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ABSTRACT

This technical bulletin documents a model, the Natural Resource Linear Programming (NRLP) model, capable of measuring the effects of land use restrictions imposed as conservation measures. The primary use for the model is to examine the government expenditures required to compensate farmers for retiring potentially erodible private cropland. The model and its uses are introduced, and the design of the base model is then described. The mathematical formulation representing the base model is then specified. Land base data used in the base model are presented, and the derivation of coefficients used in the base model are later described. Results of a base run solution are presented. The bulletin concludes with a discussion of the system's potential applications such as analysis of cropland retirement programs, optional conservation-tillage practices, and integration of soil conservation programs with commodity programs. (YLB)

United States Department of Agriculture

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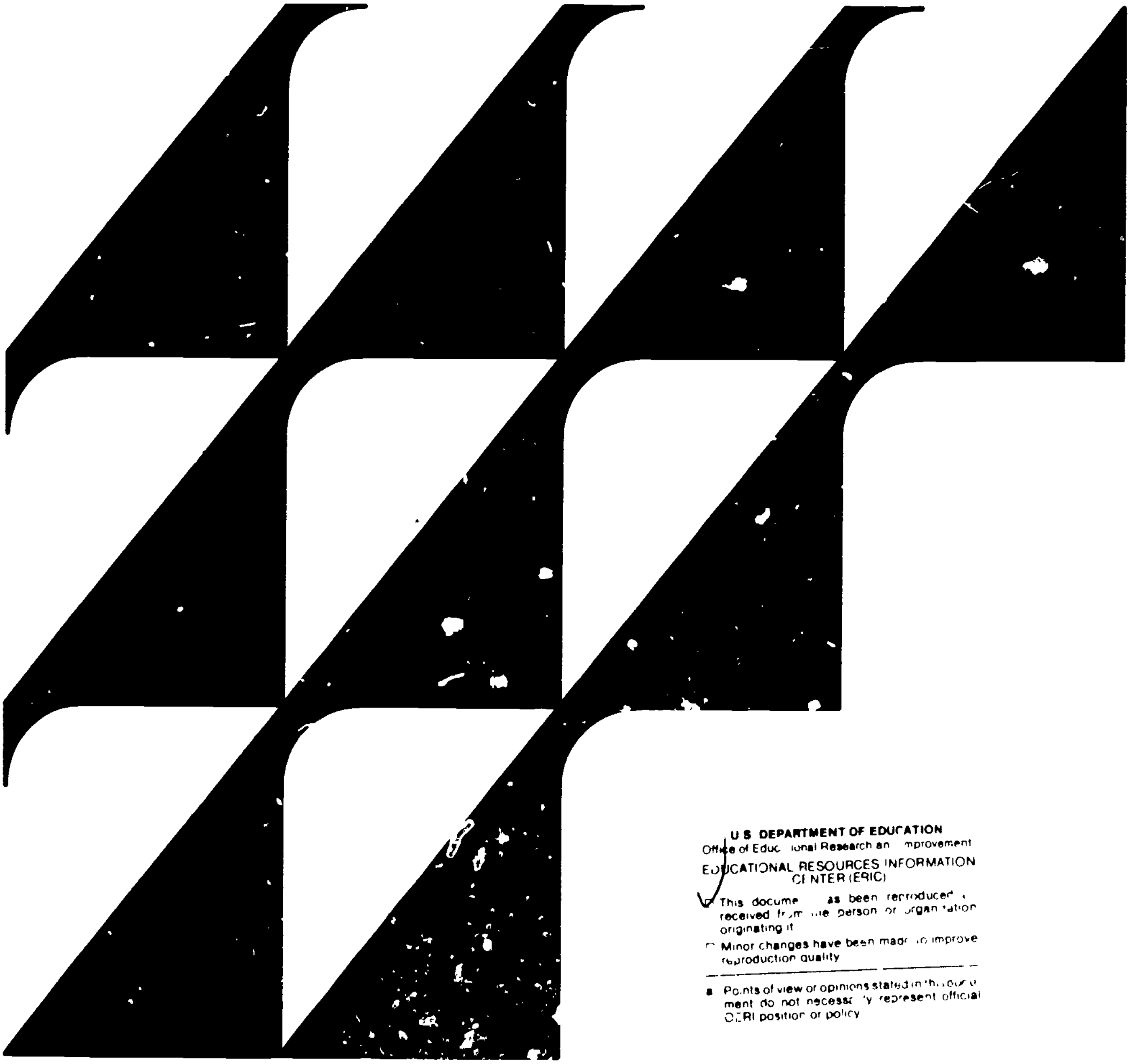
Technical Bulletin Number 1742

Land Use and Soil Erosion

A National Linear Programming Model

Wen-Yuan Huang
Michael R. Dicks
Bengt T. Hyberg
Shwu-Eng Webb
Clayton Ogg



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ABSTRACT

A newly developed interregional linear programming model provides a method to measure the effect of land use restrictions on soil erosion for use in policy analysis. The Natural Resource Linear Programming Model (NRLP) examines what Government spends to compensate farmers for taking fragile cropland out of production as a conservation measure. It also enables the researcher to determine what would happen to regional crop production, net returns, Government cost, and resource use if alternative land use policies were implemented. A sample analysis describes how the model is used in a recursive framework to estimate the effects of retiring 45 million acres of highly erodible cropland.

Keywords: Linear programming model, land use restriction, soil erosion, resource uses, crop production, net return, Government costs.

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SUMMARY

A newly developed interregional linear programming model provides a method to measure the effect of land use restrictions on soil erosion for use in policy analysis. The model examines what Government spends to compensate farmers for taking fragile cropland out of production as a conservation measure. It also enables researchers to determine what would happen to regional crop production, net returns, Government cost, and use of land, water, and inputs if alternative land use policies were implemented. A sample analysis describes how the model is used in a recursive framework to estimate the effects of retiring 45 million acres of highly erodible cropland.

The Natural Resource Linear Programming (NRLP) model contains 6 land groups, 105 producing areas, 31 market regions, and production activities consisting of a set of crops in rotation under different conservation and tillage practices. It evaluates how various policy actions would affect the productivity or erodibility of each land group. Policies which can be analyzed with the NRLP include constraining land use by productivity class, by potential damage from erosion, and by geographic preference.

The model also provides a powerful tool to analyze other soil conservation related policies. Simple modifications of the model would enable researchers to analyze alternative land use policies such as employing optional conservation-tillage practices and integrating soil conservation programs with commodity programs.

Land Use and Soil Erosion

A National Linear Programming Model

Wen-Yuan Huang
Michael R. Dicks
Bengt T. Hyberg
Shwu-Eng Webb
Clayton Ogg*

INTRODUCTION

There is a growing need for information on soil erosion. Erosion threatens the productive potential of soil and contributes to nonpoint source water pollution nationwide. This technical bulletin documents a model, the Natural Resource Linear Programming (NRLP) model, capable of measuring the effects of land use restrictions imposed as conservation measures. The model's main use is to examine Government expenditures required to compensate farmers for retiring potentially erodible private cropland.

We introduce the model and its uses and then describe the design of the base model. We specify the mathematical formulation representing the base model. We present the land base data used in the base model and later describe the derivation of coefficients used in the base model. Results of a base run solution are presented. We conclude with a discussion of the system's potential applications such as analysis of cropland retirement programs, optional conservation-tillage practices, and integration of soil conservation programs with commodity programs.

BACKGROUND

Soil erosion can be reduced through changes in cropping rotations, through increased use of conservation-tillage methods, through more efficient management of crop resid , by terracing, and through land use restrictions.

The land use restriction option controls commodity supply and soil erosion. Land use restrictions shift production from highly erosive crops such as corn and soybeans to less erosive crops such as hay and timber. One method to restrict land use is to compensate farmers for the net income they forego from setting aside acreage. Net income foregone varies from region to region and among types of land within regions. An estimate of foregone net income is needed to calculate Government program costs. The NRLP can make those calculations, and it can also examine the effects of resource use and production activities. Researchers can then use this information to compare alternative land use restriction possibilities.

*The authors are agricultural economists in the Economic Research Service, U.S. Department of Agriculture.

MODEL DESIGN CRITERIA

The model's main use is to examine Government expenditures required to compensate farmers for retiring highly erodible or fragile cropland. The compensation due a landowner is the foregone net return to land and management if the land is idled or used for other economic purposes. Data showing current resource uses are needed to determine the effects of implementing resource policies. Thus, a model designed to analyze land use restriction options should have the following features:

(1) A detailed land grouping to differentiate cropland quality among regions and different kinds of land.
(2) The ability to simulate relations between production and resource uses.
(3) The capacity to calculate marginal and average rent for lands of different quantities used in crop production.
(4) The ability to examine alternative methods of restricting land use.

