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I am submitting herewith a dissertation written by Rodney Mack Thomsen entitled "The Economic Effects of Agricultural Land-Use Management on Soil Erosion and Farm Income in the Obion-Forked Deer River Basin." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

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THE ECONOMIC EFFECTS OF AGRICULTURAL LAND-USE MANAGEMENT ON SOIL
EROSION AND FARM INCOME IN THE OBION-FORKED DEER RIVER BASIN

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee

Rodney Mack Thomsen

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ABSTRACT

The U.S. Department of Agriculture's report to the President in 1970 on agriculture-related pollution stated: ". . . from the standpoint of quantity, sediment resulting from erosion of the land is the greatest contributor to pollution of surface waters."

One major agricultural area in Tennessee contributing to this agriculture-related pollution is the Obion-Forked Deer River Basin, an area of approximately 3 million acres in parts of 14 counties in Northwest Tennessee. Approximately 94 percent of the Basin's land area was used for agricultural purposes in 1970.

Continuously cropped upland areas without conservation measures have averaged 50 tons per acre of soil loss annually. The average topsoil loss for the Basin is approximately 23 million tons per year. This amount of soil erosion through time not only leaves the uplands relatively bare and less productive, but clogs stream channels with debris which destroys opportunities for recreation and contributes to bottomland flooding. In 1972, estimated damages due to flooding and sedimentation in the Basin was \$31 million.

The overall objective of this study was to determine the effect of water and land management practices on farm income of farms on the upland areas of the Basin. The overall objective of this study was met by quantifying the various farm enterprises and resource constraints and evaluating the problematic situation in a linear programming framework, a mathematical procedure for arriving at an optimal solution of a problem when given various activities and restrictions. Within this study, farm budgets were used to obtain

information on typical farming practices and techniques used by farmers in the Basin. An objective function of net return to the uplands was maximized subject to resource constraints. The maximum potential net farm income was calculated for the upland areas of the Basin. Then, a soil erosion discharge standard available from the Soil Conservation Service and the Water Quality Control Division of the Tennessee Department of Public Health was used to set the maximum allowable level of soil that could be eroded. A system of land-use practices was generated to meet this standard. The maximum net returns to the uplands were recalculated subject to the original resource constraints plus the discharge standard and recommended cropping practices. The difference between the maximum net returns with the recommended water and land management practices and the maximum net returns without these measures was an estimate of the opportunity cost involved.

The maximum potential agricultural income under current production patterns without regard for soil erosion, Model I, was estimated to be \$186.3 million. The agricultural production organization generated stressed the production of cotton on the uplands. The universal soil loss equation was utilized in establishing the recommended crop rotational systems necessary to meet the soil erosion discharge standard of 10 tons per acre in Model II. The recommended cropping systems were entered into the second model of the study and the subsequent recalculation of potential agricultural income was estimated to be \$144.5 million. The optimal production organization generated emphasized the production of cotton in rotation with corn, wheat, and meadow (hay) crops.

The estimated opportunity cost is the mathematical difference between the maximum potential agricultural incomes calculated in Model I and Model II. Consequently, the estimated opportunity cost in terms of agricultural income foregone with the implementation of recommended cropping systems is determined to be \$41.8 million. This approximate \$42 million loss in potential agricultural income must be considered the minimum cost involved with such an agricultural production change to limit soil erosion to a maximum of 10 tons per acre.

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CHAPTER I

INTRODUCTION

Concern over the deterioration in the quality of the natural environment and the misuse of natural resources has been expressed by many interested citizens in recent years. One of the results has been the modification of national policy to emphasize the dual objectives of increasing economic well-being and of decreasing the degradation of soil, air, and water (12). Water quality and soil maintenance have been identified as important natural elements which have suffered as a consequence of economic development. Evidence is found in the proliferation of reports, reviews, and symposiums dealing with the continuing decline in water quality and increase in soil erosion (17, 26, 31, 37).

Throughout history the serious deterioration in the quality of soil and water resources have been characterized by the presence of various foreign materials and high concentrations of suspended solids found in streams. The basic difficulty lies in the increasingly subtle nature of the physical process. This process involves the persistent and continuing discharge of eroded soil and chemicals into stream channels as a by-product of production activities. The universal decline in the quality of resources have been magnified by the growing demands for water related recreation, by increased flood and sedimentation damages, and by the general inadequacy of present institutional arrangements to deal effectively with these issues (22).

Agriculture has been identified specifically as one of the major sources of soil and water degradation. The significance of the

relationship between agriculture and environmental decay was highlighted by a Presidential message to the people of the United States on March 8, 1968, which included a directive to the Secretary of Agriculture to conduct a government-wide review of the impact of agricultural waste upon the environment. In the subsequent report to the President, the Secretary of Agriculture listed sediment (eroded soil and associated chemicals) as the primary agricultural substance which has the greatest impact upon the natural environment (35). These sediments, or waste materials, transported overland by runoff into streams and lakes, have been classified in different ways. One relevant classification specifies eight classes: 1) sewage and other oxygen demanding waste, 2) infectious agents, 3) plant nutrients, 4) organic chemicals, 5) other minerals and chemical substances, 6) eroded soil, 7) radioactive substances, and 8) heat. The agricultural sector has been the major contributing source to sediments identified essentially by the first six categories (31). Sediment has the distinguishing characteristic of being a transporting agent since other substances can be adsorbed and carried along, and thus are capable of movement over time and space.

The Setting of the Study

One major agricultural area in Tennessee contributing to agriculture-related pollution¹ is the Obion-Forked Deer River Basin. This Basin includes 3,019,000 acres consisting of the combined Obion and Forked Deer River Drainage Area in Northwest Tennessee and the alluvial

¹The term pollution refers to the interaction of eroded soil and water which results in the deteriorating or defiling of the natural environment.

valley along the east bank of the Mississippi River, extending from the Kentucky state line south to the Hatchie River Divide. The Obion-Forked Deer River Basin includes all or part of 14 counties of Northwest Tennessee (Figure 1). The Basin includes Crockett, Dyer, Gibson, Lake, Obion, and Weakley counties and parts of Carroll, Chester, Haywood, Henderson, Henry, Lauderdale, McNairy, and Madison counties. The land area of the Basin is approximately 11 percent of the State's total acreage.

The largest town in the Basin is Jackson with a 1970 population of approximately 40,000. Ten other towns of over 5,000 inhabitants are also located in the Basin.

The climate of the Basin is characterized by mild winters, hot summers, and abundant rainfall. Even though the Basin is well inland, it lies in the path of cold air moving down from Canada and warm, moist air moving up from the Gulf of Mexico. Therefore, extreme and frequent changes in the weather are common.

The Basin has periods of drought and periods of plentiful and even excessive rainfall. The average annual precipitation varies from about 52 inches in the eastern portion to approximately 48 inches in the extreme western portion. About 46 percent of the total rainfall occurs during the cropping season of April through late October.

The topography of the Basin is abrupt and hilly in the extreme eastern part and slopes gradually westward through the less hilly and undulating areas to low flat plains near the Mississippi River. The highest elevation of 550 feet above sea level is in the eastern portion, while the lowest point is at the confluence of the Obion-Forked Deer and Mississippi Rivers where the elevation is 225 feet. This river system

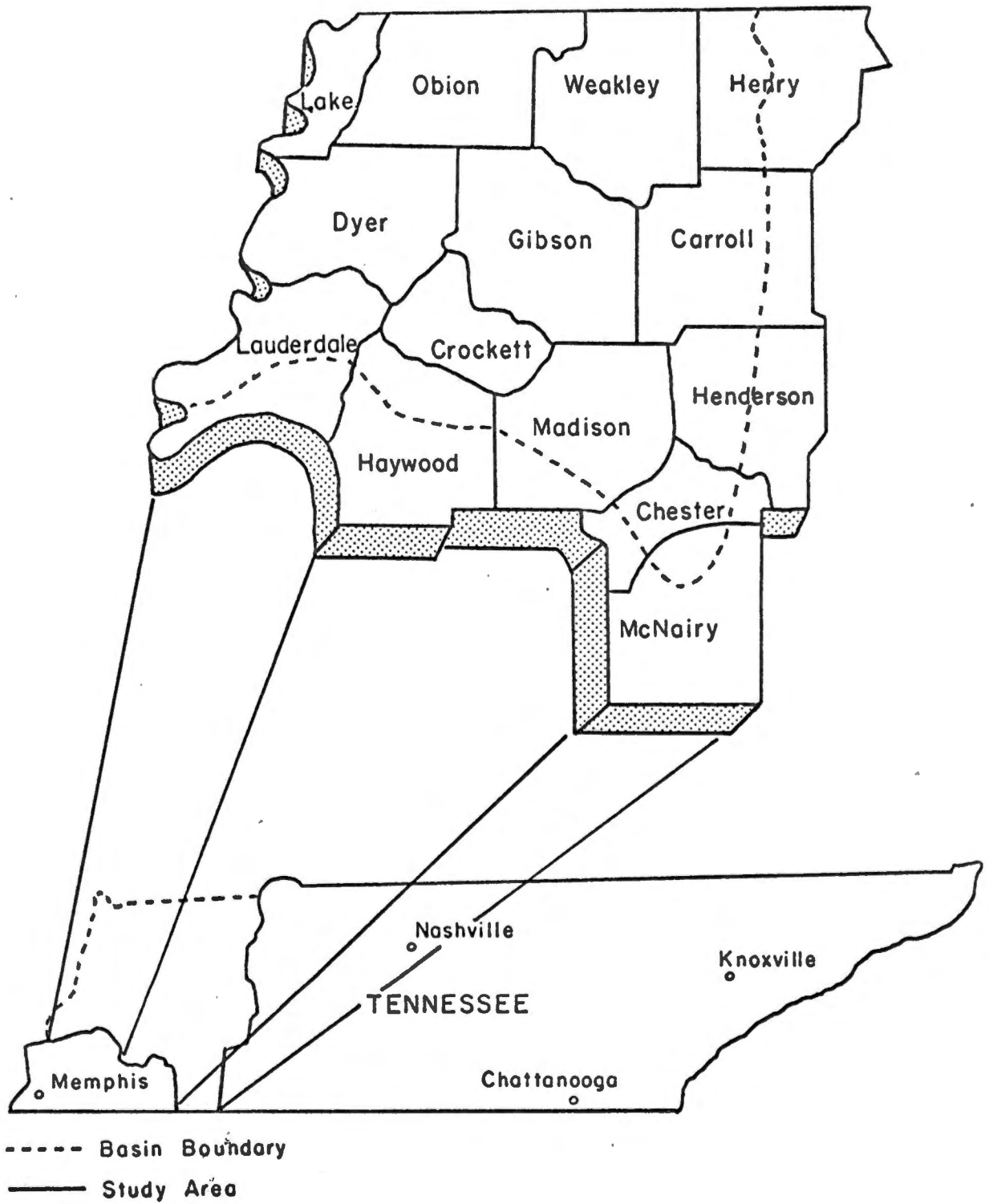


Figure 1. Obion-Forked Deer River Basin and Study Area

has a profusion of tributaries. The major ones are the North, South, Middle, and Rutherford forks of the Obion and the North, Middle, and South forks of the Forked Deer (34).

In general, the Basin has experienced sustained economic growth over the past decade. Total population, income, and employment have increased since 1960. However, this growth has been at a slower rate than the State as a whole. In the 1960's, population increased 4.4 percent in the Basin compared with the State increase of 13.0 percent. Income levels in the Basin not only are below nation averages, but also below those of Tennessee. In 1970, median family income was \$5,872 compared with \$9,867 for the Nation and \$7,447 for the State. Employment during the 1960's showed a net increase of over 35,000 persons with two-thirds of the increase being in the manufacturing industries (2).

Historically, the Basin has been a highly agriculturally oriented part of Tennessee. Approximately 94 percent of the total land area in 1970 was used in the production of agriculture and forest related products. In 1969, the value of crops sold in the Basin totaled \$82 million, representing 36 percent of the total value of crops sold in Tennessee. Farm structure has also changed in the last decade. During this time, the average size of farm increased by 53 percent to 180 acres in 1970. Meanwhile, the number of farms in the Basin declined by 32 percent. An exception to this trend was the number of commercial farms which increased by more than 40 percent between 1960 and 1970. These farms constitute the major agricultural potential of the Basin² (2).

²For further socioeconomic information of the Obion-Forked Deer River Basin; see Badenhop and Thomsen (11).

Land Resources of the Basin

Recognizing that the resources of the Basin have never been fully assessed, the Tennessee Department of Conservation in 1970 requested that the United States Department of Agriculture (USDA) conduct a comprehensive inventory of the land and water resources in the area. Consequently, the USDA organized a field advisory committee consisting of personnel of the Soil Conservation Service (SCS), Economic Research Service (ERS), and Forest Service with the Soil Conservation Service given the primary responsibility of administering the resource inventory.

