ECONOMIC AND ENVIRONMENTAL IMPACTS OF NITROGEN FERTILIZER USE

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PREFACE

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CHAPTER I

INTRODUCTION

Nitrogen is an essential element for all life on this earth. Without nitrogen the biological life chain is impaired. Plants are not able to synthesize protein for human and animal survival and the decay of waste material is slowed.

We come in contact with various forms of nitrogen everyday. It is in the atmosphere water and soil. Since the beginning of mankind, nitrogen has pervaded every part of the earth. But only in the past few decades has man been able to commercially isolate nitrogen and utilize it to improve the well-being of mankind through increased food and fiber production.

Today, with the public's growing concern for a cleaner environment, the use of commerical nitrogen fertilizer is under close scrutiny. Agriculture has taken the brunt of the nitrogen fertilizer controversy because of its increased utilization for crop production.

The increased use of nitrogen fertilizer has been a recent phenomenon in the United States. Domestic U.S. consumption of nitrogen fertilizer in 1950-54 was 1,621,003 tons; 1971 utilization was 8,016,007 tons, an increase of 395 percent in 23 years [44]. Prior to 1950 most of the Texas high plains area and a large portion of Oklahoma applied very little commercial nitrogen fertilizer. Selected counties in Oklahoma, Kansas and Texas utilized 2,142 tons in 1950 and 116,156 tons in 1972. The impact of this increased nitrogen fertilizer use has been great in the U.S.'s agricultural sector.

The use of nitrogen fertilizer by the American farmer has enabled him to maintain yields and even increase yields on both land cropped for many years and on new land brought into production. The result of this improved production is indicated in the consumer's ability to have food and fiber products of higher quality and at relatively inexpensive prices.

Industries which supply agriculture with nitrogen fertilizer were faced with a highly competitive industry, at least until 1972. Nitrogen prices in the 1950's were about 20 cents per pound of nitrogen. In 1972 nitrogen prices dropped to between five and eight cents per pound. Consequently, many nitrogen producing companies sold their facilities or went into receivership. Only the stronger, highly capitalized companies remained.

Beginning in 1972 with the devaluation of the American dollar and the sudden increase in world demand for food and feed grains, nitrogen fertilizer demand increased in both foreign and domestic markets. The ability to produce nitrogen soon reached capacity and the domestic supply of nitrogen became restricted. Increasing foreign demands for nitrogen further restricted domestic supplies. Consequently, prices have increased to as high as 30 cents per pound of nitrogen. With prices at this level new producing plants and increased plant capacities are again coming to the nitrogen fertilizer industry.[1]

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[1] Recent newspaper articles indicated four new nitrogen plants with a combined total production of one million tons per year are being built in Kansas, Oklahoma and Texas area. They are to be operational by 1975.

The impact of nitrogen fertilizer is not isolated in the farming sector of our economy. Indirectly through farm yield changes, nitrogen fertilizer use impacts on rural areas by changes in income and employment levels. These rural communities have oriented their level of business around the nitrogen induced increases in agricultural productivity. It is quite possible that many of the services provided by these communities would be curtailed if nitrogen induced productivity is diminished through laws restricting nitrogen fertilizer use.

There are problems related to the increasing use of nitrogen fertilizer in agriculture. Nitrogen may leave agricultural lands through rain or irrigation induced runoff and leaching through the soil profile. This movement may eventually reach our surface and ground water supplies causing the quality of our water to diminish.

In our water environment nitrogen is necessary for algae growth, which is a food source for aquatic life and eventually benefits man. However, too much nitrogen in our surface waters creates an imbalance in plant and animal life. Eutrophication, as this imbalance is called, is an excess of nitrogen in the water which leads to excess algae blooms, oxygen deficiency and the potential death of aquatic life.

Excessive nitrogen concentrations in water supplies used for human consumption on occasion have led to methomoglobinemia in infants. Many well waters containing over 500 ppm nitrate have never been linked to actual "blue-baby" cases, but most cases in the U.S. and Europe have been associated with waters consistently registering concentrations of more than 50 ppm nitrate [1, p. 6]. Most of these cases have been associated with wells which draw from shallow water sources near barnyards or waste-disposal sites. Excessive nitrates have also been known to cause diarrhea when one liter of water containing 500 ppm nitrate was consumed [1, p. 8].

Water quality standards set forth by the U.S. Public Health Service (1962) and Federal Water Pollution Control Administration (1968) recommend permissible surface water concentrations of nitrogen at 10 parts per million parts water. No standards for well water were reported by these agencies. These standards are difficult to apply and with present monitoring devices difficult to detect [1, p. 63].

Despite the definite benefits associated with nitrogen fertilizer use, the possibility of irrevocable damage to both our physical environment and to human beings still exists. If the agricultural sector is to maintain public confidence in its production practices the possibility of nitrogen pollution from agricultural lands must be considered.

Problem Statement

General Statement

Developments of the past decade clearly indicate the need to understand the relationship of commercial nitrogen fertilizer pollution and its impact on our way of life. Even before the publishing of Rachel Carson's book, "The Silent Spring" in 1962, scientists, conservationists and others were aware of the hazardous possibilities of "fooling around with Mother Nature." Unfortunately many of us did not realize the long lasting effects and/or the interaction of agricultural inputs and the environment. We still are not completely aware of the built-in tolerance levels of our environment; we just say nitrogen use can be a serious problem to the environment with no real evidence as to the beneficial and adverse effects of its use.

Commercial nitrogen fertilizer use does provide benefits for mankind. In a purely economic sense applications of nitrogen to crops has increased agricultural productivity, farmer incomes and has been an important aid in stabilizing productivity and income for farm and rural populations. Consumers have benefited from this increased productivity through better and cheaper food, feed and fiber crops. Although seldom recognized, the increased use of nitrogen fertilizer has improved wildlife habitat, by providing better wildlife feeding grounds. Increased productivity per acre from nitrogen fertilizer has kept the more marginal lands out of agriculture and in native type wildlife areas.

This impact of nitrogen fertilizer use is not localized within the farming sector of the agricultural community but it interacts with the supporting and supported segments of our rural communities. Increased agricultural productivity along with better and more stable farm income have maintained an income stream to local area businesses and service industries. Input industries supplying farmers with operating and capital goods have steadily increased their sales and profits, which is again directly related to increases in productivity and nitrogen fertilizer.

The continued use of nitrogen fertilizer is loaded with "trade-offs."[2] Agriculture needs nitrogen fertilizer to improve productivity, farm incomes and to maintain relatively inexpensive and high quality foods for consumers. However, there are externalities created from nitrogen use in agriculture.

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[2] A "trade-off" is defined here as what one must give up to obtain something else.

Specific Statement

This study attempts to analyze the nitrogen fertilizer-environmental quality issue. Emphasis is placed upon weighing the "trade-offs" associated with the benefits from applications of nitrogen fertilizer and the externalities created by such applications upon water and terrestrial environmental quality.

Since the late 1950's the application rate and total pounds applied in the Oklahoma-Texas area of the U.S. have increased substantially. This trend seems likely to increase in the future as more irrigated acres are brought into production and the beef feedlot industry grows. However, as the amounts of nitrogen fertilizer applied per acre increases the potential for nitrogen pollution problems also increases. At present, most scientists agree that we are not facing a serious nitrogen pollution problem. However, as the demand for food and feed grains (corn, wheat, and grain sorghum are the most important of these in the study region) increase in the future we must consider the possibility of increased nitrogen run-off and its potential impact on our economy, physical environment and social well-being.

Objectives

The overall objective of this study is to determine the "trade-offs" associated with nitrogen fertilizer useage and its impact on the area's economy, physical environment and the social well-being of its people. Specifically, the objectives are:

(1) To develop information on a nitrogen responsive land base comprised of loam, clay and sand soils, which are indicative of crop production patterns in the area of study.

(2) To develop a model which utilizes the nitrogen responsive land base to project land use and the resulting crop production for loam, clay and sand type soils, by crops, for the years 1975, 1980, 1985 and 1990;

(3) To estimate the amount of potential nitrogen pollution which might occur in the production of the crops grown in Objective 2; and

(4) To evaluate the effects of selected nitrogen fertilizer strategies over time on the area's economy, physical environment and social well-being.

A model of the 1972 wheat, grain sorghum and corn production was selected to provide a more normal pattern of nitrogen fertilization rates and crop land utilization, than the situation that has developed in the last two years. Projections of the impact of selected nitrogen fertilizer strategies on the economy, physical environment and the social well-being of the area's people to 1990 are made from the 1972 base model. "Trade-offs" between nitrogen fertilizer use and its externalities are evaluated and ranked according to their advantageous and detrimental impact on the economy, physical environment and social well-being.

Description of the Study Area

The selection of the study region was based on three basic criteria; each lends itself to a total analysis of the impact of nitrogen fertilizer in agriculture. First, the area must utilize a significant proportion of nitrogen fertilizer in its cropping activities. Second, it must include a city or cities of sufficient size to provide the necessary marketing and input functions to maintain a viable relationship with the agricultural sector. Third, the area must lie within a watershed basin of sufficient size to lend credulence to the problem of nitrogen fertilizer runoff and potential pollution.

The geographic area selected consists of 30 Oklahoma, 12 Texas the three Kansas Counties (Figure 1). The area's boundaries are defined by the 1972 OBERS report.[3] This report was prepared to provide basic economic information by public agencies engaged in comprehensive planning for the use, management and development of the nation's water and land related resources [75, p. 3]. The report presents projections for water resource areas, subareas, states and functional economic areas (FEA's). The study region defined by the OBERS report include the following sub-watersheds of the Arkansas River Basin: the Lower Canadian, sub-watershed 1105; the Arkansas-Keystone, sub-watershed 1106; the Canadian River in Texas, sub-watershed 1109; and the Lower Canadian River, sub-watershed 1110.

The study region is located within a large food and feed grain production sector of the United States. The predominant feed grains are grain sorghum and corn; wheat is the major food grain produced in this area. Wheat has been the leading cash crop in the area for many years. Grain sorghum and corn acreage increases were initiated with the advent of irrigation and a growing feedlot industry in the Texas and Oklahoma Panhandle.

In 1972, in the study region, wheat was produced on 3,810,436

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[3] OBERS is an acronyn for the Office of Business Economics, U.S. Department of Commerce and the Economic Research Service, U.S. Department of Agriculture.

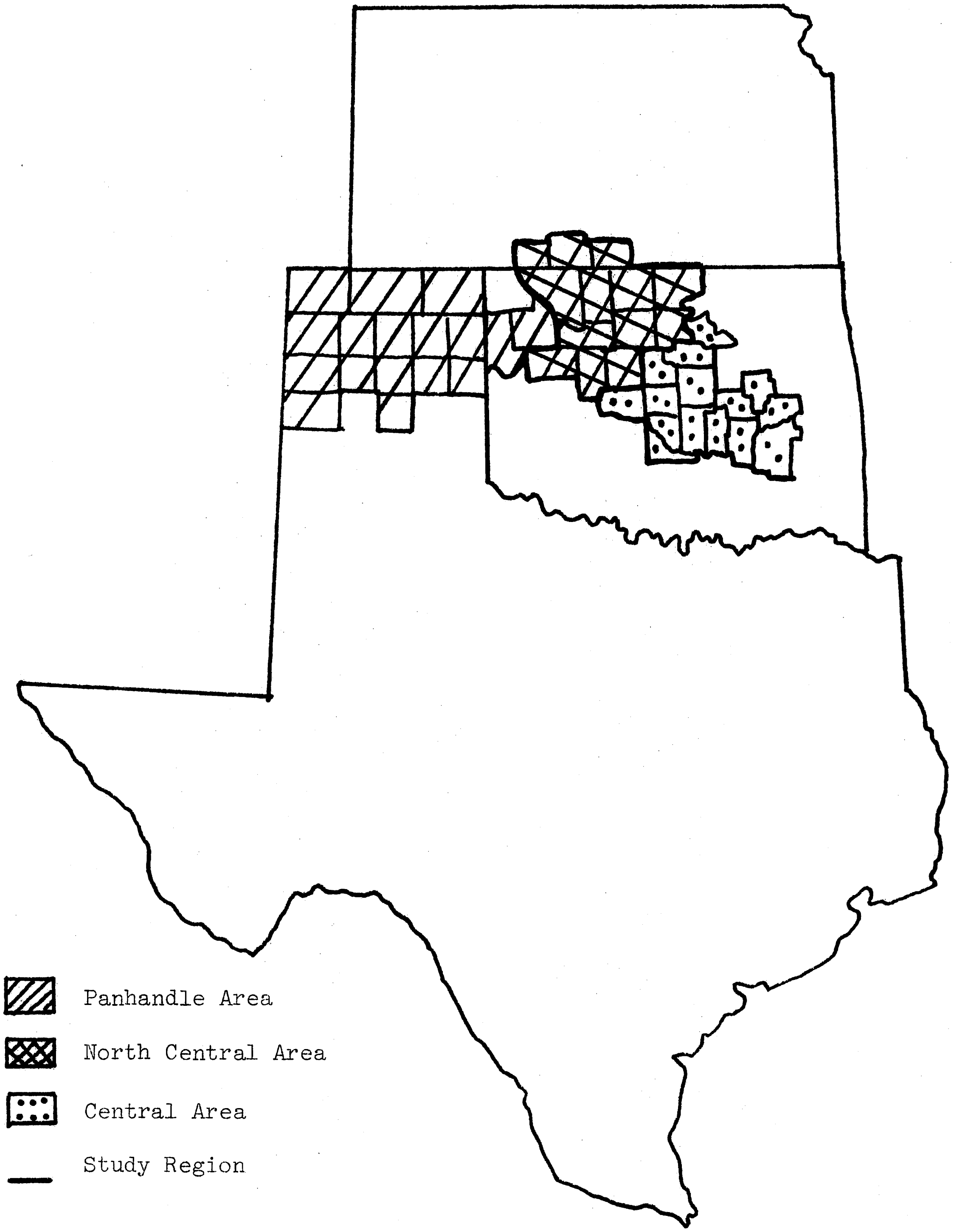

Figure 1. Delineation of the Three Areas and the Region for the Nitrogen Fertilizer Study

acres with 454,299 of these acres being irrigated; corn was produced on 180,301 acres, all irrigated; and grain sorghum was produced on 1,018,012 acres with 576,100 acres of this amount under irrigation. These three crops added 288,870,920 dollars to the area's income base: wheat 154,070,360, grain sorghum 88,753,560 and corn 46,047,000 in 1972 [46].

The soil resource found in the study region is extremely varied, ranging from heavy textured clays to loamy fine sands. The area encompasses eight land resource areas, 19 soil associations and consists of approximately 21 million acres of cultivated, pastured and forested lands.

The climate of the study area is quite diverse. The mean annual precipitation ranges from 15 inches per year at the western border of the Oklahoma and Texas Panhandle to 40 inches per year in the most eastern areas (Figure 2). Mean annual summer temperatures run from 67° to 92° F in the east. Winter temperatures vary from 24° to 50° F in the west to 22° to 42° F in the east. Summer temperature extremes may go over 100° F and winter temperatures may dip below 0° F.

The humidity factor also varies widely. Noon humidity in the western section of the study area averages between 47 percent in January and 43 percent in July. The eastern boundary humidity averages for these time periods is 63 and 50 percent. Wind speeds across the area average between 11 and 13 miles per hour giving rise to high rates of evapotranspiration especially in the High Plains Area of Texas and Oklahoma. The evapotranspiration rate falls moving from west to east [72].

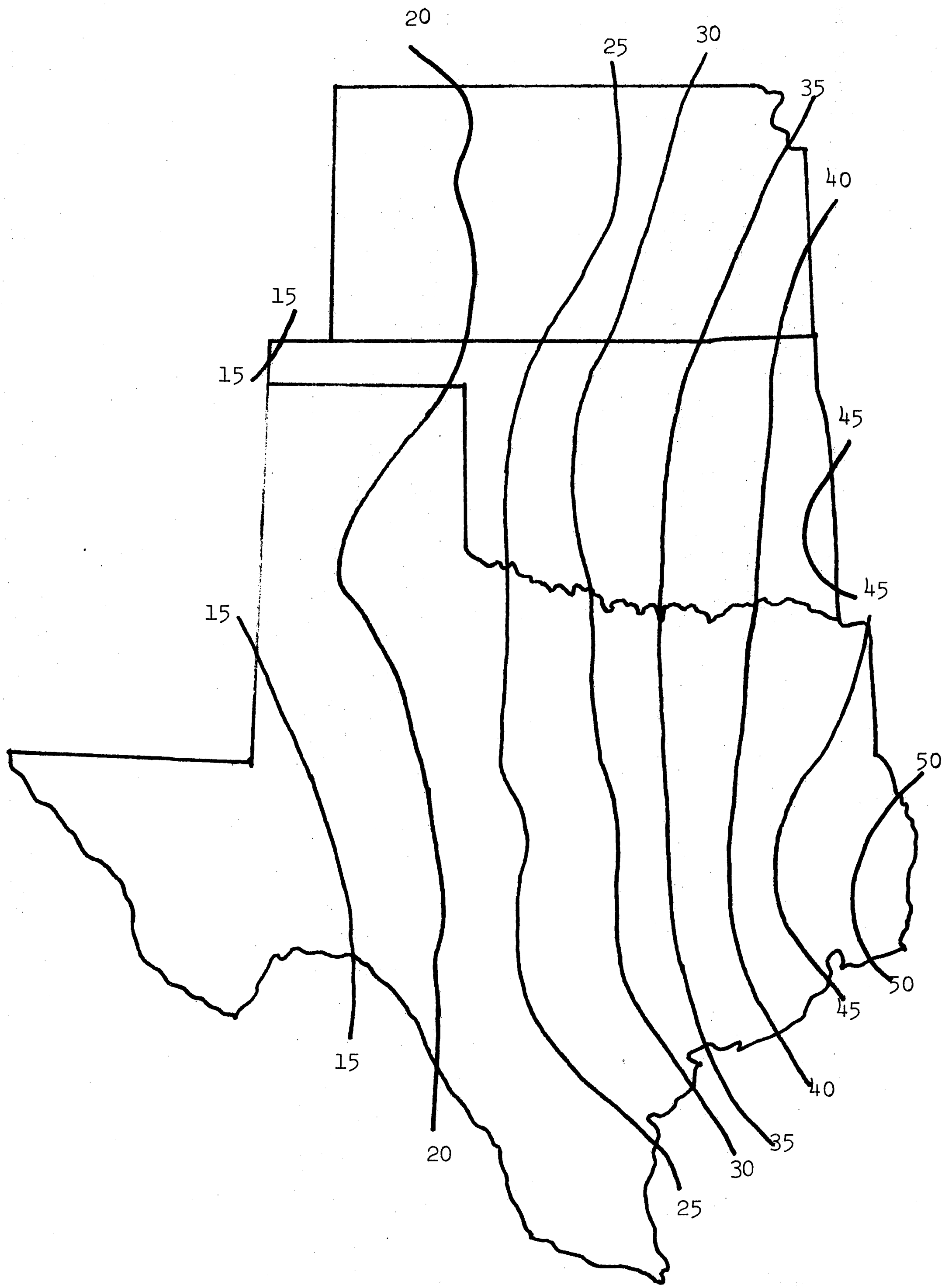

Figure 2. Mean Annual Precipitation in Inches in the Study Region

Organization of Thesis

The remainder of this dissertation is organized as follows: Chapter II discusses the current state of the literature and economic theory considerations. The first section discusses and described the applied economic studies which attempt to analyze economic and environmental "trade-offs." The second section discusses relevant previous agronomic and environmental research on nitrogen fertilizer as its use relates to both agricultural production and environmental quality issues.

Chapter III describes the methodology and assumptions employed in developing the soil classification base, in specifying the structural parameters of the linear programming model; and in development of the environmental impact matrix.

Chapter IV presents the linear programming results of the baseline strategy. Chapter V presents and analyzes the results of the alternative nitrogen fertilizer strategies and compares these to the baseline strategy. Chapter VI develops the environmental impact matrix for the nitrogen fertilizer strategies. Summary, conclusions and recommendations for future research are presented in Chapter VII.

CHAPTER II

ECONOMIC AND ENVIRONMENTAL ASPECTS OF NITROGEN FERTILIZER USE AND POTENTIAL POLLUTION

Agronomic Fertilizer Considerations

The amount of nitrogen present in our soils today is a function of a multitudinous number of biological and chemical reactions which have been affected by man's growing of food and fiber crops. It has been estimated that 2,000 pounds of natural nitrogen per acre were present in the top six inches of the soil profile in native uncultivated grasslands. But the continued cultivation of crops on these lands has decreased the amount of nitrogen present in the soil profile.

Even without the influence of crops, the amount of nitrogen available in a given soil profile is not static. Rather, the forces of "Mother Nature" continually generate a dynamic environment for nitrogen in the soil. The amount of nitrogen in the soil is a function of: (1) population of microbial organisms, (2) acidity of the soil, (3) presence of oxygen in the soil, (4) temperature, (5) moisture, (6) present cropping patterns, (7) past cropping patterns, and (8) application rate of commercial nitrogen fertilizer. Each of these factors plays a vital role in the determination of the amount of nitrogen present in the soil.

Agricultural uses have affected the amount of nitrogen present in the soil. The "dust bowl" made farmers aware of the hazards of erosion and loss of soil fertility. Large scale reversion of eroded lands back to pasture and range activities occurred. Implementation of contour farming and terracing helped reduce the erosion of better cropping lands. These cropping patterns have not significantly changed in recent years. The biggest change in commercial agriculture in the last 20 years was the introduction of commercial nitrogen fertilizer in the mid 1950's. Until this time few farmers in the study area utilized commercial nitrogen fertilizer; phosphorus in the form of rock phosphate and super-phosphate were the main soil improving materials utilized up to that time.

The dynamic impact of nitrogen fertilizer on crop yields is readily apparent. Production capacities of our land have increased trememdously. Increased use of nitrogen came as the price of commercial nitrogen fell from over 20 cents a pound in the 1950's to five cents a pound in the early 1970's.

Recently, the energy crisis and increased foreign demand have pushed the price of commercial nitrogen above 20 cents a pound. Foreign demand for nitrogen fertilizer coupled with increased United States acreages in production since 1972 have created a short-run shortage. USDA indicates this shortage is likely to continue until 1975-76. The long-run outlook is brighter. Higher prices paid for nitrogen fertilizer have stimulated production facilities and expected production of nitrogen fertilizer is estimated to more than meet United States demand within three to five years.

Physical Relationship of Nitrogen Fertilizer and Soil Retention

Plants absorb most of their nitrogen in NH_4 (ammonium) and NO_3 (nitrate) forms. The amounts of these in forms of nitrogen available to plants depends upon what happens to the commercial nitrogen fertilizer after it is applied and the amount of organically bound soil nitrogen present at the time of application.

Where does this nitrogen go? There are four alternative fates. First, some of the nitrogen is needed to aid the soil microorganisms to further decompose organic carbon residues, or become biologically unavailable, especially in clay type soils.

The nitrate form of nitrogen is a highly mobile form capable of movement within the soil profile. Under certain conditions it is this nitrate form of nitrogen which is potentially harmful. In dry weather the nitrate nitrogen can move into the upper horizons of the soil profile and even to the soil surface [65, p. 143]. It is at this time that the potential of runoff of the nitrate nitrogen is highly possible.

Another fate of nitrogen is its loss into the atmosphere in a gaseous form through volatilization of ammonia gas. Volatilization occurs quite frequently with the application of anhydrous ammonia and ammonia solution forms of nitrogen fertilizers. The amount lost through volatilization depends largely on the PH of the soil. The more alkaline the soil the greater the volatilization of ammonia gas. In certain instances, volatilization has played a significant role in nitrogen loss from soils [65, p. 148].

The most important fate of nitrogen in the soil is explained by plant uptake. The American Potash Institute reports that a 12,000 pound grain sorghum crop will consume 185 pounds of actual nitrogen per acre in a 95 day growing season [8].

Similarly, 180 bushels of corn produced on an acre of land will utilize 240 pounds of nitrogen in its growing cycle. Wheat yields of 86 bushels per acre will utilize 186 pounds of nitrogen fertilizer [45, p.3]. This "tieing-up" or use of nitrogen fertilizer does not all occur immediately after application, but throughout the crop's growing season. The Potash Institute indicates for 180 bushels of corn the uptake occurs at the rate of 19 pounds from planting to first 25 days; 84 pounds during the primary growth stage, 26-50 days; 75 pounds during the silk stage, 51-75 days; 48 pounds during the grain producing stage, 76-100 days; and 14 pounds for the kernel maturing stage, 101-125 days [45, p. 6].

The application of nitrogen fertilizer does not necessarily occur at one period in time. This is an economic consideration as well as an agronomic function. Applications of nitrogen fertilizers as well as application rates are timed to critical periods of plant growth. The farmer must consider if it is profitable to fertilize his crop given the condition the crop is in at these critical growth stages.[1]

Theoretical Framework

Increased fertilizer use in United States agriculture has resulted

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[1] Condition of crop implies the crop's potential to produce grain or forage based on prior rainfalls, insect damage, frosts, and other climatic and agronomic conditions.

in one of society's critical "externality" issues. An externality can be defined as any condition resulting in a difference between marginal private benefits and costs and marginal social benefits and costs. When marginal private effects and marginal social effects are not the same, externalities occur in the form of external benefits and/or external costs.

The externality concept is one of the most elusive concepts confronting economists because it is difficult to determine the true effect of a particular course of action. For example, if a farmer applies nitrogen fertilizer to his crop and rainfall conditions occur which flush part of this nitrogen into a nearby surface water source, then the water source is enriched in its nitrogen concentration. The ultimate destination and distribution of this enriched water source provides either external benefit or costs downstream. The nitrogen may actually improve the aquatic habitat by providing a food source for its plant life. In this case a benefit is derived. On the other hand, the water source may not be lacking in nitrogen in which case additions to its supply may generate so much plant growth that the water's oxygen demand is impaired. Fish kills may occur and unpleasant odors may arise from increased algae blooms. This would be considered an external cost. Hence, actions taken by one party may create a beneficial or harmful effect to another party.

Economic theory provides a framework for the analysis of externalities in the marginal social benefits and costs concept. Within this concept compensation to third parties for costs incurred beyond their control may be demonstrated. However, the empirical ability of this framework is exceptionally difficult to handle.

Recently, the empirical and theoretical framework for the determination of externalities has been given more attention. Most of the recent literature deals with the effects of pesticides; the concepts developed are readily applicable to the nitrogen question. Headley and Lewis have taken the "somewhat unrefined concepts of 'old' welfare economics," and adapted them to the pesticide problem in an attempt to estimate the social benefits accruing from pesticide uses [20, p. 43]. They utilize a model similar to Figure 3.

The social benefits occuring are measured through the algebraic summation of the supply and demand curves. Consequently, changes in consumer total utility or satisfaction (supply_1 to supply_2) are measured by the change in the area under the demand and supply curves [20, p. 45]. As a result of an innovation in pesticides use which produces a cost savings, the supply function shifts to the right producing more of a given crop. The price of the crop falls to OP_2 and total consumer utility increases by the additional area between the supply functions and the demand curve.

This approach was used by Edwards in a 1972 study of several crops in Dade County, Florida [13, pp. 20-63]. In essence, Edwards estimated demand and supply equations and their respective price elasticities for various crops under differing policy adaptations toward pesticide useage. The supply shifts, or alternative policies, were subjectively chosen based upon the technical substitution rate between the chlorinated hydrocarbons and organic phosphates. Cost changes associated with the alternative policies were utilized to reflect, in a parallel manner, shifts in the original supply function.

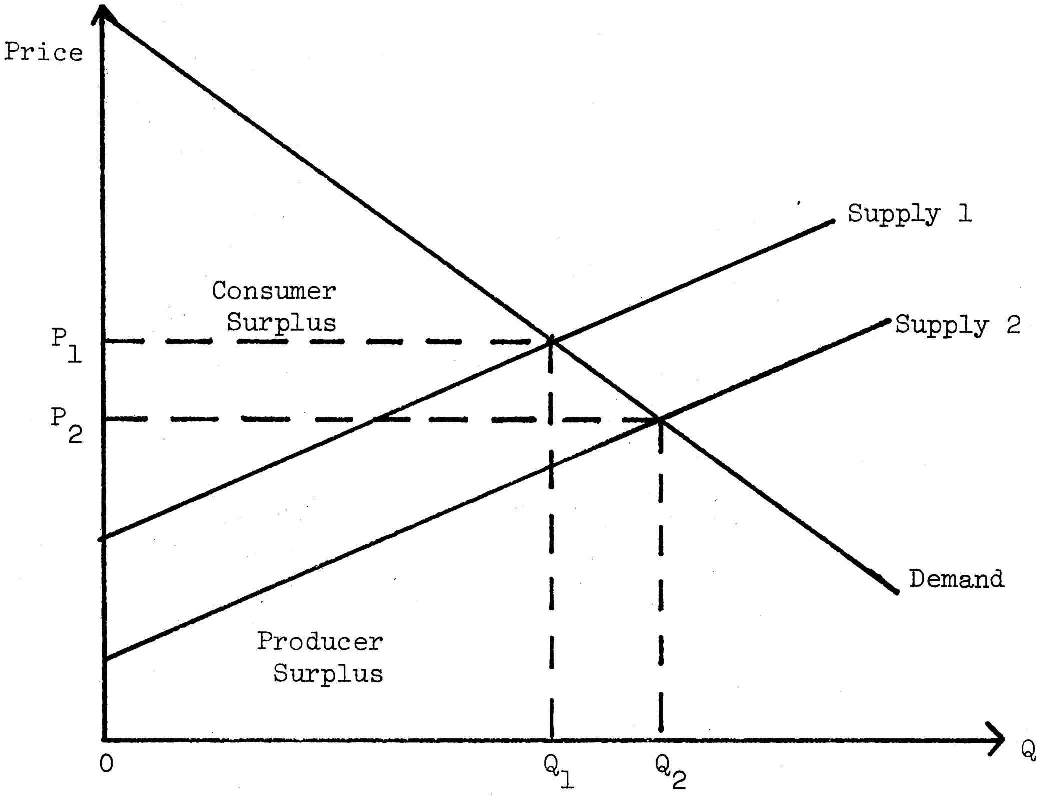

Figure 3. Hypothetical Model of Demand and Supply for an Agricultural Commodity

Estimation of externalities associated with the organic phosphate pesticides were developed by assuming a functional relationship between dollars of externalities and the quantity of pesticides used. Dollars of externalities were developed from payments made to third parties from court suits instituted and ajudicated in Dade County during 1966-67. These estimates were utilized as constraints in the model.