The first feature requires a land base that reflects the level of soil erosion for each type of land in each region. It also differentiates fragile land from other cropland. Fragile land in this study is identified as cropland having physical characteristics not conducive to annual crop production.

An important Government task is to determine a least-cost method to induce a land use shift toward land conservation. Such a shift would be converting fragile cropland from intensive crop production to hay or pasture. An optimization method is needed to accomplish this task. A profit-maximizing linear programming model is adept at solving a problem of this type. The model will have an objective function defined to maximize net returns to land and management.

The second and third features can also be satisfied by a mathematical programming model. The NRLP model therefore was designed to incorporate these features. The model, for example, specifies relationships between output (production) level and input (resources) uses by a system of equality and inequality restraints. The optimization procedures produce a marginal and average rent for each resource.

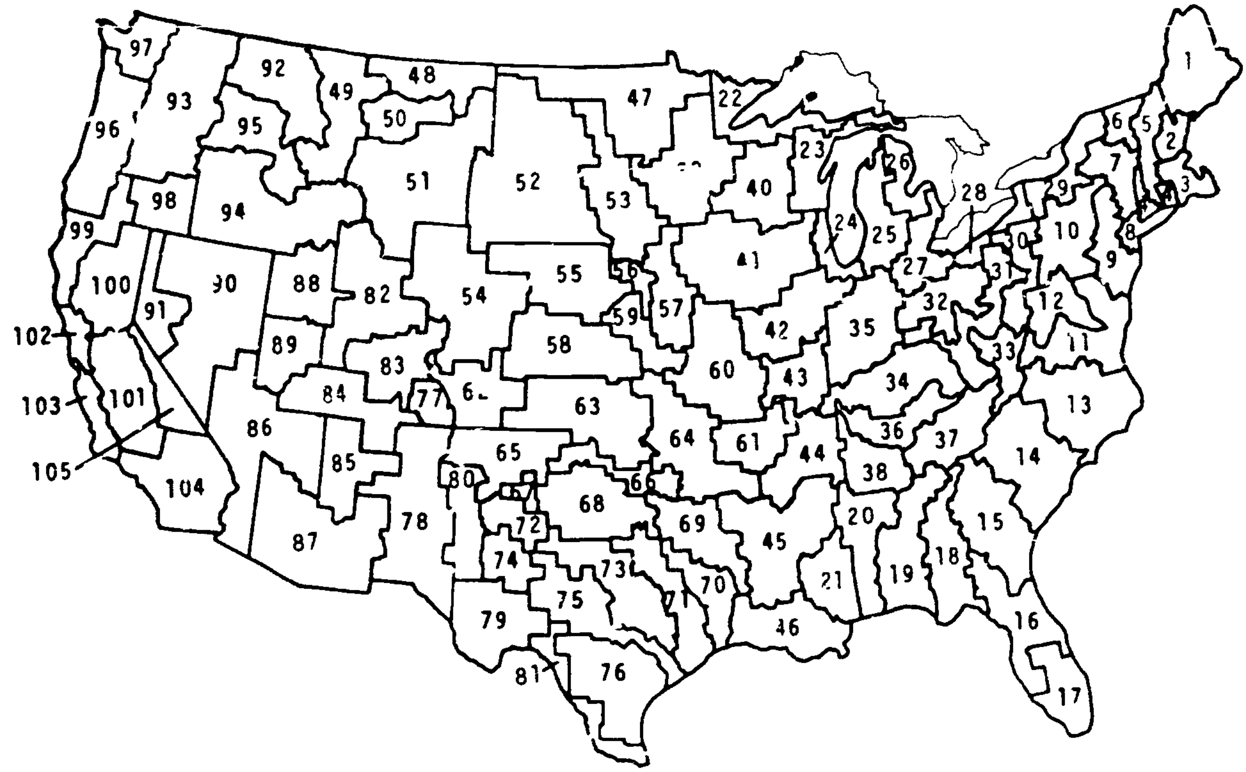
BASE MODEL OVERVIEW

A model designed to evaluate the effects of alternative policies should reflect wide regional variations in climate, soil, and crop production practices. We therefore designed a base model that divides the 48 contiguous States into 105 producing areas (PA's), based on the Water Resources Council's Aggregated Subareas (ASA's)(fig. 1).

Figure 2 shows the base model on which the NRLP model is patterned. Activities built into the model include cropping practices, crop selling, and nitrogen fertilizer purchase. A set of rotations define the cropping practices. The set of rotations are decision variables determined by crop type, conservation and tillage practices, land group variations, and regional differences. The set of rotations are related through a set of production restraints which include land, commodity, nitrogen fertilizer, tillage practice, soil loss, and water use. PA, land type, and crop type are used to

Figure 1

The 105 producing areas of the continental United States



assign values to restraints. Each crop has an associated upper bound on total production possible for a given year.

NRLP MODEL STRUCTURE

The NRLP model quantifies the relationship between crop production, resource use, and profitability using profit-maximizing criteria.

Objective Function

The objective function in the NRLP model is to maximize the returns to land and production management. This specific objective function is used because the returns represent the revenue that farmers forego when they restrict or set aside cropland.

The objective function is specified by:

$$\text{Max } Z = \sum_i \sum_j P_{ij} Q_{ij} - \sum_i \sum_k \sum_m \sum_r CD_{ikmr} XD_{ikmr}$$

$$- \sum_i \sum_k \sum_m \sum_r CI_{ikmr} XI_{ikmr} - \sum_s NP_s (NF_s + NR_s) \qquad (1)$$

i = 1,..., 105 for the producing areas.

Figure 2
Schematic representation of the base model

Activities / Constraints	Cropping practices		Cropping practices	Crop selling	Nitrogen buying	RHS
Objective	Cost/acre		Cost/acre	Selling price	Nitrogen price	
	PA 1					
Land	1					≤1
Commodity	Crop yield/acre			−1		=0
Nitrogen fertilizer	Nitrogen fertilizer use/acre				−1	=0
Tillage practice	1					≤R
Soil loss	Soil loss/acre					N
Water use	Water use/acre					N
			PA 105			
Land			1			≤L
Commodity			Crop yield/acre	−1		=0
Nitrogen fertilizer			Nitrogen fertilizer use/acre		−1	=0
Tillage practice			1			≤R
Soil loss			Soil loss/acre			N
Water use			Water use/acre			N
Bound				Production bound		

j = 1,..., 10 for the following crops in sequence: corn grain, sorghum grain, wheat, oats, barley, soybeans, cotton, legume, hay, nonlegume hay, and corn and sorghum silage.

k = 1,..., 6 for land groups.

m = 1,..., 12 for conservation and tillage practices.

r = 1,..., Rik for possible rotations defined for production area i and land group k.

s = 1,..., 28 for the market regions.

where:

P_{ij} = the price of crop j in producing area i.

Q_{ij} = the quantity of crop j produced in producing area i.

$CD(CI)_{ikmr}$ = the cost per acre for rotation r with conservation-tillage practice m in land group k for dryland (CD) and irrigated land (CI) in producing area i.

$XD(XI)_{ikmr}$ = the number of acres in rotation r with conservation-tillage practice m in land group k for dryland (XD) and irrigated land (XI) in producing area i.

NP_s = price per pound of nitrogen fertilizer in market region(s).

$NF(NR)_s$ = quantity of nitrogen fertilizer applied to dryland (NF) and irrigated land (NR) in market region(s).

Production costs for dryland (CD) and irrigated land (CI) exclude costs of nitrogen fertilizer, land, and management.

Production and Resource Restraints

Regional production and resource restraints are used to relate prevailing crop production activities to resource uses. The production restraints provide limits on the possible distribution of commodity production from rotation Rik, using conservation-tillage practice m on land group k in producing area i. The restraints are obtained from both State and national data, described later. The resource restraints set the maximum resource available for crop production in each land group in each region. They are used to limit the acreage of each crop for various policy analyses.

Land Restraints

Cropland in production is limited by cropland available in each producing area.

Dryland regions have land restrictions as:

$$\sum_{m}\sum_{r} XD_{ikmr} < DL_{ik} \qquad (2)$$

Irrigated regions also have land restrictions as:

$$\sum_m \sum_r XI_{ikmr} < IL_{ik} \qquad (3)$$

where:

DL_{ik} = the number of acres of dryland available in land group k in producing area i (i = 1,.., 105).

IL_{ik} = the number of acres of irrigated land available in land group k in producing area i (i = 48,.., 105).

