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Linear Programming

Purpose of This Technical Note

Land and water resource problems in some of the on-going and future water resource studies are of such complexity that linear programming would be an appropriate tool for analysis.

The purpose of this technical note is to facilitate the understanding of LP models by explaining assumptions underlying them and their limitations. Only when the foregoing are understood can it be determined whether LP is an appropriate tool to analyze the particular problem being considered. The information in this note will provide a basic guide for SCS personnel who have an opportunity to use LP.

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Linear programming is a mathematical technique for determining the most desirable or most profitable course of action for a situation where a number of variables are involved, where many possible courses of action are available, and where the problem can be expressed in linear terms (Howell and et al). In natural resource planning, linear programming is used to allocate resources or inputs (such as land, water, fertilizer, conservation treatments, etc.) to obtain a particular objective (such as producing crops or minimizing erosion when there are many alternative uses for the resources. LP is a tool that permits an evaluation of proposed land and water conservation practices relative to producer net income and agricultural production effect, soil erosion, and expected benefits and costs (Lacewell and Hardin).

One using linear programming makes a series of assumptions related to the "linear assumptions" of the technique. The following six assumptions have to be reckoned with in formulating an LP Model.

(1) Linearity of the Objective and Constraining Functions -- This assumption requires that all functional relationships be linear. This means that the level of a particular activity can have no influence on the weight associated with it in the objective function or on the amount of resources used in the constraining equations. Thus, each activity is assumed to exhibit constant returns to scale.

(2) Divisibility of resources and decision variables -- This assumption means that resources may be used in fractional quantities and that activities might have noninteger values. For example, .2368 hours of labor could be used to produce 1.3569 bushels of corn. If integer values are required for the activities then either integer programming or specific constraints which place strict bounds on the variables must be used.

(3) Additivity of resources -- This assumption means that the sum of the resources used by each activity must equal the total quantity of resources used. In other words, variables cannot interact to jointly use less of a resource than would be the case without interaction. Careful construction of decision variables, can however, permit such real-world interactions to be included in a linear programming model.

(4) Proportionality of decision variables to constraining variables -- This means that there is a linear relationship between the activity and constraining variables. If the amount of resources is doubled, then the values of activities will also double. This assumption means that each decision variable-constraint variable relationship displays constant resource productivity and constant returns to scale.

(5) Nonnegativity of the activities -- All activities must be either zero or positive. It is impossible to have a negative value for an activity.

(6) Single valued expectations -- All values within the linear programming matrix are known with certainty. There are no random variables or any probabilistic properties associated with the matrix coefficients.

LP represents the supply functions for the several products, of the system being modeled, with a set of linear equations relating inputs of resources and factors to output. Relationships between inputs and products represented in the equations are not expected to change through the period of analysis. Typically, prices are assumed to be fixed at current levels for the period of analysis.

The purpose of the LP model is to achieve a prescribed objective, within established resource constraints or limits, with the most economically efficient combination of inputs. The objective desired determines the specification of the objective function. A profit maximizing objective function will organize inputs in a way such that the highest possible profit can be achieved within the resource constraints.

A profit maximization model has the advantage that production levels of crops are not specified externally to the model. Rather production levels are determined within the model based on maximizing profits within the specified constraints. As the area under consideration becomes smaller, it is a more desirable analytical tool than cost minimization for making analyses of alternative development proposals because farmers in small areas do not face a fixed quantity demanded. This approach assumes that development will not be of sufficient magnitude to influence product prices.

A cost minimizing objective function on the other hand selects alternative input combinations to achieve preselected output levels within the resource constraints at minimum costs. This approach assumes that overall production is not impacted by resource conservation and development. Since overall production specified in the "without" and "with" development alternatives is the same, the economic impact is measured by the change in the cost of production and by shifts in production among subareas. Conversions of land from cropland to other uses and the reverse are sometimes considered.

Resource development projects and conservation alternatives affect the basic input-product equations and/or the level of resources available. Changes resulting from project action or program modification are reflected in changes in costs associated with production or in resource constraints within the models.

Linear Program Matrix

The alternative activities and resource constraints of a LP are tailored for each specific application within a matrix structure. To understand this basic structure, the matrix of a very simple LP will be examined (Table 1).

A linear program describes a system of simultaneous equations which is overidentified (i.e., the system has large number of solutions). On the left hand side (LHS) of the equations are recorded the amounts of resources used, the amounts of products resulting for each combination of resources, and the cost of producing the products.

Each of the values on the right hand side (RHS) shows the total amounts of a resource available for use, the total amount of a resource used, the total amount of a crop produced, or the total cost of producing all products.

Each column in the production activity section of the matrix represents an "activity." All resources and products of interest associated with that activity are recorded in that column. For example, activity A1 in Table 1 is an irrigated corn-wheat rotation which would use the following resources: one acre of soil of quality SOIL1, w1 cm of irrigation water, h1 hours of labor, f1 lbs of fertilizer, j1 gallons of fuel, plus unrecorded quantities of other resources not of immediate interest. This specific combination of resources would produce y1c lbs of corn, y1w lbs of wheat, e1 tons of soil erosion, plus unrecorded quantities of other products and by-products not of immediate interest.

Any resource or product associated with activity A1 for which one has the proper data can be recorded and monitored in this manner. This example is set up to manage three soil qualities and three crops (corn, wheat, and hay). Activities A1 and A4 are corn-wheat rotations with A1 being irrigated on SOIL1 and A4 being a dry land rotation on SOIL2. SOIL1 and SOIL2 can grow any one of three rotations (corn-wheat, wheat-hay, or continuous hay) while SOIL3 is permitted to grow only continuous hay. Specifically, the activity code "1" is positioned in the crop column(s) and soil row(s) to allow the model to allocate needed acres of the soil to the crop. Even though SOIL1 is irrigable, the continuous hay rotation (A3) is dry farmed as shown by the blank in the irrigation row.

Each of the seven activities produces a different level of soil erosion (e1 to e7) and requires different levels of labor, fertilizer, and energy. Activities can be specified into various levels of detail. Since erosion is affected by location, tillage,

TABLE 1: EXAMPLE OF LINEAR PROGRAMMING MATRIX
DESIGNED FOR EROSION ANALYSIS

COLUMN NAME		PRODUCTION ACTIVITIES								RHS
ROW NAME	UNIT	A1	A2	A3	A4	A5	A6	A7		
		PA, T, C, I*								
Objective	$/ac	$A1	$A2	$A3	$A4	$A5	$A6	$A7	=	Total Cost
Land	ac									Land Inventory
SOIL1		1	1	1					=	ac SOIL1 Irrigated
SOIL2					1	1	1		=	ac SOIL2
SOIL3								1	=	ac SOIL3
Commodity										
Corn	bu/ac	y1c			y4c				=	Corn Demand
Wheat	bu/ac	y1w	y2w		y4w	y5w			=	Wheat Demand
Hay	t/ac		y2h	y3h		y5h	y6h	y7h	=	Hay Demand
Erosion	t/ac	e1	e2	e3	e4	e5	e6	e7		Total Erosion (0)
Irrigation	cm/ac	w1	w2						=	Irr. Water in PA
Labor	hr/ac	h1	h2	h3	h4	h5	h6	h7		Total Labor (0)
Fertilizer	lb/ac	f1	f2	f3	f4	f5				Total Fertilizer (0)
All Fuel	gallons	j1	j2	j3	j4	j5	j6	j7		Total gallons in PA (0)

*PA = Producing area
C = Conservation Practice
T = Tillage
I = Irrigation

and conservation practices, specification by these categories is important. Therefore, one would repeat the relevant activities for each geographic producing area (PA), tillage practice (T) (e.g., fall plow, spring plow, conservation tillage, or zero tillage), and conservation practice (e.g., straight row, contouring, strip cropping, or terracing). Each geographic producing area will, of course, have different soils and climates and, therefore, different yields and by-products. Of necessity, new land rows must be added to the matrix to accommodate each geographic area. In the land section each row represents one type of land with the total acres of land in the producing area recorded on the right hand side (RHS).