This theoretical framework developed by Headley and Lewis and implimented by Edwards clearly show the problems associated with the attempt to estimate externalities. Our state of knowledge about social benefits and costs is exceedingly naive. Scientists are aware of the externalities arising from agriculture's cropping practices. However the magnitude of these externalities--both benefits and costs--is exceptionally difficult to obtain.

One approach to the analysis of the aggregate consequences of restricted chlorinated hydrocarbon insecticides is the partial budgeting approach employed by the USDA [9, pp. 1-48]. Estimates of the total expenditures for chlorinated hydrocarbon insecticides are computed for a given year. The cost of substituting non-persistent pesticides at an application level which would insure the same effective control is estimated. The higher cost of non-persistent pesticides at an application level which would insure the same effective control is estimated. The higher cost of non-persistent pesticides and an increased number of application rates per acre increases the total cost of producing the agricultural crop. The difference in aggregate expenditures for persistent and non-persistent pesticides is the cost society must pay for the restriction of persistent pesticides.

A 1970 study by Texas A & M utilized a comparable analysis and projected the change in consumer expenditures resulting from a complete curtailment of nitrogen fertilizer and persistent pesticides [32, pp. 1-52].

Estimates of yield reductions were made for various crops; projections of production levels based on these yield declines indicated there would be severe declines in food supplies. These declines in food output were translated to commodity prices through the use of direct price elasticities. This approach estimates the impact on total consumer expenditures and has implications concerning the increase in the percent of disposable income spent on food products.

The methodologies discussed indicate ways of estimating direct consumer costs from restricting pesticides. However, this is only part of the total impact of restrictive actions. These approaches do not consider the impact of such restrictions on employment, land use patterns, and agricultural related industries. The techniques lack a methodology of indicating potential hazards to our physical environment; water and wildlife, and the aesthetical values mankind places on our habitat. The analyses estimate the economic cost side of the pollution problem but neglect the costs associated with the physical environment and aesthetic values.

Even more evident in these approaches is a lack of social benefit estimation. Benefits do accrue. The increased use of nitrogen fertilizer has allowed idled land to remain out of cultivation as our food demands increase, providing increased wildlife habitat.

Another methodological approach for evaluating the effects of alternative agricultural practices and the resulting externalities is the environmental impact matrix. The matrix allows the ranking of strategies on the bases of the resulting economic impact, physical environmental impact, and social well-being impact.

Richardson utilized an environmental impact matrix in evaluating alternative pest management strategies on selected Oklahoma crops [50, pp. 19-36]. In effect, Richardson attempted to develop a social welfare function which would evaluate the substitution impact between organic phosphate and chlorinated hydrocarbon pesticides. An area impact was determined for economic, environmental and social well-being conditions. Each of these main categories were weighted equally. Specific sub-categories within these categories were assigned weights by a panel of economists, agronomists, wildlife and fisheries experts and entomologists. The reason for the group weighting process was to eliminate individual biases and provide a "social viewpoint" to the pesticide question.

The use of the environmental impact matrix can broaden the current analysis of externalities and the "trade-offs" associated with abatement and/or containment. Economic techniques, such as linear programming are helpful in estimating aggregate impacts from various strategies on farm income and employment levels. Estimates of land use adjustment patterns are obtainable. Regional income and employment changes associated with abatement practices and "no-control" policies are estimable. Income and employment multipliers have been used frequently to determine the direct and indirect effects of various economic policy strategies. Their adaptation to environmental research provides greater framework of analysis. All of these factors lead to a more complete analysis of total benefits and costs in analyzing environmental issues.

Environmental data, although difficult to obtain, can be utilized to a greater extent through the environmental impact matrix. Quality adjustments, i.e., those which influence the environment but are not readily measurable, are given weight in the impact statement. Social well-being variables, which the consumer-producer surplus analysis fails to recognize, are at least qualitatively discernable. The matrix is not by any means a panacea for developing environmental policy. It does allow a broader analysis of the many and diverse variables in externality research.

The environmental impact matrix approach is subjective. It, like Headley and Lewis' model, lacks absolute quantitative rigor. However, unlike Edward's effort, the environmental impact matrix provides a more complete classification of potential impacts in greater detail and gives more consideration to the social viewpoint. This later point is important. As Edwards mentions the external benefits are almost impossible to define and consequently are not estimable [13, p. 83]. The environmental impact matrix provides at least a subjective analysis of these external benefits.

An adaptation of Headley and Lewis' theoretical framework is to view nitrogen pollution and expected yield per acre in a product-product model (Figure 4).

The vertical axis represents potential nitrogen pollution in parts per million in water from each acre. The horizontal axis indicates expected yield from a given amount of nitrogen fertilizer applied on a per acre basis. Visualizing the analysis as occurring over a growing season of fixed duration, point A represents the maximum amount

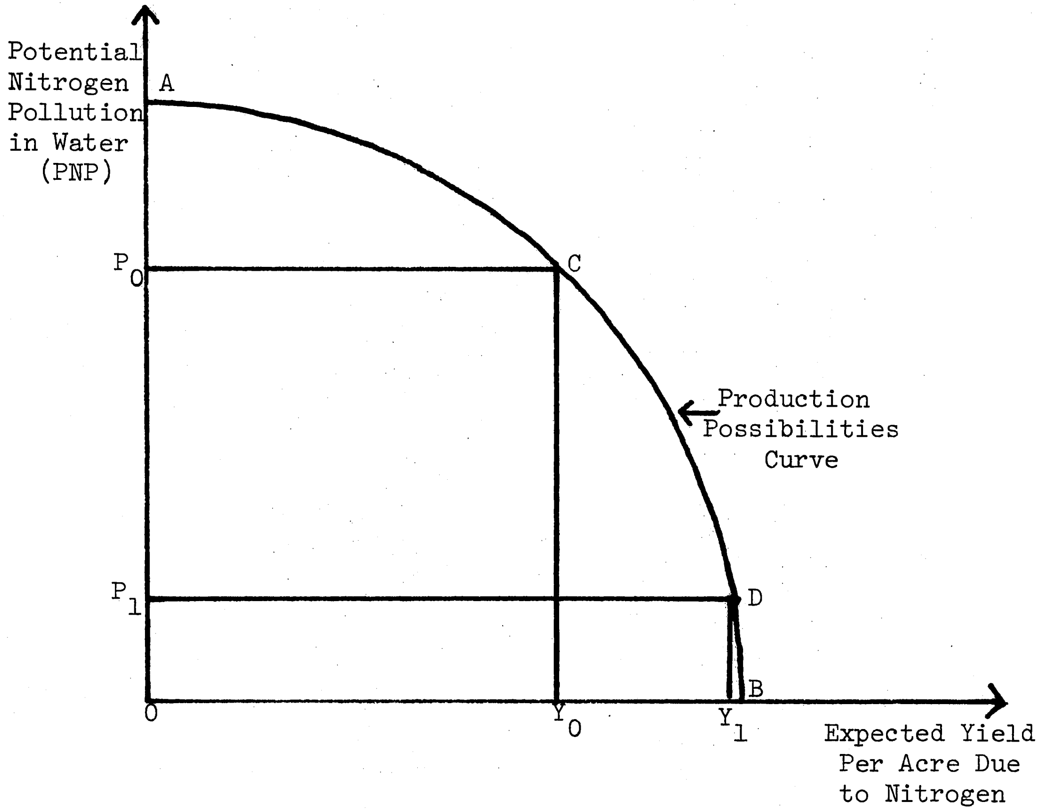

Figure 4. Production Possibilities Curve for a Given Level of Fertilizer Application Showing Potential Nitrogen Pollution and Expected Yield Per Acre

of potential pollution.[2] The potential declines toward the origin. Point B indicates the expected yield goal wanted by the farmer from nitrogen fertilization; the goal is determined before fertilization and the farmer applies nitrogen fertilizer to meet that goal. If the nitrogen applied is completely available throughout the entire growing season point B can be achieved. Losses of nitrogen may occur through runoff in heavy rainstorms, restricting the expected yield below the maximum achievable goal of point B. Thus, it is possible to develop a production possibilities frontier associated with the production of nitrogen pollution and yield levels from a given per acre application of nitrogen fertilizer.

It is conceivable to have situations such as points C and D. Point C assumes a potential pollution possibility of OP_o, indicating some nitrogen will be lost due to surface runoff in an intensive rainfall. This reduces expected yield per acre to point OY_o. Point D indicates a small pollution potential occuring (OP_1) and a resulting yield of OY_1; indicating only a small amount of nitrogen was lost and that essentially the maximum yield level at Point B was achieved.

If we visualize various levels of nitrogen fertilization per acre we can develop a family of these production possibilities functions and consequently conceptualize the magnitude of production and potential nitrogen pollution adjustments. This process is not unlike Headley

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[2] Pollution is considered potentially possible since rainfall must occur at a sufficient level and intensity to allow any runoff at all. If the amount of nitrogen applied is equal to the amount required by the crop to produce a given yield level, then unless an intense rain occurs, the nitrogen pollution potential is insignificant.

and Lewis' shifts in supply resulting from changes in input employed and their costs of production [20, pp. 43-45]. Assume the production of a given crop is in stage II of the production function with marginal physical product greater than zero. It is possible to relate a change in the production function's input mix through its related cost curves and show this impact on the supply function of this crop (Figure 5).

Assume MC_o is the marginal cost of producing a given crop. The equilibrium conditions are where MC = MR, which in this case is the price. Thus, the farmer strives to produce OQ_o and sells at price OP now let the input increase in price to the producer. The result is a shift toward the origin by the marginal cost curve. The new marginal cost is MC_1. The producer, receiving the same price (OP) for the crop (OP), will cut back production to OQ_1.

Since the marginal cost curve above the average variable cost curve is considered the supply function, i.e., the amount of product a producer is willing to produce at given price levels, the effect of an input price increase is a reduction on the supply of the crop. The resulting effect is exactly what Headley and Lewis indicate with their decrease in supply due to increased costs of production associated with more expensive methods of pest control to produce a given input level [20, p. 44]. The consumer is then affected through his constant demand curve for the crop. Decreased supply increases price levels and reduces the amount of consumer surplus.

Another way to conceptualize Headley and Lewis' consumer-producer impact is to hypothesize a consumer tolerance demand curve for potential nitrogen pollution. This curve indicates or depicts the

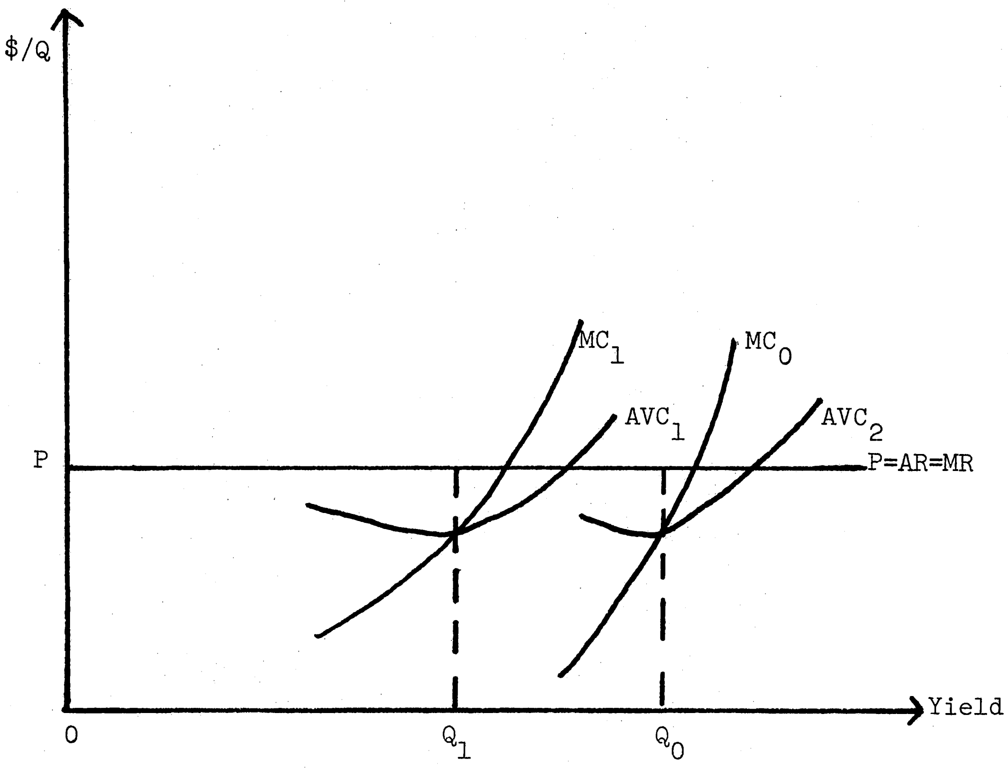

Figure 5. Hypothetical Marginal Cost Curves Associated With Selected Cropping Yields

consumer attitude toward environmental quality and aggregate regional output (Figure 6). Equal increments of increase in aggregate output result in the change in larger and larger declines in environmental quality; i.e., the consumer's requirement (preference) for environmental quality grows at an increasing rate as output increases at a constant rate. Mathematically the relationship is:

$$MRS_{EQ,AO} = \frac{\Delta EQ_1}{\Delta AO_1} < \frac{\Delta EQ_2}{\Delta AO_2} \cdot \cdot \cdot \frac{\Delta EQ_5}{\Delta AO_5} \text{ where}$$

$$AO_1 = AO_2 \cdot \cdot \cdot AO_5.$$

This implies that the marginal rate of substitution of environmental quality for aggregate output is increasing.

The tolerance demand curve suggests that the consumer is willing to accept some level of environmental degradation to obtain increased aggregate output. Another way of analyzing the interrelationship is that the amount of degradation (reduction in environmental quality) changes at an increasing rate as output increases.

Legislation Affecting Water Quality and Implications for Nitrogen Fertilizer Use

The use of commercial nitrogen fertilizer has increased the productivity of agricultural lands. This increased use of fertilizer has also caused much concern as to the impact of nitrogen runoff from agricultural lands and the quality of our surface streams and wildlife populations.

The Federal Water Quality Act of 1965 provided the initial legislation concerning maintenance and the improvement of United States interstate water quality. It provided water quality standards which

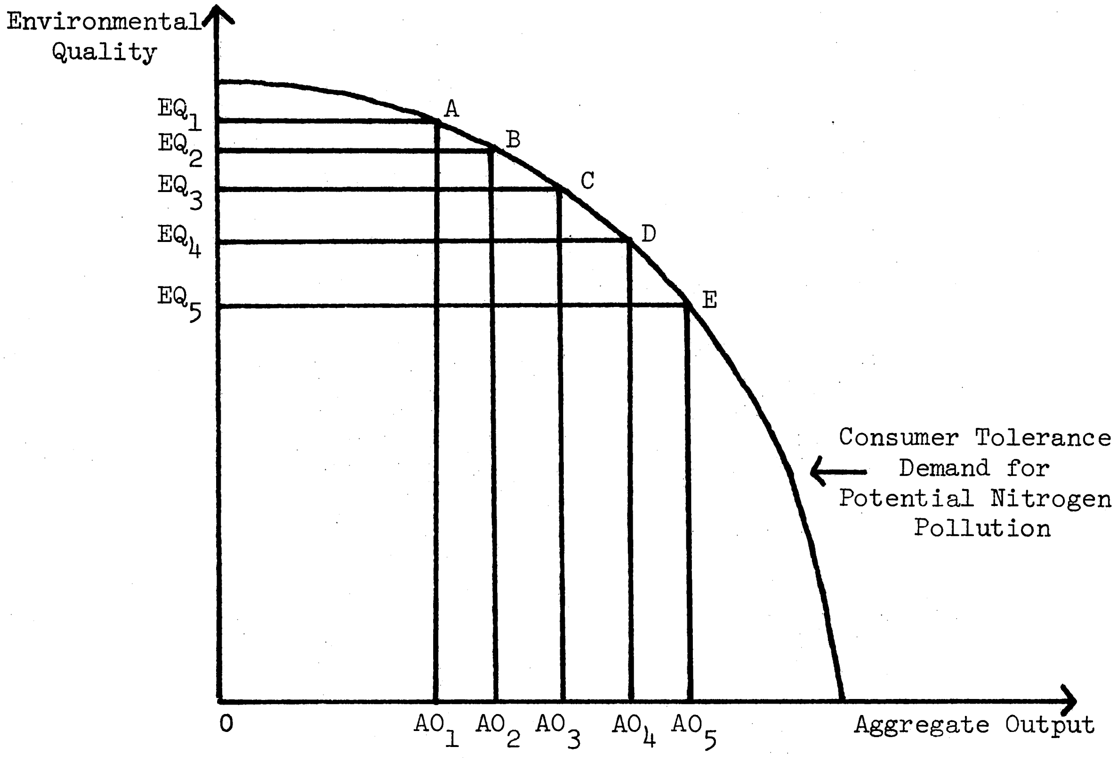

Figure 6. Consumer Tolerance Level of Demand for Environmental Quality and Aggregate Output

must be incorporated in planning government projects. Prior to this time the United States Public Health Service in 1962 recommended a limit of 45 ppm nitrate or 10 ppm nitrogen [1, p. 63]. Subsequent Federal laws improved the ability of planners to prevent the adverse effects of changes in water conditions upon the total environment.

The Estuary Protection Act of 1968 outlined policies of reasonable balance between the need to develop estuarine areas, further national development and growth, and the conservation of natural resources and the nation's natural beauty. The National Environmental Policy Act (NEPA) of 1969 and the Environmental Quality Improvement Act of 1970 authorized Federal agencies to become involved in the decision making processes and provided input into environmental legislation. The latter act emphasizes the responsibilities of state and local governments in the implementation of Federal policies. NEPA required each government project to file an environmental impact statement listing potential environmental problems.

NEPA provided the first legal impetus to project analysis. The Flood Control Act of 1970 extended this authorization in requiring that possible adverse economic, social and environmental effects be fully considered in developing government projects. Final decisions will be made with consideration for flood control, navigation and associated purposes, and the cost of eliminating or minimizing such adverse effects and the following:

(1) air, noise, and water pollution;

(2) destruction or disruption of man-made or natural resources esthetic values, community cohesion and the availability of public facilities and services;

(3) adverse employment effects and tax and property value losses;

(4) injurious displacement of people, businesses, and farms; and

(5) disruption of desirable community and regional growth.

The Federal Water Pollution Control Act Amendments of 1972, established the following goals:

(1) the discharge of pollutants in toxic amounts be prohibited;

(2) federal financial assistance be provided to construct public owned waste treatment plants;

(3) water quality and area wide waste treatment management planning including multi-objective water resource and land use planning;

(4) the best practicable control technology currently available to limit point effluent sources shall be utilized until 1977;

(5) after 1977 and until 1983 the best available technology economically achievable shall be utilized to limit point effluent sources; and after,

(6) 1985, the discharge of pollutants into navigable water be eliminated.

Whenever precipitation occurs more rapidly than the water can be absorbed by the soil, it runs off into drainage ways of soil depressions. Because of the importance of surface runoff to streamflow the potential of nitrogen fertilizers in this runoff becomes a possible hazard to man and his environment. A number of factors influence the amount of runoff derived from a given storm and consequently affect the level of nitrogen pollution, e.g., weather, topography, soil properties, and plant cover.

Weather characteristics include intensity of rainfall in a given time period, saturation point of the soils, and how much rain has preceded a given rain storm. Soil properties also influence runoff. Sandy soils absorb water at faster rates than do clayey soils. Topography or the degree of slope likewise influences runoff. Steeper slopes will yield greater amounts of runoff than smaller slopes on the same soil type. Terracing and leveling practices may be utilized to decrease runoff from cultivatable lands with slopes generally larger than two percent. Plant cover is another variable governing runoff amounts. Range lands and grass pastures generally have less rainfall runoff than cultivated lands. The heavy cover slows water movement and allows greater absorption rates. Cropped lands are more susceptible to runoff; however, fields in close grown crops (wheat, oats, barley) have less runoff than row crops (corn, grain sorghum). Summer fallowed lands with no crops have onsiderable runoff. Timmons et al. reported annual N runoff losses of 58 pounds per acre on fallow plots cultivated with the slope, but only three pounds were lost under a hay rotation [64, pp. 16-18].

The degree of runoff related to plant cover also depends upon the growing season of the crop. At planting when crop cover is at a minimum, runoff potential is at its peak. As the crop grows and matures runoff potential diminishes, reflecting a seasonal effect associated with plant uptake. Nutrient removal occurs in similar fashion [65, p. 42].

These four variables also influence, through runoff, the potential amount of nitrogen fertilizer pollution in our streams and standing bodies of water. The energy associated with the impact of falling raindrops tends to break down aggregates of soil particles at exposed soil surfaces. Runoff waters can then pick up the finer particles and carry them downslope. Much of the nitrogen which reaches streams is suspended in an organic form. The fresh organic materials are quite readily decomposed by micro-organisms but humified soil organic material is quite resistant to decomposition [79, pp. 302-309]. Hence, the amount of soluble nitrogen content depends upon the nature of organic materials affected by runoff and rainfall.

Studies by agronomists in Missouri indicate that nitrogen losses associated with sediment in the runoff accounted for 92 percent of the total nitrogen loss for a three year period from contour planted corn experiments [54, p. 299]. Sediment loss was greatest at the beginning of the cropping season and diminished as the season progressed.

Nitrogen fertilizer use on irrigated cotton has been analyzed by Oklahoma State researchers. Surface runoff estimates for a 7.08 acre plot, fertilized with 453 pounds of nitrogen indicated the total nitrogen loss was 10.1 pounds from 10.5 acre-inches of applied irrigation water [34, pp. 1-46]. In irrigated areas with heavy applications of fertilizers, it is apparent that runoff of these nutrients can be detrimental to water quality.

Although research data relating to nitrogen fertilizer losses in runoff are sparse, considerable research is now being conducted to determine the fate and magnitude of nitrogen losses. It is generally accepted that:

(1) losses are highest under fallow conditions,

(2) cultivated lands lose more nitrogen than pasture and forests,

(3) heavily fertilized croplands unprotected by soil and water conservation practices very possibly will present localized pollution problems [30, p. 11].

Another aspect of potential nitrogen pollution is the volatilization loss to the atmosphere. As far as is known, this nitrogen loss does not create significant environmental problems [30, p. 13]. This process amounts to the changing of nitrate (NO_3^-) into N_2 and ammonium (NH_4) into NH_3 ammonia. Both of these gaseous forms are already present in our atmosphere in large quantities. Estimates of the magnitude of volatilization losses range from 10 to 15 percent of the nitrogen applied on well drained soils to 100 percent on poorly drained and water-logged soils [65, pp. 140-162].

Available excessive nutrients are blamed for the increased amount of nuisance plants, such as bluegreen algae in our water bodies. These growths are what cause the degradation of our water supplies and interfere with recreation and other intended water uses.

The growth of algae plants are dependent primarily upon two inorganic elements, phosphorous and nitrogen. In most potable water sources phosphorous is abundant [30, p. 21]. Nitrogen comes into the water from the air, as ammonia with rain, from organic nitrogen as plants and animals decompose, and runoff from nearby lands. Within the nitrogen cycle the organic nitrogen is decomposed by bacterial action producing inorganic nitrogen which is readily available for new plant growth.

Most naturally developed streams, rivers and lakes have, over millions of years, created their own nitrogen balanced environment. The environment decomposes organic materials, providing new nitrogen.

This nitrogen is utilized in plant growth. As the maturing processes continues these plants die and provide their proteinaceous materials for new generations of plant life. The discharge of human and industrial waste, agricultural runoff and accidental nitrogen spillages result in an over abundance of nitrogen in all forms, causing an abrupt change in the nutrient balance of the body of water. This enriched environment produces an ideal habitat for algae bloom and other nuisance plants.

Ball and Tanner indicated "that after a 100 pound per three week application of 10-6-4 from early May to mid-September of 1946 and 1947 on a 27.5 acre lake, a definite increase in plankton followed each application of fertilizer. Heavy mats of filamentous algae appeared after the second summer. The fish growth rate showed a highly significant increase. However, an almost complete winter-kill of fish followed the second summer of fertilization as oxygen sources were utilized by algae [3, p. 23].

Ruttner showed that running water is more fertile than still water simply because its turbulent flow prevents the formation of zones of nutrient depletion around plants [51, p. 185]. Studies by Whitfort indicate that the metabolism of plants is enhanced by water movement and only in extreme instances is low fertility a limiting factor to the production of primary plant production in moving water sources [76, pp. 302-309].

Many aquatic plants are "opportunists," invading exposed shallows rapidly, but are often washed out. Both rooted plants and algae are much affected by instability of water movement. While they may achieve dense growths at times (particularly summer months), they rarely achieve a permanent vegetative cover. As a result, even though streams are potentially fertile, production is patchy [6, pp. 186-191]. Also implied in this statement is that, because of the summer life span of the phytoplankton, it does not store nutrients for future consumption. Hynes, also concluded that normal streams and rivers are then net consumers of organic matter [23, pp. 324-329].

What happens then when a normal stream or river is artifically enriched? The introduction of excess nitrogen provides the necessary criteria for increased potential production of primary algae producers. Greater impetus for production occurs during the summer months as water temperatures warm and daylight hours increase. Impoundments and dams enhance this production by providing water areas which are not readily affected by water movement instability.

Although the enrichment process is similar in both streams and rivers the volume of water in a river is much larger than in a stream. Thus, the probability of high concentrations of excess nutrients is much greater in streams than rivers. Hynes suggests that the effect of enrichment on rivers is quite small. Rivers are usually warm and open to the sky. Their production of primary algae producers is limited more by a lack of suitable sites for plant growth than nutrients. Addition of extra nutrients would, therefore, not be expected to greatly alter the aquatic balance [24, pp. 193-194].

Streams are different. The small amount of water volume and available growth sites allow a larger biomass per unit volume (biomass is a measurement of biological populations). It is this large concentration of biomass and its oxygen demand which reduces available oxygen for fish population in the stream, resulting in fish-kills.

The plant population in streams are susceptible, however, to heavy rainfall and its resultant sudden washout effect. The production sites are removed as water volumes increase [24, pp. 193-194].

The economic and environmental aspects of nitrogen fertilizer use and potential nitrogen pollution are complex and difficult to model in a "real world" framework. The technical relationship between nitrogen fertilizer applied to agricultural lands and its impact on our environment is not fully understood. Current research is providing better knowledge, but a complete understanding of these technical relations are not foreseeable in the near future. The following chapter presents, by necessity, a simplified methodology which attempts to analyze this economic and environmental issue.

CHAPTER III

PROCEDURE

Selection of Alternative Nitrogen Fertilizer Strategies

The purpose of this study was to develop estimates of the total impact of commercial nitrogen fertilizer on the economy and physical environment of a selected sub-watershed in the Arkansas River drainage basin. The methodology utilized attempts to handle a highly subjective problem; a problem which economic theory is quite competent of handling, but that is decidedly difficult to apply in a problematic situation.

Four nitrogen fertilizer strategies were developed. The first strategy was a "benchmark" from which changes in the other three strategies were measured. Each of these three strategies was an attempt to depict a practical alternative method of nitrogen fertilizer applications.

Four criteria were employed in the selection of nitrogen fertilizer applications: (1) does the strategy impact upon the area's environmental stability, (2) does the strategy have an effect on the area's income and employment generating ability, (3) does the strategy provide a "trade-off" effect between the area's environmental and economic factors, and (4) does the strategy provide a practical agronomic and environmental basis to support its implementation in the area.

Specific Assumptions Underlying
The Four Strategies

Baseline Strategy

The baseline strategy is an attempt to model the typical 1972 agricultural situation of the region. Its function is for comparison and evaluation of the three other nitrogen fertilizer strategies. The crop year of 1972 is selected since it preceded the recent fertilizer shortage and also preceded the relaxation of government acreage restrictions. It is considered a more "normal year" in the region's agriculture than either the 1973 or 1974 production years.

This baseline strategy assumes that 1972 cropping patterns, management practices and costs of production are extended to 1990. In essence, 1990 agriculture is comparable to 1972 agriculture. The only exception is that the 1972 base year maintains government payments for wheat, grain sorghum and corn; subsequent years in the 1972 baseline strategy assume Oklahoma State University outlook personnel market price projections and no government support.