Commodity Balance Rows

Commodity production in each region is computed in the following way:

$$\sum_k \sum_m \sum_{r\epsilon j} A_{ikmr} XD_{ikmr} \cdot \sum_k \sum_m \sum_{r\epsilon j} b_{ikmr} XI_{ikmr} - Q_{ij} = 0 \qquad (4)$$

where:

A_{ikmr} = yield for crop j in rotation r using conservation and tillage practice m on land group k in producing area i (B = irrigation yield).

Crop Production Bounds and Acreage Constraints

Both production bounds and acreage constraints provide a tool to restrict crop production in each producing area. The production bound is:

$$Qij \leq QBij \qquad (5)$$

where:

QB_{ij} = the maximum quantity of crop j produced in producing area i.

The acreage constraint is:

$$\sum_k \sum_m \sum_{r\epsilon j} W_{ikmr} XD_{ikmr} + \sum_k \sum_m \sum_{r\epsilon j} V_{ikmr} XI_{ikmr} < XA_{ij} \qquad (6)$$

where:

$W(V)_{ikmr}$ = the fraction of dryland (W) and irrigated (V) acres for crop j in rotation r using conservation-tillage practice m on land group k in producing area i.

XA_{ij} = the maximum number of acres of crop j in producing area i.

Nitrogen Fertilizer Rows

Nitrogen fertilizer use in each producing area is calculated separately for dryland and irrigated cropland. The use on dryland is calculated as:

$$\sum_{i \epsilon s} \sum_k \sum_m \sum_r F_{ikmr}\, XD_{ikmr} - NF_s = 0 \tag{7}$$

Fertilizer use on irrigated cropland is calculated as.

$$\sum_{i \epsilon s} \sum_k \sum_m \sum_r F_{ikmr}\, XD_{ikmr} + \sum_{i \epsilon s} \sum_k \sum_m \sum_r G_{ikmr}\, XI_{ikmr} - NR_s=0 \tag{8}$$

where:

$F(G)_{ikmr}$ = nitrogen fertilizer needed to produce dryland (F) and irrigated (G) crops in rotation r with conservation-tillage practice m on land group k in producing area i of market region s.

Tillage Practice Rows

The use of conservation-tillage practices is restricted in each producing area by the equation:

$$\sum_k \sum_r XD_{ikmr} + \sum_k \sum_r XI_{ikmr} = TA_{im} \tag{9}$$

where:

TA_{im} = the number of acres using conservation-tillage practice m in producing area i.

Resource and Input Use Accounting Rows

The accounting rows are used to track resource and water uses for a given production pattern. These rows are converted into constraints for some policy analyses.

Soil loss is calculated as:

$$\sum_m \sum_r S_{ikmr}\, XD_{ikmr} + \sum_m \sum_r T_{ikmr}\, XI_{ikmr} = SL_{ik} \tag{10}$$

where:

$S(T)_{ikmr}$ = is the number of tons of gross soil loss per acre resulting from the production of dryland (S) and irrigated (T) crops in rotation r with conservation-tillage practice m on land group k in producing area i.

Sl_{ik} = soil loss on land group k in producing area i

Water use is calculated as:

$$\sum_k \sum_m \sum_r U_{ikmr}\, XI_{ikmr} = WT_i \tag{11}$$

where:

U_{ikmr} = per acre use of water for rotation r using conservation-tillage practice m and land group k in producing area i.

WT_i = water use in producing area i.

ESTIMATION OF AVAILABLE LAND

The amount of land available for agricultural production is one of the most important restraints in the model. We used 1982 National Resource Inventory (NRI) data to estimate both current and potential cropland available in each producing area. The 1982 NRI provides crop acreages by county, reflecting 1982 crop year land use patterns. We aggregated the acreages in each producing area for each land group, assorted by dryland or irrigated land.

Land Group Delineation

Cropland acres in each producing area are aggregated into six land groups according to specific criteria (table 1). The land capability class system (7) 1/ served as our method for aggregating crop acreage data into eight

1/ Underlined numbers in parentheses refer to literature cited in the References section.

Table 1--Land group delineation

Land group	Land capability class	Erosion potential	Average crop yield
1	I IIwa 1/ IIIwa	Low	High
2	IIw, IIs, IIc IIIw, IIIs, IIIc IVw, IVs, IVc	Low	Low
3	IIe, RKLS < 50 IIIe, RKLS < 50 IVe, RKLS < 50	Medium	Medium-high
4	IIe and IIIe RKLS > 50	High	Low-medium
5	IVe, RKLS > 50	High	Low-medium
6	V VI VII VIII	Medium-high	Low

1/ Suffix denotes dominant limitation: c = climate; e = erosion; s = shallow, draughty, or stony soil; w = wetness; wa = wetness, but adequately treated.

capability classes (I-VIII). We further identified these classes by the dominant limitation to continuous crop production, such as erosion, wetness, stony soil, and climate. The land capability classes and subclasses were then aggregated into land groups based on yield and RKLS values.

The RKLS value, which represents the physical characteristics of the soil (5), was obtained by sample point from the 1982 NRI.2/ The RKLS value reflects erosion potential. Crop acres with RKLS values exceeding 50 are assumed to be highly erodible. We made the assumption that cropland in each land group would have approximately the same level of crop yield and erosion potential. We therefore combined the land capability class system with the RKLS measure of erodibility. The cropland in land group 1 combines acres with the capability class and subclass I, IIwa (where wa means adequately treated wetland), and IIIwa. Land group 1 has low erosion potential with high average crop yields. Cropland in land group 2 includes crop acres in all subclasses of land capability classes II, III, and IV except e and wa. Group 2 has low erosion potential and relatively low crop yield. Cropland in land group 3 includes crop acres of subclasses IIe, IIIe, and IVe which have RKLS's of less than 50. Land group 3 has medium erosion potential with relatively high crop yields. The fourth land group consists of crop acres in capability classes IIe and IIIe which have an RKLS exceeding 50, while the fifth land group contains cropland in capability class IVe which has an RKLS exceeding 50. Thus land groups 4 and 5 have high erosion potential but slightly lower crop yields than those of land group 3. Land group 6 consists of cropland in land capability classes V, VI, VII, and VIII. This group defines fragile land. It has the lowest crop yield and medium to high erosion potential.

Current Cropland

Current cropland available in each land group and producing area is defined as the sum of the crop acres of the following 12 crops: corn, corn silage, sorghum, sorghum silage, soybeans, cotton, wheat, oats, barley, summer fallow, legume hay, and nonlegume hay as determined in the 1982 NRI data. Table 2 presents a national summary of aggregated crop acres of these 12 crops in each land group. The distribution of cropland acreage by land group in each region is used as the upper bound restraint for the NRLP base solution. The crop constraints are defined at the national, regional, and producing area levels of aggregation (see equation 6). Crop acreage bounds are initially determined by the crop distributions based on the 1982 NRI. These crop distributions are adjusted proportionately to arrive at the actual national acreage for the period being analyzed. However, the crop acreage bounds at each level of aggregation may be relaxed as a requirement of the analysis. In analyzing what effects a policy will have, for example, the analyst may relax the land constraints to allow for interregional shifts in production. Otherwise, the analyst is forcing the future to replicate current regional crop distributions.

Potential Cropland

We obtained estimates of acreage that can be converted from pasture, range, and forest lands to cropland from 1982 NRI data. These acres are identified as having either high or medium potential for conversion to cropland. The

2/ A detailed definition of RKLS follows in the next section of the report.

conversion cost is usually lower for the high-potential land. Table 3 shows a summary of the national acreage with medium and high conversion potential for each land group. We then constructed, for use with the model, the distribution of potential cropland by producing area and land group, for both irrigated and dryland acreage.

CROP PRODUCTION AND PRODUCTION-RELATED COEFFICIENTS

Cropping practices represent the crop production activities in the model. A cropping practice is defined as a sequence of crops, known as a rotation, produced on a defined land group in a producing area using a specific tillage

Table 2--Summary of national cropland by land group 1/

Land group	Dryland	Irrigated	Total
		1,000 acres	
1	58,037	9,690	67,727
2	86,284	15,746	102,030
3	142,071	15,837	157,908
4	21,115	218	21,333
5	8,976	268	9,244
6	13,991	2,214	16,205
Total	330,474	43,973	374,447

1/ Acreage represents the following crop acres in the 1982 NRI: corn (grain and silage), soybeans, cotton, wheat, oats, barley, soybean (grain and silage), summer fallow, and hay.

Source: 1982 National Resource Inventory.