In the final solution of the linear program the sum of all acres used by all activities for that quality of land cannot exceed the total acres of that land. This is called a constraint row and is illustrated by the "less than" or "equal to" signs. The LHS of the commodity section records the yields as described above.

On the RHS the total demands for each commodity may be recorded for a given point in time (present or future). For example, when the corn yield for each activity is multiplied by the number of acres assigned to that activity and all these quantities of corn are summed for all activities growing corn in the rotation, the total must be at minimum equal to the total corn demand specified. Where irrigation water is limited, the amount of water used by all irrigation activities cannot exceed the total supply of water available for irrigation.

Rows with greater than zero for the RHS are called accounting rows. These rows, unlike the constraint rows, will not restrict activity resource assignments. They are used to record the total quantity of resources employed.

The top row is the objective row. The RHS records the dollar cost of all resources used in an activity. As was stated previously, a linear program is a system of simultaneous equations with a large number of solutions. One solution is achieved when limited resources are assigned so that none of the constraints are violated. Therefore, a restricted quantity of land will be assigned to specified (not necessarily all) activities. When acres are multiplied by their activity price and these products are summed, the total cost of producing all the commodities included in the model is determined. The linear programming algorithm uses this objective function to choose one solution from the multiple selections.

The "preferred" solution is the one which minimizes the total cost of producing all agricultural commodities considered by the model. Since returns to land, water, and other limiting resources are determined internal to the model, their return will depend on the supply and demand constraints placed on the model.

A model may be formulated as Profit Maximizing by externally determining the profit from producing one acre of each crop or crop rotation A1 to A7 and inserting a profit row as the objective function. The RHS of the profit row when maximized records the total profits from the combination of crops selected in the optimum solution of the model. Total cost is recorded in an accounting row, but does not directly effect the optimum solution of the profit maximizing model. In summary, the LP has the ability to assign resources in an optimum manner, simulate market equilibrium, record each limiting resource's market rate of return, and provide accounting for all other resources and variables of interest.

Typical Data Base Assumptions

The input data to a land resources linear-programming model usually includes a series of general assumptions. Examples of these are as follows:

1. Land Base - The land base is usually assumed to remain the same in short term analysis. Use of this assumption means that during the period of analysis conversions of land to other use are not expected. Examples of changes that could occur over longer periods of time include land clearing, land drainage, conversion to urban use, and reversion of cropland to forest-land. If land conversion is important in a study area, it could be included as an adjustment in the land availability input data.

2. Production Budgets - Production budgets for use in an LP should represent an average of the practices that are being used to produce a particular crop in the study area. They may not represent any practice exactly but they should be representative of the normal practices for the crop on a particular soil group. The budgets are based on specific year costs (usually most recent year with complete data or base year of study), average management conditions, and current normalized prices.

3. Yields - Yields are estimated as normal yields under current technology for the average producer for each crop for each soil group. This assumption recognizes that some producers will attain higher yields or lower costs while others will fall short in yields or may experience higher costs. Thus, where the LP model indicates that some crops on a soil group may be being produced at a loss, some farmers will be growing that crop on that soil group profitably.

4. Institutional and Physical Limitations - Within a particular study area, a portion of the land will have physical characteristics or facilities more suited to predominant crops and crop management than alternative crops and management strategies. Facilities may include diking for rice production or any other type of irrigation systems. Crop allotments and local traditions may also impact potential alternatives. All of these institutional constraints need to be considered in formulating the LP-model.

5. Cropping Patterns - In some areas it may be necessary or desirable to constrain cropping patterns to specific limits of shifting on soil groups between time frames. This may be done by selecting arbitrary ranges that a crop may decrease or increase on a soil group, such as 75% to 150% of the acreage of that crop on that soil group in the base run. Constraints may be relaxed in future time frames.

6. Water Availability - Water availability in areas developed for irrigation may be constrained or assumed to be adequate.

7. Land conversion costs - In studies where converting land in other uses to irrigated cropland occurs, conversion may or may not be included. Activity rows reflecting conversion acres and costs may be included as desired.

8. Labor and capitol are usually assumed to be non-constraining.

LP Data Requirements

Data needed for a specific LP-model is dependent on the study objective and the number of items of interest to be examined. The following data are needed for a LP-model to examine the effects of land treatment measures on cropland erosion.

Soil data - Basic to the formulation of a LP-model for a particular area is the grouping of soils into soil groups that are relatively homogeneous with respect to crop yield and erosion characteristics, responses to treatment measures, and management requirements. The number of soil groupings used should be determined by the soils in the study area, but should be kept to a minimum to avoid unduly enlarging the model matrix.

Land use - Acres of crops currently grown on each soil group become the starting point for the model. Acres of crops may be constrained not to change or allowed to vary between predetermined limits. Acres of crops by soil group for a particular time frame are usually not allowed to change in LP-models designed to evaluate the impacts of land treatment measures on erosion. Crops are allowed to shift between present and future time frames subject to constraints on land use change over time.

Crop yields - Estimates of crop yields for each land treatment measure or combination of land treatment measures on each soil group are needed. The yields should reflect to the extent possible the effects of the land treatment measures on maintaining or increasing yields over time, i.e. yields on erosive soils are expected to decrease over time - without land treatment measures. On the same soils with land treatment, yields would either decrease less, be maintained, or increase.

Production Costs - Crop production budgets are needed for the array of crops and land treatment alternatives included in the model. Basic budgets are usually prepared for each crop on each soil group and then adjusted to reflect the appropriate costs associated with using each applicable land treatment measure by crop and soil group. Budgets should exclude costs associated with land, overhead, and risk.

Gross receipts and Profits - Both gross receipts and profits are needed for each crop and treatment alternative. Profits are used as the objective row in a profit maximizing model. Thus, the model selects the combination of land treatment measures that maximizes profits while meeting erosion and related constraints. Gross receipts may be included in model for accounting purposes.

Erosion - Erosion rates vary dramatically by soil crop, slope, and land treatment practice. Erosion rates in tons per acre for each alternative included in a LP-model are generated externally to the LP. Erosion rates for each crop or other land use occurring on a soil group is calculated using the USLE for sheet and rill erosion. If appropriate, gully erosion computed by the direct volume or other acceptable method may be added. With an erosion estimate for each acre in the model, erosion can be constrained to lesser amounts in successive runs to determine the order that conservation measures would come in to the solutions while maximizing profits in an area.

Other data that may be included in an LP-model, if of interest, includes the following:

Sediment - Sediment rates in tons per acre originating from each crop or other land use may be included. Sediment delivery rates are estimated considering the kind of soil, length of run, and percent slope. Water Use - Water applied to irrigated crops (in acre-inches) may be included to measure total supplemental water use by the alternative model solutions. Total water use may also be constrained if water supplies are known or expected to be limited.

Fuel - Fuel in gallons may be included as an accounting row if desired. Including fuel uses by conservation treatment measures allows comparison of total fuel use among alternative solutions of the LP model.

Fertilizer - Fertilizer is usually included for comparison purposes or secondary studies related to water quality. The LP model through an accounting row will track quantities of fertilizer applied and thus allow estimates of nutrients available in various soil groups.

Mathematical Programming System (MPSIII) Software for Linear Programming Problems.

Computer assistance is necessary for solving linear programming (LP) problems. In 1985, the U.S. Department of Agriculture, Computer Center in Washington, D.C., began using the Ketron, Inc., Mathematical Programming System (MPSIII) for LP models. The MPSIII system replaced the IBM linear programming software system, Mathematical Programming System Extended (MPSX). The MPSIII system accepts data in the same format used for the MPSX system with only a few changes in the job control language. All materials and examples included in this report are based on usage of the MPSIII system. However, this technical note is not a user's guide to the MPSIII system. Therefore, it is recommended that the appropriate user's manuals for the MSPIII system be acquired in an early stage of developing a linear programming model. Ketron, Inc., MPSIII User's Manuals that may be consulted include:

1. MPSIII PRIMER - introduction to basic subset of MPSIII procedures and a description of how to use MPSIII; topics covered are sufficient to solve most models.