Technology Strategy

The technology strategy represents an attempt to visualize the "status quo" of agricultural efficiency and technological advancement. Agriculture has developed a reputation of striving for increased efficiency, i.e., more output from the same level of input over time. This is apparent in agriculture's increased crop yields. Improved varieties of crops have higher expected yield levels and higher nutrient utilization capabilities. Improved management capabilities from higher education levels and better machinery, equipment and technical research make efficiency adaptations profitable and indispensible. Therefore, it is possible to assume that technological advancement will provide the production levels necessary for maintenance of this region's share of production between 1972 and 1990.

The technology strategy assumes that due to technological advancement crop yields will increase given the same amount of nitrogen fertilizer applied per acre as occurred in 1972. For each crop, yield per acre increases one percent per year from 1972 to 1990 or a total of 18 percent.[1] Production expenses, market prices for wheat, grain sorghum and corn are comparable to the baseline strategy.

Restricted Nitrogen Strategy

The development of the restricted strategy stems from the fact that increased nitrogen fertilizer use in the production of agricultural crops also increases the potential nitrogen pollution in streams, rivers and lakes. Increased application rates per acre and more acres receiving fertilization provide a ready source for high nitrogen concentration levels in runoff water from these lands. The higher nitrogen concentrations increase the eutrophication of our waters; and if the concentrations are sufficiently large, damage municipal water supplies and human health.[2]

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[1] Estimates of crop yield increases due to the inherent ability of present varieties and the possibility of new varieties were obtained from Oklahoma State University agronomists and plant breeders.

[2] A newly developed ion-exchange process can remove nearly all the nitrate present in domestic water supplies. The treatment cost is about 12 cents per 1,000 gallons processed.

The restricted strategy reduces the per acre application rate of nitrogen fertilizer to a point where quantities lower than this level would take these acres out of crop production. This is especially evident on irrigated lands in the Oklahoma-Texas Panhandle area. Agronomic data suggest this level is 30 pounds of actual nitrogen applied per acre on dryland wheat, dryland grain sorghum and irrigated wheat. Irrigated corn and grain sorghum receive an 80 pound application rate. Market prices are the same as for the baseline strategy. Production expenses per acre were decreased by an amount equal to the per bushel yield reduction.

The restricted strategy does not affect dryland wheat or grain sorghum in the Panhandle area. Insufficient rainfall limits dryland nitrogen fertilizer applications to only the better quality lands, where yields warrant approximately 8 to 14 pounds per acre. The Central area's crop production of grain sorghum and wheat was likewise not affected by this strategy. This region does receive adequate moisture but soil conditions, i.e., more clay, have limited yield capabilities. Better classes of soils receive amounts around the 25 to 28 pound fertilization rate. Also, this area has historically not produced heavy amounts of wheat and grain sorghum. Cotton, soybeans, peanuts and hay crops have generally dominated the better soils, due to their higher profitability.

This does not, however, preclude increased use of nitrogen fertilizer on wheat in the future, especially if wheat prices remain high. Fertilizer use on sorghum is probably less important. Area budgets indicate such low yields on this area's soils that natural soil fertility will likely continue to supply a sufficient amount of nitrogen.

Also, grain sorghum has not typically been utilized in the Central area for cattle feeding operations as in the Panhandle area. Indications are that grain sorghum in the Central area is utilized primarily as a winter forage and dairy feed.

Maximum Nitrogen Strategy

The maximum nitrogen strategy attempts to approach the physical agronomic limit of present day wheat varieties. Historically, the North Central area has had wheat production from its better soils of approximately 49 bushels per acre. These yields were generally produced by innovative farmers who used high fertilizer rates and intensive management levels on very productive soils. Nitrogen fertilization rates to obtain this 49 bushel yield have been around 80 pounds of nitrogen per acre. The maximum nitrogen strategy attempts to simulate this situation for wheat. North Central and Central area soil Classes I loam through III clay are considered capable of producing this yield. Other wheat land and grain sorghum land classes are not affected and revert to yields and fertilizer rates utilized in the technology strategy. Baseline price data are again utilized and production expenses adjusted by the increased per acre harvest costs. The Panhandle area is not affected by this strategy because of insufficient rainfall.

Land Adjustment Model

The model developed to estimate land use adjustment for various nitrogen fertilizer strategies was an aggregate linear programming model. The model was developed for a base year of 1972 and projects land adjustment patterns for 1975, 1980, 1985 and 1990 assuming regional shares of production are met for each of these time periods.[3] Each of the three areas delineated in Chapter I (Panhandle, North Central and Central) were viewed as distinct and separable areas not affecting each other's production or land use pattern.

The model assumes the total land area as the unit of analysis with yield variations, fertilizer application rates, pollution estimates and land development costs attributable to an individual acre's soil type and capability classification. Hence, the model's unit of analysis was the individual acre. Aggregation across acres and within a designated area develops the model's total impact. One of the major problems associated with regional supply response analysis is this aggregation task.

Two possibilities exist. The first possibility utilizes a micro technique of programming representative farms to obtain optimal solutions and then multiply the solutions by the number of farms in each category. The regional supply is considered the summation of these products. This approach introduces "aggregation bias," a problem which has created considerable discussion [4, pp. 701-712]. Sharples has summarized these discussions and generally concludes that a new method of determining regional supply response is needed [56, pp. 353-361].

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[3] A base year of 1972 was selected since it was considered a more normal year to the study area's agricultural sector. The recent supply and demand changes for food and feed grains and fertilizer did not bias that year's production practices. After 1972 cropping patterns, government programs and input costs have had an unstable effect on the area's agricultural sector.

The second possibility utilizes a macro technique in which the complete region is defined as the unit of analysis rather than the farm. This technique yields aggregate estimates of the region's supply capabilities. While better than the micro analysis, the macro technique also has its deficiencies. It ignores the resource allocation within farms, both for fixed and variable factors of production. Implications for individual farm firm analyses are difficult to make.

The advantages of the macro approach lies largely in the data requirements and the time and costs of analysis. Another advantage, and a crucial part of this analysis, is the ability to incorporate soil information. Only rarely is there soil variation within a given farm large enough to induce large yield differences. A macro approach allows for significant differences in soils and the necessary production variations, which can give rise to considerable differences in the optimum organization of the region's farm enterprises.

If budgets are developed on the basis of per acre costs and returns in the linear-programming model, the macro and micro approaches will yield comparable enterprise organization. Day indicates that if certain proportionality conditions hold among individual representative farms, i.e., indentical input-output coefficients, proportional objective functions, and right-hand side restrictions, then macro programming may result in exactly the same values as summing the weighted solutions of the individual representative farms [10, pp. 797-813].

The macro and micro technique assumes away another critical problem. The region is not an isolated area. Rather it is influenced by and influences the demand and supply relationships outside the area.

However, the conceptual and analytical problems associated with incorporating this relationship are so large that by necessity the assumption has to be made for analysis purposes.

Each of the techniques of aggregation have their advantages and disadvantages. The main criterion for selection is which analytical approach yields the type of answer being sought. Since the purpose of this study was to investigate the total impact upon the region, the macro approach was used. The problem solved was the combination and level of enterprises which maximized net returns to the area and the resultant level of potential nitrogen pollution from this combination of enterprises. The land adjustments were obtained with a linear programming model of the type:

$$\text{Max } Z = -C_1 - C_2 - \cdot \cdot \cdot \cdot - C_n + P_w \cdot W + P_{gs} \cdot GS + P_c \cdot C - P_n \cdot N$$

subject to the following restrictions:

$$A_{11}X_1 + A_{12}X_2 + \cdot \cdot \cdot + A_{1n}X_n = Y_1$$

$$A_{21}X_1 + A_{22}X_2 + \cdot \cdot \cdot + A_{2n}X_n = Y_2$$

$$A_{31}X_1 + A_{32}X_2 + \cdot \cdot \cdot + A_{3n}X_n = Y_3$$

$$D_{11}X_1 + D_{12}X_2 + \cdot \cdot \cdot + D_{1n}X_n \leq R_1$$

$$D_{21}X_1 + D_{22}X_2 + \cdot \cdot \cdot + D_{2n}X_n \leq R_2$$

$$\vdots \qquad\qquad\qquad \vdots$$

$$D_{m1}X_1 + D_{m2}X_2 + \cdot \cdot \cdot + D_{mn}X_n \leq R_n$$

$$N_{11}X_1 + N_{12}X_2 + \cdot \cdot \cdot + N_{1n}X_n \leq B$$

$$P_{11}X_1 + P_{12}X_2 + \cdot \cdot \cdot + P_{1n}X_n \leq Y$$

$$L_{11}X_1 + L_{12}X_2 + \ldots + L_{1n}X_n \leq L$$

where Z = total area net returns to management from wheat, corn and grain sorghum less a nitrogen cost per pount applied.

$C_1 \ldots C_n$ = cost of producing a given crop on a given capability class and soil type,

P_w, P_{gs}, P_c = price received for wheat, grain sorghum and corn,

W, GS, C = bushels of wheat, grain sorghum and corn produced,

$X_1 \ldots X_n$ = acres of various land use activities,

$A_{11} \ldots A_{3n}$ = yield per acre per crop activity,

$D_{11} \ldots D_{mn}$ = acres of land by capability soil classes,

$N_{11} \ldots N_{1n}$ = amount of nitrogen applied per acre,

$L_{11} \ldots L_{1n}$ = labor requirement per acre of crop grown,

$P_{11} \ldots P_{1n}$ = amount of potential nitrogen runoff per acre,

$Y_1 \ldots Y_3$ = total production per crop per time period,

$R_1 \ldots R_n$ = land restraints by capability class for dryland and irrigation acres.

The basic sets of model restraints were: (1) production requirements, i.e., nitrogen fertilizer and yield per acre, (2) land resources, the amount of land available to produce the products; and (3) the potential nitrogen pollution, indicating the amount of potential runoff which could occur from a given application rate of nitrogen fertilizer per acre.

These restraints are inputs that were exogeneously determined, i.e., the quantity of ouput, the acres in each soil group and the potential nitrogen pollution coefficients all must be known. Also, for each soil group, yields and production costs and prices were developed.

The objective function was of the standard maximization linear-programming type. The basic cost components were: operating, ownership and capital expenses. These costs were derived from the Oklahoma State Budget Generator and extrapolated for the various capability and soil classes (Appendix A). The prices received for wheat, grain sorghum and corn were developed by Oklahoma State University outlook personnel for the years 1975 through 1990; 1972 prices received were taken from the region's mean crop price as reported by the United States Statistical Reporting Service for 1972.

The objective function was specified for each geographic area, for each soil type, and for currently producing lands and potentially producing lands. For example, enterprise budgets designate the costs per acre associated with North Central area wheat being produced on Class I loam soil.

The yields associated with each activity budget were developed on the basis of a dominant soil type in a given geographic area. Using the Oklahoma State University Budget Generator as a reference budget the deviations due to soil and land capability were considered, e.g., dryland wheat on Pond Creek loam soil in North Central area yields 33 bushels per acre. Pond Creek is designated as a Class I soil by the Conservation Needs Inventory and Soil Conservation Service, indicating it is one of the best soils in the area. Other soils lower in productivity were assigned lower yields per acres.[4]

The production level requirements for the model were developed by using a regional supply response. County data for wheat, grain sorghum and corn production from the Kansas, Oklahoma and Texas Statistical Reporting Services were aggregated by the study region's three areas (Panhandle, North Central and Central). The percent each area's production was of the 1972 United States production of wheat, grain sorghum and corn was considered the area's regional share of United States supply. This percent was then applied to the OBERS estimates for United States production for the years 1975 through 1990. In notational form the production level requirements were:

$$X = \underset{i,j=1}{\overset{3}{\P}} 1 \; \underset{i,j=1}{\overset{3}{\P}} 2$$

X = sub-area regional supply of wheat, grain sorghum and/or corn for a given time period,

$\P^{1}_{ij}$ = percent sub-area is of 1972 United States total production of wheat, grain sorghum and/or corn,

$\P^{2}_{ij}$ = OBERS estimates of United States production of wheat, grain sorghum and/or corn for a given time period.

The production levels for pasture or forage are relevant since many acres of these crops are fertilized as if for grain production but then grazed.

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[4] Dominant soil data and yields were developed from, "Productivity of Key Soils in Oklahoma," Oklahoma State University Bulletin No. B-650, October 1966 [18, pp. 1-45].

Development of Model's Land Base

There is not an available source of land data which provides a quantitative estimate of the number of acres of a given crop grown on a specified soil type. However, combination of two data sources, the Conservation Needs Inventory and the Soil Conservation Service county soil surveys allow an estimate of crops grown on a given soil classification. In addition, this procedure allows the opportunity to designate land classes on the basis of currently producing acres, temporarily idled acres and new acres never before cropped.

The 1967 Conservation Needs Inventory provides an inventory of: (1) irrigated and dryland cropland acres by capability classes, (2) irrigated cropland acres by capability classes, and (3) irrigated and dryland pasture and range, forest and other land acres by capability classes. These groups are further subdivided by close grown, row crops and various categories of idled land.

The objectives of the 1967 Conservation Needs Inventory were: (1) to develop current and detailed data on land use and conservation treatment needs by soils on non-federal rural lands; and (2) to obtain data on watershed project needs on both private and public owned lands [40, pp. 137-142]. The survey utilized a two percent random sample of an entire county's acreage. The standard size of the sampling unit was 100 acres. Some states used different sample units (Oklahoma's sample unit was 160 acres). In counties of 250,000 to 500,000 acres the two percent sample was deemed larger than necessary and the county's sampling rates were reduced.

The Conservation Needs Inventory data can be used to indicate cropping patterns by land capabilities[5] (Table I). This survey, however, did not indicate a related soil type for a given geographic area. It also biases the land area since the two percent sample is aggregated by the number of 160 acre sample units taken in the respective county. Both of these objections were eliminated by utilizing the Soil Conservation Service's County Soil Surveys to adjust the Conservation Needs Inventory.

The county soil surveys are a complete enumeration of the county soil resource base. Every soil within the county is mapped, and actual acres of land within a given soil type are indicated. Since the early 1950's the county soil surveys have also included the land capability units associated with each soil type in a county. Therefore, with the Conservation Needs Inventory and the County Soil Surveys it is possible to develop a land base designated by land capability class, soil type and crops produced.

Computation of Soil Resource Base

Soil scientists in the Oklahoma state office of the Soil Conservation Service classified each soil type in the study region. The

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[5] Land capability classification is an interpretive groupings of soils made primarily for agricultural purposes. In this classification system, arable soils are grouped according to their potentialities and limitations for sustained production of common cultivated crops that do not require specialized treatment. The classification does not apply to most horticultural crops or to rice and other crops that have special requirements. Non-arable soils are grouped according to their potentialities and limitations for the production of permanent vegetation and according to their suspectibility to soil damage or mismanagement. The capability classes are defined by eight groupings.

TABLE I

CONSERVATION NEEDS INVENTORY'S LAND CAPABILITY CLASS DESIGNATIONS

Class	Description
I	Soils have few limitations that restrict their use.
II	Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
III	Soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.
IV	Soils have very severe limitations that reduce the choice of plants, require very careful management, or both.
V	Soils are subject to little or no erosion but have other limitations, impractical to remove, that limit their use largely to pasture, range, forest, or wildlife food and cover.
VI	Soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, forest, or wildlife food and cover.
VII	Soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, forest, or wildlife food and cover.
VIII	Soils and land forms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife, or water supply or to esthetic purposes.

Oklahoma Soil Conservation Service. Oklahoma Conservation Needs Inventory. United States Department of Agriculture, Stillwater: Soil Conservation Service, March, 1970, pp. 137-142.

groupings were classified on the basis of the "contact zone"[6] of the soil's profile. These groupings were designated clays, loams and sands. This classification scheme was utilized for each soil type in the study region. The county soil surveys, which provided soil types, also showed land capability classes. By aggregating SCS soil types by land capability classes a common factor was developed to mesh soil type and the Conservation Needs Inventory's acres of cropland in production. The resultant acreage figure was the number of acres of a given crop grown on a loam, clay or sandy soil of capability Class I-VII in a particular county. The total land base development equation is:

$$X = \sum_{B=1}^{26} \sum_{C=1}^{8} \sum_{S=1}^{3} A, \text{ where}$$

X = total land in the study area,

A = the 45 counties in the study area,

B = the number of Conservation Needs Inventory cropland, pasture, rangeland and forest land categories,

C = land capability classes,

S = the soil types (loam, clay and sand).

The CNI land capability class acreage figures did not always match the land capability class acreages given by SCS county soil surveys. Since the county soil surveys are a complete soil inventory, it was assumed the more accurate source of acreage estimates. The CNI estimates were then adjusted by the SCS data. A ratio of CNI to SCS acres by land capability class and by county was determined. This ratio

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[6] The contact zone is the area of the soil profile in which the majority of the roots are located. This is usually between the eight and fortieth inch of the profile.

was utilized to adjust each cropland, pasture, range, etc., classification. The resultant acreage figures are on a SCS county soil survey basis. Also, at times the CNI and SCS data did not agree on how many different land capabilities there were per county, i.e., CNI would indicate one county had acres of Class I land and SCS indicated there was no Class I acres in this county. In this case, 2 of 45 counties, the extra land class was included in the next land class total for the county.

The next step was to determine the particular acreages for wheat, grain sorghum and corn. The CNI classifications for crops is subdivided as follows: all other row crops, and close grown field crops. All other row crops are corn, sorghums, cotton, soybeans, peanuts, tobacco, sugarcane, vegetables, potatoes and other cultivated crops. Close grown field crops are wheat, barley, rice, other small grains and other close-seeded crops not usually grown in rows and tilled. The percentage of crops in this CNI definition were calculated from the 1967 Statistical Reporting Service county estimates for the Oklahoma, Texas and Kansas counties. These percentages were then applied to the acreages in the row crop and close grown field crop groups. Since the study region is located within the wheat belt, the percentages for other close grown field crops is minor. Also the area's predominant row crops are corn and grain sorghum. Only in the eastern portion of the Central area were there significant amounts of cotton and soybeans grown.

Some additional acreage adjustments were needed to mesh the 1967 based CNI crop acres with 1972 Statistical Reporting Service county estimates. Government programs initiated after 1967 reduced cropland acreages. These acres reverted back to pasture land and land not in wheat, grain sorghum and corn production. To correct for this adjustment the percentage decline in these acres from 1967 to 1972 were obtained from SRS county estimates and applied to the CNI-SCS estimates. The excess acres were placed in a category called temporarily idled acres. These are acres readily available for future cropland needs (Tables II, III, and IV).

With the cropping calculations based upon given year (1967) bases a bias occurs with respect to the irrigated corn and grain sorghum acreages. The predominant corn acreages since the early 1960's occur in the Panhandle area of the study area. Corn was grown in the subirrigated soils in the North Central and Central areas in the early 1960's but the acreages have declined considerably. The dominant row crop is now grain sorghum. Therefore, the assumption was made that only the Panhandle area would supply the total region's corn crop.

Another assumption employed is that CNI land capability Classes V-VIII are aggregated into a common class and referred to as Class V. These acres are not considered cultivable by CNI and SCS classifications (Table I). Excessive moisture, slope and the nature of soils in groups V-VIII require extreme land corrections and maintenance and are considered unprofitable for cultivation. CNI and SCS recommendations suggest these lands remain in native pasture and wildlife habitat.

CNI lands of Classes V-VIII indicated in cultivation of wheat, grain sorghum and corn in 1967 were considered cultivated in the model's 1972 base year. For land adjustment projections to 1990 these lands and temporarily idled and new lands are available for cultivation but are classified as Class V land.

TABLE II

DISTRIBUTION OF LAND IN NORTH CENTRAL AREA, BY CAPABILITY CLASS AND SOIL TYPE

(Unites in Acres)

Capability Class and Soil Type	Land Classification					
	Wheat	Grain Sorghum	Temporarily Idled	New Lands	Miscellaneous Crops and Uncropped	Total
I_L	345,886	13,071	38,199	85,527	137,751	620,434
I_C	104,680	5,582	12,674	14,348	34,123	171,407
I_S	-	-	-	-	-	-
II_L	792,098	51,780	146,868	388,884	194,150	2,035,780
II_C	261,056	10,014	46,837	70,448	97,847	486,202
II_S	30,677	1,664	5,603	3,588	14,120	55,642
III_L	326,252	22,118	87,898	287,462	78,338	802,068
III_C	271,401	13,930	52,524	150,126	80,453	568,437
III_S	135,082	9,058	30,441	63,796	33,499	271,876
IV_L	111,368	12,378	61,702	159,807	55,835	401,090
IV_C	110,727	6,440	36,796	114,904	41,967	310,834
IV_S	80,547	5,361	44,935	113,806	47,787	292,436
V_L	36,320	30,791	39,462	1,043,727	123,027	1,273,327
V_C	12,337	8,561	10,451	451,983	18,150	501,482
V_S	14,889	4,378	7,577	481,264	53,596	561,704

TABLE III

DISTRIBUTION OF LAND IN CENTRAL AREA, BY CAPABILITY CLASS AND SOIL TYPES

(Units in Acres)

Capability Class and Soil Type	Land Classification					
	Wheat	Grain Sorghum	Temporarily Idled	New Lands	Miscellaneous Crops and Uncropped	Total
I_L	125,817	20,449	14,399	58,866	110,264	329,795
I_C	26,531	2,806	7,198	32,811	27,232	96,578
I_S	-	-	-	-	-	-
II_L	62,930	26,096	43,942	355,473	256,172	744,613
II_C	39,004	18,007	42,215	192,367	114,101	405,694
II_S	593	465	875	5,724	2,425	10,082
III_L	70,240	10,966	40,473	465,915	174,339	771,933
III_C	45,731	6,069	36,059	298,344	131,641	517,844
III_S	7,472	929	5,757	50,915	22,354	87,427
IV_L	13,377	1,923	26,223	234,255	177,563	441,301
IV_C	15,154	4,569	33,189	247,934	110,600	478,409
IV_S	7,749	1,592	6,225	62,397	29,285	107,248
V_L	10,707	3,304	15,869	1,071,930	776,649	1,878,459
V_C	5,550	903	4,059	496,023	566,289	1,072,824
V_S	1,980	252	2,618	82,788	60,239	147,877

TABLE IV

DISTRIBUTION OF LAND IN PANHANDLE AREA, BY CAPABILITY CLASS AND SOIL TYPES

(Units in Acres)

Capability Class and Soil Type	Land Classification									
	Total	Irrigated Wheat	Irrigated Grain Sorghum	Irrigated Corn	Dryland Wheat	Dryland Grain Sorghum	Temporarily Idled	New Lands	Miscellaneous and Uncropped	Irrigable
II_L	686,326	171,725	195,759	35,140	100,458	34,669	22,475	88,991	37,109	147,869
II_C	367,358	152,554	150,938	39,341	5,245	4,655	5,447	7,168	2,010	13,628
II_S	-	-	-	-	-	-	-	-	-	-
III_L	2,873,793	81,274	113,549	63,864	725,282	223,021	402,938	1,147,020	166,845	1,506,943
III_C	1,779,823	46,566	104,793	40,153	601,574	129,135	318,637	483,851	55,114	918,673
III_S	40,882	227	576	162	7,780	1,391	4,900	18,280	7,566	19,511
IV_L	1,545,005	1,590	5,876	920	188,884	44,493	106,718	1,163,105	41,503	820,620
IV_C	230,820	-	4,609	721	27,243	31,855	33,968	120,923	11,501	128,316
IV_S	316,202	363	-	-	3,645	9,034	29,629	258,915	14,616	180,609
V_L	2,913,656	-	-	-	14,313	24,558	43,915	2,805,109	25,761	-
V_C	486,952	-	-	-	1,746	2,134	4,520	461,866	16,686	-
V_S	1,439,414	-	-	-	7,956	9,265	27,677	1,381,695	12,821	-

Development of Temporarily Idled
And New Land Parameters

Dryland Acreages

Temporarily Idled Acres. These are acres within the Conservation Needs Inventory classifications that were at one time cultivated, but which were retired by government programs or by cropping necessity. The CNI categories are:

(1) Summer Fallow - cropland in semi-arid areas that are being fallowed.

(2) Conservation Use Only - cropland in grasses, legumes, or small grains not harvested or pastured. All open acreage diverted from crops under Federal programs; other such land not under Federal programs. All diverted acres including diverted acres under annual programs (except summer fallow). This does not include land that may be defined as forest land.

(3) Temporarily Idle Cropland - acreage not in any of the uses described above, but which was in such uses during one or more of the three years immediately preceding 1967.

In addition to these acreages the decline in crop acreages between 1967 to 1972, basically due to government set aside programs, was included as part of the temporarily idled acres.

New Land Acres. These are lands which have never been cultivated but are readily cultivable. As defined by the CNI they are:

(1) Pasture - lands producing forage plants, principally introduced species for animal consumption.

(2) Range - land on which the natural potential (climax) plant cover is composed principally of native grasses, forbs and shrubs valuable for forage. This includes natural grasslands and savannahs.

New lands, like temporarily idled cropland, were allocated to wheat, grain sorghum and corn on the basis of the proportion each crop was the total of the three crops in 1972. Distribution of these acres are included in Tables (II, III and IV).

Irrigable Lands in the Panhandle Area

The Panhandle counties encompass most of the Central Ogalla underground water formation. This is the only area considered irrigable in the study. The North Central and Central areas do have some irrigated feed grain acres but the proportion of these acres to total cultivated feed grains is minor.

The irrigable land parameters were developed by combining the estimates of Bekure and the Panhandle Economic Program (PEP) study developed by Texas A & M [5, p. 68; 62, p. 83]. Bekure's estimates are for the Oklahoma Panhandle and Dallham, Hansford, Hartley, Hutchison, Moore, Ocheltree and Sherman counties in Texas. These counties include the majority of irrigable lands in the study area. The remaining Texas counties lie on the extreme edges of the Ogalla formation and are not considered irrigable. The Panhandle Economic Program provided estimates of these irrigable acres in the extremities of the Ogalla formation; including the counties of Carson, Hemphill, Lepscomb, Oldham and Roberts.

Development of Irrigable Lands Estimates. The 1972 Statistical Reporting Service irrigated acres of wheat, grain sorghum and corn for the respective Oklahoma and Texas counties were assumed as the base year level of irrigation. The 1972 irrigated lands were then netted out of the irrigable land estimate; the remaining acres were considered new irrigable acres. Distribution of the new irrigable acres by soil type and capability class was accomplished by the following formula:

$$I_{ij} = \overset{4}{\underset{i}{\P}}\ \overset{4}{\underset{j}{\P}}\ A$$

I = total irrigable acres by capability class and soil type,

i = proportion capability class by soil type, is of total land in area minus currently irrigated acres,

j = proportion cultivable lands are of total acres in each capability class and soil type,

A = total irrigable acres.

The distribution of these irrigable lands by crop category is obtained by weighting total irrigable acres by the proportion each crop, i.e., wheat, grain sorghum and corn, was of the total 1972 SRS acreage estimates of wheat, grain sorghum and corn (Table V).

Nitrogen Fertilization Rate Estimates

The nitrogen fertilizer application rates per acre were developed on the basis of crop yields per acre for a given soil classification. Oklahoma State agronomists provided the technical production function relationship for nitrogen fertilizer and wheat, grain sorghum, and

TABLE V

PANHANDLE AREA IRRIGABLE ACREAGE ESTIMATES BY CAPABILITY CLASS AND SOIL TYPE[1]

(Units in Acres)

Capability Class and Soil Type	Total Irrigable Acres	1972 Acres in Production	New Irrigable Acres	Percent Cropland of Total Land in Class	Irrigable Cropland Acres
II_L	572,760	402,624	170,118	.8692	147,867
II_C	357,678	342,833	14,845	.9180	13,628
II_S	-[2]	-	-	-	-
III_L	1,865,579	258,687	1,606,892	.9378	1,506,943
III_C	1,143,209	191,512	951,697	.9653	918,673
III_S	25,038	965	24,073	.8105	19,511
IV_L	929,189	8,386	920,803	.8912	820,620
IV_C	140,542	5,330	135,212	.9490	128,316
IV_S	189,740	363	189,377	.9537	180,609
Total	5,223,735				3,736,167

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[1] Panhandle Classes V-VIII are not considered irrigable by the Soil Conservation Service due to the extreme slopes and other cultivation hazards.

[2] There is no Class II sand in Panhandle area.

corn yield per acre.[7] The application rate is measured in actual pounds of nitrogen and not nitrogen material, i.e., 100 pounds of ammonium nitrate contains 33.5 pounds of actual nitrogen available for plant use and 66.5 pounds of non-nitrogenous material.

There is assumed an adequate supply of nitrogen fertilizer for all five year period projections to 1990. This implies that the amount of nitrogen fertilizer required to produce a given crop in the total study area is dependent upon the farmer's ability to purchase and willingness to purchase the fertilizer. Recent trends in foreign fertilizer demands and the "energy crisis" are assumed not to be of major influence in the area's fertilizer demand for future years.

The price of nitrogen fertilizer is eight cents a pound for 1972 and 20 cents a pound for 1975 through 1990.

