
*       MACHINE(T)    machine hour-use accounting
       HIRELAB(M)    seasonal labor constraints
       NDX1(B)       SNP loss indices constraints
       NDX2(B)       SNP loss indices accounting
       ES            expected shortfall
       PEA1(S)       total peanut poundage in state s
       PEA2(S)       decompostion of peanut sale in state s
       RISK(S)       risk rows;
*
* Now the layout of the equations
*
INCOME..     QUOPRICE*PTQ + ADDPRICE*PTA
      + SUM(I$I2(I),PRICEA(I)*SUM((J,K), YIELDA(I,J,K)*X(I,J,K)))
      - SUM((I,J), (VINPUT(I,J)+FIXMACH(I,J))*SUM((K), X(I,J,K)))
      - PRICELAB*SUM((M),LAB(M)) + PROGPAY =E= INC;
PEANUT1.. SUM(I$I3(I),SUM((J,K),X(I,J,K)*YIELDA(I,J,K)))-PTQ-PTA =E= 0;
PEANUT2..     PTQ-QUOTA =L= 0;
LAND1(I,J,K).. X(I,J,K) - ROTAC(J,I,K)*RT(J,K) =E= 0;
LAND2(K)..     SUM((J),RT(J,K)) - RHLAND(K) =E= 0;
* MACHINE(T)..   MACHH(T)-SUM((I,J),TMACH(I,J,T)*SUM((K),X(I,J,K))) =E= 0;
HIRELAB(M)..   SUM((I,J),LABOR(I,J,M)*SUM((K),X(I,J,K)))
               - LAB(M) =L= RHLABOR(M);
NDX1(B)..      SUM((J,K),PNSINDEX(J,K,B)*RT(J,K)) =L= RHINDEX(B);
NDX2(B)..      NDXACC(B) - SUM((J,K),PNSINDEX(J,K,B)*RT(J,K)) =E= 0;
ES..           SUM((S), Z(S)*PROB(S)) =E= EXPSHORT;
PEA1(S)..      SUM((I)$I3(I),SUM((J,K),X(I,J,K)*YIELDS(I,J,K,S)))
                  - PQ(S) - PA(S) =E= 0;
PEA2(S)..      PQ(S) - QUOTA =L= 0;
RISK(S)..      QUOPRICE*PQ(S) + ADDPRICE*PA(S)
      + SUM((I)$I2(I),PRICES(I,S)*SUM((J,K), YIELDS(I,J,K,S)*X(I,J,K)))
      - SUM((I,J), VINPUT(I,J)*SUM(K, X(I,J,K)))
```

```
      - PRICELAB*SUM((M),LAB(M)) + PROGPAY + Z(S) =G= TARGET;

* the model is called TMOTAD and include all equations above
MODEL TMOTAD
      /ALL/;
SET
    PNT points to trace out efficient curve
        /POINT1*POINT15/
    NT environmental index loop
        /NIT1  no constraint at all
         NIT2  pest 10 percent reduction
         NIT3  pest 20 percent reduction
         NIT4  pest 30 percent reduction
         NIT5  pest 40 percent reduciton
         NIT6  nitr 10 percent reduction
         NIT7  nitr 20 percent reduction
         NIT8  nitr 30 percent reduction
         NIT9  nitr 40 percent reduction
         NIT10 phsp 10 percent reduction
         NIT11 phsp 20 percent reduction
         NIT12 phsp 30 percent reduciton
         NIT13 phsp 40 percent reduction
         NIT14 soil 10 percent reduction
         NIT15 soil 20 percent reduction
          NIT16 soil 30 percent reduciton
         NIT17 soil 40 percent reduction
         NIT18 all 10 percent reduction
         NIT19 all 20 percent reduction
         NIT20 all 30 percent reduciton
         NIT21 all 40 percent reduciton/;
PARAMETERS