2. MPSIIIOL - introduction to the interactive version of MPSIII emphasizing the convenience of conversational execution; parallels what PRIMER does for batch.

3. WHIZARD - an overview of the high performance, in-core optimizer which offers greater speed and effectiveness over conventional optimizers.

4. DATAFORM TUTORIAL - a brief introduction to the use of DATAFORM, the powerful database management, model generation, and report writing component of MPSIII.

5. SLEUTH - an overview of a high level language, an extension of DATAFORM, in which one may program solution strategies to successive LP applications.

6. IDF (Interactive DATAFORM) - the user's manual for conversational language, with full screen editor, which permits interactive access to DATAFORM databases.

7. MPSIII User Manual - complete reference manual for MPSIII.

8. DATAFORM User Manual - DATAFORM language reference manual.

9. MPSIII Message Manual - explanation of all error and informational messages.

10. GUB - Generalized Upper Bounding Optimizer.

These manuals are available from the USDA computer center and Ketron, Inc., MSS Division, 18th Floor, Rosslyn Center, 1700 North Moore Street, Arlington, Virginia 22209, (703-558-8700).

Data Preparation

Input required for executing MPSIII programs may be categorized into three basic areas: job control language (JCL), MPSIII control program, and data for the particular problem being analyzed. Use of the JCL cards and MPSIII control programs is discussed in Appendix I. The JCL cards and control programs are necessary to run an LP problem. Input data is the factual information supplied by the user.

Input Data

Input data provide the specific information which describes the linear programming problem to be solved. For land and water resource problems several different data sets usually make up the input data. These data sets include existing land use data by soil group (acres and yields of crops, pasture, and etc.), production costs for each crop by soil group, conservation treatments and costs applicable to each crop on each soil group, irrigation water use, irrigated crop yields and etc.

The rigidity and immensity of these data sets require an automated data assembly and input system usually called a "LP Matrix generator". "Matrix generator" being defined as a package of several computer subroutines and/or programs that sort, group, or pair several independent data sets into the proper format to go into a specific LP computer program. Matrix generator programs are problem specific, that is, they must be tailored to the specific input data in terms of number of crops, soil group, conservation treatments, etc. The programs are usually written in FORTRAN. FORTRAN allows variables to be dimensioned rather than having to create a different variable for each activity. A variable is dimensioned by formating the variable by the number of SRG's x the number of rotations x number of conservation treatments, etc.

A listing of a matrix generator is several pages long and too large to be included in this technical note. A copy of a matrix generator can be obtained from the Economics, Social Sciences and Evaluation Staff at the SNTC. Knowledge of Fortran computer language is necessary to prepare a new or adapt an existing matrix generator to a different land and water resource problem.

Interpretation of Output

There are a number of reports available from the MPSIII program. They are all discussed in detail in the user's manuals. Only the solution report will be presented here. The solution report included here is an actual run of the Southeast Georgia Cooperative Study L.P. Model. The first portion of this output section tells the type of solution (optimal, nonoptimal, or infeasible), the value of the objective function, and the names of the objective function and right-hand-side that were used for the analysis.

The next part of this output gives the status of each row. The NUMBER column gives the internal reference number which the computer assigned to each row (Table 3). Row names are then listed in the same order that they were entered in the rows section of the data. The AT column gives the status in the solution for each row. Codes and their meaning are as follows:

** ... infeasible

BS ... in the basis and feasible

FR ... nonbasis, nonrestricted

EQ ... nonbasis, fixed

UL ... nonbasis, at upper limit

LL ... nonbasis, at lower limit

The ACTIVITY column shows the amount of resource used or requirement fulfilled, while the SLACK ACTIVITY column gives the amount of excess resources available or the amount by which a constraint has been exceeded.

The LOWER and UPPER LIMIT columns indicate right-hand-side limitations placed on each row.

The final column in the rows section of the output is labeled DUAL ACTIVITY. Data found in this column are the "marginal value product" or shadow price values. They indicate, for example, that if one more (less) unit of an input was available, the objective function would be increased (decreased) by the amount indicated (Table 2).

The columns section of the output gives the levels of the activities in solution. Again, as in the rows section, the NUMBER column is the internal storage number assigned by the computer. Column names are then listed in the order that they are given in the input data. Codes for the AT column are the same as those used for the rows.

Table 2

MPSIII Solution Row Report
Southeast Georgia Land and Water Resource Cooperative Study

NUMBER	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
1	CUSLE	BS	9632383.14096	9632383.14096-	NONE	NONE	.
2	CEPHEMRL	BS	6896587.47780	6896587.47780-	NONE	NONE	.
3	CEROSGT	BS	9034067.79865	9034067.79865-	NONE	NONE	.
4	CPRECOST	BS	266584234.788	266584234.788-	NONE	NONE	.
5	CHVSCOST	BS	55168238.3813	55168238.3813-	NONE	NONE	.
6	CFIXCOST	BS	85283347.7648	85283347.7648-	NONE	NONE	.
7	CMGTCOST	BS	32391119.8056	32391119.8056-	NONE	NONE	.
8	CCPCOST	BS	4395852.20771	4395852.20771-	NONE	NONE	.
9	COMCOST	BS	8094186.96873	8094186.96873-	NONE	NONE	.
10	CTOTCOST	BS	451916979.896	451916979.896-	NONE	NONE	.
11	CGROSRET	BS	475027432.826	475027432.826-	NONE	NONE	.
12	CNETRET	BS	23110807.0616	23110807.0616-	NONE	NONE	.
13	PUSLE	BS	139904.18596	139904.18596-	NONE	NONE	.
14	PEPHEMRL	BS	.	.	NONE	NONE	.
15	PEROSGT	BS	.	.	NONE	NONE	.
16	PPRECOST	BS	60971438.8891	60971438.8891-	NONE	NONE	.
17	PHVSCOST	BS	40236401.8520	40236401.8520-	NONE	NONE	.
18	PFIXCOST	BS	17016257.6367	17016257.6367-	NONE	NONE	.
19	PMGTCOST	BS	13761358.2681	13761358.2681-	NONE	NONE	.
20	PCPCOST	BS	.	.	NONE	NONE	.
21	POMCOST	BS	.	.	NONE	NONE	.
22	PTOTCOST	BS	131985456.646	131985456.646-	NONE	NONE	.
23	PGROSRET	BS	150469592.796	150469592.796-	NONE	NONE	.
24	PNETRET	BS	18484136.1497	18484136.1497-	NONE	NONE	.
25	FUSLE	BS	967774.15870	967774.15870-	NONE	NONE	.
26	FEPHEMRL	BS	.	.	NONE	NONE	.
27	FEROSGT	BS	.	.	NONE	NONE	.
28	FPRECOST	BS	59361294.3200	59361294.3200-	NONE	NONE	.
29	FHVSCOST	BS	.	.	NONE	NONE	.
30	FFIXCOST	BS	.	.	NONE	NONE	.
31	FMGTCOST	BS	2330260.00000	2330260.00000-	NONE	NONE	.
32	FCPCOST	BS	.	.	NONE	NONE	.
33	FOMCOST	BS	.	.	NONE	NONE	.
34	FTOTCOST	BS	61691554.3200	61691554.3200-	NONE	NONE	.
35	FGROSRET	BS	54676481.8392	54676481.8392-	NONE	NONE	.
36	FNETRET	BS	7015072.48046-	7015072.48046	NONE	NONE	.
37	PROTECT	BS	5886703.16651	5886703.16651-	NONE	NONE	.
38	EROST10	BS	923672.50006	923672.50006-	NONE	NONE	.
39	EROSG10	BS	321276.33334	321276.33334-	NONE	NONE	.
40	USLEG10	BS	3033127.41003	3033127.41003-	NONE	NONE	.
41	EPHEMG10	BS	3022306.91003	3022306.91003-	NONE	NONE	.
42	NETRET	BS	34579870.7309	34579870.7309-	NONE	NONE	1.00000
43	IRRWATER	BS	1699500.45624	1699500.45624-	NONE	NONE	.
44	LAND	UL	7131651.99991	1.00000-	7131650.99991	7131651.99991	117.03000-
45	IRRLAND	UL	165784.00000	1.00000-	165783.00000	165784.00000	39.55667-
46	LAND01	BS	174276.99993	.99993-	174276.00000	174277.00000	.
47	LAND02	LL	2121246.00000	.	2121246.00000	2121247.00000	43.37000
48	LAND03	LL	499132.00000	.	499132.00000	499133.00000	39.85167
49	LAND04	LL	442872.00000	.	442872.00000	442873.00000	39.85167

Source: Southeast Georgia Land and Water Resource Cooperative Study.