Nitrogen Pollution Estimates

The nitrogen pollution coefficients used in the linear programming model were developed to consider application rates per acre and the timing of fertilizer application (preplant and side dressing). The assumption was made that potential nitrogen pollution available for runoff was the difference in the application rate and the amount uptaken by the crop at a particular time in the crop's growing season (Figure 7).

The potential pollution from an acre of wheat is greatest at

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[7] Application rates for a specified yield goal per acre are found in Oklahoma State University Fact Sheet No. 117, Oklahoma State University. Actual application rates for producing, temporarily idled and new lands are found in Appendix A.

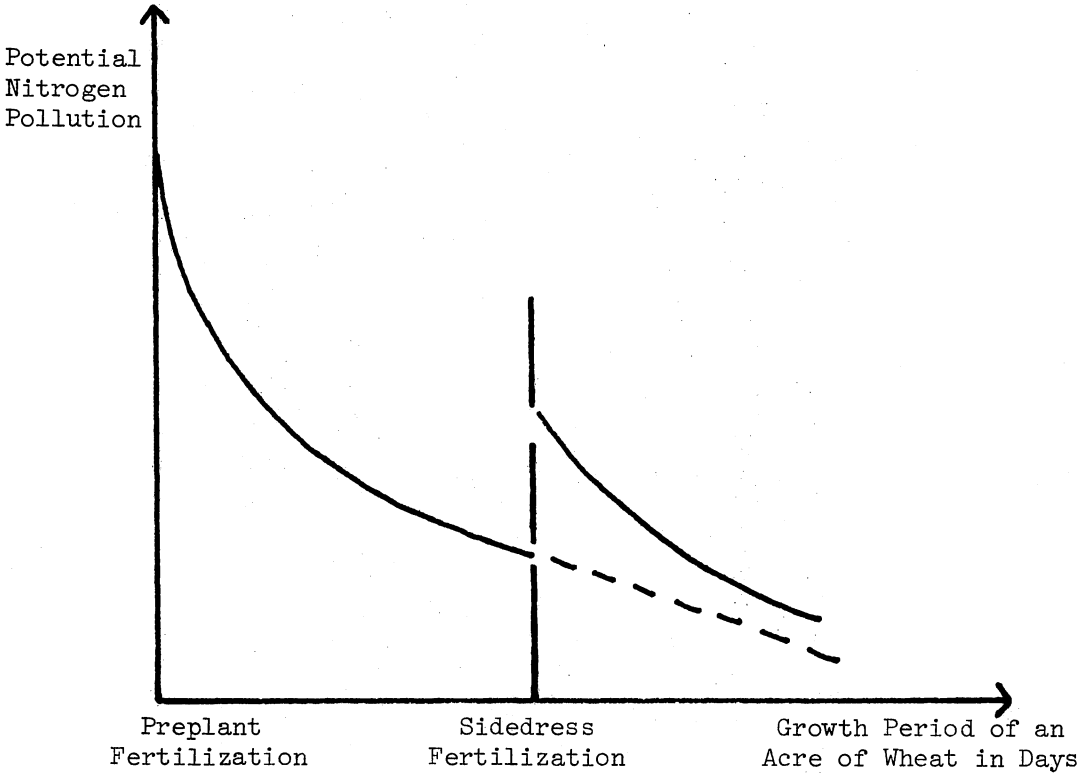

Figure 7. Potential Nitrogen Pollution From an Acre of Wheat Related to Preplant and Sidedress Fertilizer Applications

preplant fertilization (April for corn and grain sorghum and September for wheat). At this time there is no crop cover and if heavy rains occurred, runoff could be considerable. When the plant begins to grow, and continues growing, the nitrogen applied is utilized by the plant. Potential pollution declines. Side dressing of fertilizer (August for corn and grain sorghum and April for wheat) again increases the pollution potential; however, as the plant grows to maturity nitrogen available for pollution, through runoff, diminishes.

This decaying process was represented in the linear-programming model through the following functional relationship developed by Dr. James Davidson, Oklahoma State University agronomist.

$$Y = .25\ N \cdot e^{-0.04t}$$

where

Y = parts per million of nitrogen available for runoff,

N = pounds of nitrogen fertilizer applied per acre to obtain a given yield level,

t = time, in days, from fertilizer application date.

This equation estimates the physical amount of nitrogen available for runoff. Whether runoff occurs is another question. For nitrogen runoff to take place a sufficiently large amount of rainfall is required to cause the washing or eroding of soil particles from the land after the land is fertilized. Also, the nitrogen concentration levels in the runoff water will be diluted as the runoff water meets the area's streams and rivers carrying higher volumes of water. Hence, the per acre potential nitrogen pollution coefficients must be adjusted for: (1) the probability of rainfall, (2) stream flow volume, and (3) the probability of seedbed preparation.

Stream flow data were obtained for all streams and rivers within the boundaries of each of the three areas.[8] Because of variations in rainfall amounts the pollution levels were calculated separately for each area (Panhandle, North Central and Central). The data collected were for the months of April, August and September since budget information indicated these months were fertilizer application times. The linear-programming pollution estimates were then diluted by the stream volume figures, providing an estimate of nitrogen pollution potential within an area's streams.

Estimates of the percent of a given crop fertilized (seedbed preparation indicates preplant fertilization) in April, August and September by weeks were obtained from SRS data [39]. These estimates indicate how many crop acres have been fertilized (preplant and side dressed) in a given area.

Rainfall probabilities were obtained from the Department of Commerce's Climatological Data Series by weeks for the fertilization months [72]. The Goodwell, Enid and Chandler, Oklahoma reporting stations rainfall amounts were considered typical of the Panhandle, North Central and Central areas rainfall patterns, respectively. The rainfall data indicate, how many times in 34 years it has rained at least one inch on a given day in the weeks designated by the April, August and September seedbed preparation information. In notational form, the pollution estimates are:

$Z = \frac{P_R \cdot P_S \cdot R}{D}$ where,

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[8] Estimates were obtained from the United States Geological Surveys water monitoring stations located on streams in the three areas of the study region [73].

Z = the potential nitrogen pollution coefficient,

P_R = the probability of a one inch rainfall on a given day in a specified week for each sub-area,

P_S = probability of an acre fertilized (having seedbed prepared),

R = potential pollution from a given acre with a specified fertilization rate,

D = area stream flow volume.

This pollution estimate is considered the potential nitrogen pollution from an acre of land in the region.

Income and Employment Effects From Nitrogen Fertilizer Strategies

The impact of nitrogen fertilizer use on farm incomes, employment and productivity is quite apparent; however, its impact on other sectors of the area's economy is more difficult to ascertain. Increases or decreases in the amount of nitrogen fertilizer applied may influence, through increases or decreases in production and fertilizer expenditures, the ability of the other economic sectors to maintain their economic positions and to continue to grow.

The development of these parameters was accomplished by assuming the cropping patterns, fertilization methods and rates, yields and technologies present in 1972 would be maintained to 1990. This was considered as the base period. Deviations from this base due to the different nitrogen fertilizer strategies employed is considered a "direct effect" originating from the strategy utilized.

These direct effects were calculated for each strategy's farm employment and income. Farm employment was defined as total area employment needed to obtain the required production of wheat, grain sorghum and corn. Farm income was developed from the linear programming model's objective function, i.e., net income per acre of the crops produced summed over all crops acres and the three producing regions.

The regional income and employment impacts (both direct and indirect effects) from each nitrogen strategy were developed by applying an income and employment multiplier developed by Schreiner and Chang to the farm income and employment estimates [53, p. 106].

The Environmental Impact Matrix

The analysis tool used to evaluate the impact of economic and environmental "trade-offs" involved with the use of commercial nitrogen fertilizer is the environmental impact matrix. This matrix provides for an analysis of relevant factors affecting the nitrogen pollution question. Its usefulness lies in its ability to analyze qualitative as well as quantitative data.

The matrix includes three major parameters: (1) the impact on economic factors; (2) the impact on environmental factors; and (3) the impact on social well-being factors. Economic factors include those variables which influence area income, employment, prices, farm land organization and production. The environmental factors are variables associated with terrestrial and aquatic wildlife, and human consumption of water. The social well-being factors include the effects of nitrogen fertilizer strategies upon recreational opportunities, and "anxiety" considerations such as the quality of food produced with chemical fertilizer (Figure 8).

Parameters	Parameter Weights	Alternative Nitrogen Fertilizer Strategy	
		Raw Score	Weighted Score
Impact on Economic Factors			
A. Change in Farm Income	2.43		
B. Change in Farm Employment	.43		
C. Change in Cost of Goods to the Consumer	2.78		
D. Change in Acres in Production	.93		
E. Change in Regional Income	2.14		
F. Change in Regional Employment	1.29		
Sum of Economic Impact	10.00		
Impact on Environmental Factors			
A. Land Based Environment			
1. Change in Acres for Wildlife Habitat	2.00		
2. Change in Quality of Wildlife Habitat	1.81		
B. Water Based Environment			
1. Change in Algae Population	.79		
2. Change in Nitrogen Concentration	.57		
3. Change in Fish Population	.86		
4. Change in Municipal Water Supply Quality			
a. Short-run Quality	.73		
b. Long-run Quality	1.17		
5. Change in Industrial Water Supply Quality	.64		
6. Change in Erosion Potential	1.43		
Sum of Environmental Impact	10.00		
Impact on Social Well-Being			
A. Recreational Opportunities			
1. Change in Land Based Recreation	2.57		
2. Change in Water Based Recreation	1.43		
B. Anxiety Factors			
1. Change in Aesthetics			
a. Diversification-Specialization of Land Base	2.41		
b. Degradation of Water	2.08		
2. Amount of Inorganic Nitrogen in Food Supplies	1.51		
Sum of Social Well-Being Impact	10.00		
Overall Impact			

Figure 8. Model of the Environmental Impact Matrix Developed to Measure Effects of Alternative Nitrogen Fertilizer Strategies

These three major parameters were weighted equally (10 points each) on the basis of Water Resources Council Guidelines, which require that these areas be given equal weight in decision processes concerning resource use [76, pp. 1-15]. The weights assigned to individual parameters were based on values arrived at by agricultural economists, agronomists, biochemists, and fishery and wildlife personnel at Oklahoma State. Parameter weights were assigned according to the importance of the paramters in a policy decision framework. The use of this panel of researchers allows parameter weights to represent the value society, as a whole, might place on the variable and not the value one segment of society might place on these parameters.

Development of Environmental Impact Estimates

The Aquatic Environment. The nitrogen pollution coefficients are utilized in an aquatic system simulator developed by Dr. Louis Varga, Oklahoma State University chemist. The simulation model attempts to construct a viable aquatic environment. The model is compartmentalized into six nitrogen using segments: (1) algae, (2) dissolved organic nitrogen, (3) bacteria, (4) zooplankton (free floating microscopic animal forms), (5) anhydrous ammonium production, and (6) nitrogen suspended on colloidal particles. These compartments are not isolated entities but work together producing a viable aquatic system.

The model works on the basis of providing a given nitrogen concentration level to the aquatic system. Its starting point is March 21 of a given year (the first equinox, where night and day are of the same length). The model also assumes a composite of algae forms, i.e., bluegreens, greens, etc.

The model behaves as if an introduction of nitrogen occurs. As time passes, more sunlight is available, temperatures rise and the water warms, then algae begin growing using up oxygen and available organic nitrogen. Bacteria break down yielding organic nitrogen, which the bacteria have synthesized from its inorganic form. Zooplankton populations decline yielding organic nitrogen into the water, and suspension of inorganic nitrogen on fine particles of soils continues.

These processes continue throughout the summer months; a reversion process begins as fall and winter months approach. Algae die, bacteria and zooplankton populations increase. The winter months provide a dormancy period for algae growth until temperature and light conditions return the next spring.

The model calculates the amount of nitrogen utilized by the various compartments and provides an enumeriation of excess nitrogen in the aquatic system over the spring to spring season. The amount of nitrogen used by each compartment was utilized as an impact estimate for the aquatic environment.[9]

<u>The</u> <u>Terrestrial</u> <u>Environment</u>. The environmental impact upon the land is comprised of two factors: (1) the wildlife population, and (2) the quality of wildlife habitat. Estimates of wildlife populations, i.e., deer, turkey, quail and pheasant in the three areas were made by utilizing Oklahoma Department of Wildlife Conservation data. These data specified the density of the wildlife species per animal when

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[9] The model was recently developed by Dr. Louis Varga, Oklahoma State University Chemistry Department. It is not published. For information concerning the actual computer formulation contact Dr. Varga.

habitat conditions were considered fair. Specifically, they suggest deer required 150 acres, turkey and pheasant 200 acres and quail 20 acres.

Lindsey and Thomas suggested that wildlife habitat is not comparable to total acres available in an area [36, pp. 30-36; 63, pp. 1-14]. Rather, only about 30 percent of the total acreage is considered inhabitable for game population. The reasons for this uninhabitable land are predominately human pressures and availability of food and shelter areas. Hence, wildlife population impact is determined as the ratio of inhabitable acres to specific densities.

Weighting Technique to Evaluate Variables

A scale of -5 to +5 was developed to assign numerical raw scores to the qualitative variables. The value of the parameters existing under the 1972 baseline strategy were given a neutral value of zero. Alternative nitrogen strategies, which improve upon the 1972 base situation, received a positive value while those that produced effects worse than the 1972 baseline strategy were given a negative value. Where quantitative values (raw scores) were available, but exceeded the +5 to -5 range, the strategy with the most extreme value was assigned the value of five. The values associated with the other strategies were proportioned on the basis of the difference between the extreme strategy value and the baseline strategy value. Thus, raw scores between alternatives maintained the proportion initially present in the qualitative data. Zero was assigned as a strategy's raw score if no change from the 1972 base year situation was obtained.

Multiplying the raw scores by their parameter weights gave each alternative strategy a weighted score. Summing the weighted scores across the variables within each major subsection of the matrix (economic, environmental and social well-being) indicated the effect of each strategy on each major parameter in the matrix. The sum of the three major parameter weighted scores indicated a strategy's net overall impact on society. If the net overall impact was positive then the strategy was considered more favorable than the 1972 base year nitrogen fertilization strategy. Since each strategy was either positive or negative the alternatives could be ranked from highest to lowest or best to worse.

This chapter has presented the methodology improved to analyze the "trade-offs" between the social benefits and costs of nitrogen fertilizer use. The results are presented and analyzed in Chapters IV, V and VI. Chapter IV presents the baseline strategy. Chapter V presents the results of the technology, restricted and maximum nitrogen strategies and their comparison to the baseline strategy. Chapter VI develops the environmental impact matrix.

CHAPTER IV

RESULTS OF THE BASELINE STRATEGY MODEL

The study utilized a 1972 crop base for comparison of alternative nitrogen fertilizer strategies. The crop year of 1972 was chosen since it preceded the "fertilizer shortage" and the relaxing of government program acreage restrictions. In essence, 1972 was considered a "normal year" in agriculture with respect to application rates of nitrogen fertilizer and government programs.

The 1972 cropping patterns, management practices, costs of production, prices paid for nitrogen fertilizer and prices received for crops were extended into the future, with slight adjustments. The agricultural sector of the area's economy was considered to exist in the year 1990 exactly as it functioned in 1972. The only exception was that the government payment for wheat, grain sorghum, and corn was paid in 1972; in the following years the government payment was stopped. The subsequent market price for 1975 through 1990 was projected by Oklahoma State Extension Agricultural Economists.

The agricultural land base for wheat, grain sorghum and corn in 1972 is presented in Table VI. These data were derived as indicated in Chapter III. The comparison of acres planted, grain production and the magnitude of error between the thesis model's 1972 estimates and the estimates of Statistical Reporting Service personnel in each state are also shown in Table VI. The model estimates for the base year are

TABLE VI

COMPARISON OF MODEL AND STATISTICAL REPORTING SERVICE ESTIMATES OF GRAIN PRODUCTION AND ACRES PLANTED: 1972[1]

	Panhandle						North Central				Central			
	Wheat Production	Wheat Acres Planted	Grain Sorghum Production	Grain Sorghum Acres Planted	Corn Production	Corn Acres Planted	Wheat Production	Wheat Acres Planted	Grain Sorghum Production	Grain Sorghum Acres Planted	Wheat Production	Wheat Acres Planted	Grain Sorghum Production	Grain Sorghum Acres Planted
	(Bu)		(Bu)		(Bu)		(Bu)		(Bu)		(Bu)		(Bu)	
Model Estimates	29,487,442	2,138,425	63,596,716	1,090,310	15,631,984	180,301	56,883,714	2,633,320	3,103,997	195,126	7,156,583	432,835	1,069,035	98,330
SRS Estimates	28,349,800	2,203,400	62,047,780	1,136,061	15,349,000	180,300	55,986,200	2,707,800	3,104,920	203,400	6,814,200	424,700	1,081,300	96,700
Percentage Error	4.404	-.029	+.025	-.046	+.018	+.100	+.016	-.028	.000	=.041	+.050	+.019	-.011	+.017

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[1] Statistical Reporting Service data were obtained from the 1972 Oklahoma, Texas and Kansas reports by county for the counties located in each state.

reasonably close to those values indicated by the Statistical Reporting Service (SRS) of USDA. Not all of the planted acres are harvested for grain; some are grazed out or cut as forage crops. However, these acres are generally fertilized in a manner similar to harvested acres. Estimates of production of forage in 1972 are indicated in Table VII.

TABLE VII

FORAGE PRODUCTION IN THE 45 COUNTY STUDY AREA IN 1972, BY AREAS
ANIMAL UNIT MONTHS (AUM'S)[1]

	Panhandle	North Central	Central
Wheat Pasture	1,177,580	1,535,971	201,620
Grain Sorghum	5,333,024[2]	770,033	120,639

[1] AUM's are estimated by land class assuming a direct relationship with grain production on that land class.

[2] Panhandle estimate is for both grain sorghum and corn silage.

Estimates for grain and forage production, for the years 1975, 1980, 1985 and 1990 based upon this region's share of production, are presented in Table VIII. The regional shares for each region were calculated from OBERS projections for the United States, as adjusted by SRS county data. The North Central area will have a 19 percent increase in wheat production and a 140 percent increase in grain sorghum

TABLE VIII

STUDY REGION'S PROJECTED PRODUCTION OF WHEAT AND FEED GRAINS: 1975, 1980, 1985, 1990

	Panhandle Area				North Central Area				Central Area			
Crop	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
Wheat Grain (Bu)	30,081,500	30,732,313	31,823,806	33,233,383	58,575,415	61,324,557	64,767,042	67,635,780	8,822,470	9,236,538	9,755,036	10,187,117
Wheat Pasture (AUM)	1,201,301	1,227,291	1,270,880	1,327,171	1,578,570	1,652,657	1,745,429	1,822,739	261,041	273,292	288,633	201,414
Grain Sorghum Grain[1] (Bu)	84,185,197	92,351,713	99,409,400	105,403,010	5,389,620	6,492,464	7,012,130	7,445,184	1,828,621	7,202,800	2,379,115	2,526,045
Grain Sorghum Forage[1] (AUM)	5,666,650	6,216,353	6,691,418	7,094,858	1,352,133	1,628,811	1,759,183	1,867,826	206,355	248,580	268,476	285,056

[1] Contain both corn and grain sorghum projections for Panhandle area.

production from 1972 to 1990. The Central area will have an increase of 42 percent for wheat and 136 percent for grain sorghum. The Panhandle's shares will increase 13 percent for wheat and 33 percent for feed grains from 1972 to 1990.

Land Resource Adjustments

The adjustments in the land resource base are indicated in Table IX (1980, 1985 estimates are shown in Appendix B). These changes reflect increased land cultivation to meet food and feed grain projections under 1972 yields, fertilization rates per acre and management levels.

Land adjustments were achieved on the basis of net revenue per acre for each cropping activity, soil classification, land class and amount of land preparation required to bring a specific acre into production. Budgets for each land group, i.e., producing, temporarily idled and new lands, are presented in Appendix A.

Temporarily idled land or land which was cultivated at some previous time period was considered capable of returning to production with relatively minor land preparation costs. New lands require considerably more land preparation to incorporate luxuriant plant material. Terracing is required of all new dryland acres from Class II through V on the basis of Soil Conservation Service recommendations for type of crop and width of terrace spacing. Budgets for new irrigated acres in the Panhandle included a charge for drilling a well and pump and motor costs. In addition, Panhandle irrigated clay land budgets were adjusted for leveling to a one-to-two percent grade.

All budgets for currently producing acres, temporarily idled acres, and new acres are adjusted by machinery efficiency estimates.

TABLE IX

STUDY REGION'S TOTAL LAND ADJUSTMENTS FOR THE BASELINE STRATEGY: 1972, 1975, 1990[1]

(Units in Acres)

	Panhandle			North Central			Central		
Crop/Year	1972	1975	1990	1972	1975	1990	1972	1975	1990
Wheat	2,138,425	2,152,113	2,285,417	2,633,320	2,700,085	3,095,165	432,835	521,956	600,443
Grain Sorghum	1,090,310	1,191,277	1,488,075	195,126	342,540	484,089	98,330	161,124	220,265
Corn	180,301	217,659	312,764	-	-	-	-	-	-

[1] A complete list of acreage adjustments for all years, crops, soil classifications and areas are in Appendix B.

The higher the land capability class number the more terracing required, which implies a higher cost associated with machinery time in the field. This operating expense provided a basis for differentiating between land classes on the basis of land slope. The costs include the increased operating expenses, fuel, depreciation, labor and repair costs associated with farming on lands with capability Classes II through V.

Wheat Acreage Adjustments

Acres devoted to wheat production in the region increased by 15 percent from 1972 to 1990. The increases, as would be expected, occurred in the better classes of land; e.g., from Class I loam to Class III sand. Class II loam and III sand in the Panhandle area had net declines between 1975 and 1990 of four percent and seven percent, respectively, due to the substitution of higher priced feed grains for irrigable wheat lands. No new irrigated wheat acres were brought into production.

Specific land changes included an addition of 236,305 acres of temporarily idle land and 157,789 acres of new land from the Panhandle area in 1990. North Central area adjustments consisted of 231,540 temporarily idled acres and 230,307 new acres in 1990. The Central area added 79,845 acres from idled lands and 87,766 new acres between 1972 and 1990.

Grain Sorghum Acreage Adjustments

Grain sorghum acreage increased by 58 percent within the study region. These acreage adjustments occurred across a more varied composition of land types than occurred with wheat. Panhandle acreages increased by 36.5 percent (by 150,810 acres) from 1972 to 1990. Almost two-fifths of this increase was in new irrigated acres. The majority of dryland acreage increases occurred in land Classes II and III.

Temporarily idled lands provided 65,150 acres or 16 percent of dryland grain sorghum acreage increases in 1990. New land grain sorghum production in the Panhandle area amounted to 181,805 acres or 46 percent of the total increase in dryland grain sorghum acreage increases.

North Central area grain sorghum acreage changes ranged from Class I through Class V soils. The main reason for this wide range was due to the model's distribution of new and temporarily idled land on historical cropping patterns of wheat and grain sorghum for the three areas. Also, the acreage adjustment occurred in the first period of analysis (1972 to 1975), reflecting the OBERS projected 74 percent increase of grain sorghum between 1972 and 1975 for North Central area counties. Temporarily idled acres (58,256) made up 20 percent of the land adjustment; new acres (230,707) made up the other 80 percent.

Central area grain sorghum acreage increases were similar to the wheat acreage adjustments in that area. Acreages affected were in Classes I and II with the greatest impact in Class II loam. The adjustment was 121,935 acres or a 124 percent increase over 1972 acres in cultivation. The percentage change is quite large; however, grain sorghum production is relatively minor in this area as only 98,330 acres were produced in 1972. Production increases of 1,457,010 bushels or 136 percent from 1972 to 1990 show the minor role this area plays in relation to the entire study area.

Corn Acreage Adjustments

The largest percentage increases of any crop from 1972 to 1990 occurred with corn. The entire range of irrigable acres, from Class II through Class IV were affected. Actual acreage changes were 132,463 acres or 73 percent. This reflects the increased importance of corn as a feed grain and silage in the Panhandle area's cattle feeding operations.

Farm Labor Requirements

Estimates for farm labor requirements are stated in man hours for the total region (Table X). Labor utilized per acre for each of the crops produced are presented in Appendix A. Hours required were generated from Oklahoma State University crop enterprise budgets and adjusted for labor efficiency decreases as machinery time per acre increased over greater sloping land classes.

The man hour requirements assume a 55-hour work week. Relating this to the number of labor hours utilized by a cropping activity for a given acre, then wheat acreage in the North Central area in 1972 utilized 7,614,750 hours of labor (55 x 138,450). The percentage of labor hired to total labor required is estimated from SRS statistics. 1972 labor figures indicated about 15 percent of labor employed in the area was hired and 85 percent was owner-operator labor [42, p. 3]. Applying the percentages to North Central wheat in 1972, then approximately 20,767 man years are hired labor and 117,683 man years of owner-operated labor.

The requirements for wheat in the study area in 1972 amounted to

TABLE X

STUDY REGION'S FARM LABOR REQUIREMENTS FOR THE BASELINE STRATEGY: 1972, 1975, 1980, 1985, 1990

(Measured in Man Years)[1]

	Panhandle					North Central					Central				
Crop	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
Wheat	26,237	26,361	26,415	26,990	28,573	138,450	141,776	145,964	155,381	161,794	29,430	35,283	36,719	38,730	40,468
Grain Sorghum	66,949	70,825	79,153	88,400	89,599	10,444	19,821	24,304	26,438	28,241	6,454	10,507	12,532	13,485	14,263
Corn	16,075	20,007	22,760	23,167	26,014	-	-	-	-	-	-	-	-	-	-
Total	109,261	119,193	128,328	138,557	144,186	148,894	161,597	170,268	181,819	190,035	35,884	45,790	49,251	52,215	54,731

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[1] Assumes a 55 hour work week.

194,117 man years. In 1990 this requirement increased to 230,835 man years; a 19 percent increase. Grain sorghum labor needs changed by 58 percent from 1972 to 1990 with the additional 48,286 man year requirement. Corn utilized an additional 9,939 man years; up by 62 percent. In total, the three cropping activities created a demand for 94,913 man years of employment between 1972 and 1990.

Cropping Activities Contribution To Regional Income

Changes in the region's net income from the production of wheat, grain sorghum and corn is indicated in Table XI. The 1972 figure includes a $152,508,169 government payment. Based on the 1972 government program, wheat payments in this region were $117,844,949; grain sorghum payments were $27,785,597; and, corn payments were $6,878,073. The total dollar value change in the region's net income from the production of these crops was $159,437,071. This is a 60 percent increase in area income from 1972 to 1990.

Nitrogen Fertilizer and Its Potential Pollution

The change in amount of commercial nitrogen fertilizer used in the region was significant, primarily because of the large increase in feed grain acreages (Table XII). In 1972 the region utilized a total of 241,090,582 pounds of nitrogen. This included 111,146,677 pounds of commercial nitrogen for wheat production, 100,139,052 pounds for grain sorghum and 29,804,853 pounds for corn. The 1990 estimates indicate a need for 321,887,684 pounds of commerical nitrogen, a 33.5 percent increase over 1972. In comparing the additional nitrogen requirements, corn had the largest increase (93 percent) over the 1972 base. Wheat and grain sorghum requirements for nitrogen increased by 21 and 30 percent, respectively. The increases are indicative of the number of new acres brought into production and the heavy emphasis on feed grain production.

TABLE XI

STUDY REGION'S AGGREGATE NET FARM INCOME ESTIMATES FOR THE BASELINE STRATEGY: 1972, 1975, 1980, 1985, 1990[1]

Year	Regional Net Farm Income
1972	$266,461,625
1975	$347,029,224
1980	$377,007,355
1985	$402,857,686
1990	$425,898,695

[1] 1972 estimates include government payments and nitrogen fertilizer at eight cents per pound. Other years include only market prices and 20 cents a pound for nitrogen fertilizer.

The potential nitrogen pollution coefficients reflect the increase of nitrogen fertilizer use between 1972 and 1990. The Panhandle area potential nitrogen pollution coefficient for April fifteenth (preplant fertilization of grain sorghum and corn and sidedressing of wheat on irrigated lands was 42 ppm in 1972, 46 ppm in 1975 and 56 ppm in 1990. This is a 33 percent increase from 1972 to 1990. The magnitude of the potential nitrogen pollution coefficients fall significantly in September, indicating only the preplant fertilization of wheat.

TABLE XII

STUDY REGION'S NITROGEN FERTILIZER REQUIREMENT BY CROP FOR THE BASELINE STRATEGY: 1972, 1975, 1980, 1985, 1990

(Measured in Pounds of Nitrogen)

	Years				
Crop	1972	1975	1980	1985	1990
Wheat	111,146,677	117,819,878	122,458,835	132,793,963	134,223,985
Grain Sorghum	100,139,052	105,269,356	114,106,562	127,124,013	130,077,609
Corn	29,804,853	39,227,193	45,419,588	46,605,491	57,586,200
Total	241,090,582	262,316,527	281,984,985	306,523,467	321,887,684

North Central potential nitrogen pollution estimates show a similar effect. April fifteenth potential was 7 ppm in 1972 and 9 ppm in 1990, a 22 percent increase. This pollution estimate reflects preplant grain sorghum fertilization in the North Central area and sidedressing of wheat. The September fifteenth estimate of 4 ppm in 1972 and 5 ppm in 1990 reflects the next crop of wheat and its preplant nitrogen application. The decline of potential nitrogen pollution between April and September is a function of acres fertilized (grain sorghum and/or wheat) and rainfall probabilities. Since application rates are assumed split equally between preplant and sidedress applications on wheat and a preplant application on grain sorghum acres the September potential nitrogen pollution coefficient is larger than the April estimate.