    SHORTLEVEL(PNT) expected shortfall from target
      /POINT1   6000,
       POINT2   6500,
       POINT3   7000,
       POINT4   7500,
       POINT5   8000,
       POINT6   8500,
       POINT7   9000,
       POINT8   9500,
       POINT9  10000,
       POINT10 10500,
       POINT11 11000,
       POINT12 11500,
       POINT13 12000,
       POINT14 12500,
       POINT15 13000/
    OLDINDEX(B) index level when no risk and no PNS constraints;
TABLE REDUC(NT,B)
          PESTCD  NITROGEN  PHOSPHOR  SOIL
    NIT1      2      2         2        2
    NIT2       .9    2         2        2
    NIT3       .8    2         2        2
    NIT4       .7    2         2        2
    NIT5       .6    2         2        2
    NIT6     2        .9       2        2
    NIT7     2        .8       2        2
    NIT8     2        .7       2        2
    NIT9     2        .6       2        2
    NIT10    2      2           .9      2
    NIT11    2      2           .8      2
    NIT12    2      2           .7      2
    NIT13    2      2           .6      2
    NIT14    2      2          2         .9
    NIT15    2      2          2         .8
    NIT16    2      2          2         .7
    NIT17    2      2          2         .6
    NIT18     .9     .9         .9       .9
    NIT19     .8     .8         .8       .8
    NIT20     .7     .7         .7       .7
    NIT21     .6     .6         .6       .6;
SCALAR
    FMCONTROL1 initial value to control loops for fixed machine cost
    FMCONTROL2 second;

OPTION LIMROW=0;
OPTION LIMCOL=0;
OPTION SYSOUT=OFF;
OPTION SOLPRINT = On;

RHINDEX(B)=NDXINI(B);
EXPSHORT=300000;
*Note: from above it can be seen that the first run is characterized by
*     1.risk neutrality
*     2.no pollution control imposed
* Now it is ready to go first run of the MOTAD model

PARAMETER
    Y(J,I,K)
    SHOW1(B);

SOLVE TMOTAD USING LP MAXIMIZING INC;
OLDINDEX(B)=NDXACC.L(B);
```

```
Y(J,I,K)=X.L(I,J,K);
display yielda;
DISPLAY RHINDEX,EXPSHORT,Z.L,INC.L,y,PTQ.L,PTA.L;
LOOP (NT,
    RHINDEX(B)=OLDINDEX(B)*REDUC(NT,B);
    SHOW1(B)=REDUC(NT,B);
    LOOP (PNT,
       EXPSHORT=SHORTLEVEL(PNT);
       SOLVE TMOTAD USING LP MAXIMIZING INC;
       Y(J,I,K)=X.L(I,J,K);
        DISPLAY SHOW1,RHINDEX,NDXACC.L,EXPSHORT,Z.L,INC.L,y,PTQ.L,PTA.L));
```

Appendix G. Crop Rotation Response for Risk-Averse Farmers When Individual Baseline Values are Used

Individual baseline values are pesticide, nutrients (nitrogen and phosphorus), and soil loss (PNS) indices for individual risk-averse and risk-neutral farmers when there is no constraint imposed on pollution reduction. The following table is discussed in section 3 of Chapter 4.