The ACTIVITY column gives optimal values for each variable in the solution. INPUT COST data are the objective function values given for each activity. LOWER and UPPER LIMITS specify any constraints that may have been imposed on the permissible levels of the activities. Data designated as REDUCED COST indicate how much the objective function would be changed if a unit of the nonbasis variables were forced into solution. For example, if one unit of variable 010111A were forced into the solution of the Southeast Georgia LP, the objective function, net profit, would be reduced by $9.01 (Table 3).

Report Writers

The row and column output of the MPSIII are essentially matrixes of activities or resources used in optimal solution. These matrixes must be multiplied by identity matrixes to translate the data to a useful form. An "identity matrix" being defined as a file with crop yields, production costs, water use, etc., for each soil group by crop and type of land treatment. Report writers, written in fortran, are usually used to take the row LP output and perform the necessary calculations to obtain summary data. A report writer, like a matrix generator is a package of several computer subroutines and/or programs that sort, group, or pair several data sets and then perform calculations to obtain necessary data for a particular report table. Report Writer programs are also problem specific input and output data in terms of number of crops, soil groups, conservation treatments and etc. Again knowledge of fortran is necessary to prepare a new and/or adapt an existing report writer program to a different land and water resource problem.

Report writers can be as specific as printing the final table to go into a report or just a source of numbers to be transferred to other tables. Designing report-writer output tables to fit table needs for the final report is strongly recommended.

Comparison of Alternatives

The first solution of a LP model for a River Basin Study is a base run for calibrating model results to known base year data. This solution is carefully compared to a pre-established land use for the study area to determine closeness of fit of the data, assumptions, ranges, and constraints. Constraints and ranges are then adjusted as necessary to improve the fit of the LP model. Once a satisfactory base run is obtained, alternate scenarios can be formulated, inputed to the model and compared to the base run and other alternatives.

Again, the Southeast Georgia Cooperative Study LP model will be used as an example. However, it is emphasized that this is only one approach of many. In the Southeast Georgia Cooperative Study, conditions in 2000 were evaluated by first looking at 1980

Table 3
MPSIII Solution Column Report
Southeast Georgia Land and Water Resource Cooperative Study

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
282	010111A	LL	.	17.94000	.	NONE	9.01000-
283	020111A	LL	.	27.60000-	.	NONE	11.18000-
284	030111A	LL	.	6.20000	.	NONE	4.06000-
285	040111A	LL	.	58.97000-	.	NONE	19.94000-
286	050111A	LL	.	24.88000-	.	NONE	4.02000-
287	060111A	LL	.	73.06000-	.	NONE	10.26000-
288	070111A	LL	.	85.38000-	.	NONE	27.21000-
289	090111A	LL	.	125.12000-	.	NONE	75.61700-
290	100111A	LL	.	91.02000-	.	NONE	41.51700-
291	010211A	BS	29633.00000	52.25000	.	NONE	.
292	020211A	LL	.	6.60000	.	NONE	1.82000-
293	030211A	LL	.	36.02000	.	NONE	3.45000-
294	040211A	LL	.	31.42000-	.	NONE	12.59000-
295	050211A	LL	.	10.61000	.	NONE	2.15000-
296	060211A	LL	.	45.68000-	.	NONE	1.71000-
297	070211A	LL	.	66.35000-	.	NONE	26.26000-
298	090211A	LL	.	111.29000-	.	NONE	61.78700-
299	100211A	LL	.	68.43000-	.	NONE	18.92700-
300	010311A	LL	.	95.98000	.	NONE	73.05000-
301	020311A	LL	.	12.22000	.	NONE	20.43750-
302	030311A	LL	.	25.34000	.	NONE	40.65000-
303	040311A	LL	.	70.06000-	.	NONE	100.30750-
304	060311A	LL	.	84.52000-	.	NONE	116.12350-
305	070311A	LL	.	123.87000-	.	NONE	90.64562-
306	090311A	LL	.	200.84000-	.	NONE	200.41450-
307	100311A	LL	.	158.53000-	.	NONE	158.10450-
308	010511A	LL	.	363.03000	.	NONE	.
309	020511A	LL	.	363.03000	.	NONE	.
310	030511A	BS	3603.60000	227.89000	.	NONE	.
311	040511A	BS	4163.99998	363.03000	.	NONE	.
312	050511A	BS	2239.20000	272.68000-	.	NONE	.
313	060511A	BS	10483.00000	272.68000-	.	NONE	.
314	070511A	LL	.	363.03000	.	NONE	.
315	080511A	BS	2773.00000	134.84000-	.	NONE	.
316	090511A	BS	2532.80000	67.94000-	.	NONE	.
317	100511A	BS	3843.20000	272.68000-	.	NONE	.
318	110511A	BS	241.00000	67.94000-	.	NONE	.
319	010611A	BS	333.33333	1.69000	.	NONE	.
320	020611A	BS	23872.13333	103.86000-	.	NONE	.
321	030611A	BS	7127.90000	1.69000	.	NONE	.
322	040611A	BS	9860.33333	1.69000	.	NONE	.
323	050611A	BS	28872.43333	1.69000	.	NONE	.
324	060611A	BS	20066.03333	135.48000-	.	NONE	.
325	070611A	BS	4541.56667	135.48000-	.	NONE	.
326	080611A	BS	44839.16667	1.69000	.	NONE	.
327	090611A	BS	5137.43333	135.48000-	.	NONE	.
328	100611A	BS	7836.00000	135.48000-	.	NONE	.
329	110611A	BS	1133.93333	135.48000-	.	NONE	.
330	010711A	BS	364.10000	404.40000	.	NONE	.

Source: Southeast Georgia Land and Water Resource Cooperative Study.

conditions and predicting net changes in major land use (such as cropland, pasture, forest land, and urban land) and changes in irrigated acreage, regardless of the kind of conservation program to be followed. Predictions for these items for year 2000 were held constant for the other future alternatives. Major crops identified in the 1980 Base were put into 26 different cropping systems (adding small grains and legumes) that could be brought in on future runs. Eighteen of these systems were conservation cropping systems that will improve or maintain good physical condition of the soil, protect the soil during periods when erosion usually occurs, aid in the control of weeds, insects and diseases, or meet the needs and desires of the landuser for an economic return. Additional conservation treatments--contour farming and cropland conversion--were added to the future LP runs in the same way activities were created for the 1980 Base run.

Crop yields were then adjusted to future erosion rates. Water Resource Council current normalized crop prices and production costs for 1980, and a 7.125% discount rate were used in the budgeting process.

The effect of soil erosion on future crop productivity was predicted to be negative (Figure 1). These effects were captured by using Alabama's method of calculating yield reduction from soil loss. 1/ Each inch of topsoil loss from sheet and rill erosion was predicted to result in a 10 percent loss in yield for all crops on all soils. Soils with tolerable rates of erosion ("T") were able to sustain current high yields. Crop yields in areas affected by ephemeral gully erosion were expected to be half the yield found on the areas adjacent to these. These generalizations were used in the absence of better data on Georgia's erosion/productivity relationship.