For survey purposes, the 3 million acre Basin was divided into two land areas, the bottomlands and the uplands. The bottomlands, consisting of the stream channels, floodplain and adjacent lowlands, was the first area inventoried. The bottomlands contain approximately 1,279,400 acres, or 43 percent of the total land area of the Basin. The soils of the bottomlands are primarily colluvial or alluvial deposits. These water related deposits were developed from areas of higher elevation under various conditions and originating from different types of parent materials (34).

The uplands of the Basin contain the bluffs and other areas of higher elevation not found in the bottomlands. This second land area accounts for 1,701,600 acres, or 57 percent of the Basin's land area. The northwestern portion of the uplands are covered with a layer of wind deposited silty material called loess. This loess material is generally very fertile and ranges in depth from a few inches to over 50 feet. This portion of the uplands is characterized by the Memphis, Loring, and Grenada soil associations with slopes ranging from less than

5 to over 20 percent. In the southeastern part of the uplands, the predominant soil associations are Ruston, Lexington, and Dexter. These soil associations were derived from Coastal Plains parent materials which are sandy in texture and generally have steep short slopes. Consequently, the topography and contour on the upland areas of the Basin are not conducive to maximum soil retention (34).

Objectives

The Obion-Forked Deer River Basin is confronted with severe land-use problems which result in excessive erosion, sedimentation, pollution, and hydrologic runoff. The Basin has the highest ratio of rainfall to gross soil erosion in the state. Soil losses from bare roadbanks, raw gullied areas, severe sheet erosion, and areas graded for various developments may lose as much as 200 tons of soil per acre annually. The total average annual topsoil loss for the Basin is upwards of 23 million tons per year (34).

Uncontrolled erosion in the Basin has already claimed 144,000 acres of potential cropland and another 442,000 are in immediate danger of a significant loss of productivity. This degree of soil erosion not only leaves the uplands relatively bare and less productive, but clogs stream channels with silt and debris which destroys bottomland timber, wildlife habitat, and recreational opportunity. This erosion problem also raises the cost of water and electric services and generally contributes to bottomland flooding. Damages attributed to excessive soil erosion were estimated to be \$31 million in 1972 (33).

Physical efficiency criteria for dealing with the problem of excessive soil erosion would dictate the selection of abatement techniques which would minimize soil erosion or maximize sediment removal downstream. However, such a course of action ignores the economic consequences of such a choice. A complete analysis concerned with the management of scarce resources must include an examination of the economic costs involved with such a project. Therefore, this study seeks to incorporate the principle of opportunity cost in terms of potential agricultural income foregone by restricting soil loss through the use of crop rotational systems on the uplands of the Basin.

The overall objective of the study is to determine the effect of water and land-use management practices on total agricultural income on the uplands of the Obion-Forked Deer River Basin.

The specific objectives are:

- 1) To estimate the maximum potential agricultural income on upland areas of the Obion-Forked Deer River Basin given the current cropping patterns and the existing soil and water management practices.
- 2) To establish effective crop rotational schemes on upland areas in order to meet a specific soil erosion discharge standard in relation to water quality improvement and maintenance of land productivity potentials.
- 3) To evaluate the effect of crop rotational systems in the uplands on the net returns to agricultural production and to calculate the opportunity cost involved with the implementation of these systems on the uplands of the Basin.

CHAPTER II

THEORETICAL AND METHODOLOGICAL CONSIDERATIONS

An analysis of the agricultural erosion and sedimentation problem in the Obion-Forked Deer River Basin must recognize a variety of interrelationships. Specifically, the relevant aspects of such a problem encompasses both the physical relationships of soil erosion and the economic considerations involved in its abatement. An integrated approach to land-use and water quality management thus requires both the consideration of the technological possibility and economic feasibility of any proposed solution.

The Physical Nature of the Problem

Sediment as a pollutant originates from soil erosion occurring in the Basin as a result of cropping activities and precipitation. It is difficult to investigate erosion and sedimentation separately since they occur in sequence. Generally, sediment is considered as organic and inorganic solids transported by water into streams from the surrounding drainage area. Technically, sediment is composed of solid particles larger than clay and smaller than sand (38). The process of sedimentation in the Basin involves, 1) erosion of soil on the uplands, 2) transportation of sediments primarily by water, and 3) deposition of the sediment into stream channels and the adjacent bottomlands. The hydrologic Basin, which includes many smaller watersheds, is the spatial unit within which the process of sedimentation occurs.

Sediment, besides being a primary pollutant, has the associated characteristic of being a transporting agent. It has the capability of adsorbing chemicals and other organic substances on soil particles from the uplands and discharging them downstream. Soil particles have a tremendous affinity for adsorbing phosphate and nitrate molecules. Runoff from agricultural operations contributes to their presence in the streams of the Basin. These chemical molecules lead to tremendous growth in algal blooms in streams which produce objectionable odors and are unsightly. Furthermore, the presence of algal growth robs the water of dissolved oxygen and the stream becomes unsuitable as a habitat for game fish and other aquatic life (28).

The complete series of interrelationships between the land and water resources of the Basin are shown as a purely physical system in Figure 2. Among the numerous hydrologic relationships outlined in Figure 2 are several which are specified exogenously in the system. Under the source components of the system, characteristics such as rainfall, soil type, and land slope are fixed by the general topography and climatic condition of the area. Within the linkage scheme, the sediment delivery rates, water carrying capacities and stream flows are directly determined by the fixed components of the system. In the impact area, the in and out of stream uses which are primarily recreational and consumptive, respectively, are set by both the quality and quantity characteristics of the water. Also, the productive potential of the bottomlands is to a large degree predetermined by the amount of sediment deposited. Consequently, only land-use is variable in the system (6).

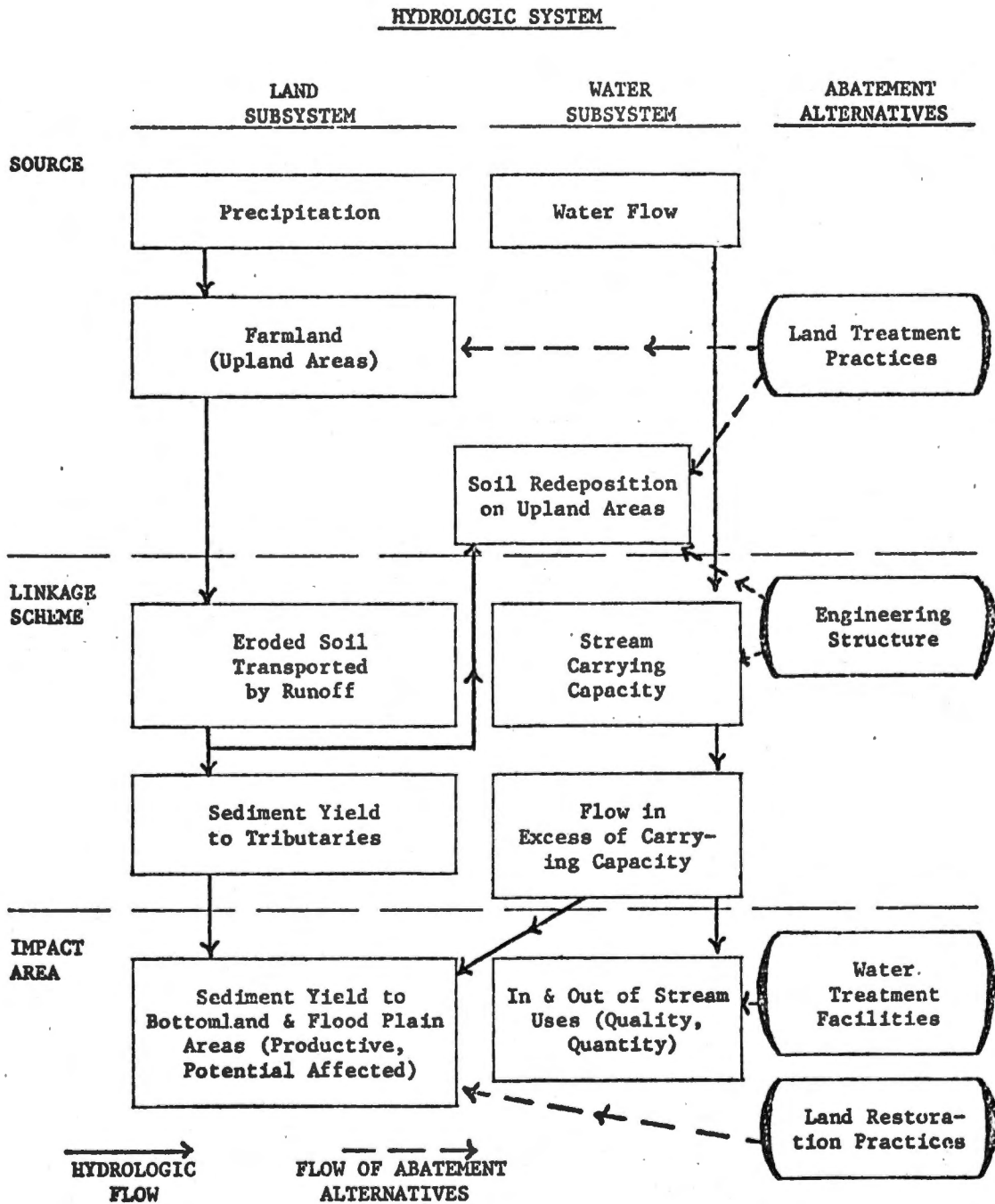


Figure 2. Diagrammatic representation of soil erosion and sedimentation attributed to agricultural production in the Obion-Forked Deer River Basin.

Within the hydrologic system of the Basin, there are a variety of methods or abatement techniques which can be used to control the amount of soil erosion and/or sediment load in streams. These methods can be classified according to two broad categories. The first group is termed land treatment practices while the second group is referred to as structural techniques.

Land treatment practices are primarily agronomic in nature, and include the use of various forms of vegetative cover and contour cultivation practices. These land treatment practices can be implemented under the source components of the hydrologic system (Figure 2).

Willrich has pointed out that these practices, "incorporate many of the same principles of water-flow control to reduce or eliminate soil erosion; i.e., interception of precipitation near the arrival site, surface detention, soil infiltration, slow the release of excess water and degradation of potential pollutants within the biologically and chemically active soil filter" (36).

The second category consists of structural techniques. Their primary function is to control the rate of water-flow, both over land and in stream channels. This group includes small grade soil retention structures, gully stabilization with water holding features, and reservoirs. Other structural practices may include various water filtration techniques employed in water treatment facilities and land restoration practices (23). These structural abatement alternatives can be implemented in the hydrologic system at specific points in the linkage scheme or the impact area.

The Economic Nature of the Problem

Any scarce productive resource has an associated cost when used by an individual or society as a whole. Therefore, an analysis of the resource problems in the Basin must consider not only the physical inter-relationship but also the economic feasibility of the solution selected.

The physical criteria for dealing with soil erosion can be summarized into the selection of those abatement techniques which minimize soil erosion or maximize sediment removal. At the Basin level, the erosion and sedimentation problem may be viewed more clearly as: 1) the production of primary agricultural products which yields returns to the farmers, and 2) the subsequent production of agricultural waste in the form of erosion and sedimentation which affects society downstream. In economic terms, what occurs is the discharge of by-products (residuals) from agricultural production into the stream channels which are treated as a common property resource (free good). In the process, those who utilize the bottomland areas pay the cost of this residual production in terms of decreased productive potential, diminished recreational use, and poorer water quality. The economics of the problem is essentially where the market system fails to internalize cost of this residual production or compensate for such economic losses.

Externalities are said to exist "when an activity on the part of one person through his production (consumption) of some good or service affects the utility or cost function of a second person" (5). The basic emphasis is on the interdependence of production (utility) functions. In contrast, the theoretical abstraction of purely competitive markets assumes away all such interdependencies and under certain assumptions

describes the allocation of resources so as to "maximize welfare." Unfortunately perfect competition breaks down in terms of Pareto-efficiency when external effects are introduced into the market system. Traditionally, the external effects are characterized by market failure or nonmarket interdependence. The influence of the externalities are upon the utility and/or output of others which are exerted directly and not via the market (price system). The familiar cases of smoke and noise as non-market interdependences are examples of externalities that may cause a divergence between social and private costs when not accounted for in the market place (1).

Given the physical and economic nature of such external effects, traditionally, economists have analyzed the allocative aspects of externalities under various conditions. For example, Coase clarified the relation of property rights to externalities and its allocative significance (7). Mishan, formalizing the mathematical concept of externalities, explained the necessary and sufficient conditions for optimum output under competitive equilibrium within the context of partial equilibrium analysis. Consequently, when given a competitive market structure and decentralized decision making the equilibrium output of production with an external diseconomy is in excess of its optimal output. This optimal output is the amount at which the market price less the social value of the external diseconomy is equal to the marginal resource cost. However, the traditional analysis of externalities only relates to the artificial case of two parties equal in economic power confronting each other in an effort to internalize the cost of the externality (25).