Table 3--Summary of national acres with a medium or high conversion potential

Land group	Medium potential for conversion to--		High potential for conversion to--		Total	
	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated
			1,000 acres			
1	8,722	195	5,307	222	14,028	417
2	25,997	851	7,831	425	33,828	1,276
3	46,383	534	15,427	260	61,810	974
4	10,973	6	2,695	2	13,669	8
5	5,700	2	620	0	6,320	2
6	12,820	161	1,389	56	14,209	217
Total	110,5[illegible]5	1,748	33,268	966	148,863	2,714

Source: 1982 National Resource Inventory.

and soil conservation practice. The model includes 12 crops: barley, corn grain, corn silage, cotton, legume hay, nonlegume hay, oats, sorghum, sorghum silage, soybeans, summer fallow, and wheat. Each rotation is described by a set of not more than four crops. The model also contains 12 possible tillage and conservation practices. Each practice is a combination of one of three tillage methods (fall plow, spring plow, and minimum tillage) together with one of four field practices (straight row, contour, strip, and terrace).

Each cropping practice has an associated set of coefficients reflecting crop yields, production cost, soil loss, fertilizer requirement, and water use. We estimated each coefficient. Estimation methods follow.

Crop Yield Coefficients

The base yield for each crop is adjusted depending upon a number of factors: the rotation in which the crop occurs, the land group on which it is produced, the conservation and tillage practices used to produce it, and the producing area in which it is grown. These adjustments are combined to produce the yield coefficients. The actual yield for each crop determined in the model is estimated in two stages. In the first stage, analysts determine the base yield by using the modified Spillman functions developed by Stoecker (10).3/ The Spillman function estimates the base yield related to fertilizer application level as the product of the various yield adjustments. In the second stage, analysts adjust for crop rotation by following the process outlined by English and others (3). That is, when a crop occurs in rotation with a legume crop or summer fallow, the yield is adjusted upward. However, a continuous rotation of a nutrient-intensive crop such as corn or wheat means that yield must be adjusted downward. The conservation and tillage practice adjustment is based on yield and tillage data obtained from the U.S. Department of Agriculture's Soil Conservation Service (SCS) questionnaire. Adjustments for the land group and producing area are achieved by first creating a productivity index.

Productivity Index

The productivity index provides the relationship between the physical characteristics of the land and its land capability class. The index is used to adjust the yield coefficient based on which group and in which producing area the crop occurs. Estimating the productivity index is carried out in three steps.

First, productivity is indexed by land capability class and producing area. The RKLS value corresponding to each land capability class is estimated from the 1977 NRI. This estimate provides a productivity function that relates crop productivity to RKLS values for each producing area.

Second, the RKLS values for each land capability class are aggregated to produce weighted RKLS values for each of the six land groups. The RKLS values for land groups 3, 4, and 5 are then computed. For land group 3, only those acres in land capability classes IIe, IIIe, and IVe with RKLS values under 50 are used in the aggregation process. For land group 4, only those acres in land capability classes IIe and IIIe with RKLS values exceeding 50 are used. For land group 5, only those acres in land capability class IVe with RKLS

3/ Each State has a modified Spillman function.

values greater than 50 are used. The RKLS values are weighted in the aggregation process by the acreage associated with each NRI point estimate on each land capability class and then combined with the land group. The result is an average RKLS value for each of the six land groups in each producing area.

Third, the products of the first two steps are combined. Corresponding to an average RKLS value, a productivity index for each crop in each land group and in each producing area is obtained from the relation between crop productivity and RKLS value. The productivity index is then used to develop the final yield coefficients.

Production Costs

Production costs are estimated using the Firm ' iterprise Data System (FEDS). Total production costs for each crop exclude costs of land and management. Production costs are weighted from the FEDS regions to the producing area.

Total production costs for each crop are broken into four major cost categories (machinery, labor, pesticides, and other costs) and four other expense items (nitrogen fertilizer, other fertilizers, water, and terracing) (3). These costs are adjusted for contouring, strip cropping, and terracing. Similar adjustments are made for tillage practices. The difference in farming time between conservation and tillage practices, surveyed by SCS, provides the basis for adjustments. Terracing construction costs are calculated from SCS data (8). Production costs for a crop rotation are the sum of the weighted cost components of all crops in the rotation. The average cost of irrigating is then added to compute final production costs for each rotation carried out in irrigated areas. Water costs were obtained from weighted prices of surface water and ground water.

Surface-water prices are acreage weighted, average reimbursable costs of the U.S. Department of Interior's Bureau of Reclamation water projects. Groundwater prices were based on values determined by Dvoskin and others (2).

Prices of nitrogen fertilizer for 31 market regions were derived from nitrogen prices normalized across States. These, in turn, were weighted by the 1974 Census of Agriculture's State and county commercial fertilizer use data (13).

Soil Loss

The Universal Soil Loss Equation (USLE) was used to estimate the gross soil loss coefficient for the NRLP model. Gross soil loss represents the average annual tons of soil displaced by water runoff.

The USLE, as described by Wischmeier and Smith (15), is expressed as:

$$A = RKLSCP \qquad (12)$$

where:

A = annual soil loss in tons per acre

R = rainfall and runoff factor

K = soil erodibility factor

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L = length of slope factor

S = steepness of slope factor

C = cover and management factor

P = tillage practice factor

The value of RKLS for each sample point in the PA is multiplied by a proportion of its representative area per land group in the PA. The result is a weighted RKLS for each land group in each PA. These newly computed values of RKLS, together with the rotation and its corresponding C and P factors, are used to compute the soil loss coefficient for each cropping practice.

Water and Nitrogen Fertilizer Uses

Crop rotations with an irrigation activity occur in PA's 48-105. Each of these rotations has a water use coefficient. The water use coefficients are based on estimates of the net diversion water requirement for crop growth. A net diversion requirement (NDR) for crops in PA i is estimated from the equation:

$$NRDij = [(1-RFi)/(IEj)(DEj)]\ CIRij \qquad (13)$$

where:

CIRij = the quantity of water required in producing area i by crop j.

IEj = the onfarm irrigation efficiency of crop j.

DEj = the delivery system efficiency between the diversion point and the farm for crop j.

RFj = the percentage of water unused by crop j which is returned for reuse.

The parameters required for estimating NDRij were derived from SCS data (11).

Nitrogen fertilizer use coefficients were defined by the net amount of nitrogen fertilizer required for a crop rotation. The coefficient is derived by solving the marginal condition in the Spillman function in estimating the crop yield for a rotation with legume crops. The nitrogen requirement estimated from the Spillman function is then subtracted from the quantity of nitrogen that legume hay produces during rotation. The amount of nitrogen legume hay produced is estimated with the method Nicol and Heady developed (8).

INTERPRETATIONS OF THE NRLP BASE SOLUTION

Several outputs of the NRLP base solution for 1982 are useful for analyzing the implications of retiring or restricting the use of cropland. Marginal net return (MR) and average net return (AR) for retiring 1 acre of land are two important pieces of information that can be obtained from the output. We present an interpretation of these two estimates in a sample land use

restriction policy. We will use only two producing areas (PA's 41 and 42) and two crops (corn and soybeans) to simplify the example.

The Lagrangian function of a reduced NRLP model can be expressed as:

$$F = Z - \sum_i \sum_k \alpha_{ik} \left(\sum_r XD_{ikr} + SDL_{ik} - DL_{ik}\right)$$

$$- \sum_i \sum_j \beta_{ij} \left(\sum_k \sum_m \sum_r A_{ikmr} XD_{ikmr} - Q_{ij}\right)$$

$$- \sum_i \sum_j \mu_{ij} \left(Q_{ij} + SQ_{ij} - QB_{ij}\right) \qquad (14)$$

where α_{ik}, β_{ik}, and μ_{ik} are the Lagrangian multipliers and where SDL_{ik} and SQ_{ij} are slack variables. Values for these multipliers and variables can be obtained from the base solution.

Because the model is linear, a global optimum is guaranteed if the Kuhn-Tucker conditions are satisfied. The Kuhn-Tucker conditions are obtained by setting the partial derivative of the Lagrangian function at zero.

Marginal and Average Net Returns

The base run solution produces two important estimates which are used to analyze various land use restriction policies. These are MR and AR for retiring 1 acre of land in each land group.

The MR is calculated by:

$$dZ^* / dDL_{ik} = \alpha^*_{ik} \qquad (15)$$

where Z^* is the objective function evaluated at the optimum solution, while α^*_{ik} is the Lagrangian multiplier at the optimum. The value of α^*_{ik} approximates how much the net return will be reduced from the objective function value Z^* if 1 acre of DL_{ik} is removed from crop production. Table 4 shows marginal net revenues for PA's 41 and 42.

Values in table 4 can be interpreted in the following way. The last acre of land group 1 brings in a net return of \$215 in PA 41 and \$221 in PA 42, given

Table 4--Sample marginal net returns for an acre of cropland

Land group	PA 41	PA 42
	Dollars	
1	215	221
2	122	137
3	175	189
4	165	158
5	134	134
6	73	33

the crop production system the model describes. The MR values show that farmland in PA 41 and PA 42 generally is comparable.