Erosion damages were calculated by looking at the loss in total value of crop production due to erosion. Erosion was predicted to have no effect on the cost of crop production. Therefore, sheet and rill erosion damages were equal to the difference in predicted crop yields at future erosion rates and potential crop yields at tolerable erosion rates, times the current normalized crop price. Ephemeral gully erosion damages were calculated by finding the difference between a 50% yield level and a 100% yield level in the affected area and then multiplying this by the current normalized crop prices.

Future alternative programs were evaluated by comparing the ongoing program to the 1980 Base and all other programs to the ongoing program, and then looking at net changes in annual erosion damages, annual conservation costs, and annual returns.

1/ The influence of Soil Erosion on Crop Productivity (Auburn University, Ben Hajek, 1983).

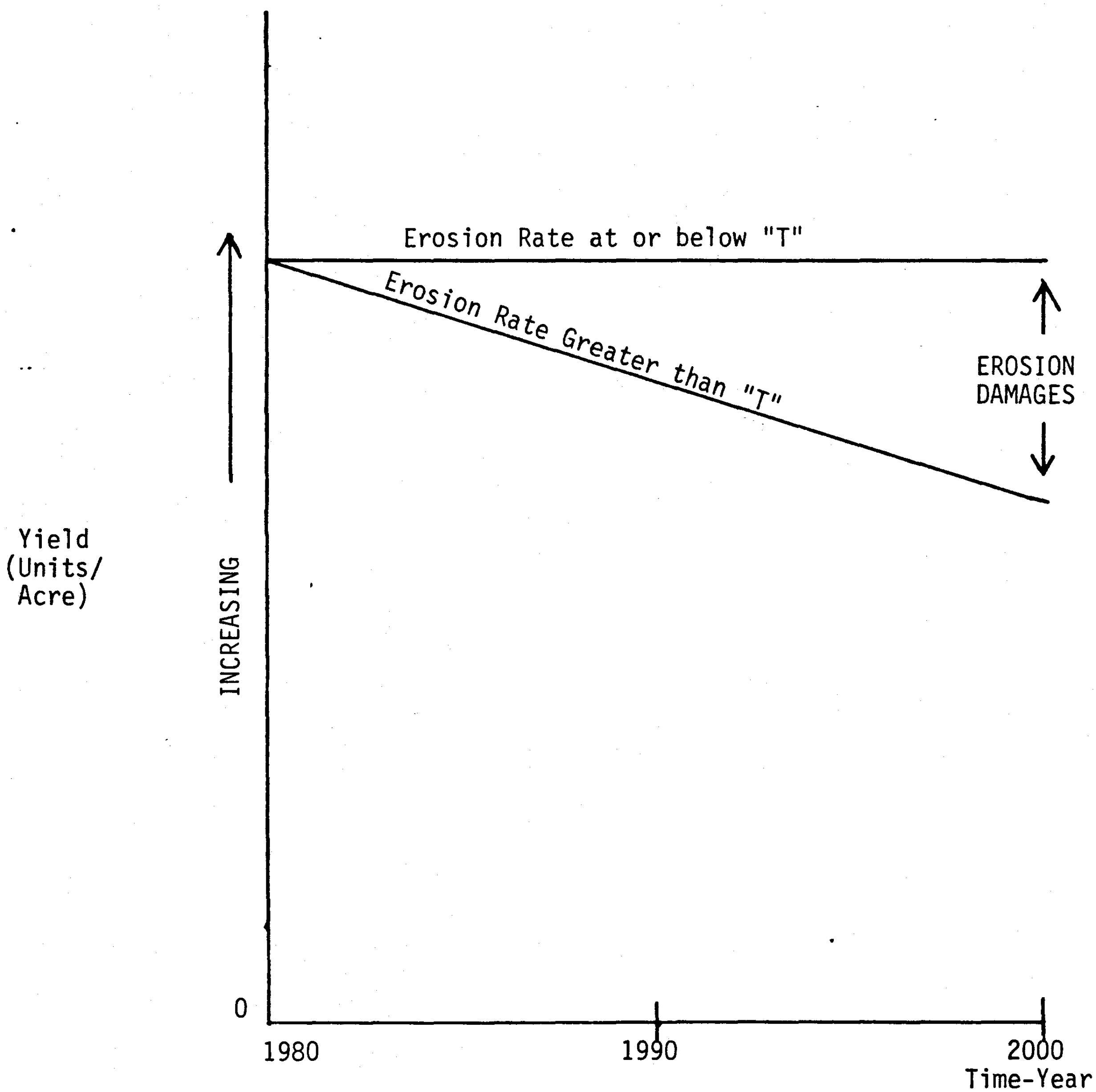

FIGURE 1 - RELATIONSHIP OF EROSION TO CROP PRODUCTIVITY

Variable preharvest and harvest costs, fixed costs, management costs, conservation installation costs, and conservation operation and maintenance costs were included in the analysis. Crop yields and cost return budgets were developed for each crop in each soil resource group. Yields for the study area were compared to yields reported by the Georgia Crop Reporting Service. Land treatment practices used in each alternative are similar to those presently available, but differ in their emphasis toward critical erosion areas. Cropping patterns and net returns in 2000 are affected by the interaction of higher yields resulting from implementation of land treatment programs, more cropland being irrigated, and more intensive use of cropland through higher levels of multiple cropping.

Erosion was calculated using the Universal Soil Loss Equation (USLE) for sheet and rill erosion and ephemeral gully erosion was estimated using the same procedure as in the 1980 Base run, except:

(a) Ephemeral gully erosion was set at zero if water disposal systems, grassed waterways, or contour stripcropping were installed; and

(b) Ephemeral gully erosion was set at zero if sheet and rill erosion was at or below tolerable ("T") levels.

The linear programming model used for the 1980 Base was modified to allow for rotations and additional conservation treatments, and then constrained to form specific alternative conservation-program runs. The final analysis was based on five future alternative conservation programs:

(a) Ongoing Program
(b) Without Ongoing Program
(c) Resource Protection Program
(d) Intermediate Resource Protection Program
(e) Maximum Net Income Program

The objectives of all alternatives were to maximize net income within each set of constraints. Certain constraints were followed for all alternatives. These included:

1. Total land area (7,131,650 acres)
    a. Total cropland acreage = 2,030,445 acres
    b. Total pasture acreage = 440,685 acres
    c. Total forest acreage = 4,660,520 acres

2. Total irrigated acreage was set at 165,785 acres (an increase of 10% over 1980).

3. Irrigated acreage was constrained by soil resource group so that future levels were greater than or equal to 1980 levels.

4. Acres of individual crops were constrained by soil resource group to fall within a range that represents a percentage of the 1980 level. Most crops were set at plus or minus 20 percent of the 1980 acreage except for peanuts and tobacco which were held relatively constant.

5. Drainage of wetlands for cropland was not permitted in future programs.

Additional constraints were added to make up the following future alternative runs.

A. ONGOING PROGRAM

1. Acreage of major land uses--cropland, pasture, forest land--were constrained by soil resource group to allow some marginal lands to change from cropland to pasture or forest.

2. Acreage of each conservation practice were constrained to equal a level projected to be installed under the ongoing conservation program.

3. Plan elements of this alternative include conservation cropping systems, contour farming, crop residue use, water disposal systems and outlets, grassed waterways, conservation tillage, contour stripcropping, land use conversion, and pasture and hayland management. Quantities of each treatment can be found in Table 4. Conservation levels were predicted using a staff load of 880 man-years over the 20-year evaluation period and an average 1,200 adequately treated acres per man-year. 1/

B. WITHOUT A PROGRAM

1. Acreage of major land uses--cropland, pasture, forest land--were very tightly constrained by soil resource group to allow little or no land use changes between soil groups.

2. This plan consists of the same practices found in 1980, but in smaller quantities, following the prediction that most current practices will gradually go out without a conservation program in the area. Practices that currently require

1/ Adequately treated does not necessarily mean reducing erosion to "T".