Table G-1. Crops and rotations with varying levels of PNS reduction

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations: 1% slope #	1% slope crop	1% slope acres	3% slope #	3% slope name	3% slope acres	5% slope #	5% slope name	5% slope acres	Total crop acres (all slopes and rotations): Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
	0	7,500	1	peanut	7.7								156.8	300.8	293.1	293.1	
				cotton	7.7												
baseline			3	peanut	94.8	3	peanut	29.3	3	peanut	25.0						
				cotton	94.8		cotton	29.3		cotton	25.0						
				wheat	94.8		wheat	29.3		wheat	25.0						
				soybean	94.8		soybean	29.3		soybean	25.0						
						5	cotton	144.0									
							wheat	144.0									
							soybean	144.0									
		8,000	1	peanut	121.8								157.3	358.1	236.1	236.1	
				cotton	121.8												
			3	peanut	10.3				3	peanut	25.0						
				cotton	10.3					cotton	25.0						
				wheat	10.3					wheat	25.0						
				soybean	10.3					soybean	25.0						
			5	cotton	12.8	5	cotton	187.5									
				wheat	12.8		wheat	187.5									
				soybean	12.8		soybean	187.5									
		8500+	1	peanut	119.7				1	peanut	37.5		157.5	375.8	218.3	218.3	
				cotton	119.7					cotton	37.5						
			5	cotton	30.3	5	cotton	187.5									
				wheat	30.3		wheat	187.5									
				soybean	30.3		soybean	187.5									
		7,500	1	peanut	14.5								139.9	312.1	297.6	297.6	
Pesticide	10			cotton	14.5												
only			3	peanut	90.2	3	peanut	10.2	3	peanut	25.0						
				cotton	90.2		cotton	10.2		cotton	25.0						
				wheat	90.2		wheat	10.2		wheat	25.0						
				soybean	90.2		soybean	10.2		soybean	25.0						
						5	cotton	172.2									
							wheat	172.2									
							soybean	172.2									
		8,000	1	peanut	124.3								150.2	362.0	237.7	237.7	
				cotton	124.3												
			3	peanut	17.1				3	peanut	8.8						
				cotton	17.1					cotton	8.8						
				wheat	17.1					wheat	8.8						
				soybean	17.1					soybean	8.8						
						5	cotton	187.5	5	cotton	24.3						
							wheat	187.5		wheat	24.3						
							soybean	187.5		soybean	24.3						
		8500+	1	peanut	119.7				1	peanut	37.5		157.5	375.8	218.3	218.3	
				cotton	119.7					cotton	37.5						
			5	cotton	30.3	5	cotton	187.5									
				wheat	30.3		wheat	187.5									
				soybean	30.3		soybean	187.5									

Table G-1. Crops and rotations with varying levels of PNS reduction (*continue*)

Pollutant	Level of	Expected	Rotations									Total crop acres (all slopes and rotations)					
under	reduction	shortfall		1% slope			3% slope			5% slope		Corn	Peanut	Cotton	Soybean	Wheat	Cover
constraint	(%)	allowed ($)	#	crop	acres	#	name	acres	#	name	acres	(ac)	(ac)	(ac)	(ac)	(ac)	only(ac)
		7,500	1	peanut	19.9								124.8	322.3	302.4	302.4	
Pesticide	20			cotton	19.9												
(continue)			3	peanut	86.6				3	peanut	18.3						
				cotton	86.6					cotton	18.3						
				wheat	86.6					wheat	18.3						
				soybean	86.6					soybean	18.3						
						5	cotton	187.5	5	cotton	10.0						
							wheat	187.5		wheat	10.0						
							soybean	187.5		soybean	10.0						
		8,000	1	peanut	128.7								131.4	373.6	244.9	244.9	
				cotton	128.7												
			3	peanut	2.7												
				cotton	2.7												
				wheat	2.7												
				soybean	2.7												
			5	cotton	17.2	5	cotton	187.5	5	cotton	37.5						
				wheat	17.2		wheat	187.5		wheat	37.5						
				soybean	17.2		soybean	187.5		soybean	37.5						
		8500+	1	peanut	150.0								151.0	374.8	241.0	241.0	
				cotton	150.0												
									3	peanut	1.0						
										cotton	1.0						
										wheat	1.0						
										soybean	1.0						
						5	cotton	187.5	5	cotton	36.3						