In considering a soil erosion problem, such as the one dealt with here, Kneese has recommended a different approach. Kneese's approach is

called the "management of common property resources." It incorporates the externality principle but is distinct in its emphasis from traditional externality theory. The traditional approach deals with the artificial case of two parties who are equal in economic power and are confronting the externality concept in a situation where all other resources are optimally allocated. The management of common property resource approach deals with land and water management problems in which producers collectively discharge waste (eroded soil) into the environment (stream). This affects a host of people (society) who are diffuse in character and have very little individual interest to bargain for solutions. The economic nature of the parties cannot be considered separate and equal because the resource management problem confronts everyone regardless of economic status. The externality producers by nature of being an economic firm have greater economic power. Society, on the other hand, is composed of large diverse groups which are not separate and equal. Consequently, traditional solutions of bargaining and merger do not directly apply (19).

The production of agricultural waste in the form of soil erosion and sedimentation, a by-product of agricultural production, is not considered an isolated and random phenomenon. Rather, the production of agricultural waste is pervasive and systematic and is not a freakish event in the process of production. These are some of the major reasons which make the common property resource management approach more appropriate for dealing with land and water resource problems than the traditional externality concept (20).

Within the context of the common property resource management approach, Kneese and Bower recommend the use of a watershed (watershed,

airshed) in terms of prescribing a method of handling resource-use generated externalities. The problemshed method involves the use of a standard (upper limit) on the amount of the residual (eroded soil) discharged by the externality producer into the environment (stream). The underlying economic principle embedded within the problemshed method is the removal of the divergence between social and private cost of the externality and to arrive at a Pareto-optimal level of agricultural output and residual production (21).

In applying this method, an upper limit or standard is set on the amount of residual (eroded soil) generated by the externality producing firms. Then, the production activities (cropping systems) can be adjusted by land treatment practices to the extent that the residuals generated do not exceed the standard set. This point is illustrated in Figure 3 (20).

The upper limit on the amount of soil erosion is set at "X." Thus, the vertical line segment "BX," representing the standard, implies that up to point "X" the marginal benefits of reducing soil loss is substantially greater than the marginal cost involved with such a reduction. At point "X" the marginal benefits achieved by a unit reduction in soil loss is cancelled by an equivalent level of marginal cost. Therefore, at point "X" net benefits accruing from soil erosion reductions are zero and thereafter negative (20).

Welfare Economics and Linear Programming

The basic issue in welfare economics and the internalization of the cost of an external diseconomy deals with the characteristics of the "best" allocation of resources in situations where the factors of

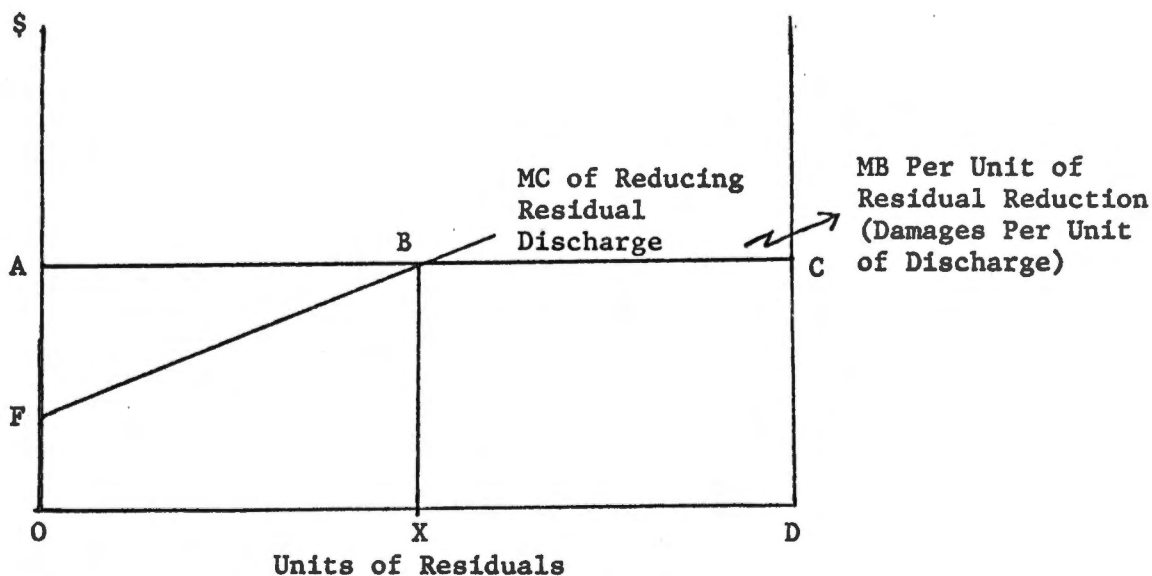


Figure 3. The Marginal Cost and Benefits of the Stream--
Standard Approach

- OD = units of soil eroded (residual discharged) if no standard is set
- OA = amount of damages per unit of soil eroded (marginal gains per unit of soil loss reduced)
- OACD = total damages associated with unrestricted soil loss
- OX = reduction of soil loss with the stream standard
- OFBX = total cost of reducing soil loss to DX
- OFBCD = total "associated cost" with DX amount of soil loss, i.e., soil loss damages plus costs of reducing soil loss (opportunity cost)
- OABX = total damages avoided (total benefits achieved by the optimal reduction of soil loss)
- ABF = net reduction in soil loss "associated costs" by reducing soil loss by OX (OABX minus OFBX)

production can be allocated and utilized by different activities through an assortment of production processes which yield unique sets of goods. It is also the problem in "linear" economics where "linear" refers to the basic restrictions in a linear programming framework which takes the form of a summation, that is, the total amount of any factor devoted to all tasks must not exceed the total amount available. Dorfman, Samuelson, and Solow recognize other similarities between welfare economics and linear programming (10). To begin with, the main thrust of welfare economics is concerned with certain normative aspects of competitive equilibrium analysis, such that, if firms maximize profits competitively with respect to any given set of prices for goods and factors, the resulting configuration of inputs and outputs will be efficiently allocated and produced. Under essentially the same assumptions as are used in welfare economics, this competitive equilibrium situation exists in a linear programming model. Likewise, economic efficiency in the allocation of scarce resources is vitally important in achieving a constrained Pareto-optimization in a linear programming model as it is in modern welfare economics (10).

Relative to externalities, Mishan points out that "correcting" the output of the externality generating goods by the social marginal cost is likely to bring the economy closer to an overall optimum (25). Linear programming performs a function similar to the "correction" of external effects that Mishan refers to by determining those activities which keep the production of externalities under control by restricting them to a given level. This is what happens when a linear programming model is utilized within the framework of a problemshed approach to the management of common property resources (21).

Procedures

This study employs the problemshed approach to land and water management problems in the uplands of the Obion-Forked Deer River Basin. The uplands are considered as one physical and economic entity, both in the production of agricultural commodities and in the generation of eroded soil.

The specific objectives will be met by quantifying the various farm enterprises and resource constraints appropriate to the area and by evaluating the soil erosion problem in a general linear programming model. University of Tennessee farm budgets, developed by farm management specialists in the Department of Agricultural Economics and Rural Sociology, will be used to obtain cost and return data on the predominant agricultural enterprises and on typical farming practices used by farmers on farms in the uplands of the Basin. An objective function of net return coefficients for the uplands will be maximized subject to selected land resource constraints. These resource constraints will consist of the different soil types found in the uplands. Soil types will be distinguished by their relative productivity, erodability characteristics, and slope. The maximum potential net agricultural income will be calculated for the upland areas of the Basin. Then, a maximum soil erosion discharge standard³ will be set to limit the amount of soil eroded into the streams of the Basin. A system of land treatment practices will then

³ For a complete discussion of the soil erosion discharge standard see Chapter III of this study.

be generated to meet this standard. These land treatment measures will be entered explicitly into the linear programming model and the maximum net return to the uplands will be recalculated subject to the original land resource constraints plus the additional constraint of land treatment practices. The difference between the maximum net return with the recommended land treatment practices to limit upland soil erosion and the maximum net return without these measures will be an estimate of the opportunity cost associated with the implementation of these land and water management systems.

CHAPTER III

DEVELOPMENT OF THE MODEL

Linear programming is one of the most important analytical developments of the post World War II era for dealing with economic optimization problems. This mathematical tool was developed by Dantzig in 1947 as a technique for planning allocation activities of the United States Air Force (10). Since its creation, linear programming has become greatly refined and has been used as a research tool by agricultural economists to specify the optimum organization of farm resources and enterprises (15). Basically, linear programming is a mathematical technique which can be utilized in the analysis of problems which consist of a linear function of variables to be maximized or minimized subject to a number of constraints in the form of linear inequalities.

Several fundamental assumptions are used in a linear programming analysis. These are:

- 1) Linearity - Which by definition, each production process is characterized by ratios of the quantities of the inputs to each other and to the quantities of each of the outputs. These ratios are defined to be constant and independent of the extent to which the process is used.
- 2) Divisibility - In the sense that it is assumed that any production process can be used to any positive level so long as sufficient resources are available. Indivisibilities and the lumpiness of factors in production are disregarded.
- 3) Additivity - It is assumed that two or more processes can be used simultaneously within the constraints of the available

resources. The quantities of outputs and inputs will be the sum of the quantities which would result if the several processes were used independently.

- 4) Finiteness - The number of production processes available are assumed to finite or limited (9).
- 5) Single-value expectations - It is generally assumed that the amount of resources available, input-output coefficients, and prices are known with certainty (15).

These five special postulates are considered essential to the mathematical analysis of all linear programming problems and are assumed to hold in this study.

Geometrical Representation of the Linear Programming Procedure

The linear programming approach used is divided into two separate models. Model I is designed to estimate the maximum potential agricultural income of the uplands as outlined under objective 1; the graphical illustration is shown in Figure 4.

Figure 4 illustrates the linear programming problem and its relationship to production economic concepts. This example involves two crop production activities or enterprises, Y_1 and Y_2 , which are subject to the three land type resource constraints, W, X, and Z. The production possibility frontier or transformation curve (OABCE) indicates all possible combinations of Y_1 and Y_2 acreages that can be undertaken from the given resource restrictions. The production possibility frontier is formally defined as a curve showing the maximum attainable output of one commodity for every possible level of output of the other commodity given

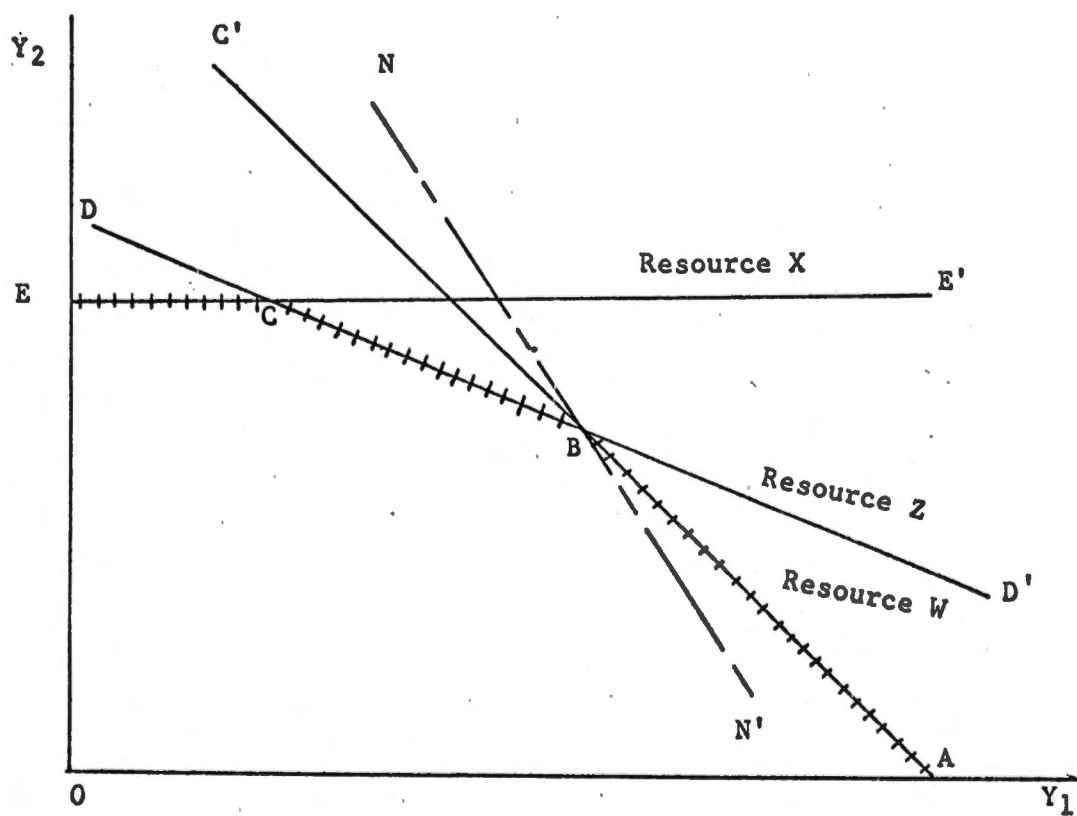


Figure 4. Production Possibility Frontier for Y_1 and Y_2 Given the Three Land Resource Constraints

the fixed resource base. The frontier represents the feasible production region generated from the absolute amount of each resource, the aggregate input ratios, and the implicit production functions of the commodity produced. The slope of the production possibility frontier is the marginal rate of substitution of Y_1 activity for Y_2 indicating the amount of area under the production of Y_2 substituted for each unit of Y_1 undertaken (13).