E 4

COMPONENTS AND TREATMENT LEVEL ELEMENTS OF FUTURE ALTERNATIVE PROGRAMS SOUTHEAST GEORGIA LAND AND WATER RESOURCE COOPERATIVE STUDY

Components & Treatment Level Elements1/	1980 Base	Plan Element Quantities - 2000				
		Ongoing Program	Without Program	Resource Protection	Intermediate Res. Protect.	Maximum Net Income
CROPLAND EROSION REDUCTION:	-Acres-					
Contour Farming	0	810,650	0	543,095	1,034,905	1,113,970
Crop Residue Use	476,910	1,353,630	429,220	1,798,260	1,741,930	1,795,210
Conservation Tillage	135,420	609,135	27,085	196,570	252,900	198,160
Water Disposal Systems2/	161,675	231,675	32,335	814,700	32,480	8,990
Grassed Waterways or Outlets	4,870	7,275	490	30,645	268,675	210,915
Contour Stripcropping	3,650	4,015	2,735	200,000	200,000	200,000
Conservation Cropping System3/	--	--	--	--	--	--
Conservations -						
Cropland-Hay & Past.	--	13,020	14,025	10,710	10,710	12,170
Cropland-Woodland	--	51,910	0	58,070	58,070	54,865
IMPROVED PRODUCTION EFFICIENCY:4/						
Pasture & Hay Mgt.	73,595	291,285	69,915	315,755	314,530	312,105

Source: SCS

1/ Practices are defined in USDA-SCS Technical Guide, Section IV, Standards and Specifications.
2/ Includes terraces, diversions, underground outlets, land smoothing, water and sediment control basins and grassed waterways or outlets.
3/ Conservation cropping systems are an integral part of the future alternative programs but have not been separately quantified.
4/ Some of the practices used to reduce cropland erosion also improve production efficiency, but are not listed here.

large amounts of technical assistance such as water disposal systems, grassed waterways, and conservation tillage were expected to be reduced by 80 percent and more, while practices with less technical assistance -- such as contour stripcropping, crop residue use, and pasture and hayland management -- can expect reduction levels of 25 percent and less. A minimum amount, 14,000 acres, of land use conversion (marginal and submarginal cropland to pasture) will occur due to higher profits from the production of hay.

C. RESOURCE PROTECTION PROGRAM

1. Land use constraints, crop constraints, and soil resource group constraints for cropland (and all crops), pasture and forest land were the same as in the ongoing program run.

2. Acres of conservation practices were constrained to greater than or equal to the without ongoing program level. Acres of stripcropping were constrained to a maximum of 200,000 acres. Grass represents 40% (80,000 acres) of the total stripcropped area. This grass brought in under stripcropping was constrained to prevent excessive hay production.

3. Total erosion (sheet, rill, and ephemeral gully) was constrained to less than or equal to tolerable ("T") levels. This run was infeasible so erosion was reduced to "T" or below on all but 175,000 acres of cropland to obtain feasibility.

D. INTERMEDIATE RESOURCE PROTECTION PROGRAM

1. Land use constraints, crop constraints, and soil resource group constraints for cropland (and all crops), pasture and forest were the same as in the ongoing program run.

2. Acres of conservation practices were constrained to greater than or equal to the without ongoing program level. Acres of stripcropping were constrained to a maximum of 200,000 acres.

3. Total erosion (sheet, rill, and ephemeral gully) was constrained to less than or equal to 10 tons per acre per year. Erosion control measures were redirected to those areas currently eroding greater than 10 tons per acre per year to reduce erosion rates on these lands to 10 tons or less. Rates greater than 10 tons per acre per year were suspected of impairing cropland productivity the most. This alternative represents a redirected conservation program.

4. This alternative was developed to represent a conservation program somewhere between the ongoing program and the resource protection program, recognizing that profits were lowered by reducing erosion on all cropland to rates less than or equal to tolerable rates, and also that the mix of practices brought in under the ongoing program may not be the best mix of practices to reduce erosion profitably.

E. MAXIMUM NET INCOME PROGRAM

1. Land use constraints, crop constraints, and soil resource group constraints for cropland (and all crops), pasture, and forest land were the same as in the ongoing program run.

2. All constraints on conservation practices were moved except for stripcropping. Acres of stripcropping were constrained to a maximum of 200,000 acres.

3. All constraints on erosion were removed. The maximum net income program represents conditions if southeast Georgia farmers were to maximize net returns to their land, concerning themselves with erosion only to the extent that it affects crop yields and resulting net income. There are no erosion reduction goals per se, as there were in the resource protection and intermediate resource protection programs. However, erosion is tied to net income through reduced yields. Conservation systems were brought into the extent that higher yields covered the cost of the conservation systems. This is the national economic development, or NED plan.

Description of Impacts of Alternative Programs

Alternative 1 - Ongoing Program (ONGOING)

Total cropland erosion will decrease by 10.3 million tons annually between 1980 and the year 2000 with most (70 percent) of the change resulting from a reduction in sheet and rill erosion (Tables 5 and 6). An additional 292,000 acres of cropland will be adequately protected, and 924,000 acres will go from erosion rates greater than 10 tons per acre per year to rates less than 10 tons. 1/

Net income from agricultural lands is predicted to be $34.6 million annually, more than double the $14 million reported in 1980. The increase in net income over the 1980 level is due to (a) a decrease in annual erosion damages from loss in total value of crop production of $5 million, and (b) an increase of $29.6 million annually from improved production efficiencies. Erosion damages were reduced by converting 65,000 acres of marginal cropland to pasture and woodland, resulting in lower erosion rates and in reducing cropland erosion on the better lands by installing more conservation practices. Improved production efficiencies come from growing higher profit crops such as tobacco, peanuts, and cotton on better lands (land capability units 1, 2e, 2s, and 2w).

Total installation cost for permanent practices in the ongoing program will be $33.9 million (or $8.2 million annually including operation, maintenance, and repair), while annual costs of management type erosion control practices will be $9.2 million (see Tables 7 and 8). Annual costs of practices that only improve production efficiency are $14.2 million.

Alternative 2 - Without Ongoing Program (WOONGO)

Without an ongoing program, total cropland erosion will increase by 25 million tons over the ongoing program level, with an equal increase occurring in sheet and rill and ephemeral gully erosion rates (Tables 5 and 6). Approximately 454,000 acres with no excessive erosion in the ongoing program will not be adequately protected, while 1,169,000 acres will go from erosion rates less than 10 tons per acre per year to rates greater than 10 tons.

Net returns to agricultural lands are projected to be $11.8 million annually by the year 2000, a reduction of $22.8 million from the ongoing program level. Erosion damages from loss in total value of crop production account for $25.2 million of this reduction, while slight gains in production efficiencies (mostly from eliminating expensive conservation practices) account for $2.4 million.

1/ Greater than 10 tons/acre/year is considered a level at which erosion severely inhibits productivity.

Total installation cost for erosion reduction practices is $6.0 million (or $1.5 million annually) for replacement of permanent practices such as terraces, waterways, and stripcropping, and establishment of pasture grasses on marginal and submarginal cropland. The cost of implementing annual management practices for reducing erosion such as conservation tillage, crop residue use, and contour farming is $705,000 each year. The cost of practices that only improve production efficiencies, such as pasture and hayland management is $3.5 million annually.

Alternative 3 - Resource Protection Program (RPP)

Total cropland erosion will be reduced 8.8 million tons annually from the ongoing program level, entirely eliminating ephemeral gully erosion (Tables 5 and 6). All agricultural land in the southeast Georgia area, except 175,000 acres of cropland, will be adequately protected from erosion. This protection program will treat an additional 1.1 million acres of cropland eroding at excessive rates in the ongoing program.