The Central area's potential nitrogen pollution estimate on April fifteenth is 68 ppm in 1972 and 134 ppm in 1990, or a 97 percent increase. The Central area sidedresses only on wheat, no preplant and grain sorghum yields are not high enough to justify fertilization. The reason for the large magnitude of pollution coefficients rests mainly in the volume of stream flows in the Central area. Low volumes do not allow a high dilution effect. Hence, significant runoff effects will enhance nitrogen concentration levels.

The baseline strategy is an attempt to simulate the 1972 wheat, grain sorghum and corn production in the study area. The extension of this agricultural sector's structure to 1990 allows a comparison of alternative nitrogen strategies' impacts on the region's land adjustments, nitrogen fertilizer use, employment, income level and potential nitrogen pollution. Chapter V compares three different nitrogen fertilizer strategies to the baseline strategy and indicates the major impacts.

TABLE XIII

STUDY REGION'S POTENTIAL NITROGEN POLLUTION ESTIMATES FOR THE BASELINE STRATEGY BY SELECTED WEEKLY PERIODS: 1972, 1975, 1990

(Measured in Parts Per Million)

	Panhandle			North Central			Central		
	1972	1975	1990	1972	1975	1990	1972	1975	1990
April 7	0	0	0	3	3	3	24	32	48
April 15	42	46	56	7	7	9	68	90	134
April 29	0	0	0	12	13	15	77	102	152
August 7	30	33	42	0	0	0	0	0	0
August 15	34	38	48	0	0	0	0	0	0
August 29	103	114	144	0	0	0	0	0	0
September 7	12	13	14	2	2	3	0	0	0
September 15	34	35	39	4	4	5	0	0	0
September 29	19	20	22	4	4	5	0	0	0

CHAPTER V

RESULTS OF THE ALTERNATIVE STRATEGY MODELS

Three different strategies were developed to evaluate the environmental and economic impact of commercial nitrogen fertilizer. The technology strategy assumes that a one percent increase in yield per acre per year will occur between 1972 and 1990. The amount of nitrogen fertilizer applied per acre remains at the 1972 application rates for the three crops. Hence, it assumes that yield increases will occur through better management practices and more efficient use of nitrogen fertilizer.

The maximum nitrogen strategy assumes dryland wheat in the North Central and Central regions were fertilized at a rate of 80 pounds of nitrogen per acre on land Classes I_L through III_C. The remaining wheat land Classes (III_S - V_S) do not have sufficient inherent soil capabilities to utilize this 80 pound rate. The Panhandle dryland wheat acres remain at their 1972 fertilization rate due to insufficient rainfall amounts. Irrigated wheat lands in the Panhandle area also remain at 1972 rates. Irrigated wheat was already using close to the 80 pound maximum. This maximum nitrogen strategy allows for yield increases at a one percent per year rate for all crops except for the North Central and Central adjusted wheat acres, which were set constant at their maximum agronomic limit of 49 bushels per acre.

The restricted nitrogen strategy forces a physical limitation on the amount of nitrogen fertilizer applied per acre. The strategy was developed to restrict fertilizer levels to an application rate per acre at which it is profitable to use this acre in production, but at a lower application level per acre would make this acre unprofitable. Specifically, dryland wheat, grain sorghum, and irrigated wheat were restricted to 30 pounds of nitrogen per acre for the three areas. Irrigated corn and grain sorghum were limited to an 80 pound per acre limitation. Temporarily idled and new lands were allowed into production at nitrogen fertilizer rates greater than producing acre limits. This exception allows new acres to obtain current producing acreage yield capabilities by supplying additional nitrogen to aid in the decomposition of surplus organic residues which occur on uncultivated acres.

Comparison of Land Utilization Adjustments

Panhandle Area Land Adjustments

The Panhandle area employed two strategies: technology and restricted (Table XIV).[1] The technology strategy's land base increased by a total of 34,732 acres from 1972 to 1990. The additional acreage came from increased corn and grain sorghum production (125,846 and 34,732, respectively) while wheat acreage declined by 125,846 acres.

The reason for the significant difference between the Panhandle

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[1] Land adjustments for each area of the region for every year, 1972-1990 are found in Appendix B. The 1975 and 1990 adjustments are used to indicate the short-run and long-run impacts from the nitrogen fertilizer strategies.

TABLE XIV

TOTAL LAND ADJUSTMENTS BY STRATEGIES AND CROP FOR THE PANHANDLE AREA: 1972, 1975, 1990[1]

(Units in Acres)

	Technology			Restricted			Maximum Nitrogen		
	1972	1975	1990	1972	1975	1990	1972	1975	1990
Wheat	2,138,425	2,131,046	2,012,579	2,138,425	2,487,404	2,376,249	2,138,425	2,131,046	2,012,579
Grain Sorghum	1,090,310	1,174,001	1,125,042	1,090,130	1,507,177	1,604,120	1,090,310	1,174,001	1,125,042
Corn	180,301	188,791	306,147	180,301	263,260	283,723	180,301	188,791	306,147
Total	3,409,036	3,493,838	3,443,768	3,409,036	4,257,841	4,264,092	3,409,036	3,493,838	3,443,768

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[1] A complete Panhandle land inventory for all years and strategies is included in Appendix B.

area's technology and restricted strategies land adjustment lies in the nitrogen fertilizer restriction's impact on crop enterprise profitability. Panhandle corn acreage adjustments in the technological run amounted to 125,846 additional acres with 8,490 coming in the 1975 adjustment. This represented 22,424 more acres being allotted for corn than with the restricted strategy. However, the restricted alternative's initial acreage adjustment was nearly ten times greater than the technology strategy (82,959 acres compared to 8,490 acres). The difference occurs in the necessity to provide a larger initial change due to the significant yield reductions per acre encountered in 1975. For example, this reduction amounted to 63.4 bushels and 25.8 AUM's on Class II_L soils. Yield reductions for lower quality soils were adjusted on a similar basis.

The impact of these two strategies is even more evident in grain sorghum acreage adjustments. In the requirement to meet regional feed grain shares of production the previously productive corn acreages are decreased in the restrictive alternative, dryland grain sorghum takes their place. The technology strategy increased grain sorghum acres by 34,732 in 1990, of which 2,458 acres were dryland. The restricted strategy increased total grain sorghum acreage by 513,990 acres; of this amount, 269,795 acres are dryland acres. The reason this substitution of dryland grain sorghum for irrigated corn occurs lies in the reduced profitability of corn relative to the profitability of the lower yielding but lightly fertilized dryland grain sorghum. The impact of the restriction was the increased total land acreage brought into production. These acres are more marginal lands but, due to the nitrogen restriction, are more profitable than irrigated corn acres.

Another significant result in the Panhandle area was the wheat acreage adjustment. The technological alternative produced a net decline of 125,846 acres of wheat between 1972 and 1990. These acres shifted into the more productive irrigated feed grains. The restricted alternative, although shifting 174,741 acres into feed grains in 1990, also had a net increase of 237,824 acres of wheat. Again the 30 pounds of nitrogen fertilizer used as a restricting yield per acre limit forced additional new dryland acres into production to meet 1990 regional shares of wheat production.

North Central Area Land Adjustments

The North Central area utilized all three strategies (Table XV). The maximum nitrogen strategy, which added 80 pounds of nitrogen per acre, had the greatest land adjustment impact in its effort to meet 1990 required wheat projections. The acres devoted to wheat production were 1,758,260 in 1990. This was a reduction of 875,060 acres or 33 percent from the 1972 base. The distribution of the maximum nitrogen strategy acres remained in the Class I_L to Class III_C land categories (Appendix B) indicating that wheat production on the lower quality acres was eliminated. Grain sorghum acreages under the maximum nitrogen strategy were not affected.

The North Central Area comparison between the technology and restricted strategies indicated a land adjustment of 32,690 and 80,973 acres, respectively, for 1972 and 1990. The differences lie again in the nitrogen fertilizer restriction. The wheat acreage adjustment indicated that between 1972 and 1980 (Appendix B) the increase in the restricted strategy's acreages occur in land Classes I_L and II_C. The

TABLE XV

TOTAL LAND ADJUSTMENTS BY STRATEGIES AND CROP FOR THE NORTH CENTRAL AREA: 1972, 1975, 1990[1]

(Units in Acres)

	Technology			Restricted			Maximum Nitrogen		
	1972	1975	1990	1972	1975	1990	1972	1975	1990
Wheat	2,633,320	2,651,619	2,666,010	2,633,320	2,693,772	2,714,293	2,633,320	1,513,945	1,758,260
Grain Sorghum	195,126	334,774	407,373	195,126	336,274	409,939	195,126	334,774	407,373
Total	2,828,446	2,986,393	3,073,383	2,828,446	3,030,046	3,124,232	2,828,446	1,848,719	2,165,633

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[1] A complete North Central area land inventory for all years and strategies is included in Appendix B.

technology increase appears only in Class I_L throughout the entire 1972 to 1990 time period.

The restriction of nitrogen fertilizer to 30 pounds per acre caused a shift in wheat production to the lower productivity lands. Not until 1985 were the Class I_C and II_L lands brought into production. In essence, the restriction of nitrogen indicated land Classes I and II could be grouped together in terms of productivity.

The pattern of reduced productivity per acre appears once more in North Central grain sorghum acreage adjustments. The technology strategy used the maximum acreage allotted to Classes I_L and I_C grain sorghum, 17,572 and 6,950, respectively, (Appendix B). With the restriction of nitrogen fertilizer to 30 pounds per acre occurring only on I_L and I_C, the restricted strategy shifted forage production from 3,042 acres of Class I_L and 927 acres of Class I_C acres to poorer quality lands.

Central Area Land Adjustments

The Central area was conducive to only the technology and maximum nitrogen strategies (Table XVI). The Central area's land adjustments were considered the same in the technology and restricted strategies. The dominant management practices in 1972 did not require 30 or more pounds of nitrogen fertilizer per acre on either wheat or grain sorghum.

The Central area's technology strategy required 515,428 acres for projected wheat shares in 1990, grain sorghum acres were 190,214. This was an increase of 82,593 acres for wheat and 91,884 acres for grain sorghum from the 1972 baseline strategy estimates. The maximum nitrogen

TABLE XVI

TOTAL LAND ADJUSTMENTS BY STRATEGIES AND CROP FOR THE CENTRAL AREA: 1972, 1975, 1990[1]

(Units in Acres)

	Technology			Restricted			Maximum Nitrogen		
	1972	1975	1990	1972	1975	1990	1972	1975	1990
Wheat	432,835	511,786	515,428	432,835	511,786	515,428	432,835	243,362	351,475
Grain Sorghum	98,330	157,734	190,214	98,330	157,734	190,314	98,330	157,734	190,214
Total	531,165	669,520	705,642	531,165	669,520	705,642	531,165	401,296	541,689

[1] A complete Central area land inventory for all years and strategies is included in Appendix B.

strategy required 351,475 acres to meet its regional share of 1990 U.S. wheat needs; this is a reduction of 81,360 acres from the 1972 estimate. Grain sorghum acreage estimates for both the technology and maximum nitrogen were 190,214 in 1990, an increase of 91,884 acres from the 1972 baseline strategy. (Grain sorghum was not affected by the maximum nitrogen strategy in the Central area).

The sharp difference in strategy estimates of wheat acreages required to meet regional shares of wheat production was expected. The 49 bushel yield per acre assumption of the maximum nitrogen strategy makes the better quality lands more productive. Wheat acreages, utilized in the technology strategy were idled in the maximum nitrogen strategy.

The three strategies impact quite differently upon the region's land use patterns. The maximum nitrogen strategy employing 80 pounds of nitrogen per acre, releases a total of 800,000 acres in all areas from cultivation. The technology strategy required an additional 454,164 total acres from all areas to meet 1990 food and feedgrain needs. The restricted nitrogen strategy requires the largest land adjustment; indicating a total area adjustment of 1,322,499 acres in 1990.

The land adjustment process of the three strategies showed the land-nitrogen fertilizer "trade-off" quite well. The inexpensive nitrogen fertilizer input can and does reduce the amount of land necessary to produce future food and feedgrain requirements. This substitution is quite evident in the maximum nitrogen strategy; and to a lesser extent in the technology strategy.

The restricted strategy's reduction of nitrogen fertilizer applied per acre indicates why agriculture has utilized more of this input. Irrigable lands are more productive than dryland cropping activities, however, these lands maintain this profitability by combining adequate water with the relatively inexpensive and yield enhancing input, nitrogen fertilizer. Without nitrogen restrictions, as evidenced by the Panhandle's technology and restricted strategies, irrigated feedgrain acres increased. With the restriction, dryland acreages become more profitable and irrigable acreages were not cultivated.

Productive lands with adequate rainfall, North Central and Central areas, increased their productivity with nitrogen fertilizer. Curtailment of nitrogen fertilizer on these acreages will require yield reductions or depletion of natural nitrogen amounts.

Comparison of Nitrogen Fertilizer Use Rates

Commercial nitrogen fertilizer use rates reflected comparable movements in land use patterns changes (Table XVII). The maximum nitrogen strategy with 80 pounds of nitrogen on the better wheat lands had the greatest increase in fertilizer applied, 54,458,123 pounds or a 49 percent rise from 1972 to 1990. The initial adjustment to the year 1975 required a 33,446,475 pound increase or about 61 percent of the total increase. Feed grain fertilizer requirements increased like the technology strategy, since grain sorghum and corn acreage application rates were not affected by the maximum nitrogen strategy.

The technology strategy produced the largest total change in nitrogen fertilizer requirements per acre. An additional 3,444,460 pounds of fertilizer were required for wheat production, 9,726,009 for grain

TABLE XVII

COMPARISON OF NITROGEN FERTILIZER STRATEGIES BY CROP FOR THE STUDY REGION: 1975, 1980, 1985, 1990

(Measured in Pounds of Nitrogen)

	Technology				Restricted				Maximum Nitrogen			
	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
Wheat	114,642,787	113,424,739	114,591,137	114,182,354	91,414,081	90,135,950	90,932,216	90,697,112	144,593,152	149,845,840	158,462,080	165,604,800
Grain Sorghum	105,893,633	110,745,951	110,456,038	109,865,061	99,358,761	92,894,243	97,289,786	93,595,769	105,893,633	110,745,951	110,456,038	109,865,061
Corn	31,787,179	43,398,998	44,752,777	47,819,072	24,379,289	22,272,160	22,606,160	22,866,640	31,787,179	43,398,998	44,752,777	47,810,072

sorghum and 18,005,219 for corn production. The restricted nitrogen fertilizer strategy actually had a net decline in the amount of nitrogen required. The wheat fertilizer requirement declined by 20,449,565 pounds, grain sorghum by 6,543,283 pounds and corn by 6,938,213 pounds from the 1972 base year estimates of fertilizer requirements. The decline in nitrogen use was compensated for by the increase in land. Much of this land increase was on acres that were not fertilized due to their small yield per acre expectations. Hence, regional shares of production were met under the restricted strategy, not by increased fertilization but, by the substitution of lower yielding unfertilized acres.

The comparison of the alternative fertilizer use rates lies in the structure of the acreage changes taking place in the four time periods. The wheat fertilizer use rate is readily apparent. The restricted strategy required a total increase in wheat acres in production for the Panhandle, North Central and Central areas. All of these 398,390 new acres brought into production between 1972 and 1990 required fertilizer applications except for 376,479 acres of Classes III_L - V_L in the Panhandle area. Conversely in the technology run only 795 acres in the Panhandle, which entered in 1975 but were released in subsequent years due to increased yields per acre, were fertilized acres. The remaining fertilizer increases to 1990 were on 32,690 wheat acres in the North Central area and 82,593 wheat acres in the Central area. Further indication of the nitrogen fertilizer increase in wheat production for the restricted strategy result was due to the absolute increase in Panhandle dryland wheat acreages. The technology alternative, in addition, lost 125,846 acres of wheat lands; lands which were irrigable, but not developed in 1972, from 1972 to 1990 to the more productive and profitable feed grains.

The feed grain fertilizer use rates were as would be expected in the North Central and Central areas. Larger acreage increases required more fertilizer in the restricted run than the technological run. The problem of interpreting the feed grain fertilizer estimates occurs in the Panhandle area. One would expect that the increased acres of grain sorghum, in the restricted run would require a larger absolute amount of nitrogen fertilizer than the technology run, since in the technology run acreages increased only by 34,732 acres compared to a restricted strategy increase of 570,162 acres. However, the restricted alternative selected 214,113 acres of dryland grain sorghum, which were not fertilized acres. These acres comprised 65 percent of the dryland acres in production in 1990 and 39 percent of the total grain sorghum acreage, i.e., of the 570,162 new grain sorghum acres brought into production in 1990, 214,113 require no nitrogen fertilizer. The remaining 114,663 new dryland acres of grain sorghum were fertilized at a rate much smaller than the 80 pound limit. Class II_L acres, 7,838, were fertilized at 14 pounds per acre. Classes II_C and III_C received 8 pounds for their combined acreage of 106,375 acres. Hence, the remaining irrigated grain sorghum acres, 241,386 (42 percent of the total grain sorghum acres) utilized the greatest part of the fertilizer amount.

In contrast, the technology strategy required only 2,458 dryland acres of Class II_L land between 1972 and 1990. Total acreage increase was 34,732 acres. Irrigated acreage then comprised 93 percent of the total. These irrigated acres were fertilized at a rate of 155 pounds of nitrogen per acre; a rate 75 pounds above the restricted strategies maximum level for producing grain sorghum acres.

For the lands currently producing grain sorghum in 1972 in the technology strategy, 576,100 acres received 92,369,057 pounds of nitrogen fertilizer. The restricted strategy which "allowed" these lands to be fertilized at a maximum of 80 pounds per acre would utilize only 46,088,000 pounds of nitrogen, which means a reduction of 46,281,057 pounds in nitrogen fertilizer consumption in 1990.

Nitrogen fertilizer consumption on corn acreage followed a similar pattern as grain sorghum acreage. The technology strategy required 47,810,072 pounds of nitrogen to meet 1990 feed grain production requirements. The restricted strategy required 22,866,640 pounds.

The analysis of why corn requirements were curtailed is found in the number of total feed grain acres brought into production. The restricted alternative requires 283,723 acres of corn and 1,604,120 acres of grain sorghum to meet regional shares of production in 1990. The technology strategy brings 306,147 acres of corn and 1,125,042 acres of grain sorghum into production in 1990. Since both corn and grain sorghum production were allowed to meet the same feed grain production limits it is obvious that dryland grain sorghum acres are replacing irrigated corn acres. Corn, when restricted to 80 pounds of nitrogen fertilizer per acre, becomes less profitable than dryland grain sorghum.

Comparison of Labor Requirements by Strategies

Area labor requirements by crops and nitrogen fertilizer strategy are shown in Tables XVIII, XIX, and XX. Comparison of the three

TABLE XVIII

AREA LABOR REQUIREMENTS FOR THE TECHNOLOGY STRATEGY BY CROP FOR THE STUDY REGION: 1975, 1980, 1985, 1990

(Measured in Man Years)

	Panhandle				North Central				Central			
Crop	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
Wheat	26,247	26,237	26,237	26,237	139,362	139,006	140,200	140,061	34,612	35,139	34,838	34,857
Grain Sorghum	69,375	68,440	68,868	68,899	17,796	20,955	21,726	22,134	10,287	11,781	12,152	12,347
Corn	17,181	23,028	23,963	27,788	-	-	-	-	-	-	-	-
Total	112,803	117,705	119,068	122,924	157,158	159,961	161,926	162,195	44,899	46,920	46,990	47,204

TABLE XIX

AREA LABOR REQUIREMENTS FOR THE RESTRICTED STRATEGY BY CROP: 1975, 1980, 1985, 1990

(Measured in Man Years)

	Panhandle				North Central				Central			
Crop	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
Wheat	33,987	32,700	32,076	32,224	141,535	140,815	141,969	141,817	34,612	35,139	34,838	34,857
Grain Sorghum	97,151	101,243	105,322	103,276	18,171	21,652	22,424	22,834	10,287	11,781	12,152	12,347
Corn	25,252	25,801	26,158	26,403	-	-	-	-	-	-	-	-
Total	156,390	159,744	163,556	161,903	159,706	162,467	164,393	164,651	44,899	46,920	46,990	47,204

TABLE XX

AREA LABOR REQUIREMENTS FOR THE MAXIMUM STRATEGY BY CROP FOR THE STUDY REGION: 1975, 1980, 1985, 1990

(Measured in Man Years)

	Panhandle				North Central				Central			
Crop	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
Wheat	26,247	26,237	26,237	26,237	77,316	80,237	85,182	89,303	16,041	16,630	17,501	18,325
Grain Sorghum	69,375	68,440	68,868	68,899	17,796	20,955	21,726	22,134	10,287	11,781	12,152	12,347
Corn	17,181	23,028	23,963	27,788	-	-	-	-	-	-	-	-
Total	112,803	117,705	119,068	122,924	95,112	101,192	106,908	111,437	26,328	28,411	29,653	30,672

strategies indicates what would be expected given the acreage changes which occurred among the fertilizer alternatives from 1972 to 1990.

The technology strategy in the Panhandle area indicated a 13 percent increase from the 1972 base man years requirement to 1990. The restricted strategy had an increase of 43 percent for the same time period. Thus, the restricted strategy required 43,587 more man years from 1972 to 1990 to meet projected regional shares of production than did the technology strategy. This represents a 39 percent increase in man years of employment. The increase in man years is a reflection of the change in land in cultivation between the restricted and technology strategies. The direct implication is that 43,587 additional man years of employment are needed to bring into production the 820,324 additional acres of wheat, grain sorghum and corn required by the restricted nitrogen strategy above that suggested by the technology strategy from 1972 to 1990.

The same implications may be made in the North Central area. The restricted strategy required 164,651 man years of employment in 1990, an increase of 15,757 man years above the 1972 base line requirement. The technology strategy required 162,195 man years, 13,301 man years above the 1972 base line estimate. The net effect of restricting nitrogen fertilization to 30 pounds per acre was an additional labor requirement of 2,456 man years in the North Central area. As indicated in the previous section, the Central area was not affected by the restricted nitrogen assumption.

The effect of increasing nitrogen fertilizer applications to 80 pounds of nitrogen per acre on Class I_L - III_C soils in the North Central and Central wheat lands was to drastically reduce the agricultural labor force between 1972 and 1990. This was expected due to the wheat acreage reductions indicated by this alternative. The North Central area had a reduction of 78,598 man years (190,035 to 111,437) in the agricultural sector from the 1990 base line estimate to 1990 estimate under the maximum nitrogen strategy. For the same time period the Central area reduction in the labor force was 24,059 man years of employment (54,731 to 30,672).

The implications of the impact of the three alternative nitrogen fertilizer strategies on each areas labor force is far-reaching. The technology and restricted strategies suggested the need for a larger agricultural sector labor force, with the restricted strategy having even greater requirements than the technology strategy. The extra nitrogen strategy, as applied to North Central and Central wheat lands, resulted in a reduction in the labor complement. The pertinent questions that then arise are where would farmers obtain the additional labor for the technology and restricted nitrogen fertilizer strategies; and what would happen to the labor currently in use if nitrogen fertilization rates would increase to 80 pounds of nitrogen per acre on dryland wheat? Neither question is easy to answer.

Considering first the new labor requirements under the technology and restricted strategies, it is conceivable that new labor would be introduced from sources exogeneous to agriculture; i.e., new farm families. Another possibility would be increased use of current family labor, much of this family labor currently is moving out of the agriculture sector to find jobs elsewhere. This labor would consist of farm family children who previously found the family farm too small to support an additional family. These people also found the cost of establishing their own enterprise prohibitive.

A third possibility, and probably the most realistic hypothesis, is the continued mechanization of agriculture to achieve greater output per unit of labor. Over the last 50 years agriculture has grown more food and feed grain production on a smaller number of acres due to the substitution of capital resources for human and land resources. It is quite likely that the largest amount of this labor force requirement indicated by the technology and restricted strategies will come from greater dollar outlays for more labor saving farming equipment.

The maximum nitrogen strategy's suggestion of the need to displace a total of 102,657 man years of employment presents a different problem to the agricultural sector. What other sectors of the economy will absorb these extra man years of employment? Historically two primary alternatives are available. First, those capable of moving to an urban environment in search of new jobs will move. Secondly, those unwilling or unable to relocate must find employment in other sectors of the region's economy in their present rural location. Both solutions to labor displacement have their shortcomings.

Relocation in an urban environment and finding new employment in the same area require knowledge of skills other than purely farming abilities. Hence, suitability of job to skill levels becomes important. Even more important is the question of whether other sources of employment are available at all.

The real issue or "trade-off" is found in asking whether or not the increased revenues generated from additional fertilizer expenditures and increased farm and regional incomes from the reduction in acreages in production will produce additional jobs in rural service and supportive industries. Rural migration may be curtailed if the income effect from reduced expenditures in the production of a given level of food and feed grain output will sufficiently offset the employment reduction. If such a possibility occurs, it could bring enough additional dollars in supportive and service industries to employ the displaced workers in the rural area.

Comparison of Strategies' Contribution To Regional Income

Individual strategy contributions to regional incomes are presented in Table XXI. These figures indicated net incomes i.e., net of production and fertilizer costs, to the three areas of the study region for the production of wheat, grain sorghum and corn. There is no government payment and prices paid and received are identical to the base line strategy prices for the years 1975 through 1990.

The maximum nitrogen strategy's regional income change from 1972 to 1990 was $301,563,754, a 113 percent increase. The technology restricted strategies' income increases were $287,732,280 and $261,014,145, 108 and 98 percent increases, respectively. The maximum nitrogen strategy ranked first, technology strategy second and the restricted strategy was third. The maximum nitrogen strategy income level indicates the dominance of reduced acreage expenditures over the increased cost of fertilization i.e., the reduced cost of production generated from the idling of 956,420 total acres of wheat lands was more than the increased aggregate fertilizer costs.

The restricted strategy's regional income estimates moved in an opposite direction to the maximum nitrogen strategy. The difference in incomes ranged from $52,229,768 in 1972 to $40,549,609 in 1990 between these strategies. The 1990 estimate diminished as lands in production began increasing again in the maximum nitrogen strategy from 1975 to 1990 to meet regional shares of wheat production. The restricted strategy substituted the cultivation of new land for nitrogen fertilizer. Hence, the model's objective function declined.

TABLE XXI

CONTRIBUTION TO REGIONAL INCOME BY THE SELECTED NITROGEN FERTILIZER STRATEGIES: 1975, 1980, 1985, 1990

Year	Technology	Restricted	Maximum Nitrogen
1975	$429,458,397	$402,372,073	$454,601,841
1980	$472,864,436	$446,528,600	$494,846,192
1985	$512,561,013	$488,971,002	$530,281,900
1990	$554,193,904	$527,475,769	$568,025,378

The technology strategy's income estimate lies between the maximum nitrogen and restricted alternative's income levels. The implications of this strategy are found in the smaller land adjustments and larger fertilizer application rates per acre. This "middle ground" alternative avoids the large substitutions of land and nitrogen fertilization prevalent in the other strategies.

The aggregate regional farm income estimates generated by each nitrogen fertilizer strategy reflected the impact of nitrogen fertilizer application levels. Substitution of the more expensive land input for fertilizer reduced the farm based income levels. Fertilizer substitution for land increases income to the agricultural sector as this sector attempts to meet regional shares of production.

Comparison of Strategies' Potential Nitrogen Pollution Coefficients

The potential nitrogen pollution coefficients estimated nitrogen movement from cultivated acres. These estimates were based upon a probability of a one inch rainfall in a given day and the probability of an acre being fertilized on that same day. The potential nitrogen pollution coefficients indicated the potential nitrogen concentration level in the area's streams from the amount of nitrogen applied per acre and the number of acres fertilized.

The Panhandle area potential nitrogen pollution coefficients for the technology strategy on April fifteenth are: 39, 44, and 46 ppm of nitrogen for 1972, 1975, 1990, respectively. These estimates are based upon the April fertilization of dryland grain sorghum, top dressing of irrigated wheat and preplant applications of grain sorghum and corn (Table XXII). August fifteenth estimates are 1 ppm for 1972 and 1 ppm of nitrogen in 1990. The application of nitrogen fertilizer at this time of year is a top dressing of grain sorghum and corn. September fifteenth estimates include preplant application for irrigated and dryland wheat and are 34 ppm and 37 ppm for 1972 and 1990. The restricted strategy's potential nitrogen pollution coefficients were

TABLE XXII

POTENTIAL NITROGEN POLLUTION COEFFICIENTS BY STRATEGY FOR PANHANDLE AREA: 1975, 1980, 1985, 1990

(Measured in Parts Per Million)

	Technology				Restricted				Maximum Nitrogen			
Selected Time Period	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
April 7	-	-	-	-	-	-	-	-	-	-	-	-
April 15	39	44	44	46	32	31	32	32	39	44	44	46
April 29	-	-	-	-	-	-	-	-	-	-	-	-
August 7	1	1	1	1	1	1	1	1	1	1	1	1
August 15	1	1	1	1	2	2	2	2	1	1	1	1
August 29	4	4	4	4	5	5	5	5	4	4	4	4
September 1	12	12	12	12	9	9	9	9	12	12	12	12
September 15	34	33	33	34	24	24	24	24	34	33	33	34
September 29	19	19	19	19	14	14	14	14	19	19	19	19

32, 2 and 24 ppm of nitrogen for the fifteenth of April, August and September 1990, respectively.