Average dryland net return (AR) can be calculated from:

$$AR_{ijk} = (\sum_{m}\sum_{r} (A_{ikmr}XD_{ijkmr}P_{ij} - CD_{ijkmr}XD_{ijkmr}) / \sum_{m}\sum_{r} XD_{ijkmr} \qquad (16)$$

Table 5 shows the AR for producing corn and soybeans in each of the six land groups within PA's 41 and 42. The values can be interpreted in the following way. One acre of land group 1 in PA 41 will bring an average net return of \$248 for growing corn and \$166 for growing soybeans. It will bring \$226 for growing corn and \$165 for growing soybeans in PA 42. Corn produces a higher average net return than soybeans. The values also show that the average net return for corn in PA 41 is comparable to that in PA 42. Comparability holds for soybean production. Negative values in land group 6 for soybeans in PA 41 and for both crops in PA 42 indicate that it is unprofitable to produce either crop on cropland defined by land group 6. These crops enter the solution because they are planted in rotation with other profitable crops.

Another estimate this solution generates is the marginal net return per unit of production (MRP) μ_{ij}. This variable measures the net returns from reducing one unit of production of a specific crop in each PA.

The relationship between β_{ij}, Pij, and μ_{ij} can be derived by taking the partial derivation of the Lagrangian function F with respect to Qij.

The equation depicting the relationship is:

$$\mu_{ij} = P_{ij} - \beta_{ij} \qquad (17)$$

The value of Pij for corn in PA 41 is \$3.08. Thus, reduction of the last bushel of corn will reduce the net return \$0.20 ($\mu_{41,1}$), which is the difference between the corn price of \$3.08 and its opportunity production cost of \$2.88 ($\beta_{41,1}$). The corresponding amount for PA 42 is $\mu_{42,1} = 0$, because $P_{42,1} = \beta_{42,1}$ = \$3.21. Since MRP is zero, a reduction of one unit of corn in PA 42 will not reduce the net return from corn production.

Uses of Marginal and Average Net Returns

The MR estimated the net return to the last piece of land of a particular land group entering into crop production without targeting a specific crop. The AR calculates the average net return for growing a specific crop on a specific

Table 5—Sample average net revenues

Land group	PA 41		PA 42	
	Corn	Soybeans	Corn	Soybeans
	Dollars			
1	248	166	226	165
2	136	94	123	95
3	191	136	178	141
4	179	123	138	112
5	145	94	107	89
6	0	-7	-1	-8

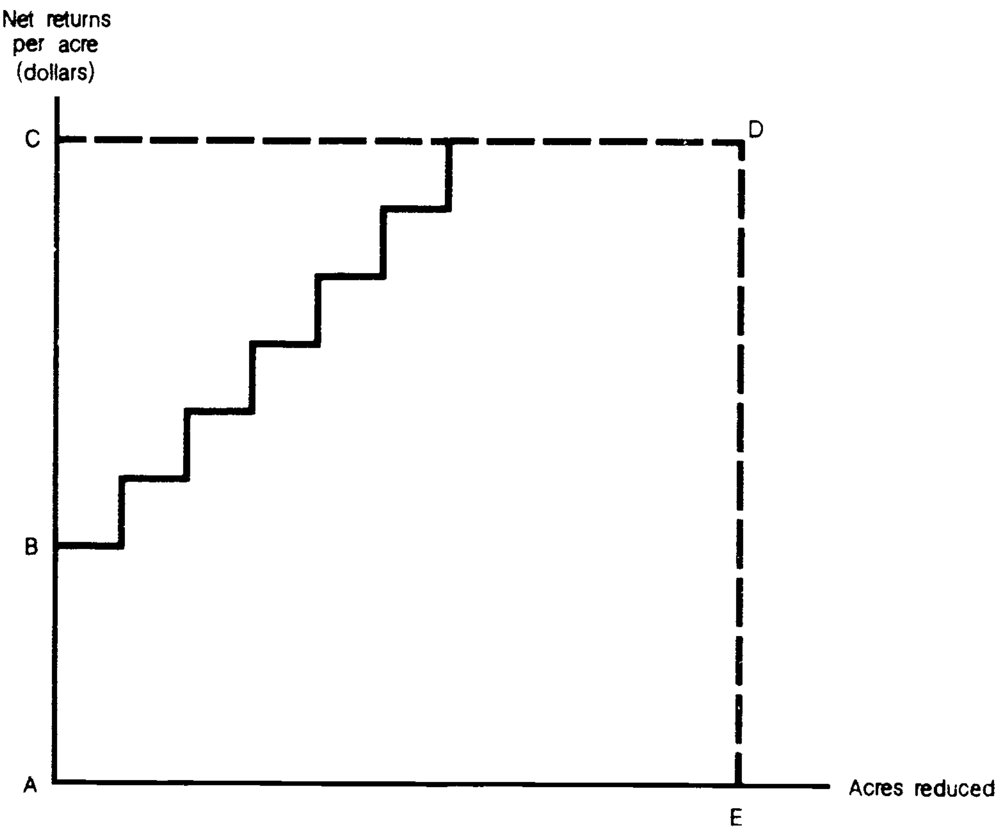
land group. The marginal net return per unit of production (MRP) computes the net return for producing the last unit of a specific crop.

The MR, in a land retirement study, can be used as an approximation of the foregone net return after retiring 1 acre of land under the 1982 cropland use pattern in a region. The AR provides an approximation of the foregone net return for retiring an average unit of cropland in which a specific crop is grown. The AR may also accurately estimate the relative per acre Government payment necessary to induce farmers to reduce acreage of specific crops. The MRP provides an estimate of the payment to a farm for reducing one unit of production of a specific crop. A farmer in PA 41 should receive 20 cents for reducing the last bushel of corn production from the 1982 level, while a farmer in PA 42 should receive no payment for the same action. Thus, these values provide useful estimates for designing land use programs, especially supply control programs.

Calculating Government Cost for Land Use Restriction Options

How much it costs the Government to induce land use changes can be calculated under bid or offer systems. It is assumed, under a bid system, that producers submit bids representing the minimum payment required to compensate them for any loss of net returns resulting from land use change. The foregone net return for reducing each parcel of land thus equals the bid. On the other hand, a specific per acre payment is offered to all farmers under an offer system, and they may enroll as many acres as they wish at the payment level. Figure 3 shows the relationship of the total Government payment under the bid and offer systems. Total Government payments for land retirement under the

Figure 3
Government payments under bid and offer systems



bid system are represented by the area ABDE. Total Government payments are represented by the area ACDE under the offer system. The figure clearly shows that the Government cost for retiring land is always less under the bid system than under the offer system.

Government cost, calculated under the bid system, is the sum of the foregone marginal net return for each piece of cropland retired. Because cropland is aggregated by land group for each producing area, the aggregated acres of a specific land group are assumed to approximate the marginal net return. The sum of all the net returns by land group and PA produce an estimate of cost under a bid system.

The following assumptions are required to estimate Government cost for a short-term land retirement option under a bid system: (1) No additional administration or other costs are required for implementing a land retirement program, (2) Retired land is paid for according to its marginal net return, (3) Production patterns will not change, and (4) Retired land is not put to other productive use or economic gain.

The model allows for adjustments in cropland use when users are examining long-term land use restrictions. Farmers in long-term land retirement programs may be allowed to put the retired cropland to other economic use. Use of the bid system for calculating Government cost for long-term land retirement requires the following assumptions: (1) There are no administrative or other costs for implementing land retirement programs, (2) The net profit situation assumed in the base mode will not change, and (3) Optimal cropping patterns are used in each region.

APPLICATIONS AND IMPROVEMENTS

The NRLP model has been used to examine three methods of retiring land aimed at reducing crop production (14, 9). The first method was the least-Government cost method. This method retired marginal land in each region to achieve a specific level of production cutback for the minimum Government expenditure. The second method targeted fragile land. Production was reduced by targeting only land groups 4 and 5 (which have the most sheet and rill erosion) and land group 6 (which is fragile land). A third method used the 1978 program pattern. Production was reduced by cutting back output in each producing area by following the Government's 1978 pattern of acreage diversion and set-aside.

The model has also been used to evaluate production and conservation effects of special long-term land use restrictions, whereby permanent easements were purchased (1).

The NRLP model provides a powerful tool for analyzing other problems related to soil conservation policies. Simple modifications to the model will enable researchers to analyze alternative land use policies such as cropland retirement programs, optimal conservation-tillage practices, and integrating soil conservation programs with commodity programs.