Net income from agricultural lands is predicted to be $31.5 million annually. This is less than the net income in the ongoing program, but more than net income without an ongoing program. This indicates some cost and return inefficiencies in forcing erosion to tolerable levels, but also that a certain level of erosion control is profitable. Because 175,000 acres of cropland will be eroding at rates greater than "T", there will still be about $3.3 million remaining annual erosion damages, a damage reduction of $14.3 million each year over the ongoing program level. Production efficiency will suffer by $17.4 million annually from installing expensive conservation practices.

Total cost of installing permanent erosion control practices for this alternative is $112.7 million (or $27.3 million annually), $78.8 million over the ongoing program. The annual cost of implementing management-type erosion control practices is $7.9 million, a decrease of $1.3 million from the ongoing program. Annual costs of practices that only improve production efficiency are $15.4 million.

Alternative 4 - Intermediate Resource Protection Program (IRPP)

Total cropland erosion will be reduced 4.4 million tons annually from the ongoing program level with almost all of this reduction occurring on areas affected by ephemeral gully erosion (Table 5 and 6). Sheet, rill, and ephemeral gully erosion on all agricultural land will be reduced to rates of 10 tons per acre per year and below. However, there will still be about 1,066,000 acres of cropland eroding greater than tolerable levels. Implementation of the intermediate resource protection program will adequately protect 179,000 acres not protected in the ongoing program.

TA[illegible]5

COMPARISON OF EFFECTS OF ALTERNATIVE PROGRAMS ON EROSION
SOUTHEAST GEORGIA LAND AND WATER RESOURCE COOPERATIVE STUDY

ITEMS	1980 Base	2000 Ongoing Program	2000 Without Program	2000 Resource Protection	2000 Intermediate Res. Protect	2000 Maximum Net Income
ALL LAND USES:						
1. Total Erosion (1000 TNS)	27,300	17,635	43,105	8,845	13,265	15,305
CROPLAND:						
1. Total Sheet & Rill Erosion (1000 TNS)	16,850	9,630	22,110	7,735	9,420	9,610
2. Total Ephemeral Erosion (1000 TNS)	9,970	6,895	19,895	0	2,740	4,590
3. Annual Erosion Rate 1/ (TNS/AC/YR)	13.2	8.1	20.7	3.8	6.0	7.0
4. Acres Protected (Erosion 1/ LE T) 2/	493,765	785,495	331,775	1,855,445	964,520	960,875
5. Acres Eroding Greater than T 1/	1,536,680	1,244,950	1,698,670	175,000	1,065,925	1,069,570
6. Acres Eroding Greater than 10 T 1/	1,302,205	321,275	1,490,220	0	0	186,810

Source: SCS

1/ Includes sheet, rill and ephemeral gully erosion.

2/ LE = Less than or equal to.

6

ANNUAL COSTS, BENEFITS AND EROSION DAMAGES OF ALTERNATIVE CONSERVATION PROGRAMS FOR CROPLAND, PASTURE AND FOREST LAND SOUTHEAST GEORGIA LAND AND WATER RESOURCE COOPERATIVE STUDY

ITEMS	1980 Base	2000				
		Ongoing Program	Without Program	Resource Protection	Intermediate Res. Protect.	Maximum Net Income
Agricultural Land Area (ac)	7,165,985	7,131,650	7,131,650	7,131,650	7,131,650	7,131,650
Total Production Cost ($1000/yr)[1/]	582,415	614,025	613,295	633,355	635,685	633,605
Total Cons. Cost ($1000/yr)[2/]	10,990	31,565	5,735	50,490	30,175	27,945
Cropland	7,620	17,375	2,240	35,130	14,870	12,745
Pasture	3,370	14,190	3,495	15,360	15,305	15,200
Total Cost ($1000/yr)	593,405	645,590	619,030	683,845	665,860	661,550
Gross Return to Land ($1000/yr)[3/]	607,500	680,170	630,825	715,345	710,160	708,715
Net Return to Land ($1000/yr)	14,095	34,580	11,795	31,500	44,300	47,165
Erosion Damages-Cropland Only						
Sheet & Rill ($1000/yr)	10,540	8,290	30,135	3,290	9,850	9,545
Ephemeral ($1000/yr)	12,020	9,290	12,670	0	4,900	6,140
TOTAL ($1000/yr)	22,560[4/]	17,580	42,805	3,290	14,750	5,685
Annual Net Benefits ($1000/yr)[5/]			-22,785	-3,080	9,720	12,585

Source: SCS
1980 Constant Dollars

Includes annual cost of conservation cropping systems, but does not include annual costs of other management and permanent conservation practices.
Excludes annual cost of conservation cropping systems. Includes annual cost of other management and permanent conservation practices.
Includes gross return from production of major crops, hay and timber. Does not include gross receipts from livestock, specialty crops, agricultural by-products or custom work.
Damages are equal to the loss in total value of crop production. Erosion damages for 1980 are non-recoverable in the study period. Damages listed for future programs may be less than damages in 1980 due to a different mix of cropping systems.
Difference in net returns when compared to future Ongoing program.

TABLE 7

ANNUAL COSTS OF COMPONENTS OF FUTURE ALTERNATIVE PROGRAMS
SOUTHEAST GEORGIA LAND AND WATER RESOURCE COOPERATIVE STUDY

Components & Treatment Level Elements	UNITS	2000				
		Ongoing Program	Without Program	Resource Protection	Intermediate Res. Protect.	Maximum Net Income
CROPLAND EROSION REDUCTION:						
Management Practices -						
Contour Farming	$1000	4,310	0	3,190	5,650	6,085
Crop Residue Use	$1000	475	450	490	510	500
Conservation Tillage	$1000	4,350	215	1,390	2,505	1,380
Contour Stripcropping1/	$1000	55	40	2,800	2,800	2,770
Permanent Practices -						
Water Disposal Systems	$1000	7,720	1,220	26,715	1,410	340
Grassed Waterways or Outlets	$1000	60	5	185	1,635	1,280
Conversions:						
Cropland to Hay & Pasture	$1000	290	310	235	235	270
Cropland to Woodland	$1000	115	0	125	125	120
SUBTOTAL	$1000	17,375	2,240	35,130	14,870	12,745
IMPROVED PRODUCTION EFFICIENCY:						
Pasture & Hay Management	$1000	14,190	3,495	15,360	15,305	15,200
SUBTOTAL	$1000	14.190	3,495	15,360	15,305	15,200
TOTAL	$1000	31,565	5,735	50,490	30,175	27,945

Source: SCS
1980 Constant Dollars

Including establishment

8

INSTALLATION COSTS OF PERMANENT PRACTICES IN FUTURE ALTERNATIVE PROGRAMS SOUTHEAST GEORGIA LAND AND WATER RESOURCE COOPERATIVE STUDY

Components & Treatment Level Elements	UNITS	2000				
		Ongoing Program	Without Program	Resource Protection	Intermediate Res. Protect.	Maximum Net Income
CROPLAND EROSION REDUCTION:						
Permanent Practices - Installation						
Water Disposal Systems	$1000	30,965	4,420	109,250	5,215	1,315
Grassed Waterways or Outlets	$1000	180	15	765	6,720	5,275
Conversions:						
Cropland to Hay & Pasture	$1000	1,440	1,550	1,185	1,185	1,345
Cropland to Woodland	$1000	1,300	0	1,455	1,450	1,370
TOTAL	$1000	33,885	5,985 1/	112,655	14,570	9,305

Source: SCS
1980 Constant Dollars

1/ Replacement Costs

Net income from agricultural land is predicted to be $44.3 million annually by 2000. This is the largest net income of all the alternatives looked at so far, indicating that it may be cost efficient to reduce erosion on all cropland to rates of 10 tons per acre per year or less and to treat areas affected by ephemeral gully erosion. Remaining erosion damages from loss in total value of crop production will be $14.8 million annually, a reduction of $2.8 million from the ongoing program level. Increased efficiencies of switching from more expensive erosion control practices to less expensive, erosion control practices account for $6.9 million annually.