The changing magnitude of the potential pollution coefficients within a cropping year reflect the growth cycles of the various crops and their nitrogen uptake rates. For example, in April corn receives a preplant treatment before seeding. There is no crop cover to a small crop cover over the month of April. Consequently, the potential nitrogen pollution from corn acreage is quite high. Side dressing of corn occurs in August. The crop is in a crucial stage of its development cycle and ground cover is at its peak. Applications of nitrogen at this time are readily absorbed by the crop and potential pollution is minimized.

Comparing the technology and restricted strategies in the Panhandle area shows the greatest potential nitrogen pollution would occur under the technology strategy. At any point in the growing year the restricted strategy produces a smaller potential nitrogen hazard for our rivers and streams. The reason for the difference was the large amount of dryland wheat and grain sorghum acres brought into production with the restriction of nitrogen applied per acre.

The North Central area's maximum nitrogen strategy suggests that on April fifteenth 1975 there is a potential nitrogen concentration of 3 ppm in its streams due to runoff and this increases to 4 ppm in 1990 (Table XXIII). Fertilization on September fifteenth results in a concentration of 3 ppm of nitrogen in steams in 1975 and 3 ppm in 1990.

These concentration levels appear low in comparison with the restricted strategy pollution coefficients; 6 ppm of nitrogen on April fifteenth in 1975. Although the restricted strategy effectively

TABLE XXIII

POTENTIAL NITROGEN POLLUTION COEFFICIENTS BY STRATEGY FOR NORTH CENTRAL AREA: 1975, 1980, 1985, 1990

(Measured in Parts Per Million)

	Technology				Restricted				Maximum Nitrogen			
Selected Time Period	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
April 7	3	3	3	3	2	2	2	2	1	1	1	2
April 15	8	8	8	8	6	6	6	6	3	4	4	4
April 29	13	13	13	13	10	10	10	10	7	7	7	7
August 7	-	-	-	-	-	-	-	-	-	-	-	-
August 15	-	-	-	-	-	-	-	-	-	-	-	-
August 29	-	-	-	-	-	-	-	-	-	-	-	-
September 1	2	2	2	2	1	1	1	1	1	1	1	1
September 15	4	4	4	4	2	2	2	2	3	3	3	3
September 29	4	4	4	4	2	2	2	2	4	5	5	5

reduced nitrogen applications to 30 pounds of nitrogen more wheat acres were planted under this strategy. The maximum nitrogen strategy reduced acreages of wheat production in the North Central area by 875,060 acres in 1990 leaving 1,758,260 acres in cultivation. The restricted strategy increased wheat acreages by 80,973 acres for a total of 2,714,293 acres in production in 1990.

The North Central area's technology strategy gave the highest potential nitrogen pollution estimates. This was expected since it kept a large number of acres in production between 1975 and 1990 and many of these acres received 30 or more pounds of nitrogen fertilizer per acre. The potential pollution coefficients were: 8 ppm, 4 ppm and 8, 5 for April and September 15, 1972 and 1990 respectively.

The same relationship found between the North Central area's maximum nitrogen and technology strategies was found in the Central area's comparison of these two strategies (Table XXIV).[2] The magnitude of the coefficients is higher due to the lower volume of water moving at any one time in the Central area's streams, implying higher potential nitrogen concentration levels.

The Central area's pollution potential estimates for its streams under the maximum nitrogen strategy were: 60 ppm for April 15, 1975 and 68 for 1990. The technology strategy estimates for the same time periods were 87 ppm and 88.

Given the probabilities of rainfall and seedbed preparation the potential pollution coefficients indicated the "trade-off" relationship

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[2] The Central area's technology and restricted strategies are the same.

TABLE XXIV

POTENTIAL NITROGEN POLLUTION COEFFICIENTS BY STRATEGY FOR CENTRAL AREA: 1975, 1980, 1985, 1990

(Measured in Parts Per Million)

	Technology				Restricted				Maximum Nitrogen			
Selected Time Period	1975	1980	1985	1990	1975	1980	1985	1990	1975	1980	1985	1990
April 7	31	31	31	31	31	31	31	31	21	22	23	24
April 15	87	88	88	88	87	88	88	88	60	62	66	68
April 29	99	99	100	100	99	99	100	100	68	71	74	78

between the nitrogen concentration levels in our streams and the application of nitrogen fertilizer required to meet the respective area's regional shares of production. The North Central area is the only area which can successfully approach the United States Public Health requirement of water concentration levels of 10 ppm of nitrogen.

However, it would be misleading to suggest that the Panhandle and Central area, because of their high pollution coefficients, are a considerable threat to our environment. A threat, yes, but the assumptions of rainfall is a sufficient amount to cause significant runoff and that it occurred when these acres were most susceptible to runoff <u>must be</u> realized. The model by necessity depicts the greatest potential hazard. It is difficult to conceive of a 21 million acre watershed receiving a one inch rainfall in a short enough duration to cause significant runoff from each acre. Also, the fertilization of the crop acres must occur at a time which is advantageous to rainfall vagarities.

CHAPTER VI

ENVIRO-ECONOMIC IMPACTS OF ALTERNATIVE NITROGEN FERTILIZER APPLICATION STRATEGIES[1]

The three nitrogen fertilizer strategies selected in Chapter III were considered feasible alternatives for the study area's agricultural sector. A feasible strategy was defined as a policy alternative available to a governmental agency which allowed maintenance of projected food and feed grain supplies without a harsh adjustment process in the area. The impacts of these nitrogen fertilizer alternatives were evaluated using an environmental impact matrix for the years 1975 and 1990. This gave a short-run and long-run view of nitrogen fertilizer strategies' impact. Economic, environmental and social well-being parameters were weighed on the basis of each strategy's overall impact on the three area's of the study region.

Analysis of the Panhandle Area

Two of the three alternative nitrogen fertilizer application strategies were considered feasible in the Panhandle area: (1) the restricted strategy which restricted nitrogen to 30 pounds per acre for wheat production and 80 pounds per acre for corn and grain sorghum

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[1] Appendix C contains the environmental and social well-being impact estimates used in the environmental impact matrices. Each table indicates how its respective qualitative variable was estimated for 1975 and 1990.

and (2) the technology strategy which provided a continuation of present levels of nitrogen fertilizer to both irrigated and dryland acres.[2] The impact of these methods upon economic, environmental and social well-being factors are shown in Table XXV for the years 1975 and 1990.

Economic Impact

The estimated economic impact from restricting nitrogen fertilizer application levels in the Panhandle area was 15.71 in 1975; the technology strategy impact in 1975 was 24.97. The difference was due to the influence of the cultivated acreage adjustments required to maintain regional shares of food and feed grain production. The Panhandle area utilized an additional 615,483 acres in the restricted strategy and released 148,520 acres from the technology strategy in comparison to the 1972 base acreage projections.

The influence of these acreage changes are apparent to the income and employment impacts of the two strategies. The restricted strategy's 1975 income impact was 6.25 and its labor impact was 2.15. The technology strategy's impact was higher for income, 9.31 and lower for employment 1.52, a direct result of the number of acres in cultivation.

The restricted strategy, by its nitrogen fertilizer limitation assumption, is substituting land in cultivation for nitrogen fertilizer. This, in effect, forces the agricultural sector to employ a combination of resource costs, i.e., land, labor, seed, depreciation, machinery

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[2] The maximum nitrogen strategy is identical to the technology strategy. Only the North Central and Central areas receive sufficient moisture to support an 80 pound per acre application rate of nitrogen fertilizer for dryland wheat lands.

TABLE XXV

PANHANDLE AREA ANALYSIS OF SELECTED NITROGEN FERTILIZER STRATEGIES: 1975-1990

	Parameter Weights	1975				1990			
		Restricted		Technology		Restricted		Technology	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Parameters									
I. Impact on Economic Factors:									
A. Change in Farm Income	2.43	+2.57	+6.25	+3.83	+9.31	+3.57	+8.68	+4.51	+10.97
B. Change in Farm Employment	.43	+5.00	+2.15	+3.54	+1.52	+3.54	+1.52	-5.00	-2.15
C. Change in Cost of Goods to the Customer	2.78	0	0	0	0	0		0	
D. Change in Acres in Production	.93	-5.00	-4.65	+1.33	+1.24	-1.42	-1.32	+5.00	+4.65
E. Change in Regional Income	2.14	+2.57	+5.50	+3.83	+8.20	+3.57	+7.65	+4.51	+8.89
F. Change in Regional Employment	1.29	+5.00	+6.45	+3.54	+4.56	+3.54	+4.57	-5.00	-6.45
Economic Impact	10.00		+15.71		+24.97		+21.11		+17.85
II. Impact on Environmental Factors:									
A. Land Based Environment									
1. Change in acres for wildlife habitat	2.00	-5.00	-10.00	+1.09	+2.05	-1.31	-2.63	+5.00	+10.00
2. Change in quality of wildlife habitat	1.81	-5.00	-9.05	-4.01	-7.26	-5.00	-9.05	-.27	-.50
B. Water Based Environment						+5.00	+3.95	+4.61	+3.64
1. Change in algae population	.79	+5.00	+3.95	+4.56	+3.60	+3.63	+2.86	+5.00	+3.95
2. Change in nitrogen concentration	.57	+5.00	+2.85	+2.79	+1.59	+5.00	+2.85	+4.46	+2.54
3. Change in fish population	.86	+5.00	+4.30	+4.56	+3.92	+5.00	+4.30	+4.61	+3.96
4. Change in municipal water supply quality									
a. short-run quality	.73	+5.00	+3.65	+4.56	+3.33	+5.00	+3.65	+4.46	+3.26
b. long-run quality	1.17	+5.00	+5.85	+4.56	+5.34	+5.00	+5.85	+4.46	+5.22
5. Change in industrial water supply	.64	0		0		0	0	0	0
6. Change in erosion potential	1.43	-5.00	-7.15	+1.20	+1.72	-2.16	-3.09	+5.00	-7.15
Environmental Impact	10.00		-5.60		+14.29		+4.74		+21.28
III. Impact on Social Well-Being:									
A. Recreational Opportunities									
1. Change in land based recreation	2.57	-5.00	-12.85	+1.45	+3.73	-.24	-.62	+5.00	+12.85
2. Change in water based recreation	1.43	+3.59	+5.13	+5.00	+7.15	+3.60	+5.15	+5.00	+7.15
B. Anxiety Factors									
1. Change in aesthetics									
a. diversification-specialization of land base	2.41	-5.00	-12.05	+1.20	+2.89	-1.38	-3.33	+5.00	+12.05
b. degradation of water	2.08	+5.00	+10.40	+3.94	+8.20	+5.00	+10.40	+3.77	+7.84
2. Amount of inorganic nitrogen in our food supplies	1.51	+5.00	+7.55	-.21	-.32	+5.00	+7.55	+.50	+.75
Social Well-Being Impact	10.00		-1.82		+21.65		+19.15		+40.64
Overall Impact			+8.29		+60.91		+45.00		+79.77
Rank			2		1		2		1

maintenance, etc., for a cheaper resource, nitrogen fertilizer. For example,[3] in the restricted strategy, one acre of Class II loam irrigated grain sorghum costs $117.41 in production expenses in 1975. Additional nitrogen fertilizer expenses on this restricted acre was $16.00 ($.20 x 80 pounds). The yield per acre was 100 bushels. The technology strategy production expenses were $120.01 per acre of grain sorghum; with nitrogen fertilizer expenses of $32.80 ($.20 x 164 pounds) and a yield per acre of 132.6 bushels in 1975. Total production expenses were $133.41 and $152.81 per acre, respectively for the restricted and technology strategies. The projected price of $2.61 per bushel provides a net revenue per acre comparison of $127.59 for the restricted run and $193.28 for the technology run. Hence, the substitution of land for nitrogen fertilizer reduced the aggregate farm income estimate and necessarily the regional income estimate.

The employment situation was just the opposite. The restricted strategy, brought in additional acreages and required more labor within the agricultural sector. As suggested in Chapters IV and V, the availability of this labor is a key issue.

The 1990 economic impact indicated a different position. The restricted strategy's total economic impact was 21.11; the technology strategy's was 17.85. The major reason behind this shift lies in the technology strategy's impact on farm and regional employment levels. While the restricted strategy, through additional acreages had an impact

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[3] Production expenses excluding nitrogen fertilizer application rates per acre are presented in Appendix A. The cost of nitrogen fertilizer in all strategies after 1972 is assumed at 20 cents per pound. The value of grain sorghum per bushel is also comparable for all strategies at $2.61 per bushel.

of 4.57 the technology strategy's employment impact was -6.45. The technology strategy in effect, decreased farm and regional employment in 1990.

Environmental Impact

In 1975 the environmental impact for the restricted strategy was -5.60, the technology strategy impact was 14.29. The restricted strategy effectively diminished the possible aquatic damage from nitrogen fertilizer runoff with respect to the base strategy. The technology strategy suggested some aquatic improvement in algae populations, nitrogen concentrations, erosion and municipal water quality, but not nearly as large as the restricted strategy.

The major difference in the 1975 environmental impact between these strategies lies in the impact on terrestrial wildlife and their habitat. The release of 148,520 acres of cropland (148,520 acres less than the base line strategy estimate) by the technology strategy provided improved wildlife conditions. The 615,483 additional crop acres required by the restricted strategy reduced wildlife benefits. The environmental aquatic impact was improved more by the restricted strategy than the technology strategy. However, the wildlife impact was so much greater that it suppressed the restricted strategies aquatic benefits.

Estimates of the environmental impact of the two strategies in 1990 provided a pattern similar to that occurring in 1975. The aquatic environmental factors showed improvements for both strategies; however, the terrestrial impact worsened in the restricted strategy. The restricted strategy wildlife acreage impact was -2.63 while the technology impact was 10.00. Again the negative impact on wildlife, associated with increased cultivated acreages, was not offset by the aquatic benefits shown in the restricted strategy.

Social Well-Being Impact

The social well-being impact for each strategy appeared quite diverse in 1975 and 1990. In both years the technology strategy's impact was greater; 21.65 in 1975 and 40.64 in 1990 for the technology strategy and -1.82 in 1975 and 19.15 in 1990 for the restricted strategy.

The major factor apparent was the change in land based recreation opportunities. Comparing the changes in land based recreation in 1975 and 1990 the restricted strategy ranked lower than the technology strategy. For the restricted strategy, this impact was -12.85 for 1975 and -.62 for 1990; for the technology strategy the social well-being impact was +3.73 and 12.85 for 1975 and 1990, respectively.

Analysis of the North Central Area

All nitrogen fertilizer strategies were utilized in the North Central area. The maximum nitrogen fertilizer strategy was utilized in this area at an 80 pound nitrogen application rate per acre. The restricted and technology strategies' assumptions were the same as indicated in the Panhandle analysis.

Economic Impact

In 1975, the largest economic impact occurred with the maximum nitrogen strategy (18.9); the technology strategy was second (18.36);

and, the restricted strategy was third (12.84). The differences arose from the income and employment adjustments as land use patterns changed among strategies (Table XXVI). The land adjustments by strategy from the base line estimates for 1975 were: a 164,329 acre increase in the restricted strategy, a 120,676 acre increase in the technological strategy; and a 1,016,998 acre decrease in the maximum nitrogen strategy.

The reasoning behind the differences in income impact were similar to the Panhandle area analysis. The maximum nitrogen strategy utilized a larger amount of nitrogen fertilizer per acre requiring the least amount of land. The technology strategy utilized the second smallest amount of land and the restricted strategy required the most land resource.[4] Again, the substitution of the less expensive production input, nitrogen fertilizer, for the more expensive land input caused the restricted strategy to produce smaller aggregate farm and regional income levels. The maximum nitrogen strategy utilizing the nitrogen fertilizer substitution had the largest total income impact.

The farm employment impact showed the maximum nitrogen strategy creating the largest impact on farm and regional labor factors in 1975. The restricted strategy's impact is .46, the technology strategy impact is .82 and the maximum nitrogen impact is -2.15. Once again,

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[4] Cost of producing an acre in 1972 of Class I_L wheat in the North Central area is $26.49 for the technological run, $26.35 for the restricted run and $27.24 for the maximum nitrogen strategy. Nitrogen fertilizer at 20 cents per pound was applied at rates of 36, 30 and 80 pounds to the respective strategy acres. The net revenue per acre, assuming wheat at $3.50 per bushel was $84.12 for the technology run, $74.75 for the restricted strategy and $128.26 for the maximum nitrogen strategy.

TABLE XXVI

NORTH CENTRAL AREA ANALYSIS OF SELECTED NITROGEN FERTILIZER STRATEGIES: 1975-1990

	Parameter Weights	1975				1990			
		Technology		Maximum Nitrogen		Technology		Maximum Nitrogen	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Parameters									
I. Impact on Economic Factors:									
A. Change in Farm Income	2.43	+3.83	+9.31	+5.00	+12.15	+4.51	+10.97	+5.00	+12.15
B. Change in Farm Employment	.43	+4.57	+1.96	-1.50	-.64	-1.50	-.64	-5.00	-2.15
C. Change in Cost of Goods to the Customer	2.78	0	0	0	0	0	0	0	0
D. Change in Acres in Production	.93	+.14	+.13	+5.00	+4.65	+2.07	+1.92	+5.00	+4.65
E. Change in Regional Income	2.14	+3.83	+8.20	+5.00	+10.70	+4.51	+9.65	+5.00	+10.70
F. Change in Regional Employment	1.29	+4.57	+5.89	-1.50	-1.94	-1.50	-1.94	-5.00	-6.45
Economic Impact	10.00		+25.49		+24.92		+19.96		+18.90
II. Impact on Environmental Factors:									
A. Land Based Environment									
1. Change in acres for wildlife habitat	2.00	+.13	+.26	+5.00	+10.00	+2.01	+4.02	+5.00	+10.00
2. Change in quality of wildlife habitat	1.81	+.08	+.15	+5.00	+9.05	-1.03	-1.86	+5.00	+9.05
B. Water Based Environment									
1. Change in algae population	.79	+4.99	+3.94	+5.00	+3.95	+5.00	+3.95	+4.18	+3.30
2. Change in nitrogen concentration	.57	+1.03	+.59	+5.00	+2.85	+2.80	+1.60	+5.00	+2.85
3. Change in fish population	.86	+4.99	+4.29	+5.00	+4.30	+5.00	+4.30	+4.18	+3.60
4. Change in municipal water supply quality									
a. short-run quality	.73	+.40	+.29	+5.00	+3.65	+3.49	+2.55	+5.00	+3.65
b. long-run quality	1.17	+.40	+.47	+5.00	+5.85	+3.49	+4.08	+5.00	+5.85
5. Change in industrial water supply	.64	0	0	0	0	0	0	0	0
6. Change in erosion potential	1.43	+.13	+.19	+5.00	+7.15	+1.99	+2.85	+5.00	+7.15
Environmental Impact	10.00		+10.19		+46.80		+21.49		+45.45
III. Impact on Social Well-Being:									
A. Recreational Opportunities									
1. Change in land based recreation	2.57	+.08	+.21	+5.00	+12.85	+1.54	+3.96	+5.00	+12.85
2. Change in water based recreation	1.43	+5.00	+7.15	+3.48	+4.98	+5.00	+7.15	+3.91	+5.59
B. Anxiety Factors									
1. Change in aesthetics									
a. diversification-specialization of land base	2.41	+.14	+.34	+5.00	+12.05	+2.52	+6.07	+5.00	+12.05
b. degradation of water	2.08	+5.00	+10.40	-3.72	-7.74	+5.00	+10.40	+4.83	+10.05
2. Amount of inorganic nitrogen in our food supplies	1.51	+.98	+1.48	-5.00	-7.55	+1.30	+1.96	-5.00	-7.55
Social Well-Being Impact	10.00		+19.58		+14.59		+29.54		+32.99
Overall Impact			+55.26		+86.31		+70.99		+97.34
Rank							2		1

increased acreages increases employment; conversely, reduced acreages reduce employment. The total impact of all economic factors indicated a more favorable economic situation in 1975 under the maximum nitrogen strategy.

The ranking of economic impact among strategies did not change in 1990. The maximum nitrogen strategy impact remained exactly the same (18.9). The technology strategy impact decreased to 17.70 and the restricted strategy impact increased to 13.66.

The economic impact of the technology strategy declined as the labor impact fell indicating a smaller divergence of acres planted between strategies. In 1990 there was a difference of 505,871 acres between the base line estimate of acres planted and the technology strategy. Although, there was an increase of 86,990 acres from 1975 to 1990 in the technology strategy the base line acreage adjustment was 731,537 between 1975 and 1990.

The restricted strategy improvement in total economic impact came from the increase in the employment impact. This was due to the restricted strategy's increased acreage, 1975 to 1990. There was also an income increase in the restricted strategy reflecting the yield increases per acre assumed by the linear programming model from 1975 to 1990.

Environmental Impact

The 1975 environmental impact was 9.58, 1.42 and 46.80 for the restricted, technology and maximum nitrogen strategies, respectively.[5] It is apparent, once again, that reductions in cultivated acreages benefit wildlife populations and habitat.

The maximum nitrogen strategy's reduction of 1,016,988 acres of 1972 cultivated wheat provided an extremely large benefit to game population and the quality of their habitat. The restricted and the technology strategies' impacts on terrestrial wildlife populations were -1.20 and -.88 respectively. This resulted since increased cultivated acres in these strategies reduced the area's wildlife population potential.

The aquatic environment received the least potential damage from the maximum nitrogen strategy. Algae bloom and municipal long-run water quality affects were 1.84 and 4.81 for the restricted run. The technology strategy's algae and long-run water quality impacts were -.09 and -.11 respectively. The maximum nitrogen strategy impacts were 3.95 and 5.85 for algae and water quality.

The 1990 overall environmental impact received the same ranking as 1975, but the magnitude of the impacts have increased significantly for all but the maximum nitrogen strategy. The restricted strategy's impact was 23.47, the technological strategy's impact was 12.36 and the maximum nitrogen strategy's impact was 45.92. The slight decline in the impact of the maximum nitrogen strategy was due to the necessity of returning some of the idled 1972 heavily fertilized lands to wheat

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[5] The maximum nitrogen strategy yielded a more favorable impact on aquatic factors because of its tremendously large acreage reduction. The per acre potential pollution under this strategy was significantly higher than that seen in the restricted strategy. However, the absolute amount of pollution (amount from every acre in production) was somewhat smaller, Chapter V.

production. This was required to meet the 1990 production projection. Consequently, the algae factor and nitrogen concentration factor had less favorable impacts on the environment.

The restricted strategy and technology strategy 1990 environmental impact improvements were achieved in both terrestrial and aquatic environments. Acres available for wildlife habitat impacts were 1.68 for the restricted strategy and 1.86 for the technological strategy. Algae bloom potential was reduced in 1990 in the two strategies and municipal short-run and long-run water quality impacts were improved.

Social Well-Being Impact

The social well-being overall impact for the restricted strategy was 20.10 the technological strategy was 7.88, the maximum nitrogen strategy was 23.97 in 1975. A major factor influencing the social well-being impact was the amount of inorganic nitrogen present in our food; and as was expected, the maximum nitrogen strategy yielded the worst impact since, it provided the greatest amount of nitrogen per bushel of wheat produced.

The recreational opportunities, both terrestrial and aquatic were only slightly affected. Land recreation opportunities were less inhibited by the maximum nitrogen strategy on land. Water recreation was least affected by the technology strategy.

The 1990 social well-being impacts were similar to 1975 impacts with the restricted strategy providing the best impact and the technology strategy better than the maximum nitrogen strategy. The maximum nitrogen strategy provided a somewhat larger inorganic nitrogen in our food supply impact -4.59 and an equivalent land based recreational opportunity, 12.85; aquatic recreational opportunities increased slightly to 3.52.

The restricted and technology strategies' land and aquatic impacts improved somewhat. They were 2.88 and 3.24 for land and 5.31 and 7.15 for aquatic based recreation in 1990. In general, the restricted nitrogen and technology strategies had more favorable increases between 1975 and 1990; however, the maximum nitrogen strategy continued to maintain the largest favorable overall impact.

Analysis of the Central Area

Only two strategies were appropriate for the Central area: the technological strategy and the maximum nitrogen strategy (Table XXVII). The 1972 base cropping practice for wheat and grain sorghum did not indicate that the application of 30 pounds of nitrogen fertilizer per acre was a common practice in the Central area. However, soil and weather conditions did indicate that larger quantities of nitrogen could be applied to obtain the maximum nitrogen strategy's yield of 49 bushels of wheat per acre on the better classes of soil.

Economic Impact

The Central area's economic impact ranking indicated the technology strategy's impact was 25.49 in 1975. The maximum nitrogen impact in 1975 was 24.92. The slight difference between strategies was derived from the income and employment impacts. Although, the maximum nitrogen strategy had a farm income impact of 12.15 and the technology strategy's impact is 9.31, the employment impact diminished the larger income affect of the maximum nitrogen strategy. The

TABLE XXVII

CENTRAL AREA ANALYSIS OF SELECTED NITROGEN FERTILIZER STRATEGIES: 1975-1990

	Parameter Weights	1975						1990					
		Restricted		Technology		Max. Nitrogen		Restricted		Technology		Max. Nitrogen	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Parameters													
I. Impact on Economic Factors:													
A. Change in Farm Income	2.43	+2.57	+6.25	+3.83	+9.31	+5.00	+12.15	+3.57	+8.68	+4.51	+10.96	+5.00	+12.15
B. Change in Farm Employment	.43	+1.08	+.46	+.82	+.35	-5.00	-2.15	-2.53	-1.09	-2.78	-1.20	-5.00	-2.15
C. Change in Cost of Goods to the Consumer	2.78	0	0	0	0	0	0	0	0	0	0	0	0
D. Change in Acres in Production	.93	-.82	-.76	-.60	-.56	+5.00	+4.65	+1.82	+1.69	+2.02	+1.88	+5.00	+4.65
E. Change in Regional Income	2.14	+2.57	+5.50	+3.83	+8.20	+5.00	+10.70	+3.57	+7.64	+4.51	+9.65	+5.00	+10.70
F. Change in Regional Employment	1.29	+1.08	+1.39	+.82	+1.06	-5.00	-6.45	-2.53	-3.26	-2.78	-3.59	-5.00	-6.45
Economic Impact	10.00		+12.84		+18.36		+18.90		+13.66		+17.70		+18.90
II. Impact on Environmental Factors													
A. Land Based Environment													
1. Change in acres for wildlife habitat	2.00	-.60	-1.20	-.44	-.88	+5.00	+10.00	+.84	+1.68	+.93	+1.86	+5.00	+10.00
2. Change in quality of wildlife habitat	1.81	-.55	-1.00	+.91	+1.65	+5.00	+9.05	+.88	+1.59	+.90	+1.63	+5.00	+9.05
B. Water Based Environment													
1. Change in algae population	.79	+2.33	+1.84	+.11	+.09	+5.00	+3.95	+3.51	+2.77	+1.24	+.98	+5.00	+3.95
2. Change in nitrogen concentration	.57	+2.75	+1.57	-.14	-.08	+5.00	+2.85	+5.00	+2.85	+1.37	+.78	+3.45	+1.97
3. Change in fish population	.86	+2.33	+2.00	+.11	+.09	+5.00	+4.30	+3.51	+3.02	+1.24	+1.07	+5.00	+4.30
4. Change in municipal water supply quality													
a. short-run quality	.73	+4.11	+3.00	-.15	-.11	+5.00	+3.65	+4.88	+3.56	+1.84	+1.34	+5.00	+3.65
b. long-run quality	1.17	+4.11	+4.81	-.15	-.18	+5.00	+5.85	+4.88	+5.71	+1.84	+2.15	+5.00	+5.85
5. Change in industrial water supply	.64	0	0	0	0	0	0	0	0	0	0	0	0
6. Change in erosion potential	1.43	-.80	-1.44	+.59	+.84	+5.00	+7.15	+1.60	+2.29	+1.74	+2.55	+5.00	+7.15
Environmental Impact	10.00		+9.58		+1.42		+46.80		+23.47		+12.36		+45.92
III. Impact on Social Well-Being:													
A. Recreational													
1. Change in land based recreation	2.57	-.49	-1.26	-.37	-.95	+5.00	+12.85	+1.12	+2.88	+1.26	+3.24	+5.00	+12.85
2. Change in water based recreation	1.43	+3.75	+5.36	+5.00	+7.15	+2.38	+3.40	+3.71	+5.31	+5.00	+7.15	+2.46	+3.52
B. Anxiety Factors													
1. Change in aesthetics													
a. diversification-specialization of land base	2.41	-.81	-1.95	-.59	-1.42	+5.00	+12.05	+1.61	+3.88	+1.79	+4.31	+5.00	+12.05
b. degradation of water	2.08	+5.00	+10.40	0	0	-.59	-1.23	+5.00	+10.40	0	0	-3.13	-6.51
2. Amount of inorganic nitrogen in our food supplies	1.51	+5.00	+7.55	+2.05	+3.10	-2.05	-3.10	+5.00	+7.55	+2.42	+3.65	-3.04	-4.59
Social Well-Being Impace	10.00		+20.10		+7.88		+23.97		+30.02		+18.35		+17.32
Overall Impact			+42.52		+27.66		+89.67		+67.15		+48.41		+82.14
Rank			2		3		1		2		3		1

technology strategy's employment impact was 1.96 while the maximum nitrogen strategy's farm employment impact was -.64. The regional employment impacts indicated a similar relationship between these strategies. The reduction in acres planted in the maximum nitrogen increased the income impact and decreased the employment effect.