The resource constraints are graphic counterparts of the equations representing the requirements and availability of the resources from the production of Y_1 and Y_2 commodities. These equations are illustrated by the line segment ECE' for the available level of resource X , the line segment DBD' for the amount of resource Z , and the line segment $C'BA$ for the endowment of resource W .

Given the fixed set of resource restrictions, the greatest net revenue possible from the production of Y_1 and Y_2 is determined by the tangency of the iso-net revenue line and the production possibility frontier. An iso-net revenue line is defined as the locus of output combinations of crop activities which will yield the same economic return (16). The iso-net revenue line, NN' , is tangent at point B giving the optimal crop production plan for Y_1 and Y_2 subject to the given resource constraints.

Objective 3 incorporates the additional constraints of land treatment practices in the form of crop rotational systems and a soil erosion discharge standard upon the linear programming problem of maximizing agricultural income on the uplands. This recalculation of maximum

potential agricultural return is undertaken in Model II. Figure 5 illustrates the geometrical aspects of the additional restrictions contained in the second linear programming model.

The only difference between Figure 4, representing Model I, and Figure 5, illustrating Model II, is the change in production processes from continuously cropped upland resources to a scheme of crop rotational systems. These systems are formulated to meet the new constraint upon the amount of soil erosion allowed per unit of land. This limitation in conjunction with the three original land resource restrictions is graphically presented as the vertical line segment ABJ in Figure 5. With this new limitation represented by the line segment ABJ, the feasible region of the production possibility frontier is reduced in size. This changes the point of tangency between the iso-net revenue line and the production possibility frontier, thereby, producing a lower absolute level of total potential agricultural income. The difference between the amount of agricultural income produced under the land resources constraints of Model I and the level of agricultural income produced in Model II is an estimate of the opportunity cost of the additional constraint of the soil erosion discharge standard. Underlying this design of the second model is the basic economic principle of the internalization of the effects of an external diseconomy. This is accomplished through the use of crop rotational systems which limit the amount of soil erosion.

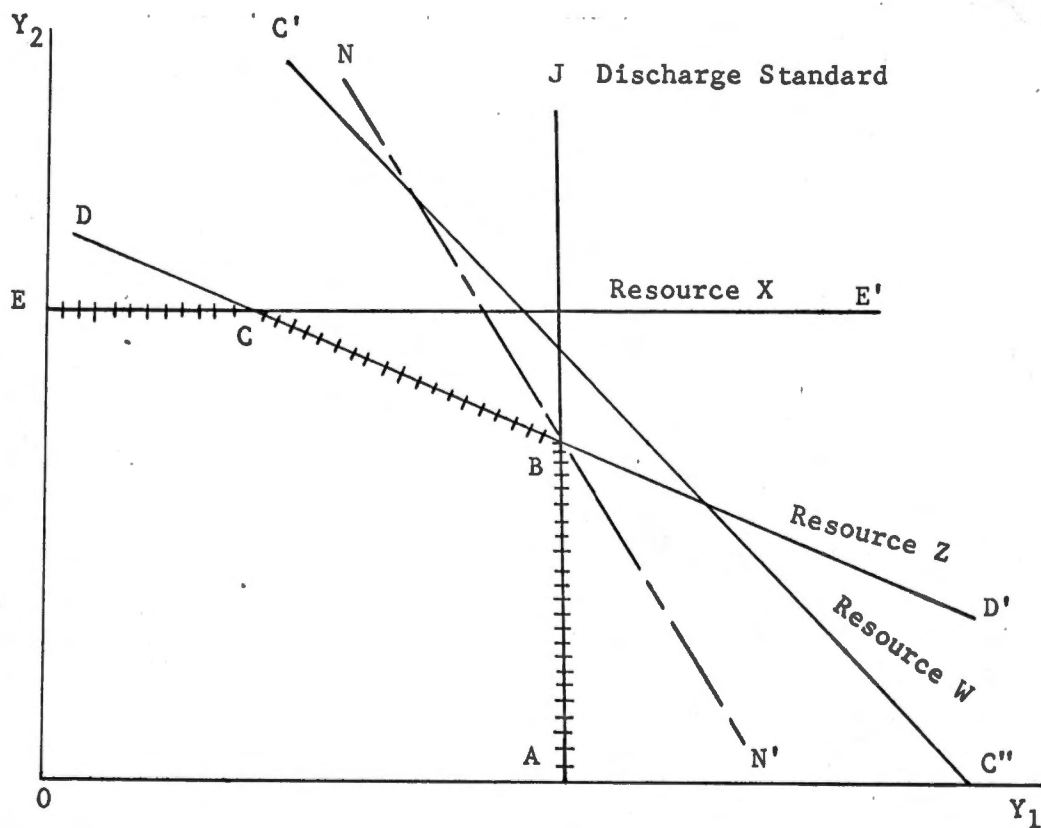


Figure 5. Production Possibility Frontier for Y_1 and Y_2 Given the Three Land Resource Constraints and a Soil Erosion Discharge Standard

Mathematical Formulation of the Models

The mathematical formulation of both linear programming models is composed basically of the same general format which consists of the objective function and the restricting equations. Model II is uniquely different from Model I only by the introduction of different crop rotational systems as the enterprises and the subsequent soil erosion discharge standard restriction.

It is assumed that there are "K" land types in the uplands of the Basin as specifically identified by soil classification. These land types are subject to "J" types of agricultural production activities common to the area. These activities in Model I consist of strictly continuous cropping and/or livestock producing enterprises. In Model II, these "J" type production activities are made up of various crop rotational systems producing varying levels of income and discharges of eroded soil into the streams of the Basin. The following parameters are common to both models:

A_{jk} = the amount of input or level of resource required per unit of agricultural activity "J"; where $j = 1 \dots J$ and $k = 1 \dots K$.

d_k = the total amount of land types, "K," acreages available under each land classification.

C_{jk} = the net return from production activity, "J," per unit of k^{th} land type.

The linear programming technique then solves for a set of variables X_{jk} which are interpreted as the area of land types "K" taken under the j^{th} production activity in such a way as to maximize the net returns

from the upland areas of the Basin. This set of relationships are shown by the following equations:

$$1) \quad Z = \sum_{j=1}^J C_{jk} X_{jk} \quad \text{where } k=1\dots K$$

Equation 1) is the objective function of the general mathematical form common to both models. It represents the net returns of the production activities which are to be maximized subject to equation 2).

$$2) \quad \sum_{j=1}^J A_{jk} X_{jk} \leq d_k \quad \text{where } k=1\dots K$$

Equation 2) simply states that the total amount of inputs required by all production activities must be less than or equal to the total amount of k^{th} type resource available.

$$3) \quad \sum_{j=1}^J X_{jk} = d_k \quad \text{where } k=1\dots K$$

Equation 3) states that all the land areas under each type has to be accounted for in the models. It is also required that the area of land types, "K," taken under the j^{th} production activity be nonnegative according to equation 4).

$$4) \quad X_{jk} \geq 0 \quad \text{where } j=1\dots J \text{ and } k=1\dots K$$

These four equations are common to both models. However, Model II consist of one additional equation.

$$5) \quad \sum_{j=1}^J B_{jk} X_{jk} \leq b_1 \quad \text{where } k=1\dots K$$

Where: B_{jk} = the soil erosion discharge standard, which represents the maximum amount of soil eroded by the j^{th} production process operated on a unit of land of k^{th} type. The units of B_{jk} are in tons per acre.

b_1 = the maximum total allowable level of soil loss from the uplands of the Basin.

Equation 5) requires that the total amount of soil erosion be equal to or less than the total number of acres of land brought into production times the soil erosion discharge standard. This linear programming approach emphasizes the characteristics of production and erosion elements, restrictions on resources and residuals, then, considers them simultaneously in the optimization procedure. Given the data necessary to quantify the parameters of the models, the maximizing technique will not only yield an optimal production plan but other valuable information concerning the stability of the solution to changes in the profitability of the various enterprises.

Data Requirements, Sources, and Calculations

Data required to make the models operational are:

- 1) Data concerning the land types and soil classifications on the uplands of the Basin.
- 2) Data measuring land availability for agricultural production activities under each soil classification.
- 3) Data dealing with the erosion characteristics of the soils in the area.
- 4) Information concerning the soil erosion discharge standard for the uplands.
- 5) Data indicating the appropriate set of crop and/or livestock activities entering the objective function of the models.

- 6) Cost and return data for agricultural activities considered in the models for production on the uplands.
- 7) Data measuring the current levels of the major crops grown on the uplands of the Basin.

Land Types and Soil Classifications

In the inventory of the land resources of the Basin, the field advisory committee members, consisting of personnel of the SCS, ERS, and Forest Service, grouped various soil associations into economically manageable land units. This classification system arranges similar soils into soil productivity classes.⁴ A soil productivity group is defined as a group of land capability units having similar cropping patterns, yield characteristics, response to fertilizers, management practices, and land treatment measures. Ten of these SPG's were formed for the entire Obion-Forked Deer River Basin. These SPG's were considered homogenous enough to permit a reasonable degree of accuracy in estimating crop yields and appropriate management practices. The basic data used to formulate the SPG's included published county soil surveys, United States Geological Survey Maps, and the Soil Conservation Service's Tennessee Soil and Water Conservation Needs Inventory (31).

Of the 10 SPG's identified in the Basin, groups 1 through 4 were separated by the major soil series representing the uplands. Soil productivity groups 5 through 8 contain bottomland soil associations while groups 9 and 10 were areas of the Basin not considered suited for

⁴For further information concerning the land capability classes in the Basin see Badenhop and Thomsen (2).

agricultural production. Since the models of this study deal only with the uplands, SPG's 1 through 4 were considered as the only land areas available for agricultural production activities. A brief description of these four SPG's are given below:

SPG 1 - These soils consist generally of upland soils which have slopes that range from 2 to 5 percent. These soils were formed from loess materials and are at least three feet deep. Half of the soils have a fragipan and are moderately well drained, while the other soils in this group are considered well drained. In this group, the major soils include the Memphis, Grenada, and Loring associations.

SPG 2 - The soils in this group have a dominate slope of 5 to 8 percent but may range up to 12 percent in some areas. Generally, the soils in this group are brown silt loams. Approximately two-thirds of these soils have a fragipan and are moderately well drained, while the remaining third is considered well drained. The major soil associations in this group are Ruston, Loring, and Grenada.

SPG 3 - These soils are located on the flat and low terraces of the uplands. They are basically gray silt loams which are poorly drained. The water table is near the soil surface during the wet season. The soil series in this group includes Calloway, Center, and Hatchie.

SPG 4 - This upland soil group contains a mixture of soils formed by loess and coastal plain sediment. Most of the soils

are well drained, but a few have fragipans and are moderately well drained. With slopes varying from eight to more than 20 percent, these soils erode easily when cultivated or when not protected adequately by cover. The most prominent soils in this group are the Memphis, Loring, and Lexington-Ruston series.

The upland soil productivity groups identified by the major soil series or associations, percent slope, erosion factors, and number of acres are shown in Table 1.

The estimates of the slopes listed by soil series were taken from both field surveys and United States Geological Survey Maps by the personnel of the Soil Conservation Service. The length of slope for all estimates were set at a standardized measurement of 100 feet. The slope steepness measurements correspond directly to the "A" through "F" slope symbols in common use by the Soil Conservation Service for West Tennessee county surveys (34).

The erosion factors are used to distinguish between soils having different levels of soil erosion caused by precipitation. Erosion factors give an indication of the history of soil management practices upon specific land units. The following are definitions of the several erosion factors.

Erosion Factor 0,1 - Indicates that a minimal amount of erosion has occurred on the land unit. This factor level is usually termed slightly eroded in the sense that very little of the original top soil has been lost.