							wheat	187.5		wheat	36.3						
							soybean	187.5		soybean	36.3						
		7,500	1	peanut	23.6								111.8	430.8	307.2	307.2	
	30			cotton	23.6												
			3	peanut	84.2				3	peanut	4.0						
				cotton	84.2					cotton	4.0						
				wheat	84.2					wheat	4.0						
				soybean	84.2					soybean	4.0						
						5	cotton	187.5	5	cotton	31.5						
							wheat	187.5		wheat	31.5						
							soybean	187.5		soybean	31.5						
		8,000	1	peanut	97.0								97.0	375.0	278.0	278.0	
				cotton	97.0												
			5	cotton	53.0	5	cotton	187.5	5	cotton	37.5						
				wheat	53.0		wheat	187.5		wheat	37.5						
				soybean	53.0		soybean	187.5		soybean	37.5						
		8,500+	1	peanut	115.1								115.1	375.1	260.0	260.0	
				cotton	115.1												
			5	cotton	35.0	5	cotton	187.5	5	cotton	37.5						
				wheat	35.0		wheat	187.5		wheat	37.5						
				soybean	35.0		soybean	187.5		soybean	37.5						

Table G-1. Crops and rotations with varying levels of PNS reduction (*continue*)

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations										Total crop acres (all slopes and rotations)					
			1% slope			3% slope			5% slope								
			#	crop	acres	#	name	acres	#	name	acres	Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
Pesticide		7,500	1	peanut	29.9								81.7	349.0	319.1	319.1	
	40			cotton	29.9												
			3	peanut	51.8												
				cotton	51.8												
				wheat	51.8												
				soybean	51.8												
			5	cotton	42.3	5	cotton	187.5	5	cotton	37.5						
				wheat	42.3		wheat	187.5		wheat	37.5						
				soybean	42.3		soybean	187.5		soybean	37.5						
		8,000	1	peanut	62.6								62.6	375.0	312.4	312.4	
				cotton	62.6												
			5	cotton	87.4	5	cotton	187.5	5	cotton	37.5						
				wheat	87.4		wheat	187.5		wheat	37.5						
				soybean	87.4		soybean	187.5		soybean	37.5						
		8,500+	1	peanut	78.0								78.0	375.0	297.0	297.0	
				cotton	78.0												
			5	cotton	72.0	5	cotton	187.5	5	cotton	37.5						
				wheat	72.0		wheat	187.5		wheat	37.5						
				soybean	72.0		soybean	187.5		soybean	37.5						
	10	8,000	1	peanut	25.5				1	peanut	8.9		34.4	346.4	312.0	312.0	57.2
Nitrogen				cotton	25.5					cotton	8.9						
only			5	cotton	124.5	5	cotton	187.5									
				wheat	124.5		wheat	187.5									
				soybean	124.5		soybean	187.5									
									13	cover only	57.2						
		8,500+	5	cotton	30.0	5	cotton	187.5					134.6	352.1	217.5	217.5	45.0
				wheat	30.0		wheat	187.5									
				soybean	30.0		soybean	187.5									
			9	peanut	120.0				9	peanut	14.6						
				cotton	120.0					cotton	14.6						
				winter cover	240.0					winter cover	29.2						
									13	cover only	45.0						
		7,500	1	peanut	33.8								53.6	366.4	312.8	312.8	
Phosphorus only	10			cotton	33.8												
			3	peanut	19.8												
				cotton	19.8												
				wheat	19.8												
				soybean	19.8												
			5	cotton	87.8	5	cotton	187.5	5	cotton	37.5						
				wheat	87.8		wheat	187.5		wheat	37.5						
				soybean	87.8		soybean	187.5		soybean	37.5						
		8,000	1	peanut	63.8								63.8	375.1	311.3	311.3	
				cotton	63.8												
			5	cotton	86.3	5	cotton	187.5	5	cotton	37.5						
				wheat	86.3		wheat	187.5		wheat	37.5						
				soybean	86.3		soybean	187.5		soybean	37.5						

Table G-1. Crops and rotations with varying levels of PNS reduction (*continue*)

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations: 1% slope #	1% slope crop	1% slope acres	3% slope #	3% slope name	3% slope acres	5% slope #	5% slope name	5% slope acres	Total crop acres (all slopes and rotations): Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