The 1990 economic estimates indicated a constant relationship between strategies. The maximum nitrogen impact was 18.90 while the technological impact was 19.96. The reason lies in that as the maximum nitrogen strategy maintained its superiority in aggregate income effects the technology strategy lost its large dominance in the employment effect. This occurred since, the difference in base line and technology strategy acres in production (-7,491 acres in 1975) widened to 108,993 in 1990. The opposite impact occurred in the maximum nitrogen strategy. From a difference of 275,715 acres in 1975 between the maximum nitrogen and base line strategies the gap closed to 172,946 acres in 1990. The maximum nitrogen strategy increased its employment benefits over time as the technology strategy tended to loose its employment dominance.

Environmental Impact

The acreage adjustment between 1975 and 1990 was reflected in the environmental impacts of the two strategies. The 1975 maximum nitrogen strategy impact was 46.80 while the technology impact was 10.19. Again, the rapid adjustment in wheat acreage between 1972 and 1975, which allowed acres to return to an idle state, provided a large positive environmental impact (10.00) for terrestrial wildlife.

The minor land adjustment in the technology strategy provided an insignificant wildlife effect (.26).

For the first time the maximum nitrogen impact on the aquatic environment was slightly larger than the technology strategy's impact. Algae growth estimates were 3.94 for the technology strategy and 3.95 for the maximum nitrogen alternative. The short-run and long-run municipal water quality impacts were 3.65 and 5.85 for the maximum nitrogen strategy and .29 and .47 for the technology alternative.

The 1990 estimated environmental impact showed the improved position of the technology strategy, 21.49 compared to 45.45 for the maximum nitrogen strategy. The improvement came from the larger beneficial wildlife impact (4.02). Also, the technology strategy provided less potential algae growth, 3.95 in 1990 and municipal water quality was considerably improved (2.55 in the short-run and 4.08 in the long-run). The maximum nitrogen strategy's potential algae population declined and the municipal water quality impacts remained the same between 1975 and 1990.

Social Well-Being Impact

The acreage adjustment trend was carried into the Central area's social-well-being factors. The maximum nitrogen impact was 14.59 for 1975 and 32.99 for 1990. The technology strategy impact was 19.58 in 1975 and 29.54 in 1990. The land base recreational opportunities were large for the maximum nitrogen strategy in 1975 (12.85 to technology strategy's .21). The aquatic recreational opportunities increased over time in both strategies.

Summary of Impacts for Three Areas

The major influencing factor in 1975 and 1990 in each area was the magnitude of land adjustment and when this adjustment occurred. From these land adjustments the various factors within the three environmental impact matrix sub-categories were influenced.

The technology strategy provided the largest net impact for 1975 and 1990 in the Panhandle area. Restriction of nitrogen fertilizer application levels improved aggregate employments levels but significantly reduced the aggregate income impact. Wildlife populations and land based recreation opportunities faired better under the technology strategy. The restricted strategy had improvements in water related recreational opportunities, algae potential and municipal water quality.

In the North Central region maximum nitrogen ranked first, technology second and restricted nitrogen third. This is true both in 1975 and 1990. Acreages cultivated determined the economic, environmental and social well-being impacts. The maximum nitrogen strategy provided the greatest income, wildlife and land based recreation impacts. The restricted strategy provided beneficial impacts for employment, aquatic related environmental quality and recreation opportunities. The technology strategy fell generally below the restricted and maximum nitrogen strategies in all categories and related beneficial effects.

The Central area strategies provided the closest economic impacts in both 1975 and 1990. The greatest difference in impact was in the environmental section. The reduction of previously cultivated wheat land and its return to native conditions provided a large beneficial impact to wildlife and land based recreation. Water related aspects of environmental and social well-being impacts were not able to offset the wildlife effect in 1975 or 1990.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Increased use of nitrogen fertilizer in agriculture has caused a growing public awareness of potential nitrogen pollution of our waters. Higher nitrogen application rates per acre, to produce increased food and feed grain yields per acre, create a greater probability that runoff from agricultural land will contain higher nitrogen concentration levels. This continued nitrogen enrichment of streams and lakes provides an already balanced aquatic habitat and the potential for eutrophication. Human health hazards also increase as nitrogen concentrations increase in domestic water supplies. The problem becomes one of "trade-offs" between higher nitrogen concentration levels and increased food production.

The overall objective of this study was to determine the "trade-offs" associated with nitrogen fertilizer use and the resulting impacts on the region's economy, and on the region's physical environment, and on the social well-being of its people. The specific objectives were: (1) to develop a nitrogen responsive land base, (2) to develop a model which will project land adjustments, potential nitrogen pollution levels and cropping patterns for this land base; and (3) to evaluate the effects of various nitrogen fertilizer strategies on the region's economy, environment and social well-being.

The study region selected for analysis was a 45 county region consisting of 30 Oklahoma counties in Central, North Central and North Western Oklahoma, the 12 Northermost Texas Panhandle counties and 3 South Central Kansas counties. The region is an OBERS delineation of the Arkansas-White-Red River Basin. The region is in a major wheat producting area of the United States and produces grain sorghum and corn. This region is a large consumer of commercial nitrogen fertilizer.

The basic analysis tool was an environmental impact matrix. The matrix evaluates the economic, environmental and social well-being impact of various nitrogen fertilizer strategies. Both quantitative and qualitative data were estimated and analyzed for each strategy. The parameters in the matrix were developed specifically to fit this study of nitrogen fertilizer use. Weights were assigned to each parameter according to its value in a policy making framework.

Land use adjustment and potential nitrogen pollution coefficients for the environmental impact statement were developed with a linear programming model. The affects of these pollution levels on the aquatic environment were determined with a biological simulation model.

The nitrogen responsive land base was developed by combining Conservation Needs Inventory and Soil Conservation Service county data. This approach allowed the determination of the number of acres of Classes I-V land of each soil type (loam, clay and sand) which were capable of growing wheat, grain sorghum and corn. Using the dominant soils within each of these soil types yield estimates were made. From the yield estimates nitrogen fertilizer application rates were obtained.

The nitrogen pollution coefficients per acre were developed with an agronomic decay function relating the amount of nitrogen applied and the time of application (e.g., the wheat plant development). These coefficients then were adjusted by the probability of rainfall and seedbed preparation. The aquatic environmental effects of nitrogen pollution were estimated with a biological simulator, which utilized nitrogen as its growth inducing parameter and simulated an aquatic system's growth potential under various nitrogen concentration levels.

Results of the Nitrogen Fertilizer Strategies

The three strategies, technology, restricted and maximum nitrogen, induced quite different land use patterns. The Panhandle area required 106,578 additional acres from the 1972 base line strategy for feed grain production under the technology strategy. The restricted strategy required an addition of 617,412 new feed grain acres. Wheat acreage changes between the 1972 base line estimates and 1990 were -125,896 acres for the technology strategy and 237,824 acres for the restricted strategy.

The major reason for such a difference of acreages was the shifting of dryland lightly fertilized feed grain acres for heavily fertilized irrigated feed grain acreages. The profitability of irrigation was severely curtailed when fertilization was restricted to 80 pounds of nitrogen per acre. This became evident in 1990 when the restricted strategy utilized 269,795 dryland acres of feed grain out of a total of 617,412 feed grain acres produced. In contrast the technology strategy utilized only 2,458 dryland feed grain acres out of a total of 34,732 acres in 1990.

The impact of the restricted strategy's land base increase was a decrease in area income levels and a larger labor requirement. Environmentally the land adjustment impacted quite negatively on the Panhandle area's wildlife populations as more acres were required to produce projected food and feed grain requirements in 1990. The aquatic environment suggested that restriction of nitrogen fertilizer use was quite favorable.

The best strategy in the North Central and Central area's was the maximum nitrogen alternative. Less land was required to produce projected food and feed grain requirements. Area income levels increased as the production costs associated with land use declined. Short-run (1975) farm and regional labor requirements were decreased, but showed signs of increasing again as production requirements returned some land to production in 1990.

The maximum nitrogen strategy in the North Central and Central areas improved environmental factors; both wildlife and aquatic. Decreased land in cultivation produced additional acreages for wildlife populations and habitat. Acreage reductions also decreased the land surface area available to runoff. Hence, less acres produced a smaller absolute amount of potential nitrogen pollution.

The North Central area's restricted nitrogen strategy produced results similar to the results found in the Panhandle area. Increased acres of cultivated land were required to meet projected regional shares of production. Area income levels declined as land was substituted for the cheaper input, nitrogen fertilizer, and labor requirements increased. The environmental impact was favorable for the aquatic environment variables, but the negative wildlife impact negated the beneficial aquatic effect.

Conclusions and Recommendations

The alternative strategy that provides the greatest positive overall impact on society was assumed to be the preferred alternative for policy implementation. In the North Central and Central area's this was the maximum nitrogen strategy. The Panhandle preferred strategy was the technology alternative.[1]

The North Central and Central area's preferred strategy allowed the smallest amount of nitrogen pollution potential and provided the return of cultivated acres to an idle state. This in turn, led to improved wildlife populations and improved habitat conditions. With respect to environmental hazards, the maximum nitrogen strategy can be considered the best strategy.

The maximum nitrogen strategy, however, creates an economic problem; particularly acute in the short-run. Decreased acreages in cultivation dominishes employment. The long-run indications suggest that employment levels will rise again as food and feed grain demands increase to 1990. Income level increases, due to more nitrogen fertilizer use and less land cultivated. This undoubtedly would provide a dampening affect on unemployment in the long-run.

The Panhandle area's preferred strategy is the technology

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[1] The maximum nitrogen strategy was not applicable to the Panhandle region due to the insufficient rainfall in the area. At high rates of nitrogen fertilization water becomes a limiting factor. Insufficient rainfall and high fertilization can destroy a crop.

alternative. The Panhandle is a unique area. It does not utilize large quantities of nitrogen fertilizer on dryland cultivation but it consumes significant amounts on irrigated cropland. Rainfall patterns are quite sparse and consequently, dryland runoff is limited. The impact of the pollution problem lies with irrigated lands. Restriction of nitrogen fertilization makes irrigation considerably less profitable and reversion back to dryland farming will increase. Hence, economically the area income level suffers as land is substituted for nitrogen fertilizer. The environmental impact developed by the technology strategy is greatest for terrestrial populations but aquatic hazards are evident.

The potential hazards of nitrogen pollution from agricultural applications is readily apparent; however, the probability of a nitrogen pollution occurrence in our streams is not this apparent today. The probability of pollution is greatest at preplanting time when crop cover is minimal, but the probability of rainfall occurring simultaneously with application is small. The potential nitrogen pollution becomes smaller when the magnitude of the geographic area is considered. The analysis has assumed for model simplification, the worst of all possible conditions, i.e., all cultivated acres of fertilized wheat, grain sorghum and corn in a given area will receive an exactly distributed and intense rainfall pattern. The probability of such a pattern is extremely small.

The impact most apparent to our environment is the reduction in lands available to wildlife. The pressure to produce food and feed grain for both domestic and foreign markets is increasing daily. Meeting this objective at reduced nitrogen application levels requires the utilization of more land, which had been providing food and cover for an area's wildlife population. Hence, the "trade-off" between nitrogen pollution and economic factors is broadened. Policy makers must also weigh the "trade-off" between the probability of significantly high nitrogen concentrated runoff from agricultural lands to the certainty of required reductions in wildlife populations.

The economic factors lend impetus to nonrestricting nitrogen fertilizer policies. Restrictions of nitrogen fertilizer in each study area required the substitution of land for commercial nitrogen fertilizer to meet food and feed grain projected production levels. The cost of production associated with this substitution increased. Consequently, farm and regional income levels declined. Labor requirements increased as more acres were cultivated and regional employment increased. The labor increase with declining income levels suggests lower per capita income levels for the region's people. This also implies underemployed labor and undoubtably the substitution of capital for labor as the area adjusts toward more efficient production processes.

From a policy making standpoint the high levels of nitrogen pollution rests with the simultaneous occurrence of intense rainfall conditions and timing of fertilizer applications. If conditions are ideal for large rainfall amounts on fertilized acres then runoff waters will contain high nitrogen concentration levels. The amount of rain occurring at a given point in time is the determining factor. Restricting nitrogen fertilizer will decrease the probability of large runoff on highly susceptible lands (just fertilized land) and unemployment. The certainty involved with restricting nitrogen fertilizer is the reduction of land available for wildlife populations and lower area per capita income levels.

Limitations and Future Research Needs

There are two limitations which should be constantly considered in the minds of policy makers. First, the nitrogen pollution issue is not "cut and dried." Considerable evidence can be developed for restricting nitrogen fertilizer levels and for allowing these levels to increase. Furthermore, the data needed to critically and objectively analyze this problem is scarce and not universally applicable to all geographic areas.

Second, the role of "value judgments" can not be separated from the analysis. Research can effectively show alternative actions and plans, but the ultimate goals are still value judgments. These value judgments must reflect the consensus of <u>all</u> the people. Other limitations are primarily technical.

The basic model and techniques developed in this study require expansion and refinement. The best approach for future research would be to isolate a small land area (e.g., a county) where significant amounts of nitrogen fertilizer are used. The county should be close to a stream where monitoring stations are located. The county should also have a population base which is not entirely agriculturally oriented. Several counties in Oklahoma meet these criteria; e.g., Oklahoma, Garfield, Noble and Texas.

This approach to the potential nitrogen pollution problem could allow the necessary information base for a more complete analysis. Stream monitoring station data could be checked at various time periods in the crop growing season to determine nitrogen concentration levels before and after rainfalls. Income and employment multipliers could be obtained through a "from to analysis" of county industrial and commercial sectors.

The isolation of a study region this small would also provide detailed production cost, yield, and fertilization data. Soil data could be utilized more completely providing better potential nitrogen pollution estimates. Thus, a pollution production equation could be developed which would better predict the effect of runoff and nitrogen movement. Using this approach, nitrogen fertilizer strategies could be developed from the county data which could simulate nitrogen fertilizer levels and develop a more complete estimate of their resultant impact on the economy and on the environment.

Modifications of this methodology could include the restriction of nitrogen levels to the United States Public Health standard of 10 ppm in water, and also allow production limits to exceed their regional shares of production. Weather modification simulation could be employed to induce varied and random rainfall patterns. Efforts should consider the substitution of leguminous crops as nitrogen soil builders. Other commercially produced plant nutrients should be considered as they improve yields and alter environmental balances. The leaching of nitrogen fertilizer and how it may affect domestic water supplies also should be included.

The number of variables required to fully understand the physical relationships of nitrogen pollution are infinitesimal. Agronomic research needs to provide a broader data base which will indicate potential nitrogen movements, via either runoff or leaching. The data available now are limited and only suggest a nitrogen residual, i.e., the amount of nitrogen fertilizer applied but which cannot be accounted for through volatilization, plant uptake and soil immobilization.

Additional research is required by biochemists, and wildlife experts to determine actual tolerance levels of nitrogen in our water supplies. The effort should consider agricultural related nitrogen pollution sources and not the broad eutrophic research of areas influenced by various other industrial and municipal pollutant sources. New research efforts, should focus on this residual nitrogen component and where it goes. Does it provide a hazard to the environment or is it effectively tied up? Improvements in measurement techniques will aid in this effort.

Another needed research effort lies in the relationship of the timing of fertilizer applications. Peak rainfall conditions are known. Critical plant growth periods are known. Is it possible and profitable to spread applications out over the growing period? This could decrease the "slug effect" of severe rainfall conditions and provide information which would decrease nitrogen application costs and levels by timing applications to critical plant growth periods.

Finally, research is needed to better estimate the social costs and benefits associated with nitrogen strategy impacts within the economic and social structure of the area's people. Research in this area would require information pertaining to income and employment "trade-offs." If unemployment occurs as a result of a nitrogen policy can the area's present economic structure absorb the excess labor? If not, where can this labor source be employed outside the region?

The kind of research necessary to achieve these answers will be obtained only with cooperative effort of many disciplines. Better communications among agronomists, sociologists, environmentalists, biologists and economists will go a long way toward developing an objective data base and a better understanding of how the complexities of nitrogen fertilizer affect <u>our</u> environment.

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APPENDIX A

ENTERPRISE BUDGETS

TABLE XXVIII

BASELINE STRATEGY PER ACRE COSTS OF PRODUCTION FOR WHEAT GRAIN BY SOIL CLASSES: 1972[1]

Soil Class	North Central Dryland Wheat[1]	Central Dryland Wheat[2]	Panhandle Dryland Wheat[2]	Panhandle Irrigated Wheat[2]
I_L	26.44	35.67	-	-
I_C	26.35	35.62	-	-
II_L	26.83	35.96	11.82	89.44
II_C	26.72	35.86	11.77	68.20
II_S	26.61	35.76	-	-
III_L	26.79	36.03	12.21	89.85
III_C	26.69	35.88	12.16	68.66
III_S	26.59	35.78	11.87	89.75
IV_L	27.95	37.05	13.39	90.76
IV_C	27.90	36.95	13.34	70.14
IV_S	27.75	36.85	13.24	90.58
V_L	28.89	38.07	14.30	-
V_C	28.74	37.97	14.20	-
V_S	28.64	37.87	14.15	-

---

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXIX

BASELINE STRATEGY PER ACRE COST OF PRODUCTION FOR FEED GRAIN BY SOIL CLASS: 1972[1]

Soil Class	North Central Dryland Grain Sorghum[2]	Central Dryland Grain Sorghum[2]	Panhandle Dryland Grain Sorghum[2]	Panhandle Irrigated Grain Sorghum[2]	Panhandle Irrigated Corn
I_L	31.13	35.41	-	-	-
I_C	30.97	35.33	-	-	-
II_L	31.36	35.68	21.63	119.81	137.17
II_C	31.30	35.60	21.23	101.52	117.55
II_S	31.22	35.44	-	-	-
III_L	31.54	35.61	21.85	118.46	136.63
III_C	31.46	35.53	21.21	100.17	116.84
III_S	30.98	35.21	20.81	118.06	135.83
IV_L	32.47	36.74	22.49	116.89	137.28
IV_C	32.39	36.58	22.25	95.58	116.64
IV_S	32.13	36.42	22.09	116.49	135.48
V_L	33.48	37.76	23.29	-	-
V_C	33.32	37.60	22.97	-	-
V_X	33.34	37.52	22.81	-	-

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[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXX

PANHANDLE AREA IRRIGATED WHEAT YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
II_L	46	3.82	63
II_C	48	3.99	69
III_S	43	3.58	56
III_C	46	3.92	63
III_S	42	3.49	54
IV_L	36	3.00	42
IV_C	38	3.16	48
III_S	34	2.83	38

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXI

PANHANDLE AREA IRRIGATED GRAIN SORGHUM YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
II_L	130	15.36	164
II_C	135	15.95	173
III_L	120	14.18	146
III_C	125	14.77	155
III_S	115	13.59	140
IV_L	100	11.82	114
IV_C	105	12.41	126
IV_S	100	11.82	114

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by substracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXII

PANHANDLE AREA IRRIGATED CORN YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
II_L	121	49.60	173
II_C	130	53.34	185
III_L	113	46.41	149
III_C	122	50.14	176
III_S	109	44.81	146
IV_L	109	44.81	146
IV_C	113	46.41	149
IV_S	100	41.19	140

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] New irrigated lands received nitrogen fertilizer at a rate of 1.5 times the 1972 nitrogen estimate.

TABLE XXXIII

PANHANDLE AREA DRYLAND GRAIN SORGHUM YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
II_L	38	4.49	14
II_C	33	3.90	8
III_L	33	3.90	8
III_C	25	2.93	-
III_S	20	2.34	-
IV_L	21	2.47	-
IV_C	18	2.15	-
IV_S	16	1.89	-
V_L	14	1.63	-
V_C	12	1.43	-
V_S	10	1.17	-

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXIV

PANHANDLE AREA DRYLAND WHEAT YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
II_L	18	1.51	8
II_C	17	1.43	7
III_L	14	1.16	-
III_C	13	1.07	-
III_S	9	.74	-
IV_L	12	.99	-
IV_C	11	.91	-
IV_S	9	.74	-
V_L	10	.83	-
V_C	8	.66	-
V_S	7	.58	-

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXV

NORTH CENTRAL AREA WHEAT YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
I_L	33	2.75	36
I_C	31	2.58	32
II_L	30	2.50	30
II_C	29	2.42	28
II_S	26	2.17	22
III_L	27	2.25	24
III_C	25	2.08	20
III_S	23	1.92	16
IV_L	24	2.00	18
IV_C	23	1.92	16
IV_S	20	1.67	16
V_L	19	1.58	-
V_C	16	1.33	-
V_S	14	1.17	-

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[1] Yields for the years 1975, 1980, 1985 and 1990 assume a one percent per year increase from the 1972 baseline estimate.

[2] Temporarily idled land and new lands receive initial period fertilization at rates 1.2 and 1.5, respectively, of the 1972 nitrogen estimate.

TABLE XXXVI

CENTRAL AREA GRAIN SORGHUM YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
I_L	27	3.19	-
I_C	26	3.06	-
II_L	23	2.73	-
II_C	22	2.60	-
II_S	20	2.34	-
III_L	18	2.15	-
III_C	17	2.02	-
III_S	13	1.56	-
IV_L	14	1.63	-
IV_C	12	1.43	-
IV_S	10	1.17	-
V_L	11	1.30	-
V_C	9	1.04	-
V_S	8	.98	-

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXVII

CENTRAL AREA WHEAT YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
I_L	27	2.26	24
I_C	26	2.17	22
II_L	24	2.01	18
II_C	22	1.84	14
II_S	20	1.68	10
III_L	21	1.76	12
III_C	18	1.51	9
III_S	16	1.32	-
IV_L	15	1.24	-
IV_C	13	1.07	-
IV_S	11	.91	-
V_L	12	.99	-
V_C	10	.83	-
V_S	8	.66	-

---

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by subtracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXVIII

NORTH CENTRAL AREA GRAIN SORGHUM YIELDS AND NITROGEN FERTILIZER RATES BY SOIL CLASSES FOR THE BASELINE STRATEGY: 1972

Soil Class	Yield Per Acre (Bu)[1]	Yield Per Acre (AUM)[1]	Nitrogen Per Acre (Lbs)[2]
I_L	55	6.50	32
I_C	53	6.26	30
II_L	52	6.15	28
II_C	51	6.03	28
II_S	50	5.91	26
III_L	52	6.15	28
III_C	51	6.03	28
III_S	45	5.32	20
IV_L	47	5.55	22
IV_C	46	5.44	22
IV_S	44	5.20	18
V_L	45	5.32	20
V_C	43	5.08	18
V_S	42	4.96	16

[1] Per acre production costs exclude the purchase of nitrogen fertilizer.

[2] Temporarily idled land and new land costs of production are adjusted by machinery efficiency, labor, capital items indicated in Table XXXIX, Appendix A. Grazing budgets are determined by substracting harvesting costs from grain producing budgets. Harvesting costs are shown in Table XXXIX, Appendix A.

TABLE XXXIX

COST OF PRODUCTION ADJUSTMENTS FOR LAND CLASSES AND PRODUCTION CATEGORIES[1]

(Measured in Dollars)

Land Class	Machinery Efficiency Adjustment[2]	Tillage Adjustments[3]	
		Temporarily Idled Land	New Land
I	0	.24	.48
II	.47	.26	.52
III	.65	.29	.58
IV	1.98	.37	.74
V	3.15	.37	.74

[1] Data developed from Oklahoma State University budget generator enterprise budgets. Machinery efficiency rates are estimated from Renoll article (48).

[2] Adjustments for extra machinery costs associated cropping on higher sloped land and nonparallel terraces.

[3] Cost for incorporation of luxuriant crop residues. This includes one additional plowing for temporarily idled lands and two plowages for new lands.

TABLE XL

RAINFALL PROBABILITIES BY AREA FOR SELECTED WEEKS[1]

Week	Panhandle Area	North Central Area	Central Area
April 7	0	.143	.143
April 15	.143	.286	.286
April 29	0	.429	.286
August 7	.143	-[2]	-
August 15	.143	-	-
August 29	.286	-	-
September 1	.143	.286	-
September 15	.286	.357	-
September 29	.143	.286	-

Source: U.S. Department of Commerce National Oceanic and Atmospheric Administration. Oklahoma Daily Precipitation. Fiscal years 1938-1973.

[1] Rainfall probabilities are for amounts of at least one inch in a given week. Reporting stations were Goodwell, Enid and Chandler for the Panhandle, North Central and Central area, respectively.

[2] Rainfall data were not collected for these weeks since budget information indicated no fertilization occurred at this time in this area for wheat, grain sorghum or corn.

TABLE XLI

PERCENT OF CROP FERTILIZED BY WEEKS OF SELECTED MONTHS[1]

Week	Wheat	Grain Sorghum	Corn
April 7	62	30	45
April 15	87.5	34.5	51.5
April 29	99	52.5	74
August 7	-	30	45
August 15	-	34.5	51.5
August 29	-	52.5	74
September 1	62	-	-
September 15	87.5	-	-
September 29	99	-	-

Source: Oklahoma State Board of Agriculture, "Seedbed Preparation," Crop Calendar. Fiscal years 1964-1973 [39].

[1] Preplant fertilization is assumed to occur at the approximately same time as seedbed preparation. Side-dressed acreages are fertilized at the same percentage as preplant fertilization.

TABLE XLII

PANHANDLE AREA IRRIGATED LABOR REQUIREMENTS FOR LAND CLASSIFICATIONS[1]

(Measured in Hours Per Acre)

Land Class	1972 Producing Wheat Acres	New Wheat Acres	1972 Producing Corn and Grain Sorghum Acres	New Corn and Grain Sorghum Acres
II_L	2.82	2.85	3.08	3.11
II_C	4.75	4.78	7.00	7.03
III_L	2.95	2.98	3.21	3.24
III_S	2.95	2.98	3.21	3.24
IV_L	3.33	3.38	3.59	3.64
IV_C	5.26	5.31	7.51	7.56
IV_S	3.33	3.38	3.59	3.64

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[1] The labor requirements for new lands included labor expanded for a two additional plowings to incorporate luxuriant grass cover.

TABLE XLIII

PANHANDLE AREA DRYLAND LABOR REQUIREMENTS FOR LAND CLASSIFICATION[1]

(Measures in Hours Per Acre)

Land Class	1972 Producing Wheat Acres	Temporarily Idled Wheat Acres	New Wheat Acres	1972 Producing Grain Sorghum Acres	Temporarily Idled Grain Sorghum Acres	New Grain Sorghum Acres
II	.68	.71	.75	1.45	1.48	1.52
III	.81	.84	.88	1.58	1.61	1.65
IV	1.19	1.24	1.28	1.96	2.00	2.04
V	1.19	1.24	1.28	1.96	2.00	2.04

[1] The labor requirement for temporarily idled and new land included labor expanded for one and two additional plowings, respectively, to incorporate luxuriant grass cover.

TABLE XLIV

NORTH CENTRAL AREA LABOR REQUIREMENTS FOR LAND CLASSIFICATIONS[1]

(Measured in Hours Per Acre)

Land Class	1972 Producing Wheat Acres	Temporarily Idled Wheat Acres	New Wheat Acres	1972 Producing Grain Sorghum Acres	Temporarily Idled Grain Sorghum Acres	New Grain Sorghum Acres
I	2.71	2.74	2.78	2.62	2.64	2.68
II	2.80	2.83	2.91	2.71	2.74	2.78
III	2.93	2.97	3.01	2.84	2.87	2.91
IV	3.31	3.36	3.40	3.32	3.27	3.31
V	3.31	3.36	3.40	3.32	3.27	3.31

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[1] The labor requirement for temporarily idled and new land included labor expanded for one and two additional plowings, respectively, to incorporate luxuriant grass cover.

TABLE XLV

CENTRAL AREA LABOR REQUIREMENTS FOR LAND CLASSIFICATIONS[1]

(Measured in Hours Per Acre)

Land Class	1972 Producing Wheat Acres	Temporarily Idled Wheat Acres	New Wheat Acres	1972 Producing Grain Sorghum Acres	Temporarily Idled Grain Sorghum Acres	New Grain Sorghum Acres
I	3.58	3.61	3.64	3.45	3.48	3.52
II	3.67	3.70	3.74	3.54	3.47	3.61
III	3.80	3.84	3.87	3.67	3.71	3.75
IV	4.18	4.23	4.27	4.05	4.10	4.14
V	4.18	4.23	4.27	4.05	4.10	4.14

[1] The labor requirement for temporarily idled and new land included labor expanded for one and two additional plowing, respectively, to incorporate luxuriant grass cover.