Table 1. Inventory Acreage by Soil Productivity Groups, Soil Series, Slopes, and Erosion Factors for the Uplands of the Obion-Forked Deer River Basin

SPG's	Soil Series	Slope (Percent)	Erosion Factor	Inventoried Acres
<u>SPG 1</u>	Memphis	2-5	1,2	151,461
	Memphis	2-5	3	51,027
	Memphis	5-8	1,2	15,274
	Grenada	2-5	1,2	120,646
	Loring	2-5	3	54,014
	Loring	2-5	1,2	78,392
	Lexington-Dexter	2-5	1,2	28,330
	Lexington-Dexter	2-5	3	10,496
	Lexington-Dexter	5-8	1,2	11,776
	Other SPG 1	5-8	3	56,690
<u>SPG 2</u>	Grenada	2-5	3	78,077
	Grenada	5-8	3	75,261
	Grenada	5-8	1,2	16,213
	Loring	5-8	3	51,966
	Lexington-Dexter	5-8	3	40,105
	Memphis	5-8	3	26,876
	Ruston	8-12	1,2	13,055
	Other SPG 2	8-12	1,2	116,561
<u>SPG 3</u>	Calloway, Center, Hatchie	0-2	0,1	92,922
	Calloway, Center, Hatchie	2-5	1,2	7,765
	Henry, Routon, Alamo	0-2	0,1	27,306
	Other SPG 3	2-5	1,2	11,511
<u>SPG 4</u>	Memphis	22	1,2	69,117
	Memphis	22	3	13,226
	Memphis	8-12	3	13,311
	Loring	8-12	3	49,832
	Lexington-Dexter	8-12	3	26,538
	Ruston	22	1,2	24,404
	Ruston	12-20	1,2	22,527
	Ruston	12-20	3	14,335
	Lexington-Ruston	12-20	1,2	22,612
	Lexington-Ruston	12-20	3	15,957
	Lexington-Ruston	8-12	3	13,653
	Grenada	8-12	3	15,359
	Other SPG 4	22	1,2	163,941

Erosion Factor 1,2 - Implies that erosion has progressed to the extent that ordinary tillage implements go well below the original plow layer of the land. Moderately eroded is the term used to describe this condition.

Erosion Factor 3 - Signifies a severely eroded land surface. Erosion has progressed to the point that virtually all of the original surface soil has been lost. This degree of erosion indicates that an eminent decline in production can be expected if adequate soil conservation measures are not implemented (34).

The total number of acres available for agricultural production activities in this study is approximately 101,000 acres less than the total acreage of the uplands. This difference is accounted for by SPG 9 which consist of upland areas not available for agricultural production activities. Of this total inventoried acreage, SPG 1 makes up the largest single group with 578,106 acres, or 36 percent of the area. SPG's 2 and 4 contain 418,114 and 464,812 acres, respectively, which represents 26 and 29 percent, respectively, of the upland area of the Basin. The smallest and least eroded portion, SPG 3, contains 139,504 acres, or approximately nine percent of the uplands.

Crop and Livestock Activities, Yields, and Net Returns

Considered in Model I

Crop and livestock activities considered in Model I are listed in Tables 2 and 3. These enterprises depict the production choices that

Table 2. The Agricultural Production Activities, Yields, Total Variable Costs and Returns by Soil Productivity Groups Considered in Model I for the Uplands of the Obion-Forked Deer River Basin

Agricultural Activities	SPG's	Average Yield Per Acre	Total	
			Variable Cost Per Acre	Net Return ^a Per Acre
-----dollars-----				
<u>Cotton</u>				
	SPG 1	684 lbs.	--	191.83
	SPG 2	612 lbs.	--	158.00
	SPG 3	621 lbs.	--	162.22
	SPG 4	486 lbs.	--	98.77
<u>Corn</u>				
	SPG 1	50 bu.	80.83	--
	SPG 2	42 bu.	80.83	--
	SPG 3	38 bu.	80.83	--
	SPG 4	33 bu.	80.83	--
<u>Soybeans</u>				
	SPG 1	28 bu.	--	82.80
	SPG 2	23 bu.	--	57.80
	SPG 3	19 bu.	--	37.80
	SPG 4	14 bu.	--	12.80
<u>Grain Sorghum</u>				
	SPG 1	62 bu.	69.68	--
	SPG 2	50 bu.	69.68	--
	SPG 3	38 bu.	69.68	--
	SPG 4	33 bu.	69.68	--
<u>Wheat</u>				
	SPG 1	35 bu.	74.99	--
	SPG 2	27 bu.	74.99	--
	SPG 3	23 bu.	74.99	--
	SPG 4	20 bu.	74.99	--

Table 2 (continued)

Agricultural Activities	SPG's	Average Yield Per Acre	Total		Net Return ^a Per Acre
			Variable Cost Per Acre	Cost	
-----dollars-----					
<u>Oats</u>					
	SPG 1	59 bu.	72.49	--	--
	SPG 2	50 bu.	72.49	--	--
	SPG 3	41 bu.	72.49	--	--
	SPG 4	47 bu.	72.49	--	--
<u>Barley</u>					
	SPG 1	40 bu.	--	32.30	32.30
	SPG 2	34 bu.	--	20.30	20.30
	SPG 3	29 bu.	--	10.30	10.30
	SPG 4	25 bu.	--	2.30	2.30
<u>Wheat and Soybeans Double Cropped</u>					
	SPG 1	35 bu. wheat	--	108.12	108.12
	SPG 2	24 bu. soybeans	--	66.12	66.12
	SPG 3	27 bu. wheat	--	40.12	40.12
	SPG 4	20 bu. soybeans	--	6.87	6.87
<u>Wheat and Grain Sorghum Double Cropped</u>					
	SPG 1	35 bu. wheat	--	67.73	67.73
	SPG 2	44 bu. grain sorghum	--	28.53	28.53
		27 bu. wheat	--	--	--
		36 bu. grain sorghum	--	--	--
<u>Corn Silage</u>					
	SPG 1	17.5 tons	128.20	--	--
	SPG 2	14.8 tons	128.20	--	--
	SPG 3	11.9 tons	128.20	--	--
	SPG 4	10.0 tons	128.20	--	--

Table 2 (continued)

Agricultural Activities	SPG's	Average Yield Per Acre	Total	
			Variable Cost Per Acre	Net Return ^a Per Acre
-----dollars-----				
<u>Alfalfa Hay</u>	SPG 1	3.0 tons	108.99	--
	SPG 2	2.3 tons	108.99	--
	SPG 3	2.8 tons	108.99	--
	SPG 4	2.5 tons	108.99	--
<u>Red Clover and Timothy Hay</u>	SPG 1	2.0 tons	54.63	--
	SPG 2	1.85 tons	54.63	--
	SPG 3	1.65 tons	54.63	--
	SPG 4	1.50 tons	54.63	--
<u>Lespedeza Hay</u>	SPG 1	1.80 tons	44.83	--
	SPG 2	1.60 tons	44.83	--
	SPG 3	1.30 tons	44.83	--
	SPG 4	1.00 tons	44.83	--
<u>Permanent Pasture</u>	All SPG's	No yield calculated ^a	18.96	--
<u>Temporary Pasture</u>	All SPG's	No yield calculated	43.27	--

^a No average yield was calculated on a per acre basis for the permanent and temporary pasture activities.

Sources: (34, 27)

Table 3. The Agricultural Livestock Production Activities, Unit Size, and Net Returns Considered in Both Models for the Uplands of the Obion-Forked Deer River Basin

Agricultural Activities	SPG's	Production Unit	Net Return Per Unit ^b (dollars)
<u>Large Dairy</u>	All SPG's	60 cow unit	37,456.00
<u>Farrow to Finish Hogs</u>	All SPG's	Sow and 2 litters	749.55
<u>Feeder Pigs</u>	All SPG's	Sow and 2 litters	161.90
<u>Beef Cow and Calf</u>	All SPG's	35 animal units ^a	3,841.47

^aThirty-five animal units for the best cow and calf activity are defined as follows:

30 cows = 30 animal units
 1 bull = 1 animal unit
 5 heifers = 4 animal units

^bThe livestock budgets used in estimating the net return values are given in the Appendix.

Sources: (34, 27)

have prevailed in the Basin throughout the 1960's and early 1970's (2).

The net returns and variable costs shown in Tables 2 and 3 were derived from University of Tennessee Agricultural Experiment Station farm budgets and by personal consultation with members of the field advisory committee (27, 24). These agricultural activities were broken down by specific enterprises and by SPG's. The segmentation of agricultural activities by SPG's emphasized the rationale behind the use of manageable land units in which the average production yields were equal. These yields were used primarily to calculate the gross return to each activity. The gross returns for the cropping activities were nothing more than the average crop yield times the price of the product produced. The product prices used are listed in Table 4, while the gross returns, variable costs, and net returns for the livestock production activities listed in Table 3 were taken from University of Tennessee farm budgets (see Appendix).

Total variable cost used in estimating the profitability of each activity included the direct costs involved with its production. The variable cost incurred included such items as the costs of fertilizers, insecticides, herbicides, labor and capital. The land rent was not included in the variable cost figure since land appears as a constraint in the models. The variable cost of production was assumed to be constant for all SPG's.

Given the estimated gross returns of each activity and its associated variable cost, the net returns were the simple subtraction of the two figures. This is illustrated in the following example (27).

Table 4. Product Prices by Crops of the Agricultural Activities Considered in Both Models for the Uplands of the Obion-Forked Deer River Basin

Agricultural Crops	Product Prices Per Unit ----Dollars----
Cotton	.47 lb.
Corn	2.25 bu.
Soybeans	5.00 bu.
Grain sorghum	2.15 bu.
Wheat	3.30 bu.
Oats	2.20 bu.
Barley	2.00 bu.
Alfalfa hay	55.00 ton
Red clover and Timothy hay	45.00 ton
Lespedeza hay	42.00 ton

Source: (27)

Estimated soybean yield in bushels per acre on SPG 1	=	28.0
Price per bushel	=	\$ 5.00
Gross returns per acre	=	\$140.00
Variable cost of production per acre	=	\$ 57.20
Net returns per acre	=	\$ 82.80

This example illustrates the procedure used in estimating the net return coefficients of the objective function of Model I.

The Soil Erosion Discharge Standard Implemented in Model II

Soil Erosion Discharge Standard

The soil erosion discharge standard, which sets the parameters on the amount of erosion generated on the uplands of the Basin, is set at a maximum of 10 tons per acre in this study. This level of gross soil erosion was determined to be the optimum amount by advisory committee members, by personnel of the Tennessee Water Quality Control Board of the Department of Public Health, and by University of Tennessee agronomists (24, 3, 11). The soil erosion discharge standard is instrumental in determining the appropriate set of land treatment practices in the form of crop rotational systems considered in Model II.

Universal Soil Loss Equation

A form of the universal soil loss equation was used to quantify the factors affecting soil erosion and parameters which determine the proper set of agricultural activities. This soil loss prediction equation considers the effect of all the major variables known to influence soil erosion. The universal soil loss equation is capable of making reasonably accurate predictions concerning soil erosion. The equation is normally written as follows:

$$A = R K LS CP$$

Where A is the average soil loss in tons per acre
 R is the rainfall erosion factor
 K is the soil erodability factor
 LS is the factor for length and steepness of slope
 P is the erosion control practice factor
 C is the cropping and management factor.

Some of these variables such as the rainfall erosion, soil erodability, and length and steepness of slope factors are considered constant with respect to climatic conditions, predominant soil associations, and related physical characteristics of the uplands. The R factor in the soil loss equation is the erosion potential of rainfall in a specific area. The amount, intensity, or frequency of rainfall does not directly determine the degree of erosion; however, soil losses are considered a function of each individual rainstorm's total kinetic energy and its maximum intensity (18). The relationship between the amount of energy exerted and intensity is referred to as the rainfall erosion index for each rainstorm. The average annual value of the erosion index in any specific area is the rainfall erosion factor, R, which is assumed to be an average of 270 for the uplands. This rainfall erosion index is considered the highest of any region in the state (34).

Different soil associations on the uplands erode at different rates even when other factors in the soil loss equation are constant. Soil texture, degree of coarseness, percentage of organic matter, rate of infiltration, permeability, and soil depth are some of the important physical properties of soil which influence erodibility. The soil erodibility factor, K, in the universal soil loss equation is the variable which identifies the rate of erosion for different soils (18). The K values for the various associations are shown in Table 5.

Table 5. Variable Values of the Universal Soil Loss Equation by Soil Productivity Groups and Upland Soil Series of the Obion-Forked Deer River Basin^a

SPG's	Soil Series	R Factor	K Factor	A Factor	P Factor	C Factor
<u>SPG 1</u>	Memphis	270	.37	10	.5	.38841
	Memphis	270	.37	10	.6	.16762
	Grenada	270	.43	10	.5	.33422
	Loring	270	.37	10	.5	.38841
	Lexington-Dexter	270	.37	10	.5	.38841
	Lexington-Dexter	270	.37	10	.6	.16762
	Other SPG 1	270	.37	10	.6	.16762
<u>SPG 2</u>	Grenada	270	.43	10	.5	.33422
	Grenada	270	.43	10	.6	.14462
	Loring	270	.37	10	.6	.16762
	Lexington-Dexter	270	.37	10	.6	.16762
	Memphis	270	.37	10	.6	.16762
	Ruston	270	.28	10	.6	.12556
	Other SPG 2	270	.28	10	.6	.12556
<u>SPG 3</u>	Calloway, Center, Hatchie	270	.43	10	.6	1.00454
	Calloway, Center, Hatchie	270	.43	10	.5	.33422
	Henry, Routon, Alamo	270	.43	10	.6	1.00454
	Other SPG 3	270	.43	10	.5	.33422
<u>SPG 4</u>	Memphis	270	.37	10	.9	.02711
	Memphis	270	.37	10	.6	.09502
	Loring	270	.37	10	.6	.09502
	Lexington-Dexter	270	.37	10	.6	.09502
	Ruston	270	.28	10	.9	.03582
	Ruston	270	.28	10	.9	.04094
	Lexington-Ruston	270	.37	10	.9	.03098
	Lexington-Ruston	270	.37	10	.9	.09502
	Grenada	270	.43	10	.6	.08176
	Other SPG 4	270	.37	10	.9	.02711

^aThe calculation of the values of the variables in the universal soil loss equation was accomplished through the use of a computer program within which the LS factors were figured implicitly.