Land Retirement

Many long-term land retirement programs can be analyzed with a modified base model, usually achieved by eliminating, adding, or revising the restraints

between crop production and resource supply. Data can be revised and updated to reflect the long-term changes in productivity and profitability. Some of the long-term problems that can be analyzed are (1) long-term conversion of cropland to other uses, (2) long-term effects attributable to soil erosion, and (3) efficient allocation of limited Government resources for long-term soil conservation.

Many short-term land retirement programs can also be analyzed by using a data base system developed from the 1982 solution of the base model. The data base system provides detailed information such as current production cost, crop yield, soil erosion, and crop prices for crop acres of each land group in each producing area. Cost and consequences of various short-term land retirement programs can be evaluated annually. Some of the programs that can be analyzed are: (1) strategies for retiring fragile and marginal lands, (2) interaction between commodity and soil conservation programs, and (3) dynamic allocation of limited Government resources to reduce soil erosion.

Tillage and Conservation Practices

Soil erosion on some erosive land can be controlled by using different conservation-tillage practices. Conservation-tillage practices are a combination of the following six elements:

(1) Types of tillage equipment (moldboard or disk plow) used,

(2) Time of tilling (spring or fall plowing),

(3) Intensity of tilling (number of times plowed),

(4) Crop residue management (removed or left),

(5) Type of tilling practiced (straight, strip, contouring, or terracing), and

(6) Crop sequence (rotation) used.

Evaluating each combination of practices on various land groups and producing areas is very important. Each land group is likely to have a set of "best" practices suited to its potential for soil conservation and crop production.

Because the production activities and conservation-tillage practices used in the base model are defined similarly, the base model can be used as an evaluation tool. Any activity can be preselected and built into the model so that a particular set of practices targeted to various land groups can be appraised.

Program Integration

Consistency between Government commodity programs and soil conservation programs is vital. Commodity programs need to be assessed on the basis of their cost and soil erosion consequences. Any newly developed soil conservation program also needs to be evaluated for its effects on farm incomes and consumer expenditures. A program that leads to a desired level of commodity production while being consistent with soil conservation goals is highly desirable.

The NRLP model provides information on crop production, production cost, net return, and soil loss on each piece of land in each land group in each producing area. Data contained on plowing activities, potential cropland, and land resources can be used to evaluate how changes in production subsidies will affect conservation. The model can also be applied to studies of supply control.

Model Improvements

One application of the NRLP model is to examine resource use of current crop production in each of the 105 producing areas. The estimated current crop production is imposed on the NRLP model in each producing area to achieve this objective. But, there are problems associated with this approach.

Some minor crops are omitted in the base model, resulting in an underestimate of resource use in each producing area. This shortcoming, however, can be overcome by adding the production activities of minor crops to the producing area.

The optimization method, rather than actual land use patterns, determines what cropland is used in each PA. The optimization method assigns acres in each land group to various crops so that net returns in each PA are maximized for the required crop production levels. Although production levels are equivalent by definition, the difference between the land use estimate in the model and the actual land use pattern in 1982 can be significant. The 1982 NRI data can be used to adjust the estimates for analyses that do not require optimizing runs of the model.

Potential problems may also exist with the data base used to build the model. These data need to be examined and improved. Productivity index data should be compared with the results obtained from productivity models such as the Erosion Productivity Impact Calculator (EPIC). Production cost data require constant updating, particularly those costs associated with various tillage and conservation practices.

Since there are many ways to define fragile land, it is possible that each region may have different types: wetlands, wind erodible, and water erodible. The data base should be designed to accommodate policies focusing on those types. A researcher, by manipulating the data base, will be able to build a new land base, calculate productivity indexes, and compute production costs for the analysis of a specific land use policy or policies.

The limitation of the NRLP model stems from the assumptions of a linear programming model. These assumptions are proportionality, additivity, divisibility, and certainty. Proportionality assumes dependence between production and other activities the model contains. The use of each resource and the effectiveness of a production activity are directly proportional to the level of the activity. Additivity assumes that there are no interactions between any of the production activities. Therefore, the additivity assumption requires that the total use of each resource and resulting total measure of effectiveness equal the sum of the corresponding quantities generated by each activity. The divisibility assumption asserts that the activity units can be divided into any fractional level, so that noninteger values for the decision variables are permissible. A similar assumption is also applied to resource use. The certainty assumption maintains that all the coefficients used in each activity, and resources available, are constant.

Understanding the implication of these assumptions is important for using the NRLP model and interpreting its results. The limitations that these assumptions present, however, can be surmounted. There are some techniques which can be used to avoid or lessen the effect of any of the assumptions. They should be used to construct any NRLP model which will assess policy problems, since policy applications require special treatment.

Model Update

The NRLP model was designed before 1982 NRI and 1985 RCA data were available. Thus, our description of the model is somewhat outdated. The data sources used to construct the NRLP have been replaced, but the model structure remains unchanged. (See the appendix for methodology and data used to update the model).

Sample Policy Analysis Using the NRLP Model

The NRLP model provides economists with a means to analyze the effects of agricultural and conservation policy on regional and national agricultural production. Its ability to capture the shifts in input use, land shifts, and production practices in response to price changes and regulatory constraints allows economists to understand the consequences of agricultural policy.

We used the NRLP model, updated to 1985, to estimate the regional implications of a land restriction placed on highly erodible soils. We used a recursive modeling technique to link estimated prices obtained from the price-response equations of an econometric model with the supply response algorithms of the NRLP model. The technique ties together a system of demand equations with the NRLP model's system of supply equations (6, 1).

The NRLP adjusts acreage and yields based on price and cost changes, while the econometric model adjusts price and quantity demands based on production changes. The two models are linked in a base year by forcing their national solutions to have equal commodity prices, acreages, yields, and production costs.

The program used in our example aims at retiring 45 million acres of highly erodible cropland by 1990. Retired cropland was distributed across production regions by eliminating the most erosive and least productive land from the NRLP model's acreage base. This step was taken to determine the program's effects on the base estimates. The process was carried out incrementally, until 45 million acres of highly erosive land were removed from the model's acreage base. Econometric projections were then used to set both commodity prices and supply necessary to support those prices (table 6). The NRLP is then used to estimate the regional adjustments in crop rotations, yields, conservation and tillage practices, erosion levels, production cost, and crop acreages.

Results

Table 7 shows crop acreages of seven major crops for 1987, 1990, and 1995. The general trend indicates that cropland acreage will remain constant from 1987-90, and will then increase 7.6 percent by 1995. Because regional distributions of cropland were held constant by invoking regional acreage constraints, the model yields little information on shifts in regional acreage.

Although the quantity of croplar in production is important, production of individual commodities is of greater interest. Shifts in the relative prices of commodities will induce changes in crop rotations, tillage practices, and

Table 6--Commodity acreage and price projections

Commodity	Unit	1987	1990	1995
Wheat	Acres	1.000	0.969	1.085
	Dollars	1.000	1.089	1.156
Corn	Acres	1.000	.962	1.021
	Dollars	1.000	.970	1.030
Soybeans	Acres	1.000	1.079	1.140
	Dollars	1.000	1.010	1.104
Barley	Acres	1.000	.936	1.009
	Dollars	1.000	1.000	1.069
Sorghum	Acres	1.000	1.076	1.144
	Dollars	1.000	1.032	1.032
Oats	Acres	1.000	.987	.955
	Dollars	1.000	1.043	1.000
Cotton	Acres	1.000	1.067	1.076
	Dollars	1.000	1.070	1.123

Table 7-- Regional crop acres, 1987-95 1/

Region	1987	1990	1995
		1,000 acres	
Northeast	5,566.0	5,603.0	6,177.0
Appalachia	11,348.0	11,845.0	12,613.0
Southeast	9,408.3	10,149.3	10,481.3
Delta	24,208.0	24,901.0	26,913.0
Corn Belt	67,265.0	67,967.0	72,485.0
Lake States	13,532.5	14,292.3	15,107.5
Northern Plains	41,747.6	41,808.6	47,534.7
Southern Plains	21,489.4	20,433.5	21,362.5
Mountain	16,398.2	14,237.2	14,744.2
Pacific	8,254.4	8,122.4	3,750.4
Total	219.21	219,359.2	236,168.7

1/ Crops used were barley, corn, cotton, oats, sorghum, soybeans, and wheat.

agricultural produc' .on. .. is these yield responses and the consequent production changes that shed light on agricultural policy effects.

Tables 8-11 show corn and wheat acreage and production. Corn and wheat acres in each region change by the same amount across regions, consistent with model constraints.