		8,500+	1	peanut	78.7								78.7	375.0	296.3	296.3	
				cotton	78.7												
			5	cotton	71.3	5	cotton	187.5	5	cotton	37.5						
				wheat	71.3		wheat	187.5		wheat	37.5						
				soybean	71.3		soybean	187.5		soybean	37.5						
	20	8,000	5	cotton	150.0	5	cotton	187.5	5	cotton	23.4			360.9	360.9	360.9	26.5
				wheat	150.0		wheat	187.5		wheat	23.4						
				soybean	150.0		soybean	187.5		soybean	23.4						
									13	cover only	28.2						
		8,500+	5	cotton	150.0	5	cotton	187.5	5	cotton	26.5			364.0	364.0	364.0	22.0
				wheat	150.0		wheat	187.5		wheat	26.5						
				soybean	150.0		soybean	187.5		soybean	26.5						
									13	cover only	22.0						
		7,500	1	peanut	24.0								107.9	332.9	308.9	308.9	
soil	10			cotton	24.0												
only			3	peanut	83.9												
				cotton	83.9												
				wheat	83.9												
				soybean	83.9												
						5	cotton	187.5	5	cotton	36.3						
							wheat	187.5		wheat	36.3						
							soybean	187.5		soybean	36.3						
									6	cotton	1.2						
										wheat	1.2						
										soybean	1.2						
										cover	1.2						
		8,000	1	peanut	81.8								134.6	359.6	277.8	277.8	
				cotton	81.8												
			3	peanut	30.9												
				cotton	30.9												
				wheat	30.9												
				soybean	30.9												
						5	cotton	187.5									
							wheat	187.5									
							soybean	187.5									
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										winter cover	37.5						
			9	peanut	21.9												
				cotton	21.9												
				winter cover	43.8												

Table G-1. Crops and rotations with varying levels of PNS reduction (*continue*)

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations									Total crop acres (all slopes and rotations)					
			1% slope			3% slope			5% slope								
			#	crop	acres	#	name	acres	#	name	acres	Corn (ac)	Peanut (ac)	Cotton (ac)	Soybean (ac)	Wheat (ac)	Cover only(ac)
			1	peanut	88.5								150.0	375.0	225.0	225.0	
Soil only	10	8500+		cotton	88.5												
(continue)						5	cotton	187.5									
							wheat	187.5									
							soybean	187.5									
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										winter cover	37.5						
			9	peanut	61.5												
				cotton	61.5												
				winter cover	123.0												
		7,500	1	peanut	24.9								24.9	375.0	350.1	350.1	
	20			cotton	24.9												
			5	cotton	125.1	5	cotton	187.5	5	cotton	25.6						
				wheat	125.1		wheat	187.5		wheat	25.6						
				soybean	125.1		soybean	187.5		soybean	25.6						
									6	cotton	11.9						
										wheat	11.9						
										soybean	11.9						
										cover	11.9						
		8,000	5	cotton	67.3	5	cotton	187.5					82.7	375.0	292.3	292.3	
				wheat	67.3		wheat	187.5									
				soybean	67.3		soybean	187.5									
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										cover	37.5						
			9	peanut	82.7												
				cotton	82.7												
				cover	82.7												
		8,500+	5	cotton	56.0	5	187.5						94.0	375.0	281.0	281.0	
				wheat	56.0		187.5										
				soybean	56.0		187.5										
									6	cotton	37.5						
										wheat	37.5						
										soybean	37.5						
										winter cover	37.5						
			9	peanut	94.0												
				cotton	94.0												
				winter cover	188.0												

Table G-1. Crops and rotations with varying levels of PNS reduction (*conclude*)

Pollutant under constraint	Level of reduction (%)	Expected shortfall allowed ($)	Rotations									Total crop acres (all slopes and rotations)					
			1% slope			3% slope			5% slope			Corn	Peanut	Cotton	Soybean	Wheat	Cover