Sources: (34, 18)

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of slope is generally considered to
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he uplands of the Basin were measured at
engths, only the steepness of each varied
thin the SPG's.

ce factor, P, is one variable in the soil
rectly tied to the physical properties of
the farming practices used on the land.
on practices emphasized were of a non-

structural nature, given the most common methods of cultivation on the
uplands. Therefore, the P factor values corresponding to different
contour farming techniques were assumed to be the recommended conserva-
tion practice. Contour farming simply involves crop cultivation with

the slope and is assumed to be no more costly than up and down tillage. The effectiveness of contour farming depends upon field crop row ridges which reduces the washing effects of rainfall on soil particles. The numerical value of the P factor is closely aligned with the steepness of slope since the maximum conservation effects of contour farming occur on slopes of two to seven percent. The P values which are used in Model II appear in Table 5.

The average soil loss variable, or A factor, is the unknown element when the universal soil loss equation is written in the standard form, that is, $A = R K L S C P$, but in Model II of this study the average soil loss factor, A, is specified at a maximum amount of 10 tons per acre which coincides with the soil erosion discharge standard. With the value of the A factor held constant, the universal soil loss equation is transformed into the following expression:

$$C = \frac{1/R \times A/K \times 1/LS}{P}$$

In this form of the equation, the unknown variable becomes the C factor. The cropping-management variable, or C factor, is the expected ratio of soil loss from land cropped to corresponding soil loss from land held in continuous fallow under the same type of soil, slope, and climatic conditions (18). The C factor values listed in Table 5 is an index number specifying the crop rotational systems necessary to keep expected soil losses less than or equal to the soil erosion discharge standard of 10 tons per acre. The most common cropping systems for West Tennessee combined with the appropriate C factor values have been published by the Agricultural Experiment Station of the University of Tennessee and were used in identifying the recommended crop rotational activities for Model II.

Cropping Systems, Yields, Net Returns and Constraints Considered in Model II

Cropping Systems

The agricultural production activities considered in Model II consist of cropping systems which range from continuous row crop without a winter cover crop to land in permanent meadow with a variety of combinations between these two extremes. The specific crop rotational systems were identified so as to stay within the calculated C factor values which limits the amount of erosion to the level of the soil erosion discharge standard. The length of rotational cycles varied from one to six cropping sequences. Since both Model I and Model II are static and deal with a single time period, the length of rotational cycle corresponds directly to the number of acres of available land required by the cropping systems (4). Also, because of the deterministic nature of the models, the estimated yields of the crops grown in rotation were assumed to be independent. Nevertheless, given an extended period of time, land treatment practices to reduce soil loss will tend to have a positive effect upon maintaining and even increasing the productivity of agricultural land. However, the specific length of time required and the physical properties necessary are to a large degree unquantifiable (18).

Net Return and Variable Cost

The net returns and variable costs for the agricultural production activities considered in Model II were calculated in the same manner as they were in Model I. These cost and return coefficients of the objective

function were the combined profitability of each crop grown in the rotation while the input-output coefficients used were identical to the length of the rotational sequence (4). The livestock activities for use in Model II were the same as those examined in Model I. All agricultural crop activities for Model II, including yields and net returns, are shown in Table 6 by the corresponding SPG and cropping-management factor.

Additional Constraints

The basic constraints upon land types were the same for both models. Even though the total amount of each land types available for production were identical, Model I incorporated requirements on the production levels of specific agricultural commodities. These additional requirements were identified to reflect the mixture and pattern of particular production activities present on the uplands. The supplementary production constraints were included in Model I in such a way as to produce at least so many acres of these activities. The total acreage of the additional requirements are listed in Table 7.

Model II did not include the supplemental constraints of producing at least a minimum number of acres of the crops listed in Table 7 since the second model sought to change the production alternatives accessible to farmers on the uplands. The particular pattern and amount of crops produced were dependent upon the cropping systems which limit soil losses to no more than 10 tons per acre. Nevertheless, Model II had the unique constraint of limiting total soil loss to a maximum of 16,005,360 tons from the uplands, which is the total available agricultural acreage in the uplands times the soil loss discharge standard. This total allowable

Table 6. The Agricultural Production Activities, Yields, Total Variable Cost and Returns by Soil Productivity Groups and Cropping-Management Factors Considered in Model II for the Uplands of the Obion-Forked Deer River Basin^a

Agricultural ^b Activities		Average Yield Per Activity	Total Variable Cost Per Acre	Net Returns Per Activity
SPG C			-----dollars-----	
No.	Factor			
<u>SPG 1 .38841</u>				
	SB Cont. W.C.	28.0 bu.	--	49.27
	SB-M-M	28.0 bu.	--	75.94
		3.6 tons		
	SB Cont.	28.0 bu.	--	82.80
	CN Cont.	50.0 bu.	80.83	--
	CT Cont. W.C.	684.0 lbs.	--	156.87
<u>SPG 1 .16762</u>				
	CN-CN-M-M	100.0 bu.	251.32	--
		3.6 tons		
	CRSL WH	17.5 tons	87.69	--
		35.0 bu.		
	WH Cont.	35.0 bu.	--	40.51
	CT-CN-M-M	684.0 lbs.		
		50.0 bu.	--	19.91
		3.6 tons		
	CT-M-M-M	684.0 lbs.	--	55.91
		5.4 tons		
<u>SPG 1 .33422</u>				
	WH Cont.	35.0 bu.	--	40.51
	CN Cont. W.C.	50.0 bu.	114.36	--
	CRSL Cont. W.C.	17.5 tons	161.73	--
	CT-CT-M-M	1,368.0 lbs.	--	291.14
		3.6 tons		
	SB-SB-M	56.0 bu.	--	120.77
		1.8 tons		
<u>SPG 2 .16762</u>				
	CT-M-M-M	612.0 lbs.	23.51	--
		4.8 tons		
	CRSL-WH	14.8 tons	114.09	--
	WH Cont.	27.0 bu.	--	14.11

Table 6 (continued)

Agricultural ^b Activities		Average Yield Per Activity	Total Variable Cost Per Acre	Net Returns Per Activity
SPG C			-----dollars-----	
No.	Factor			
<u>SPG 2 .16762</u>				
CT-CN-M-M		612.0 lbs.		
		42.0 bu.	12.49	--
		3.2 tons		
CN-CN-M-M		84.0 bu.	251.32	--
		3.2 tons		
<u>SPG 2 .3422</u>				
CN Cont. W.C.		42.0 bu.	114.09	--
CRSL Cont. W.C.		14.8 tons	161.73	--
CT-CT-M-M		1,224.0 lbs.	--	226.34
		3.2 tons		
SB-SB-M		46.0 bu.	--	70.77
		1.6 tons		
WH Cont.		27.0 bu.	--	14.11
<u>SPG 2 .14423</u>				
CN-M-M-M		42.0 bu.	215.32	--
		4.8 tons		
CN-M-M		42.0 bu.	170.49	--
		3.2 tons		
CT-M-M		612.0 lbs.	--	68.34
		3.2 tons		
CN-CN-M-M		84.0 bu.	251.32	--
		3.2 tons		
SB-WH-M-M		23.0 bu.		
		27.0 bu.	17.75	--
		3.2 tons		
<u>SPG 2 .12556</u>				
SB-WH-M-M		23.0 bu.		
		27.0 bu.	17.75	--
		3.2 tons		
CRSL W.C.-CRSL-M-M		29.6 tons	379.59	--
		3.2 tons		

Table 6 (continued)

Agricultural ^b Activities	Average Yield Per Activity	Total Variable Cost Per Acre	Net Returns Per Activity
		-----dollars-----	
SPG C No. Factor			
<u>SPG 2 .12556</u>			
CT-M-M	612.0 lbs. 3.2 tons	--	68.34
CN-WH-M-M	42.0 bu. 27.0 bu. 3.2 tons	156.38	--
<u>SPG 3 1.00454</u>			
CT Cont.	621.0 lbs.	--	162.22
SB Cont.	19.0 bu.	--	37.80
CN Cont.	38.0 bu.	80.83	--
CRSL Cont.	11.9 tons	128.20	--
WH Cont.	23.0 bu.	--	.91
<u>SPG 3 .33422</u>			
CN Cont. W.C.	38.0 bu.	114.36	--
CRSL Cont. W.C.	11.9 tons	161.73	--
CT-CT-M-M	1,242.0 lbs. 2.6 tons	--	234.44
SB-SB-M	38.0 bu. 1.3 tons	--	30.77
WH Cont.	23.0 bu.	--	.91
<u>SPG 4 .02711</u>			
Pasture	No yield calculated	18.96	--
Idle land	No yield calculated	18.96	--
<u>SPG 4 .09502</u>			
WH Cont. W.C.	20.0 bu.	8.99	--
CRSL-WH-M-M-M	10.0 tons 20.0 bu. 3.0 tons	271.68	--
CN-M-M-M-M	33.0 bu. 4.0 tons	260.15	--
CT-WH-M-M-M-M	486.0 lbs. 20.0 bu. 4.0 tons	87.01	--
SB-M-M-M-M	14.0 bu.	166.52	--

Table 6 (continued)

Agricultural ^b Activities		Average Yield Per Activity	Total Variable Cost Per Acre	Net Returns Per Activity
SPG C			-----dollars-----	
No.	Factor			
<u>SPG 4 .03582</u>				
Pasture		No yield calculated	18.96	--
<u>SPG 4 .04094</u>				
CN-WH-M-M-M-M		33.0 bu.		
		20.0 bu.	296.14	--
		4.0 tons		
WH-M-M-M		20.0 bu.	143.48	--
		3.0 tons		
Pasture		No yield calculated	18.96	--
<u>SPG 4 .08176</u>				
CN-WH-M-M		33.0 bu.		
		20.0 bu.	179.48	--
		2.0 tons		
CRSL-WH-M		10.0 tons		
		20.0 bu.	182.02	--
		1.0 tons		
CT-WH-M-M-M-M		486.0 lbs.		
		20.0 bu.	87.01	--
		4.0 tons		
WH-M-M		20.0 bu.	98.65	--
		2.0 tons		
SB-WH-M-M		14.0 bu.		
		20.0 bu.	85.85	--
		2.0 tons		

^aThe interpretation of the abbreviations for the various agricultural activities are as follows: CT = cotton; SB = soybean; CN = corn; W.C. = winter cover crop (oats); WH = wheat; Cont. = continuously cropped; CRSL = corn silage; M = Lespedeza Meadow (for hay).

^bIdentical livestock production activities were considered in Model I and Model II as were listed in Table 3.

Sources: (34, 24, 3, 18)

Table 7. Acreage of Major Crops by Soil Productivity Groups Grown on the Uplands of the Obion-Forked Deer River Basin

Major Crops	SPG 1	SPG 2	SPG 3	SPG 4
	-----Acres-----			
Soybeans	79,975	60,096	46,400	28,734
Corn	47,985	32,194	15,464	7,184
Cotton	121,563	64,388	20,619	7,184
Grain Sorghum	22,393	15,024	10,310	--
Wheat	15,995	10,731	--	7,184
Lespedeza Hay	15,995	21,463	--	43,107

Source: (32)

amount of soil loss represents an estimated minimum reduction of
7,000,000 tons of soil annually lost from the uplands of the Basin (34).

CHAPTER IV

RESULTS

Analysis of the Optimal Solution of Model I

Agricultural Activities in the Optimal Solution of Model I

Given the current cropping patterns and the amount of available land as constraints upon Model I, the maximum potential agricultural income for the uplands was estimated at approximately \$186.3 million. The set of agricultural activities which were found to be the most profitable are in Table 8. To maximize income on the uplands, approximately 395.8, 278.6, 67.3, and 378.5 thousand acres of cotton would be produced, respectively, on SPG 1 through SPG 4. The second most profitable crop production activity was soybeans with 80 thousand acres produced on SPG 1, 60.1 thousand acres produced on SPG 2, 46.4 thousand acres produced on SPG 3, and 28.7 thousand acres produced on SPG 4. The only livestock activity in the optimal production plan was the farrow to finish hog enterprise which produced 500 units. The selling activities of agricultural commodities, which could have been used in the production of livestock, were very active with the selling of approximately 4.5 million bushels of corn, 2.5 million bushels of grain sorghum, 933 thousand bushels of wheat, and nearly 107 thousand tons of lespedeza hay from the uplands.