Note that the change in the amount of production of these crops varies from region to region. Extreme examples of these variations are the sharp decline in corn production in the Mountain region and the large increases in wheat production in the Delta, Mountain, and Northern Plains regions. Results generated from the model indicate that farming practices in the regions vary in their ability to raise yields while increasing net revenues. Practices which are shown to change are the types of crops irrigated, the quality of the

Table 8--Change in corn acreage, 1987-95

Region	1990	1995
Northeast	-0.038	0.021
Appalachia	- .038	.021
Southeast	- .042	.015
Delta	- .038	.021
Corn Belt	- .038	.021
Lake States	- .038	.021
Northern Plains	- .038	.021
Southern Plains	- .061	-.044
Mountain	- .041	.015
Pacific	- .038	.021
Total	- .039	.019

Table 9--Corn production distribution by region, 1987-95

Region	1987	1990	1995
Northeast	0.03186	0.03182	0.03212
Appalachia	.04714	.04712	.04647
Southeast	.01889	.01778	.01764
Delta	.17559	.18060	.18061
Corn Belt	.56309	.57479	.57432
Lake States	.00175	.00177	.00175
Northern Plains	.12953	.11522	.11701
Southern Plains	.01655	.01702	.01608
Mountain	.00963	.00778	.00800
Pacific	.00597	.00610	.00601
Total	1.00000	1.00000	1.00000

land used to produce corn and wheat, forms of tillage, and the quantities of inputs used.

A key strength of the NRLP model is its ability to examine the effects of agricultural policy on the Nation's soil resource. Table 12 presents estimated total soil erosion for 1987, 1990, and 1995. Two important effects can be observed. The first is a 25-percent decrease in total soil erosion that results from removing 45 million acres of highly erodible cropland from agricultural production. The second is a 0.5-percent increase in soil erosion that occurs as the acreage under cultivation rises in response to the higher prices expected in 1995.

Table 10--Change in wheat acreage, 1987-95

Region	1990	1995
Northeast	-0.031	0.084
Appalachia	-.025	.054
Southeast	.000	-.094
Delta	.029	.154
Corn Belt	-.031	.084
Lake States	-.030	.075
Northern Plains	-.021	.096
Southern Plains	-.037	.074
Mountain	-.031	.084
Pacific	-.030	.088
Total	-.025	.084

Table 11--Wheat production distribution by region, 1987-95

Region	1987	1990	1995
Northeast	0.00735	0.00641	0.00633
Appalachia	.03214	.03091	.02991
Southeast	.02173	.02197	.01735
Delta	.03857	.03995	.04055
Corn Belt	.10905	.10514	.10536
Lake States	.09479	.08746	.08620
Northern Plains	.34179	.34827	.35209
Southern Plains	.11932	.11671	.11464
Mountain	.14351	.14912	.15353
Pacific	.09175	.09406	.09405
Total	1.00000	1.00000	1.00000

Table 13 shows the effects of agricultural policy on net farm revenue. It suggests that, nationally, net farm revenues are expected to rise in 1987-95. The rise, however, is distributed unevenly across regions. The Corn Belt and Southern Plains will have the largest dollar value increase in net returns during this period. The reason for this large increase is due to the large value of agricultural production in those regions. The Northeast moves from a positive to a negative net revenue. The deficit in the Northern Plains shrinks, but expenditures continue to exceed revenues. When production subsidies are incorporated into the analysis all regions will show positive net revenues. The only change in the regional distribution, however, will be the rise of the Northern Plains, resulting from a large influx of deficiency payment funds.

Table 12--Regional wind and water erosion, 1987-95

Region	1987	1990	1995
		1,000 tons of soil	
Northeast	176,982.8	164,254.1	165,786.6
Appalachia	271,333.1	195,090.9	195,335.1
Southeast	186,254.1	122,069.9	125,227.1
Delta	290,970.7	163,027.9	155,155.0
Corn Belt	971,751.8	655,206.6	645,112.5
Lake States	292,763.4	270,554.2	280,644.3
Northern Plains	605,013.6	406,849.8	413,874.8
Southern Plains	538,420.8	476,771.3	481,987.5
Mountain	461,408.9	366,827.5	369,715.3
Pacific	89,064.0	75,237.2	78,136.1
Total	3,883,963.1 1/	2,895,889.2 1/	2,910,974.3

1/ Column does not add due to rounding.

Table 13--Change in net returns, 1987-95

Region	1990	1995
Northeast	-2.0	-1.6
Appalachia	-.3	-3.3
Southeast	-.5	1.8
Delta	.1	.8
Corn Belt	.1	.8
Lake States	.2	.4
Northern Plains	-1.8	-.5
Southern Plains	1.0	1.5
Mountain	2.4	4.1
Pacific	.3	.4
Total	.7	1.0

When analyzing input use change by means of the NRLP model, researchers should supplement the model with data on current input use and future input prices. Changes are best expressed in percentages. Table 14 presents changes in input use between 1987, 1990, and 1995. Between 1987 and 1990, there was little change in acreage cultivated but a shift to less intensive crop production. These trends, as well as the increased use of conservation tillage, explain the decrease in tillage energy, machinery costs, nitrogen applied, and labor costs. The increase in pesticide use is also due to greater use of conservation tillage practices. Acreage in crop production increased 8.5 percent between 1987 and 1995. This increase in tilled acreage together with the use of conservation tillage practices explains the shifts in input use in 1995.

This example shows how the NRLP model can be used to analyze the effects of a program that reduces the amount of highly erosive cropland in agricultural production. The same techniques could have been used to examine other conservation facets of the 1985 Food Security Act such as conservation compliance, the sodbuster provision, and the swampbuster provision. Conservation compliance can be modeled by placing restrictions on the model which prohibits cropping practices resulting in extensive erosion. Extensive erosion is erosion in excess of twice the soil tolerance level. The NRLP would then select the most profitable tillage and conservation practices needed to meet this constraint. The swampbuster and sodbuster provisions can be examined by constraining the land conversion activities in the NRLP.

Table 14--Change in input use, 1987-95 1/

Item	Unit	Change from 1987 in-- 1990	1995
		Percent	
Tillage energy	Billion gallons diesel fuel	-2.5	3.5
Machinery costs 2/	Billion dollars	-2.3	3.6
Labor costs 2/	Billion dollars	-2.4	3.5
Pesticide costs 2/	Billion dollars	3.4	14.0
Nitrogen applied	Million tons	-1.0	7.3
Potash applied	Million tons	1.0	8.5
Phosphate applied	Million tons	1.2	8.0
Total acres planted	Million acres	.8	8.5

1/ 1985 constant dollars.

2/ Calculations performed on the seven major commodities of barley, corn, cotton, oats, sorghum, soybeans, and wheat.

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APPENDIX: UPDATING THE NRLP MODEL TO 1985

We describe the procedures used to produce a crop MIDSET for the NRLP model, termed NRLP MIDSET. It is derived from the crop MIDSET used in the 1985 Resources Conservation Act (RCA) analysis, hereafter called RCA MIDSET. MIDSET is a data set containing detailed input uses, cost of production, yield, and soil erosion for each combination of crop rotation and conservation-tillage practices. The procedures condense the RCA's MIDSET of land groups into a NRLP MIDSET of six land groups. This MIDSET is used to update the NRLP to 1985. Appendix table 1 shows the difference in land groups between the two models.

Comparing the land groups between these two MIDSETS results in th following observations:

(1) Land groups 1 and 8 of the RCA MIDSET are identical to land groups 1 and 6 of the NRLP MIDSET.

(2) Land groups 5, 6, and 7 of the RCA MIDSET are combined into land group 2 of the NRLP MIDSET.

(3) The land in groups 2, 3, and 4 of the RCA MIDSET is rearranged into land groups 3, 4, and 5 in the NRLP MIDSET.