TABLE XLVI

TERRACE SPACING AND COSTS BY AREA, CROP, AND LAND CLASS[1]

Land Class	Panhandle				North Central				Central			
	Wheat Spacing (Ft)	Cost of Wheat Spacing	Feed Grain Spacing (Ft)	Cost of Feed Grain Spacing	Wheat Spacing (Ft)	Cost of Wheat Spacing	Feed Grain Spacing (Ft)	Cost of Feed Grain Spacing	Wheat Spacing (Ft)	Cost of Wheat Spacing	Feed Grain Spacing (Ft)	Cost of Feed Grain Spacing
II	300	1.16	250	1.39	230	1.52	100	3.48	150	2.32	100	3.48
III	290	1.20	100	3.48	100	3.48	100	3.48	100	3.48	100	3.48
IV	160	2.18	100	3.48	100	3.48	100	3.48	100	3.48	100	3.48
V	100	3.48	100	3.48	100	3.48	100	3.48	100	3.48	100	3.48

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[1] Terracing costs were developed from estimates provided by the Oklahoma State office of the Soil Conservation Service. The formula is: length of terrace equals 43,560 divided by spacing width. Cost of terracing was $8.00 per 100 running feet. The cost includes drainage ways for surplus water. This cost is prorated on the basis of a life of 10 years.

APPENDIX B

RESULTS OF THE LINEAR PROGRAMMING MODEL

TABLE XLVII

WHEAT ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE BASELINE STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	345,886	412,651	447,541	465,036	465,036	125,817	188,839	188,839	188,839	188,839
I_C	-	-	-	-	-	104,680	104,680	123,892	130,336	130,336	26,531	50,770	62,718	62,718	62,718
II_L	272,183	305,360	300,941	293,766	293,766	792,098	792,098	822,138	938,844	1,064,027	62,930	64,790	75,066	95,087	101,445
II_C	157,799	160,435	160,435	160,435	160,435	261,056	261,056	261,056	304,758	306,166	39,004	39,004	39,139	49,201	67,884
II_S	-	-	-	-	-	30,677	30,677	30,677	30,677	30,677	593	593	593	593	593
$I\ II_L$	806,566	823,394	892,275	895,128	968,082	326,252	326,252	326,252	326,252	326,252	70,240	70,240	70,240	70,240	71,242
$I\ II_C$	648,140	609,177	548,041	589,011	609,959	271,401	271,401	271,401	271,401	271,401	45,731	45,731	45,731	45,731	45,731
$I\ II_S$	8,007	8,007	8,007	8,007	7,435	135,082	135,082	135,082	135,082	135,082	7,472	7,472	7,472	7,472	7,472
IV_L	190,474	190,474	190,474	190,474	190,474	111,368	111,368	111,368	111,368	111,368	13,377	13,377	13,377	13,377	13,377
IV_C	27,243	27,243	27,243	27,243	27,243	110,727	110,727	110,727	110,727	110,727	15,154	15,154	15,154	15,154	15,154
IV_S	4,008	4,008	4,008	4,008	4,008	80,547	80,547	80,547	80,547	80,547	7,749	7,749	7,749	7,749	7,749
V_L	14,313	14,313	14,313	14,313	14,313	36,320	36,320	36,320	36,320	36,320	10,707	10,707	10,707	10,707	10,707
V_C	1,746	1,746	1,746	1,746	1,746	12,337	12,337	12,337	12,337	12,337	5,550	5,550	5,550	5,550	5,550
V_S	7,956	7,956	7,956	7,956	7,956	14,889	14,889	14,889	14,889	14,889	1,980	1,980	1,980	1,980	1,980
Totals	2,138,425	2,152,113	2,155,439	2,192,087	2,285,417	2,633,320	2,700,085	2,784,227	2,968,574	3,095,165	432,835	521,956	544,315	574,398	600,443

TABLE XLVIII

WHEAT ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE TECHNOLOGY STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	345,886	364,185	351,717	381,141	378,576	125,817	188,839	186,006	188,839	188,839
I_C	-	-	-	-	-	104,680	104,680	104,680	104,680	104,680	26,531	42,460	35,548	42,460	42,460
II_L	272,183	272,977	258,191	256,232	267,764	792,098	792,098	792,098	792,098	792,098	62,930	62,930	62,930	66,286	66,286
II_C	157,799	157,799	157,799	157,799	157,799	261,056	261,056	261,056	261,056	261,056	39,004	39,004	39,004	39,004	39,004
II_S	-	-	-	-	-	30,677	30,677	30,677	30,677	30,677	593	593	593	593	593
III_L	806,556	806,556	783,265	749,365	773,088	326,252	326,252	326,252	326,252	326,252	70,240	70,240	70,240	70,240	70,240
III_C	643,140	639,967	599,918	604,984	560,181	271,401	271,401	271,401	271,401	271,401	45,731	45,731	45,731	45,731	45,731
III_S	8,007	8,007	8,007	8,007	8,007	135,082	135,082	135,082	135,082	135,082	7,472	7,472	7,472	7,472	7,472
IV_L	190,474	190,474	190,474	190,474	190,474	111,368	111,368	111,368	111,368	111,368	13,377	13,377	13,377	13,377	13,377
IV_C	27,243	27,243	27,243	27,243	27,243	110,727	110,727	110,727	110,727	110,727	15,154	15,154	15,154	15,154	15,154
IV_S	4,008	4,008	4,008	4,008	4,008	80,547	80,547	80,547	80,547	80,547	7,749	7,749	7,749	7,749	7,749
V_L	14,313	14,313	14,313	14,313	14,313	56,320	56,320	56,320	56,320	56,320	10,707	10,707	10,707	10,707	10,707
V_C	1,746	1,746	1,746	1,746	1,746	12,337	12,337	12,337	12,337	12,337	5,550	5,550	5,550	5,550	5,550
V_S	7,956	7,956	7,956	7,956	7,956	14,889	14,889	14,889	14,889	14,889	1,980	1,980	1,980	1,980	1,980
Totals	2,138,475	2,131,046	2,052,920	2,012,579	2,012,579	2,633,320	2,651,619	2,639,151	2,668,575	2,666,010	432,835	511,786	501,951	515,142	515,422

TABLE XLIX

WHEAT ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE RESTRICTED STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	345,886	361,229	353,284	364,185	364,135	125,817	188,839	186,006	188,839	188,839
I_C	-	-	-	-	-	104,680	104,680	104,680	116,712	116,712	26,531	42,460	42,460	42,460	42,460
II_L	272,183	300,941	300,941	300,941	299,123	792,098	792,098	792,098	796,553	797,631	62,930	62,930	62,930	66,285	66,572
II_C	157,799	160,435	160,435	160,435	160,435	261,056	306,165	306,165	306,165	306,165	39,004	39,004	39,004	39,004	39,004
II_S	-	-	-	-	-	30,677	30,677	30,677	30,677	30,677	593	593	593	593	593
III_L	806,556	1,162,622	1,109,105	1,066,779	1,076,834	326,252	326,252	326,252	326,252	326,252	70,240	70,240	70,240	70,240	70,240
III_C	648,140	609,958	609,958	609,958	609,958	271,401	271,401	271,401	271,401	271,401	45,731	45,731	45,731	45,731	45,731
III_S	8,007	7,435	5,942	7,435	5,942	135,082	135,082	135,082	135,082	135,082	7,472	7,472	7,472	7,472	7,472
IV_L	190,747	190,747	190,747	190,747	168,691	111,368	111,368	111,368	111,368	111,368	13,377	13,377	13,377	13,377	13,377
IV_C	27,243	27,243	27,243	27,243	27,243	110,727	110,727	110,727	110,727	110,727	15,154	15,154	15,154	15,154	15,154
IV_S	4,008	4,008	4,008	4,008	4,008	80,547	80,547	80,547	80,547	80,547	7,749	7,749	7,749	7,749	7,749
V_L	14,313	14,313	14,313	14,313	14,313	36,320	36,320	36,320	36,320	36,320	10,707	10,707	10,707	10,707	10,707
V_C	6,746	1,746	1,746	1,746	1,746	12,337	12,337	12,337	12,337	12,337	5,550	5,550	5,550	5,550	5,550
V_S	1,956	7,956	7,956	7,956	7,956	14,889	14,889	14,889	14,889	14,889	1,980	1,980	1,980	1,980	1,980
Totals	2,138,425	2,487,404	2,432,314	2,391,561	2,376,249	2,633,320	2,685,827	2,685,827	2,714,293	2,714,293	432,835	511,786	508,953	515,141	515,428

TABLE L

WHEAT ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE MAXIMUM NITROGEN STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	345,886	345,886	345,886	345,886	345,886	125,817	125,817	125,817	125,817	125,817
I_C	-	-	-	-	-	104,680	104,680	104,680	104,680	104,680	26,531	26,531	26,531	26,531	26,531
II_L	272,183	272,977	258,191	256,232	267,764	792,098	792,098	792,098	792,098	792,098	62,930	62,930	62,930	62,930	62,930
II_C	157,799	157,799	157,799	157,799	157,799	261,056	261,056	261,056	261,056	261,056	39,004	28,284	37,301	39,004	39,004
II_S	-	-	-	-	-	30,677	29,470	30,677	30,677	30,677	593	-	149	593	593
III_L	806,556	306,556	783,265	749,365	773,088	326,252	-	53,679	146,507	223,863	20,240	-	72,506	84,673	96,600
III_C	643,140	639,967	599,918	604,984	560,181	271,401	0	0	0	0	45,731	0	0	0	0
III_S	8,007	8,007	8,007	8,007	8,007	135,082	0	0	0	0	7,472	0	0	0	0
IV_L	190,474	190,474	190,474	190,474	190,474	111,368	0	0	0	0	13,377	0	0	0	0
IV_C	27,243	27,243	27,243	27,243	27,243	110,727	0	0	0	0	15,154	0	0	0	0
IV_S	4,008	4,008	4,008	4,008	4,008	80,547	0	0	0	0	7,749	0	0	0	0
V_L	14,313	14,313	14,313	14,313	14,313	36,320	0	0	0	0	10,707	0	0	0	0
V_C	1,746	1,746	1,746	1,746	1,746	12,337	0	0	0	0	5,550	0	0	0	0
V_S	7,956	7,956	7,956	7,956	7,956	14,889	0	0	0	0	1,980	0	0	0	0
Total	2,138,475	2,131,046	2,052,920	2,012,579	2,012,579	2,633,320	1,513,945	1,588,976	1,680,904	1,758,260	432,835	243,562	325,234	339,548	351,475

TABLE LI

GRAIN SORGHUM ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE BASELINE STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	13,071	17,573	17,573	17,573	17,573	20,449	30,692	30,692	30,692	30,692
I_C	-	-	-	-	-	5,582	6,950	6,950	6,950	6,950	2,806	6,631	6,631	6,631	6,631
II_L	230,428	245,882	246,303	246,303	246,303	51,780	84,676	84,676	84,676	84,676	26,096	61,487	93,209	108,165	120,628
II_C	155,593	138,939	161,572	161,572	161,572	10,014	14,341	14,341	14,341	14,341	18,007	31,342	31,342	31,342	31,342
II_S	-	-	-	-	-	1,664	2,138	2,138	2,138	2,138	465	465	465	465	465
III_L	336,570	403,759	481,233	514,634	518,443	22,118	45,954	45,954	45,954	45,954	10,966	10,966	10,966	10,966	10,966
III_C	233,928	248,906	311,190	380,276	380,276	13,930	23,819	23,819	23,819	23,819	6,069	6,069	6,069	6,069	6,069
III_S	1,967	1,967	2,049	2,049	2,927	9,058	13,964	13,964	13,964	13,964	929	929	929	929	929
IV_L	50,369	50,369	52,517	53,107	82,858	12,378	34,529	34,529	34,529	34,529	1,923	1,923	1,923	1,923	1,923
IV_C	36,464	36,464	36,464	36,464	50,705	6,440	14,783	14,783	14,783	14,783	4,569	4,569	4,569	4,569	4,569
IV_S	9,034	9,034	9,034	9,034	9,034	5,361	15,267	15,267	15,267	15,267	1,592	1,592	1,592	1,592	1,592
V_L	24,558	24,558	24,558	24,558	24,558	30,791	49,604	125,054	161,109	191,153	3,304	3,304	3,304	3,304	3,304
V_C	2,134	2,134	2,134	2,134	2,134	8,561	12,843	12,843	12,843	12,843	903	903	903	903	903
V_S	9,265	9,265	9,265	9,265	9,265	4,378	6,099	6,099	6,099	6,099	252	252	252	252	252
Totals	1,090,310	1,191,277	1,336,319	1,439,390	1,488,075	195,126	342,540	417,990	454,045	484,089	98,330	161,124	192,846	220,802	220,265

TABLE LII

GRAIN SORGHUM ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE TECHNOLOGY STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	13,071	17,572	17,572	17,572	17,572	20,449	30,692	30,692	30,692	30,692
I_C	-	-	-	-	-	5,582	6,950	6,950	6,950	6,950	2,806	6,631	6,631	6,631	6,631
II_L	230,428	238,716	232,525	242,823	232,155	51,780	84,676	84,676	84,676	84,676	26,096	58,097	58,097	58,097	58,097
II_C	155,593	157,286	155,593	155,593	156,324	10,014	14,341	14,341	14,341	14,341	18,007	31,342	54,864	60,777	63,822
II_S	-	-	-	-	-	1,664	2,138	2,138	2,138	2,138	465	465	465	465	465
III_L	336,570	410,280	359,860	336,570	368,844	22,118	45,954	45,954	45,954	45,954	10,966	10,966	10,966	10,966	10,966
III_C	233,928	233,928	233,928	233,928	233,928	13,930	23,819	23,819	23,819	23,819	6,069	6,069	6,069	6,069	6,069
III_S	1,967	1,967	1,967	1,967	1,967	1,058	13,681	14,976	14,976	14,976	929	929	929	929	929
IV_L	50,369	50,369	50,369	50,369	50,369	12,378	34,529	34,529	34,529	34,529	1,923	1,923	1,923	1,923	1,923
IV_C	36,464	36,464	36,464	36,464	36,464	6,440	14,765	14,765	14,765	14,765	4,569	4,569	4,569	4,569	4,569
IV_S	9,054	9,054	9,054	9,054	9,054	5,361	8,511	8,511	8,511	8,511	1,592	1,592	1,592	1,592	1,592
V_L	24,558	24,558	24,558	24,558	24,558	30,791	48,896	99,749	113,218	120,200	3,304	3,304	3,304	3,304	3,304
V_C	2,134	2,134	2,134	2,134	2,134	8,561	12,843	12,843	12,843	12,843	903	903	903	903	903
V_S	9,265	9,265	9,265	9,265	9,265	4,378	6,099	6,099	6,099	6,099	252	252	252	252	252
Totals	1,090,310	1,174,001	1,115,697	1,102,705	1,125,042	195,126	334,776	386,922	400,391	407,373	98,330	157,734	181,256	187,169	190,214

TABLE LIII

GRAIN SORGHUM ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE RESTRICTED STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	13,071	14,530	14,530	14,530	20,449	30,692	30,692	30,692	30,692	30,692
I_C	-	-	-	-	-	5,582	6,023	6,023	6,023	6,023	2,806	6,631	6,631	6,631	6,631
II_L	230,428	233,716	238,716	238,716	263,546	51,780	84,676	84,676	84,676	84,676	26,096	58,097	58,097	58,097	58,097
II_C	155,593	157,286	159,915	157,286	159,915	10,014	14,341	14,341	14,341	14,341	18,007	31,342	54,864	60,777	63,822
II_S	-	-	-	-	-	1,664	2,138	2,138	2,138	465	465	465	465	465	465
III_L	336,570	441,252	441,252	441,252	441,252	22,118	45,954	45,954	45,954	45,954	10,966	10,966	10,966	10,966	10,966
III_C	233,928	444,809	429,899	476,956	429,899	13,930	23,819	23,819	23,819	23,819	6,069	6,069	6,069	6,069	6,069
III_S	1,967	2,976	4,469	2,976	8,344	9,058	13,680	14,976	14,976	929	929	929	929	929	929
IV_L	50,369	135,377	148,700	135,377	157,433	12,378	34,529	34,529	34,529	34,529	1,923	1,923	1,923	1,923	1,923
IV_C	36,464	41,770	92,627	73,746	92,627	6,440	14,765	14,765	14,765	14,765	4,569	4,569	4,569	4,569	4,569
IV_S	9,034	9,034	15,147	15,147	5,361	8,784	10,809	10,809	10,809	10,809	1,592	1,592	1,592	1,592	1,592
V_L	24,558	24,558	24,558	24,558	24,558	30,791	54,092	105,224	118,704	125,732	3,304	3,304	3,304	3,304	3,304
V_C	2,134	2,134	2,134	2,134	2,134	8,561	12,843	12,834	12,834	12,834	903	903	903	903	903
V_S	9,265	9,265	9,265	9,265	9,265	4,378	6,099	6,099	6,099	6,099	252	252	252	252	252
Totals	1,090,130	1,507,177	1,566,682	1,577,413	1,604,120	195,126	336,274	389,431	402,911	409,939	98,330	157,734	181,256	187,169	190,214

TABLE LIV

GRAIN SORGHUM ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE MAXIMUM NITROGEN STRATEGY: 1972-1990

Soil Classification	Panhandle Area					North Central Area					Central Area				
	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990	1972	1975	1980	1985	1990
I_L	-	-	-	-	-	13,071	17,572	17,572	17,572	17,572	20,449	30,692	30,692	30,692	30,692
I_C	-	-	-	-	-	5,582	6,950	6,950	6,950	6,950	2,806	6,631	6,631	6,631	6,631
II_L	230,428	238,716	232,525	242,823	232,155	51,780	84,676	84,676	84,676	84,676	26,096	58,097	58,097	58,097	58,097
II_C	155,593	157,286	155,593	155,593	156,324	10,014	14,341	14,341	14,341	14,341	18,007	31,342	54,864	60,777	63,822
II_S	-	-	-	-	-	1,664	2,138	2,138	2,138	2,138	465	465	465	465	465
III_L	336,570	410,280	359,860	336,570	368,844	22,118	45,954	45,954	45,954	45,954	10,966	10,966	10,966	10,966	10,966
III_C	233,928	233,928	233,928	233,928	233,928	13,930	23,819	23,819	23,819	23,819	6,069	6,069	6,069	6,069	6,069
III_S	1,967	1,967	1,967	1,967	1,967	1,058	13,681	14,976	14,976	14,976	929	929	929	929	929
IV_L	50,369	50,369	50,369	50,369	50,369	12,378	34,529	34,529	34,529	34,529	1,923	1,923	1,923	1,923	1,923
IV_C	36,464	36,464	36,464	36,464	36,464	6,440	14,765	14,765	14,765	14,765	4,569	4,569	4,569	4,569	4,569
IV_S	9,054	9,054	9,054	9,054	9,054	5,361	8,511	8,511	8,511	8,511	1,592	1,592	1,592	1,592	1,592
V_L	24,558	24,558	24,558	24,558	24,558	30,791	48,896	99,749	113,218	120,200	3,304	3,304	3,304	3,304	3,304
V_C	2,134	2,134	2,134	2,134	2,134	8,561	12,843	12,843	12,843	12,843	903	903	903	903	903
V_S	9,265	9,265	9,265	9,265	9,265	4,378	6,099	6,099	6,099	6,099	252	252	252	252	252
Totals	1,090,310	1,174,001	1,115,697	1,102,705	1,125,042	195,126	334,776	386,922	400,391	407,373	98,330	157,734	181,256	187,169	190,214

TABLE LV

CORN ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE BASELINE STRATEGY: 1972-1990

Soil Classification	Panhandle Area				
	1972	1975	1980	1985	1990
II_L	35,140	35,140	35,140	42,315	42,315
II_C	39,341	40,161	40,161	40,161	40,479
III_L	63,864	63,864	63,864	64,159	117,201
III_C	40,153	69,503	91,774	91,774	91,774
III_S	162	162	162	162	162
IV_L	920	920	920	920	920
IV_C	721	721	10,692	10,692	12,725
IV_S	-	7,188	7,188	7,188	7,188
Totals	180,301	217,659	249,901	257,371	312,764

TABLE LVI

CORN ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE TECHNOLOGY STRATEGY: 1972-1990

Soil Classification	Panhandle Area				
	1972	1975	1980	1985	1990
I_L	-	-	-	-	-
I_C	-	-	-	-	-
II_L	35,140	35,140	47,035	50,229	39,559
II_C	39,314	39,658	39,658	39,341	39,341
II_S	-	-	-	-	-
III_L	63,864	63,864	63,864	89,078	97,332
III_C	40,153	48,326	88,374	83,310	128,112
III_S	162	162	162	162	162
IV_L	920	920	920	920	920
IV_C	721	721	721	721	721
IV_S	-	-	-	-	-
Totals	180,301	188,791	240,734	263,761	306,147

TABLE LVII

CORN ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE RESTRICTED STRATEGY: 1972-1990

Soil Classification	Panhandle Area				
	1972	1975	1980	1985	1990
I_L	-	-	-	-	-
I_C	-	-	-	-	-
II_L	35,140	42,336	42,336	42,336	42,336
II_C	39,341	39,658	39,658	39,658	39,658
II_S	-	-	-	-	-
III_L	63,864	78,769	88,864	95,012	99,232
III_C	40,153	100,122	100,122	100,122	100,122
III_S	162	734	734	734	734
IV_L	920	920	920	920	920
IV_C	721	721	721	721	721
IV_S	-	-	-	-	-
V_L	-	-	-	-	-
V_C	-	-	-	-	-
V_S	-	-	-	-	-
Totals	180,301	263,260	273,355	279,503	283,723

TABLE LVIII

CORN ACRES IN PRODUCTION BY AREA AND LAND CLASS FOR THE MAXIMUM NITROGEN STRATEGY: 1972-1990

Soil Classification	Panhandle Area				
	1972	1975	1980	1985	1990
I_L	-	-	-	-	-
I_C	-	-	-	-	-
II_L	35,140	35,140	47,035	50,229	39,559
II_C	39,314	39,658	39,658	39,341	39,341
II_S	-	-	-	-	-
III_L	63,864	63,864	63,864	89,078	97,332
III_C	40,153	48,326	88,374	83,310	128,112
III_S	162	162	162	162	162
IV_L	920	920	920	920	920
IV_C	721	721	721	721	721
IV_S	-	-	-	-	-
Totals	180,301	188,791	240,734	263,761	306,147

APPENDIX C

RESULTS OF THE BIOLOGICAL SIMULATOR AND ENVIRONMENTAL IMPACT MATRIX ESTIMATES

TABLE LIX

REGIONAL INCOME IMPACT BY STRATEGY: 1975-1990

Year	Strategy			
	Baseline	Restricted	Technology	Maximum Nitrogen
1975	1,069,370,554	1,239,909,543	1,323,375,995	1,400,855,573
1990	1,312,406,829	1,625,416,582	1,707,748,515	1,750,370,202

Regional income impact estimates are obtained by assuming an income multiplier of 3.0815 for agricultural crops multiplied times the farm income estimates.

TABLE LX

FARM INCOME IMPACT BY STRATEGY: 1975-1990

Year	Strategy			
	Baseline	Restricted	Technology	Maximum Nitrogen
1975	347,029,224	402,372,073	429,458,397	454,601,841
1990	425,898,695	527,475,769	554,193,903	568,025,378

TABLE LXI

QUALITY OF WILDLIFE HABITAT IMPACT ESTIMATES BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	.3982	.3442	.3108	.0094	.2893	.3259	.2893	.3259
North Central	.0845	.0897	.1092	.0641	.0696	.0647	.2211	.2317
Central	.1459	.2207	.1627	.1544	.1627	.1544	.2211	.2317

[1] Quality of Wildlife Habitat estimates are developed by using the combined ratios of feed grain acres to wheat acres times temporarily idled land cultivated to new lands cultivated.

TABLE LXII

AQUATIC NITROGEN CONCENTRATION LEVEL IMPACT BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	31.0658	40.2690	29.1912	33.9588	32.1123	31.5869	32.1123	31.5869
North Central	8.8717	10.4846	6.8789	6.9113	8.9789	9.0645	5.2538	5.3137
Central	100.2066	120.0447	92.1900	92.9620	92.1900	92.9620	61.3778	71.1848

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[1] Aquatic nitrogen concentration levels are considered nitrogen residuals in ppm's after algae, bacteria, colloillal suspension, etc., have occurred within the aquatic system.

TABLE LXIII

DIVERSIFICATION-SPECIALIZATION IMPACT ESTIMATES BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	.2872	.3223	.3358	.3363	.2755	.2716	.2755	.2716
North Central	.3431	.4285	.3628	.3740	.3575	.3680	.2213	.2593
Central	.0955	.1149	.0944	.0995	.0944	.0995	.0566	.0764

[1] Estimates are calculated on the basis of cultivated acreages to total acres in each area in 1975 and 1990.

TABLE LXIV

ADJUSTMENTS IN ALGAE AND FISH POPULATION BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	.3501	.3828	.0643	.0645	.0895	.0896	.0895	.0896
North Central	.1034	.1231	.0784	.0781	.1046	.1055	.0498	.0519
Central	1.4124	1.6910	.0136	.0137	.0136	.0137	.0094	.0107

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[1] It is possible to utilize algae population estimates jointly with fish populations since algae impact upon fish populations by utilizing oxygen in the water thus, depriving fish populations of oxygen. Hence, increased algae growth deterimental itself also impact negatively on fish populations.

TABLE LXV

LAND BASED RECREATION IMPACT BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	.0459	.0389	.0366	.0365	.0486	.0496	.0486	.0496
North Central	.0354	.0247	.0325	.0310	.0332	.0318	.0651	.0529
Central	.1752	.1425	.1774	.1674	.1774	.1674	.3084	.2236

[1] Land based recreation estimated impact is calculated from the ratio of wildlife populations to cultivated acreages.

TABLE LXVI

ACRES PROVIDED FOR WILDLIFE HABITAT IMPACT BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	167,201	158,989	155,815	155,698	169,949	170,875	169,949	170,875
North Central	101,510	88,309	98,469	96,727	99,277	97,668	120,324	114,461
Central	118,642	116,096	118,780	118,113	118,780	118,113	123,743	121,146

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[1] Wildlife population estimates are obtained by the following equation, (30 percent). (Total area acres - cultivated area acres/habitat requirement.) Only 30 percent of area acres are considered habitatable for wildlife (Thomas, 1955).

TABLE LXVII

DEGRADATION OF WATER QUALITY IMPACT ESTIMATES BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	.0000494	.000058	.0000144	.0000144	.0000219	.0000243	.0000219	.0000243
North Central	.0000058	.0000058	.0000041	.0000041	.0000058	.0000057	.0000060	.0000058
Central	.0001502	.0001863	.0001477	.0001416	.0001477	.0001416	.0001688	.0001432

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[1] Water quality estimates are developed on the basis of the ratio of area potential nitrogen coefficients to cultivated acres.

TABLE LXVIII

AMOUNT OF INORGANIC NITROGEN IN FOOD SUPPLY IMPACT BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	1.300	1.210	.495	.444	1.267	1.133	1.267	1.133
North Central	1.820	1.671	1.150	.998	1.546	1.345	2.094	2.080
Central	1.280	1.166	1.043	.832	1.043	.832	2.486	2.449

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[1] Inorganic nitrogen in food supply is estimated by the ratio of nitrogen fertilizer per bushel of wheat produced.

TABLE LXIX

FARM LABOR ADJUSTMENTS BY STRATEGY AND AREA: 1975-1990

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	117,193	144,186	156,390	161,903	112,803	122,924	112,803	122,924
North Central	148,894	190,035	159,706	164,651	157,158	162,195	95,112	111,437
Central	35,884	54,731	44,899	47,204	44,899	47,204	26,328	30,672

TABLE LXX

REGIONAL EMPLOYMENT ADJUSTMENTS BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	261,903	322,227	349,500	361,820	252,092	247,711	252,092	247,711
North Central	332,748	424,690	356,911	367,962	351,217	362,473	212,556	249,039
Central	80,194	122,313	100,340	105,491	100,340	105,491	58,838	68,546

TABLE LXXI

TOTAL ACRES OF LAND IN CULTIVATION BY STRATEGY AND AREA: 1975-1990[1]

Area/Year	Strategy							
	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	3,642,358	4,086,256	4,257,841	4,264,092	3,493,838	3,443,768	3,493,838	3,443,768
North Central	2,865,717	3,579,254	3,030,046	3,124,232	2,986,393	3,073,383	1,848,719	2,165,633
Central	677,011	814,635	669,520	705,642	669,520	705,642	401,296	541,689

[1] Acres of land in cultivation is also used as an estimate for erosion potential. More acres taken out of native cover implies a higher potential erosion problem if erosion controls are not heavily utilized.

TABLE LXXII

SHORT-RUN AND LONG-RUN MUNICIPAL WATER QUALITY IMPACT ESTIMATES BY STRATEGY AND AREA: 1975-1990[1]

	Strategy							
Area/Year	Baseline		Restricted		Technology		Maximum Nitrogen	
	1975	1990	1975	1990	1975	1990	1975	1990
Panhandle	179.915	221.312	50.605	50.688	61.936	68.986	61.936	68.986
North Central	17.106	20.417	12.437	12.580	17.297	17.448	10.941	12.387
Central	101.633	151.742	98.872	99.883	98.872	99.883	67.708	77.525

[1] Municipal water quality estimates are developed by summing each months highest potential nitrogen pollution coefficient. The impact estimates are then adjusted to fit the +5 to -5 criterion of the environmental impact matrix.

VITA

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