Total cost for installing permanent erosion control practices for this alternative is $14.6 million (or $3.4 million annually). The annual cost of implementing management type erosion control practices is $11.5 million. Production efficiency practices such as pasture and hayland management will cost $15.3 million annually. Total annual costs of this alternative ($30.2 million) will be $1.4 million less than for the ongoing program ($31.6 million), while erosion is being reduce even more.

Quantities of conservation practices in the output of the LP are listed in Table 4. There is a tremendous increase in acreage of contour farming, grassed waterways, crop residue use, and strip-cropping over the ongoing program level, while acres of conservation tillage and water disposal systems and outlets decreased by over 50 percent of the ongoing program level. The most cost effective way of reducing ephemeral gully erosion seems to be with grassed water-ways or contour stripcropping and not with terraces, diversions, and water and sediment control basins. Acres of landuse conversion remain about the same as in the ongoing program. Acres of pasture and hayland management increased by about 10 percent over the level predicted for the ongoing program.

<u>Alternative 5</u> - Maximum Net Income Program (MAXNET)
There will be a 14.2 million tons remaining cropland erosion, a level somewhere between the ongoing program (16.5 million tons) and the intermediate resource protection program (12.2 million tons) levels (Tables 5 and 6). Acres of cropland adequately protected from erosion (961,000 acres) are about the same as in the IRPP (965,000). However, whereas the IRPP treats all cropland eroding greater than 10 tons per acre per year, the maximum net income program allows 187,000 acres of cropland to continue to erode at rates greater than 10 tons. This acreage was not economical to treat. Returns from the higher yields obtained by reducing erosion damage were not sufficient to cover the cost.

Net income from agricultural land use is $47.2 million each year under the maximum net income program, only $2.9 million more than the IRPP. This represents the maximum net income that can be obtained in the area under the original set of constraints. This program, which is very close in plan elements and net income to the intermediate resource protection program, reveals that a certain level of erosion control treatment is indeed profitable. That level is one near the IRPP level of reducing erosion to rates 10 tons per acre per year or less. Remaining erosion damages from loss in total value of crop productivity under the maximum net income program will be $15.7 million annually, a reduction of $2.8 million over the ongoing program. Increases in production efficiencies account for $9.8 million more than in the ongoing program. Efficiency increases come from eliminating expensive conservation practices (water disposal and conservation tillage systems, and from adding other practices (crop residue use, grassed waterways, stripcropping, and contour farming) that both reduce erosion and improve production efficiency.

The cost of installing permanent practices brought in under the maximum net income program is $9.3 million (or $2.0 million annually). The cost of implementing management type erosion control practices is $10.7 million annually. The cost of practices that only improve production efficiency and do not significantly reduce erosion is $15.2 million. Total annual cost of this alternative to the area is $27.9 million.

Appendix I

Job Control Language and Program Statements

Job control language allows a user to access a particular computer system and identifies that user to the system. In addition, JCL serves to inform the computer of any program packages and data sets that will be utilized in the analysis. Card 1 and 2 in Appendix I, Table 1, is referred to as the "job card." This card begins with two slashes followed by the name to be assigned to the particular job. The name may be up to eight characters in length, it must not have any blank spaces. The word JOB is necessary. This is followed by the user's account number, an identifier telling the location of the computer operator, the user's name or other identifying word, processing priority, maximum length of execution time, and number of copies of output.

Card 3 identifies location where output is to be sent for printing.

The next card indicates to the system that the user wishes to execute the MPSIII program and that the computer should locate the program in its library. In this illustration, MPSIII refers to the name given to the Ketron, Inc. MPSIII program package by the Washington, DC, USDA computer system analysts. This name or the procedure for accessing the program package will likely be different for other computer centers.

The fourth JCL card informs the computer system that the next section of input is the MPSIII control program. The control program tells the computer system how to use the linear programming package.

After the computer has been instructed by the appropriate JCL to execute the MPSIII program package, it is then necessary to tell it how to use the program procedures contained in the MPSIII system. This is accomplished through the MPSIII control program. The basic steps are explained in the following discussion.

Program statements, PROGRAM, and PEND are the necessary first and last card for every MPSIII control program. They indicate the beginning and ending of the control program statements. Statement INITIALZ, is necessary for establishing initial values for tolerances, frequencies, demands, etc. The basic function of this statement is to prepare the system to perform the linear programming analysis. The "Title" statement is optional. The descriptive name inserted on this card will appear on each page of the printout. The title may be up to 127 characters in length. Syntax (instructions) for continuation of a control statement to a second, third, etc., card is discussed in the users manual.

Appendix I

Table 1: Typical Control cards for a Linear Programming Problem using MPSIII at the Washington, D.C., Computer Center

```
  //SCSLP JOB(       ,RJ114,°NAME',CLASS=D,TIME=(2,00),
 //PRTY=3,MSLEVEL=(1,1)
//STEP5 EXEC MPSIII,PREFIX=SYS2,REGION.EXEC=3000K
//CPC.SYSIN DD *
            PROGRAM
            INITIALZ
            TITLE('SOUTHEAST GEORGIA - 2000 FUTURE - ONGOING')
            MOVE(XDATA,'SEGA')
            MOVE(XPBNAME,'PBFILE')
            MOVE(XRHS,'RHS1')
            MOVE(XRANGE,'RANGE1')
            MOVE(XOBJ,'NETRET')
            CONVERT('SUMMARY')
            SETUP('MAX','RANGE',XRANGE)
            WHIZARD('NOFE')
            SOLUTION
            EXIT
            PEND
//EXEC.STEPLIB DD DISP=SHR,DSN=SYS2.MPS3FIXS.LOADMODS
//               DD DISP=SHR,DSN=SYS2.MPS3.LOADMODS
//EXEC.SYSIN DD DSN=&&MPSIII,UNIT=SYSDA,DISP=(OLD,DELETE)
/*
//
```

Appendix I (con't)

The next four statements are necessary commands to the system. The first moves the user assigned name of the data for the problem into the storage cell XDATA. The name on this card may be up to 8 characters and must be the same name given on the first data card. The second "move" statement places the user assigned problem name in the cell, XPBNAME. The name assigned to this file, "PB File", can also include up to 8 characters. Importance of this name is evident in the discussion of REVISE in the users manual.

Statement XRHS (right-hand-side), XRANGE (range limits) and XOBJ (objective function) provide column and row names for the current problem. RHSI is a column name and Range 1 and Netret are row names. When data are entered, the user may include information for one or more objective functions and for one or more sets of constraining values or right-hand-sides. Each solution, however, will optimize only one objective, with one set of limitations.

The CONVERT command instructs the computer to read input data, convert it to binary code, and store it on the problem file under the PBNAME. The SUMMARY command directs the printing of the number of elements associated with each decision (columns) and constraining (rows) variable in the model. The SUMMARY parameter is optional but is important in verifying the accuracy of input data. The check command may also be used with SUMMARY to analyze the column names to determine if there are any duplications. Such duplications, which may come from cards being out of order, are not corrected but are noted so that the user might correct the problem and resubmit the program.

After the input data have been converted to binary code, the problem may be SETUP. The SETUP statement prepares the system for the optimization process through reading the problem file and analyzing problem statistics. This step also determines the computational strategy to be used, allocates available memory, and produces the work files that are used during computation. The parameter, MAX, indicates that the specified objective function is to be maximized. If minimization is desired, MIN may be used, or the parameter may be omitted since the system default is to minimize. RANGE statements identifies the limits of the variables specified.

The statement WHIZARD directs the computer to select the WHIZARD optimizer from the MPSIII software package.

Appendix I (Con't)

The WHIZARD command initiates the iterative procedure for solving the linear programming problem. This command is terminated after an optimal, infeasible, or unbounded solution is found. SOLUTION instructs the computer system to print the current solution or basis. EXIT returns program control to the computer operating system.

The next two JCL cards provide system information for the Washington, D.C., computer center. The following JCL card is required and indicates to the computer system that the next set of information to be input is data. The final JCL card is a simple double slash which instructs the computer system that the job has ended.

The slash star(/*) is a proxy for all input data for the model.

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