Yield Coefficients

These three observations indicate that the yield indexes of land groups 1 and 8 in the RCA MIDSET can be used directly. Furthermore, weighted yield indexes

Appendix table 1—How the RCA and NRLP MIDSETS define land groups

Land group	RCA MIDSET LCC and SC 1/	NRLP MIDSET LCC and SC 1/
1	I, IIwa, IIIwa	I, IIwa, IIIwa,
2	IIe	IIc, IIIc, IVc, IIs, IIIs, IVs, IIw, IIIw, IVw
3	IIIe	IIe, IIIe, IVe, RKLS < 50
4	IVe	IIe, IIIe, RKLS > 50
5	IIc, IIIc, IVc	IVe, RKLS > 50
6	IIs, IIIS, IVs	V, VI, VII, VIII
7	IIw, IIIw, IVw	
8	V, VI, VII, VIII	

1/ LCC and SC denote land capability class and subclass.

for land group 2 of the NRLP MIDSET will have to be developed from the yield indexes of land groups 5, 6, and 7 of the RCA MIDSET. The new yield indexes are computed using the following equation:

$$NYI_{ij}2 = \frac{\sum_{k=5}^{7} RYI_{ijk} A_{ijk}}{\sum_{i=5}^{7} A_{ijk}} \quad \text{for all i and j,} \tag{18}$$

where NYI^{i}_{j2} is the yield index for crop i grown on land group 2 in producing area j, which is defined in the NRLP MIDSET; where RYI_{ijk} is the yield index of crop i grown on land group k in producing area j, which is used in the RCA MIDSET; and where A_{ijk} is the crop acreage for i, j, and k obtained from NRI data. The new $NYLD_{ij2}$ coefficient is computed using the equation:

$$NYLD_{ij2} = \frac{RYLD_{ij5} \times NYI_{ij2}}{YI_{ij5}} \tag{19}$$

A procedure to derive the yield indexes for land groups 3, 4, and 5 follows. Let $A^1{}_{ijk}$ and $A^2{}_{ijk}$ be the acres of crop i in land group k (k = 2, 3, or 4) in producing area j with RKLD < 50 and > 50, respectively. Let RYI_{ijk} be the RCA yield indexes for i, j, and k (k = 2, 3, or 4). The new yield indexes can be computed using equations (20)-(22):

For land group 3, in NRLP MIDSET we have:

$$NYI_{ij3} = \frac{\sum_{k=2}^{4} RYI_{ijk} * A^1{}_{ijk}}{\sum_{k=2}^{4} A^1{}_{ijk}} \tag{20}$$

For land group 4, we have:

$$NYI_{ij4} = \frac{\sum_{k=2}^{3} RYI_{ijk} \times A^2{}_{ijk}}{\sum_{k=2}^{3} A^2{}_{ijk}} \tag{21}$$

For land group 5, we have:

$$NYI_{ij5} = RYI_{ij4} \tag{22}$$

Using equations (20)-(22), we develop a table of yield indexes of crop i on land group k in producing area j to be used for the NRLP MIDSET. The new yield indexes are used to adjust the yield coefficients in the RCA MIDSET. New yield coefficients are calculated using the equations:

$$NYLD_{ij3} = \frac{RYLD_{ij2}}{RYI_{ij2}} \times NYI_{ij3} \tag{23}$$

$$NYLD_{ij4} = \frac{RYLD_{ij2}}{RYI_{ij2}} \times NYI_{ij4} \tag{24}$$

$$NYLD_{ij5} = \frac{RYLD_{ij4}}{RYI_{ij4}} \times NYI_{ij5} \quad (25)$$

where $RYLD_{ijj2}$ and $NYLD_{ijk}$ for k = 2, 3, and 4 are yields for crop i in region j, in RCA and NRLP MIDSETS, respectively.

Soil Loss Coefficients

The soil loss coefficients in land groups 1 and 6 of the NRLP MIDSET are identical to the coefficients in land groups 1 and 8 of the RCA MIDSET. The procedures for estimating the coefficients for land groups 2, 3, 4, and 5 of the NRLP MIDSET are described. The procedures allow researchers to calculate soil loss coefficients by using Universal Soil Loss Equation (USLE) data in the RCA MIDSET. The method for computing coefficients for land group 2 of the NRLP MIDSET has three steps.

(1) Compute weighted RKLS for land groups 5, 6, and 7 in each PA from the RKLS values by using the 1982 NRI data.

(2) Compute the acreage (AC_{ij}) RKLS of land groups 5, 6, and 7 in the RCA MIDSET by using NRI data. The average RKLS T_j for region j is computed by using the following equation:

$$T_j = \frac{\sum_{i=5}^{7} (RKLS_{ij} \times AC_{ij})}{\sum_{i=5}^{7} A_{ij}} \quad (26)$$

(3) Read rotation activities of land group 6 in the RCA MIDSET. The USLE and RKLS values in each rotation are used to calculate the CP by the equation:

$$CP = \frac{USLE}{RKLS} \quad (27)$$

The adjusted soil loss coefficient from the rotation is computed by using the equation:

$$NUSLE = CP \times T_j \quad (28)$$

Land group 6 in the RCA model is selected as the basis for computing soil loss coefficients of land group 2 in the NRLP model. The estimated coefficients will give higher soil loss than the averaged estimates of land groups 5, 6, and 7 of the RCA MIDSET. The discrepancy, however, probably will not significantly contribute to total regional soil erosion because the summed acreage of these three land groups is small.

The soil loss coefficients for land groups 3, 4, and 5 of the NRLP model are estimated from data of land groups 2, 3, and 4 in the RCA MIDSET. The estimation procedure is carried out in three steps.

(1) Compute RKLS for land groups 2, 3, and 4 of the RCA MIDSET for each PA by using the 1982 NRI data.

(2) Compute the weighted RKLS for land groups 3, 4, and 5 used in the NRLP model from 1982 NRI data.

We compute the weighted average RKLS for land groups 3, 4, and 5 (T_{3j}, T_{4j}, T_{5j}) in PA j for the NRLP MIDSET, using the following equations:

$$T_{3j} = \frac{\sum_{k=2}^{4} B^{1}{}_{jk} \times RKLS_{j2}}{\sum_{k=2}^{4} B^{1}{}_{jk}} \tag{29}$$

$$T_{4j} = \frac{B^{2}{}_{j2} \times RKLS_{j2} + B^{2}{}_{j3} \times RKLA_{j3}}{B^{2}{}_{j2} + B^{2}{}_{j3}} \tag{30}$$

$$T_{5j} = RKLS_{j4} \tag{31}$$

where $B^{1}{}_{j2}$, $B^{1}{}_{j3}$, and $B^{1}{}_{j4}$ are cropland acres with RKLS < 50 for land groups 2, 3, and 4; and, where $B^{2}{}_{j2}$, $B^{2}{}_{j3}$, and $B^{2}{}_{j4}$ are cropland acres with RKLS > 50. $RKLS_{j2}$, $RKLS_{j3}$, and $RKLS_{j4}$ are the average RKLS values for corresponding land groups 2, 3, and 4 in PA j. These values are also calculated from the NRI data.

(3) Use USLE and RKLS in land group 2 of the RCA MIDSET to calculate soil loss coefficients of land group 3 in the NRLP MIDSET. Use USLE and RKLS data in land group 4 of the RCA MIDSET to calculate the soil loss coefficients for land groups 4 and 5 of the NRLP MIDSET. The procedure uses equations (27) and (28).

Cost Coefficients

Production cost per acre for each nonirrigated production activity is the sum of the following costs: machinery; labor; pesticides; phosphorous, potassium, and nitrogen fertilizers; terracing; and liquid propane gas.

The following application costs are added, in the case of irrigated production activity: variable, fixed, and sunk. Most of these cost items will be constant for a specific type of rotation in a producing area regardless of land groups, except for the following items: phosphorus, potassium, and nitrogen fertilizers, and liquid propane gas for drying.

Yield level determines the cost difference between land groups. Different land groups have different levels of yield, and these costs are adjusted in proportion to yield change. The following procedure describes how to estimate the cost coefficients for the NRLP MIDSET.

(1) Cost coefficients for the second land group in NRLP MIDSET are estimated in the following way:

$$YR_{ij2} = \frac{NYI_{ij2}}{RYI_{ij5}} \tag{32}$$

where RYI_{ij5} is the yield index coefficient in the MIDSET of the RCA MIDSET. NYI_{ij2} is an index calculated by equation (18).

By using YR, the new costs are calculated by the equations:

$$NPHOS_{ij2} = YR_{ij2} \times PHOS_{ij5} \quad (33)$$

$$NPOTA_{ij2} = YR_{ij2} \times POTA_{ij2} \quad (34)$$

$$NNITR_{ij2} = YR_{ij2} \times NITR_{ij5} \quad (35)$$

$$NLPG_{ij2} = YR_{ij2} \times LPF_{ij5} \quad (36)$$

$PHOA_{ij5}$, $POTA_{ij5}$, $NITR_{ij}$, and LPF_{ij} are variables for phosphorus, potassium, nitrogen, and liquid propane in the RCA MIDSET. The variables $NPHOS_{ij2}$, $NITR_{ij2}$, $NITR_{ij2}$, and $NLPG_{ij2}$ are corresponding variables used in the NRLP MIDSET.

(2) Cost coefficients for land groups 3, 4, and 5 of the NRLP MIDSET are calculated in the following way. The yield indexes YI_{ij3}, NYI_{ij4}, and NYI_{ij5}, which were calculated from equations (21)-(23), are used. Procedures similar to those shown in equations (32) and (36) are used for the computation.

(3) The cost coefficient in land groups 1 and 6 in the NRLP MIDSET are the same as the coefficients of land groups 1 and 8 in the RCA MIDSET.

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