			#	crop	acres	#	name	acres	#	name	acres	(ac)	(ac)	(ac)	(ac)	(ac)	only(ac)
		8,000	5	cotton	150.0	5	cotton	157.2						370.0	370.0	370.0	10.0
	30			wheat	150.0		wheat	157.2									
				soybean	150.0		soybean	157.2									
						6	cotton	30.3	6	cotton	32.5						
							wheat	30.3		wheat	32.5						
							soybean	30.3		soybean	32.5						
							winter cover	30.3		winter cover	32.5						
									13	cover only	10.0						
		8,500+	5	cotton	150.0	5	cotton	120.4						375.0	375.0	375.0	
				wheat	150.0		wheat	120.4									
				soybean	150.0		soybean	120.4									
						6	cotton	67.1	6	cotton	37.5						
							wheat	67.1		wheat	37.5						
							soybean	67.1		soybean	37.5						
							winter cover	67.1		winter cover	37.5						
		8,000	5	cotton	150.0	5	cotton	174.4						354.7	354.7	354.7	67.8
	40			wheat	150.0		wheat	174.4									
				soybean	150.0		soybean	174.4									
						6	cotton	13.1	6	cotton	3.6						
							wheat	13.1		wheat	3.6						
							soybean	13.1		soybean	3.6						
							winter cover	13.1		winter cover	3.6						
									13	cover only	67.8						
		8500+	5	cotton	150.0									355.1	355.1	355.1	39.8
				wheat	150.0												
				soybean	150.0												
						6	cotton	187.5	6	cotton	17.6						
							wheat	187.5		wheat	17.6						
							soybean	187.5		soybean	17.6						
							winter cover	187.5		winter cover	17.6						
									13	cover only	39.8						
All PNS	10	8,000	1	peanut	25.5				1	peanut	8.9		34.4	346.4	312.0	312.0	57.2
				cotton	25.5					cotton	8.9						
			5	cotton	124.5	5	cotton	187.5									
				wheat	124.5		wheat	187.5									
				soybean	124.5		soybean	187.5									
									13	cover only	57.2						
		8,500+	5	cotton	26.1	5	cotton	187.5	5	cotton	3.6		134.9	352.1	217.2	217.2	46.0
				wheat	26.1		wheat	187.5		wheat	3.6						
				soybean	26.1		soybean	187.5		soybean	3.6						
			9	peanut	124.0				9	peanut	10.9						
				cotton	124.0					cotton	10.9						
				winter cover	248.0					winter cover	21.8						
									13	cover only	46.0						

Vita

Wei Peng was born in April, 1965 in Jingdong County, Yunnan Province, China. His childhood was spent in a forestry production area where his father and mother, Ruixian Peng and Yuzhi Zhao, worked during the "Great Cultural Revolution." His family moved to Dali, Yunnan which is a beautiful area of Bai People in 1975 and he went to high school there. In 1981, he went to Yunnan University to study mathematics as an undergraduate and graduated with a BS in 1985.

From 1986 to 1988, he was a research trainee doing extension work in rural area in Yunnan Province. He then worked for Yunnan Academy of Agricultural Sciences for six years. During this period, he worked with data-processing and information management related work for the academy's Testing and Analysis Center for two years, was in charge of the micro-computer lab of the academy's Bio-technology Institute for one year, and was the manager of the academy's Bio-electronic Technology Company for three years. He married his wife, Mary, in 1988 and their son, Ziyou (Rick), was born in 1991. He arrived at Virginia Tech in the Spring of 1995 to pursue his master's degree in agricultural and applied economics and now is a Ph.D. student of the same department.

His son and his wife came to join him in the United States in 1995 and with the birth of his daughter, Nancy, in May 1997, his family size has doubled since he started it.

He likes to play soccer and strongly believes that only soccer is a real sport. He broke one leg while playing soccer on September 30, 1995 in Richmond, Virginia and now is about to retire forever from the game.