The overall production plan generated in Model I was composed basically of various crop production activities and one livestock enterprise. Primarily, the solution of Model I revolved around the production of row and hay crops which were sold as outputs and not used as inputs in

Table 8. Agricultural Activities Identified by SPG's, and Total Production Which Entered the Solution of Model I for the Uplands of the Obion-Forked Deer River Basin

Agricultural Activity	SPG 1	SPG 2	SPG 3	SPG 4	Total	Units
Cotton	395,763	278,606	67,330	378,514	1,120,213	acres
Corn	47,985	32,194	15,464	7,184	102,827	acres
Soybeans	79,975	60,096	46,400	28,738	215,209	acres
Grain sorghum	22,393	15,024	10,310	--	47,727	acres
Wheat	15,995	10,731	--	7,184	33,910	acres
Lespedeza hay	15,995	21,463	--	43,107	80,565	acres
Permanent pasture	--	--	--	85	85	acres
Farrow to finish hogs	--	--	--	--	500	sow and 2 litters
Selling corn	--	--	--	--	4,484,052	bushels
Selling grain sorghum	--	--	--	--	2,531,346	bushels
Selling wheat	--	--	--	--	993,242	bushels
Selling lespedeza hay	--	--	--	--	106,718.65	tons

other production activities. With the exception of cotton, the other crops of soybeans, grain sorghum, wheat, corn, and lespedeza hay were produced at their current production levels. Consequently, cotton produced on the SPG's under the restrictions of Model I was determined to be the most profitable crop production activity.

Sensitivity of the Agricultural Activities in Model I

By varying the required crop production constraints on Model I, an indication of the relative stability of the solutions to changing cropping patterns was obtained. Under the costs and returns used in this study, if the required production constraints were increased to produce more acres of corn, soybeans, grain sorghum, wheat, and lespedeza hay, the total net return to the uplands would decrease. On the other hand, if the required production levels were decreased, the corresponding released land units would be transferred into the production of cotton on the SPG's with an increase in the total net return to the uplands. However, the possibility of positive aggregation bias would also increase, giving less resemblance to the actual production patterns of the area.⁵

⁵Positive aggregation bias is simply an over estimation of the value of the objective function when effective and often unquantifiable constraints are underestimated in a linear programming problem. By aggregating to only land resource restrictions, the actual number of constraints is reduced. Such a reduction removes to some extent the limitations on the freedom of action which can be taken by the decision-maker. This aggregation of restrictions probably increases profit above the actual income potential of the area. Conversely, in an effort to normalize and simulate the actual production patterns, other constraints are added which limit production activities to a required level and, thereby, removes to some extent the alternative means of profit making. This adjustment for positive aggregation bias reduces the amount of potential profit to a normalized or more realistic level (14).

Analysis of the Optimal Solution of Model II

Agricultural Activities on the Optimal Solution of Model II

The agricultural production activities considered in Model II were established to meet the soil erosion discharge standard. As previously described, these production activities were in the form of crop rotational systems which were identified by both SPG and the corresponding cropping-management factor. The incorporation of the crop rotational systems in the model explicitly reduced the number and variety of production possibilities available to the farmers on the uplands when compared to the first model. Consequently, by reducing the production alternatives available to the decision-maker (farmer), it was expected that total net returns to the uplands of the Basin would likewise be diminished. This expectation was realized when the optimal solution of Model II calculated potential total net return from agriculture on the uplands to be an estimated \$144.5 million.

The production patterns for SPG 1 and SPG 3 given in the solution of Model II basically consist of the production of cotton either grown continuously or in rotation with a corn and/or meadow crop. Agricultural production on SPG 2 also centered around the production of cotton grown in rotation with meadow but some corn and wheat was also produced. A major portion of the land area in SPG 4 was put into permanent meadow and used either in the production of livestock or left idle. However, cotton, wheat, and soybeans in long rotations with meadow was also produced on SPG 4. The hay produced, when meadow was included in the crop rotational systems with row crops, amounted to 648 thousand tons which was sold at \$42 per ton. Likewise, corn produced on the SPG's went into

the production of farrow to finish hogs and the production of feeder pigs which required the additional purchase of approximately 20 million bushels of corn as seen in Table 9.

Sensitivity of the Agricultural Activities in Model II

The SOILLOSS agricultural constraint in Table 10 is the only agricultural restriction in the production plan of Model II at less than its maximum level. The SOILLOSS constraint entered the solution at a level of 10.2 million tons, which is below the maximum allowable level of 16 million tons, leaving 5.8 million tons of soil erosion not produced by the production plan of Model II. Consequently, the amount of soil loss did not reach the maximum limit of 10 tons per acre but approximately 6.4 tons per acre of soil was eroded from the uplands.

The values seen in Table 10 imply that if SOILLOSS decreased to 10.0 million tons (lower activity value), the agricultural constraint SPG-3-.095 would be forced to re-enter the production plan of Model II with 103.3 thousand acres. Conversely, if SOILLOSS increased above 11.1 million tons (upper activity value) on the uplands, WH Cont. SPG-4 (wheat continuously produced on SPG 4) would enter the solution with one acre produced. Nevertheless, the optimal value of soil erosion was determined to be 10.2 million tons; and if deviated above or below this amount, the total net return to the uplands would decrease by \$.15 and \$1.16 (unit cost values) per ton, respectively. In other words, under the agricultural production plan generated in Model II it would cost the uplands \$1.11 more per ton in agricultural income foregone to increase erosion through agricultural production practices than to decrease soil loss.

Table 9. Agricultural Activities Identified by SPG's and C Factors Which Entered the Solution of Model II for the Uplands of the Obion-Forked Deer River Basin

Agricultural ^a Activities		Activity ^b Level	Units
SPG No.	C Factor		
<u>SPG 1</u>	<u>.38841</u>		
CT Cont. W.C.		373,720	1-acre
<u>SPG 1</u>	<u>.16762</u>		
CT-CN-M-M		20,935	4-acre
<u>SPG 1</u>	<u>.33422</u>		
CT-CT-M-M		30,161.5	4-acre
<u>SPG 2</u>	<u>.16762</u>		
CT-CN-M-M		29,736.75	4-acre
<u>SPG 2</u>	<u>.33422</u>		
CT-CT-M-M		19,519.25	4-acre
<u>SPG 2</u>	<u>.14423</u>		
CN-M-M-M		22,868.5	4-acre
<u>SPG 2</u>	<u>.12556</u>		
CN-WH-M-M		32,404	4-acre
<u>SPG 3</u>	<u>1.00454</u>		
CT Cont.		120,228	1-acre
<u>SPG 3</u>	<u>.33422</u>		
CT-CT-M-M		4,819	4-acre
<u>SPG 4</u>	<u>.02711</u>		
IDLELAND		246,284	1-acre
<u>SPG 4</u>	<u>.09502</u>		
SB-M-M-M-M		20,666.8	5-acre

Table 9 (continued)

Agricultural ^a Activities		Activity ^b Level	Units
SPG No.	C Factor		
<u>SPG 4</u>	<u>.03582</u>		
PERPAST		62,973	1-acre
<u>SPG 4</u>	<u>.04094</u>		
PERPAST		36,862	1-acre
<u>SPG 4</u>	<u>.08176</u>		
CT-WH-M-M-M-M		2,559.83	6-acre
<u>All SPG's and C Factors</u>			
FARFIN		500	sow and 2 litters
FEEDPIG		586,764.71	sow and 2 litters
Buying corn		20,353,735.03	bushels
Selling hay		648,176.93	tons

^aThe interpretation of the abbreviations for the various agricultural activities are as follows: CT = cotton; SB = soybean; CN = corn; W.C. = winter cover crop (oats); WH = wheat; Cont. = continuously cropped; M = lespedeza meadow (for hay); PERPAST = permanent pasture; IDLELAND = permanent meadow; FARFIN = farrow to finish hogs; FEEDPIG = feeder pigs.

^bCaution must be taken in interpreting the levels of activities entered in the solution of Model II. The units of the values listed correspond directly to the length of the rotational cycle of each individual cropping system. For instance, CT-CN-M-M-SPG 1 is a cropping system with a cycle length of four seasons which means that it requires four acres of land to produce the whole activity in one season. Therefore, CT-CN-M-M-SPG 1 entered the production plan at a level of 20,935 4-acre units or 83,740 acres (4 times 20,935).

Table 10. The Soil Loss Production Constraint Which Entered the Solution at a Level Less Than the Maximum Amount Identified by Activity Level, Erosion Not Produced, Maximum Allowable Erosion, Lower Activity, Upper Activity, Unit Cost, Entering Process, and Entering Process Level Values in Model II for the Uplands of the Obion-Forked Deer River Basin

Agricultural Constraint	Activity Level	Erosion Not Produced	Maximum Allowable Erosion	Unit ^b Cost (Dollars)		Entering Process	Entering Process Level
				Upper Activity ^a	Lower Activity		
				-----Tons-----			
SOILLOSS	10,237,377	5,767,983	16,005,360	10,030,709.13	-.15	SPG-4-.095	103,334
				11,064,047.38	-1.16	WH-SPG-4	1

^aIf the level of SOILLOSS varies above or below the lower or upper activity levels, the constraint or activity in the "Entering Process" column would enter the solution.

^bThe "Unit Cost" column identifies the values by which the total net return to the uplands will decrease for each acre deviation above or below the optimum level listed in the "Activity Level" column.

Since the land type production constraints, identified by SPG and C factor, were the only restrictions on Model II that were fully utilized, a variation in the available levels of the constraints are quite limited in economic meaning. However, an important implication was discovered when the levels of availability were increased. In general, a relatively large increase in the amount of land was required before the SOILLOSS restriction would reach its maximum of 16 million tons of soil erosion. This implies that to achieve the maximum total allowable soil loss level, given the current optimal set of production activities, the total land area of the uplands would have to increase which is a physical impossibility. Conversely, the amount of available land for agricultural production would have to decrease to zero acres available before the optimal set of production activities would be replaced by the other enterprises which were not as profitable as the activities in production plan of Model II.

In conclusion, the optimal production plan generated to control soil erosion on the uplands is relatively more stable with respect to changes in the production constraints when compared to the production organization of Model I. This stability implies that the degree of substitutability of the cropping systems under the restrictions of Model II is less than where erosion control was disregarded in Model I. Therefore, this analysis gives a brief comparison of the sensitivity of the optimal solutions of Models I and II to changes in the production constraints upon the agricultural activities recommended for the uplands of the Obion-Forked Deer River Basin.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study began with the introduction of the problem investigated. The major focus was on the management of land and water resources by adjusting agricultural production practices with emphasis on reducing the production of soil erosion and maintaining soil productivity potentials. Water, a common property natural resource, was the environmental medium transporting discharges of the residual (eroded soil) generated from intensive crop production practices on the uplands and displacing sediment on the bottomland areas of the Basin. The maximum potential agricultural income was calculated without regard to gross soil erosion under typical production patterns. Then, crop rotational systems were established to meet a per acre soil erosion discharge standard of 10 tons per acre. These cropping systems were entered explicitly into a linear programming framework which recalculated maximum potential agricultural income to the uplands subject to the new cropping systems and the maximum allowable soil loss standard.

Main Findings

The general objective of this study was to determine the effect of water and land-use management practices on total agricultural income on the uplands of the Obion-Forked Deer River Basin. Specifically, this involved: 1) an estimation of the maximum potential agricultural income on the uplands given the current cropping patterns and the existing soil and water management practices; 2) the establishment of effective crop rotational systems on the uplands to meet the soil erosion discharge

standard; and 3) the evaluation of the crop rotational systems in the uplands on the net returns to agricultural production with an estimate of the opportunity cost involved with the implementation of these systems.

These specific objectives were met in the study. Consequently, the maximum potential agricultural income under current production patterns in Model I was estimated to be \$186.3 million. The agricultural production organization generated stressed the production of cotton on the four SPG's of the uplands with the farrow to finish hog activity being the only livestock enterprise which entered the optimal solution. Under the second objective, the universal soil loss equation was utilized in establishing the recommended crop rotational systems necessary to meet the soil erosion discharge standard. These cropping systems ranged in intensity from continuous cropping without a winter cover crop to continuous permanent meadow with a variety of rotational mixtures in between the extremes. The recommended cropping systems were entered into the second model of the study and the subsequent recalculation of potential agricultural income was estimated to be \$144.5 million. The optimal production organization generated emphasized the production of cotton in rotation with corn, wheat, and meadow (hay) crops for SPG's 1 through 3, while the majority of the land area in SPG 4 went into permanent pasture and idle land.

With the evaluation of the optimal solutions of Model I and Model II, it is realized that an estimate of the opportunity cost involved with the implementation of the recommended crop rotational systems can be obtained. The estimated opportunity cost is the mathematical difference between the maximum potential agricultural incomes calculated in

Model I and Model II. Consequently, the estimated opportunity cost in terms of agricultural income foregone with the implementation of recommended cropping systems is determined to be \$41.8 million. This approximate \$42 million loss in potential agricultural income must be considered the minimum cost involved with such an agricultural production change. Since the study did not incorporate labor or capital restrictions upon the models and because the effects upon individual farms were not analyzed, the \$42 million estimate is the least amount that can be expected to be lost from potential agricultural income on the uplands of the Basin if soil loss is restricted to a maximum of 10 tons per acre.

Policy Implications

The major policy implication for decision-makers seeking to implement a plan to control agricultural erosion on the uplands must involve the opportunity cost of such a program, as well as the benefits achieved downstream. If the cost involved in terms of agricultural income foregone is greater than the benefits achieved, then the net economic advantages to the region are not realized. Conversely, if the expected benefits outweigh the cost involved, net economic advantages are achieved and a means of implementation is in order.

The traditional economic incentives to achieve policy implementation must involve either the taxation or subsidization of the upland farmers in an effort to obtain adoption of the recommended cropping practices. A scheme of subsidization would provide an incentive for the farmers to withhold sediment production by adjusting cropping practices. The upland farmers could be subsidized by the amount of the opportunity cost involved with the change in agricultural production plans. The

allocation of the subsidy payments could be proportional to the income foregone by changing production practices on each SPG. On the other hand, a plan of taxation would assess upland farmers by the amount of damages incurred by society downstream which are attributed to soil erosion and sedimentation. The level of taxation would be based upon the inherent erosiveness of the soils in the uplands. However, such a program of subsidization or taxation would require detailed estimates of the benefits gained downstream from the controlled production of sediment and annual physical data concerning the amounts, origins, and points of sedimentation in the Basin.

Advantages and Limitations of the Results

The first major advantage of the programmed solutions of the models in this study lies in the fact that the solutions are optimal, i.e., the maximum that the net return value can take under the given set of restrictions. To this extent the results are better than any set of suboptimal solutions arrived at by any conventional budgeting method. Secondly, the models are amenable to welfare theory by way of the common property resource approach and marginal analysis conclusions, although a heavy reliance is placed on the soil erosion discharge standard value. Thirdly, the model contributes to matters of policy making for government officials. The greatest usefulness comes from the opportunity cost value generated as a result of the models. In this respect, the models demonstrate their advantages by providing a clear, specific, and systematic way of arriving at a recommended agricultural production plan to control soil erosion on the uplands of the Basin.

There is one aspect of the results which is not considered in the study. This aspect refers to the implementation of the results to different individual farms in the uplands. It is likely that some farms may be required to incorporate only low profit crops under the programmed solution of Model II. This is dependent upon the soil type, slope, and location of the farms within the Basin. However, the utilization of the representative farm approach would be more applicable to the problems of individual farms than the regional nature of the common property resource management approach used in this study. Also, a revision of the models to include additional tillage systems and structural techniques to control erosion would make the models more versatile. Conversely, the strength of the type of analysis used in this study lies in the optimal specification of the relationship between the potential agricultural income of a region and the control of gross soil erosion through the use of crop rotational systems.

Suggestions for Future Research

Changes in Conservation Practices

In this study the production plan of the linear programming solution to Model II assumed the use of contour farming techniques to decrease soil erosion. The possible changes in the conservation system could incorporate the establishment of sediment retention structures and terracing. These two systems are helpful in reducing gross erosion and subsequent sedimentation. At the same time, there will be some extra cost incurred in terms of construction and maintenance of these soil conservation structures. Some portion of the land which goes under these

structures will also become unavailable for cultivation. The following modifications in the model will be required:

1. Changes in net return values for crop sequences to account for the cost of constructing and maintaining sediment retention and terrace structures.
2. Changes in the erosion coefficients to account for the slope length factor, LS, and the conservation practice factor, P, values of the universal soil loss equation.
3. The introduction of fixed areas into the model with a single cropping sequence to represent the area under terraces which are usually cropped with forages noted for their soil holding characteristics.

The upland areas of the Basin could then be reprogrammed to arrive at an optimal net return value and set of agricultural activities.

Changes in Tillage Operations

This study assumed standard conventional tillage operations as carried out by the farmers in the area. Research has shown that tillage operations and losses of organic matter account for much of the destruction and breakdown of natural soil structure. Minimum tillage cultivation helps reduce soil destruction and retards the process of erosion. Minimum tillage is defined as the least amount of tillage necessary to result in quick seed germination, good crop stands, and satisfactory yields. Planting should be accomplished at the time of plowing or immediately thereafter. The loose soil bed achieved with minimum tillage results in less soil erosion. The methods used under minimum tillage are: 1) plow plant--which involves plowing on the contour with furrows lined with the

slope and planting inside the tractor wheel tracks so that there is minimum compaction between plowing and planting; and 2) chisel plowing--which involves chisel plowing, disking, and planting (8).

Under minimum tillage, adjustments would be needed with respect to the crop management factor, C, and cost of crop production. The C factor would have to be changed to reflect the reduction in field operations. With respect to cost, there would be some reduction in cost due to less field operation, but the reduction would probably be offset by the increased use of herbicides.

With reference to the economic analysis of a minimum tillage system to control soil erosion, the linear programming model could be set up to: 1) maximize net returns for the three cultivation methods of conventional, plow plant, and chisel plowing separately, thereby calculating agricultural income three times and comparing the results; or 2) incorporate and analyze the three cultivation methods in one linear programming model.

In conclusion, future research dealing with the problems of water and land-use management will be required before adequate policy decisions can be made in an attempt to abate the current situation of soil erosion and sedimentation. There is a definite need for a coordinated interdisciplinary research effort to establish, estimate, and analyze all facets of the highly complex series of physical, biological, and economic systems at work in the Obion-Forked Deer River Basin.

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APPENDIX

Budget

BEEF COW AND CALF FED HAY OVER WINTER

Estimated Returns and Expenses^a (30 Cow Herd-35 Animal Units)

Item	Description	Unit	Quant.	Price (Dollars)	Amount (Dollars)
REVENUE					
Feeder calves	485 lbs. grading good or better	cwt.	106.7	\$37.75	\$4,027.92
Cull cows	900 lbs. utility, 5 hd.	cwt.	45.0	27.00	1,215.00
TOTAL					\$5,242.92
EXPENSES					
Direct					
Min. & salt		an.un.	35	1.25	43.75
Vet. & medicine		an.un.	35	3.50	122.50
Mktg. & auction fees		head	27	3.50	94.50
Trucking		head	27	1.00	27.00
Tractor	38 PTO-HP	hour	40	1.13	45.20
TOTAL Direct Expenses					\$332.95
Interest					
Cow and replacements	\$432 at 7½%	head	30	\$32.40	\$972.00
Buildings	1/2 of \$70 at 7½%	head	30	2.63	78.90
TOTAL Interest					\$1,050.90

Labor	hour	8.8	\$2.00	\$	17.60
Net Return to Land and Management					\$3,841.47

^aThe budget was adjusted not to charge an explicit cost to feed stuffs in the forms of hay, pasture, corn, or corn silage since the cost of production is accounted for within the production activity of each of the feed stuffs in the models.

Source: (27)

Budget

FARROW-TO-FINISH

Estimated Returns and Expenses for Sow and
Two Litters of Pigs^a
(24-Sow Units)

Item	Description	Unit	Quant.	Price (Dollars)	Amount (Dollars)
REVENUE					
Market hogs	15.5 @ 230 lbs.	cwt.	35.65	\$32.00	\$1,140.80
Cull sow	.5 of a sow	cwt.	2.25	27.00	60.75
Death loss	1½% of \$22 x 16				(5.28)
TOTAL					\$1,196.27
EXPENSES					
Direct					
Supplement	Soybean meal + premix	cwt.	25.03	8.06	201.74
Creep feed	50 lb. per pig	cwt.	8.0	10.00	80.00
Vet. & medicine		head	1	18.00	18.00
Electricity		head	1	5.00	5.00
Grind & Mix	Owned mach., includ. tractor	cwt.	128.1	.15	19.22
Truck	Slaughter hogs	head.	16	1.25	20.00
TOTAL Direct Expenses					\$343.96

INTEREST				
Sow & boar replacement	\$127 @ 9%	sow	1	\$11.43
Bldgs. & equip.	$\frac{1}{2}$ of \$12,374 @ 7 $\frac{1}{2}$ %	sow	1	<u>19.33</u>
				\$30.76
TOTAL Interest				
LABOR				
		hour	36	\$2.00
				\$72.00
Net Return to Land and Management				
				\$749.55

^aThe budget was adjusted not to charge an explicit cost to feed stuffs in the forms of hay, pasture, corn, or corn silage since the cost of production is accounted for within the production activity of each of the feed stuffs in the models.

Source: (27)

Budget

FEEDER PIGS

Estimated Returns and Expenses for Sow and Two Litters of Pigs^a
(20-Sow Unit)

Item	Description	Unit	Quant.	Price (Dollars)	Amount (Dollars)
REVENUE					
Feeder pigs	Grade 1-2, Wt. 45 lbs.	head	15.5	\$22.00	\$341.00
Cull sow	.5 of a sow	cwt.	2.25	27.00	60.75
TOTAL					\$401.75
EXPENSES					
Direct					
Supplement	Sow & boar replacement	cwt.	5.7	10.00	57.00
Creep feed	50 lb. per pig	cwt.	8.0	10.00	80.00
Marketing pigs		head	15.5	.75	11.63
Marketing sows		head	.5	1.25	.63
Vet. & medicine		head	1	10.00	10.00
Grind & mix		cwt.	23.74	.40	9.50
Electricity		sow	1	5.00	5.00
Truck	Feeder pigs	head	15.5	.25	3.88
Tractor	38 PTO - H.P.	hour	.25	1.13	.28
TOTAL Direct Expenses					\$177.92

Interest				
Livestock	\$127 @ 7½%	sow	1	\$ 9.53
Bldgs. & equip.	1/2 of 224 @ 7½%	sow	1	8.40
TOTAL Interest				\$17.93
Labor				
		hour	22	\$ 44.00
Net Return to Land and Management				\$161.90

^aThe budget was adjusted not to charge an explicit cost to feed stuffs in the forms of hay, pasture, corn, or corn silage since the cost of production is accounted for within the production activity of each of the feed stuffs in the models.

Source: (27)

Budget

DAIRY

GRADE A, LARGE BREEDS, 1,250 POUND COWS

Estimated Returns and Expenses--5 Months Pasture^a
60 Cow Unit--13,000 Pounds of 3.7% Milk Per Cow

Item	Description	Unit	Quant.	Price (Dollars)	Amount (Dollars)
REVENUE					
Milk	13,000 lb./cow	cwt.	7,800	\$ 8.66	\$67,548
Calves	2-3 days old	head	40	40.00	1,600
Cows - cull	25% cull rate - 1,250 lb. cow	head	14	337.50	4,725
Non-bred heifers	Yearlings	head	2	245.00	490
TOTAL					\$74,363

EXPENSES

Direct	2.2 T. 16% concentrate				
Dairy feed	per cow + 500 lb. per heifer	ton	140	\$110.00	\$15,400
Salt		cwt.	9	3.00	27
Bone Meal		cwt.	18	20.00	360
Milk replacer		cwt.	7.5	34.00	255
Calf starter		cwt.	27	9.00	243
Breeding fees	Artificial	head	72	9.00	648
DHIA		head	60	7.60	456
Dues	Association & ADA	cwt.	7,800	.35	2,730
Milk hauling		cwt.	7,800	.35	2,730
Vet. & medicine	Includes replacement stock head	head	60	6.00	360

Dairy supplies				
Bedding	Sawdust - includes replacement stock	head	60	4.00
				240
Electricity		head	60	7.00
Marketing fees	14 cows - 42 calves	kwh	15,000	.02
Trucking fees	14 cows - 42 calves			420
Tractor	38 PTO - H.P.			300
		hour	450	1.13
				60
				508
TOTAL Direct Expenses				\$24,838

Interest				
Livestock	706 @ 7½%	head	60	\$52.95
Bldgs. & equip.	1/2 of 748 @ 7½%	head	60	28.05
				\$ 3,177
				1,683
TOTAL Interest				\$ 4,860
Labor	60 hrs./cow	hour	3,600	\$2.00
				\$ 7,200
Net Return to Land and Management				\$37,465

^aThe budget was adjusted not to charge an explicit cost to feed stuffs in the forms of hay, pasture, corn, or corn silage since the cost of production is accounted for within the production activity of each of the feed stuffs in the models.

Source: (27)

VITA

Rodney Mack Thomsen was born in Jackson, Tennessee, on October 8, 1949. He attended Madison County Schools and graduated from North Side High School in May 1967. The following September he entered the University of Tennessee at Martin, and in June 1971, he received a Bachelor of Science degree in Agricultural Education. The following September he accepted a National Defense Education Act Fellowship at the University of Tennessee, Knoxville, and began working toward a Master's degree. He received the Master of Science degree with a major in Agricultural Economics in August of 1973 and the Doctor of Philosophy degree in August of 1975.

He is married to the former Rosiland Riddell of Jackson, Tennessee.