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Programmed Interrelationships Between Soil Loss and Exports

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I. INTRODUCTION AND PURPOSE OF STUDY

American farmers welcome announcements of increased exports of grain and agricultural commodities. Increases in exports lead to increases in prices and farm income which spreads with multiplier effects throughout the agribusiness, industry, and rural areas. Increased exports may also entail higher consumer prices, but this effect is small relative to prosperity engendered in rural communities and the increased level of economic activity throughout the economy. Consequently, the support and promotion of farm exports easily gains acceptance from all parts of the political spectrum.

Some individuals [Schuh, 1976] have proposed exports as the major solution to U.S. farm price and income problems. However, it is possible that complexities eventually unravel which cause high qualification of this proposition. The farmer is the beneficiary of the initial effect of increased prices, but the effects are not permanent. The industry adjusts over time, with an intensification of production practices, the increased adoption of yield-increasing technologies, and by the expansion of the area cultivated with the conversion of land from lower valued uses. Increased commodity prices also tend to increase the value of cropland. When farmland changes hands, as eventually it must, the buyer pays a higher price because the increased returns are capitalized into land values.

With crop shortfalls in major world regions during the 1970s and a move of developing countries to import more U.S. grains, our growing exports brought an era of unprecedented prosperity to American agriculture. Both farm commodity prices and farm income increased greatly. Under these conditions, more marginal lands were farmed and row cropping became especially intense. Too, it is generally believed that soil erosion greatly increased as a result of these conditions.

American exports of agricultural commodities (Table 1) grew almost continually since at least 1950, with a slight set back in 1982. The most dramatic increase overall was in soybean exports which grew at an average annual rate of 11.7 percent between 1950-59, 21.9 between 1960-69, and 9.9 percent between 1970-79. Average grain exports increased at nearly the same rates: 10.1 percent annually between 1950-59, 6.7 percent between 1960-69, and 28.5 percent between 1970-79. Wheat exports also grew although at lower annual rates: 5.5 percent annually between 1950-59 and 8.0 percent between 1970-79. Cotton exports declined slightly between 1950-59 and 1960-69 and increasing by 14.4 percent average annually between 1960-69 and 1970-79. Record world grain crops, the strong value of the dollar and world recession caused U.S. agricultural exports to slacken after 1982 and into 1983. However, they are still at high levels as compared to earlier times.

The growth in exports generally exceeded expectations during the late 1970s. The original OBERS [1973] series E 2000 projections for

Table 1. The growth of U.S. feed grain, soybean, wheat and cotton exports 1950-82[a]

Year	Feed grains	Soybean	Wheat	Cotton
		(million bushels)		
1950	218	28	335	4.1
1951	166	17	470	5.5
1952	182	32	316	3.0
1953	127	40	216	3.8
1954	185	61	273	3.4
1955	279	67	346	2.2
1956	256	85	550	7.6
1957	336	86	403	5.7
1958	433	110	443	2.8
1959	439	141	510	7.2
1960	454	135	654	6.6
1961	618	149	716	4.9
1962	602	181	649	3.4
1963	672	187	847	5.8
1964	774	212	723	4.2
1965	1,034	251	852	3.0
1966	786	262	771	4.8
1967	832	267	765	4.4
1968	658	287	544	2.8
1969	756	433	603	2.9
1970	739	434	741	3.9
1971	978	417	610	3.4
1972	1,541	479	1,135	5.3
1973	1,594	539	1,217	6.1
1974	1,409	421	1,018	3.9
1975	1,970	555	1,173	3.3
1976	1,993	564	950	4.8
1977	2,219	701	1,124	5.5
1978	2,370	739	1,194	6.2
1979	2,808	875	1,375	9.4
1980	2,743	724	1,510	5.9
1981	2,916	840	1,900	7.0

[a]Source: Agricultural Statistics, various years.

[b]Exports of corn grain, grain sorghum, barley and oats in corn equivalent (56 lbs.) bushels.

corn exports of 1.275 million bushels were exceeded in 1975; the projection was made in 1972. The OBERS projection for 2000 was revised upwards to 1,069 million bushels in 1975, but the revised projection for the 2000 level exports was nearly exceeded in 1980 despite the embargo on further sales to the Soviet Union.

Recent growth rates in exports may not be substainable. U.S. yields have been increasing at a rate of around 3 percent. The rapid expansion in exports were possible because of large stocks in the early 1970s and because domestic demands have been growing more slowly than yields; consequently, an increasing proportion of agricultural cropland is being used for the export market. As the proportion of cropland used for exports increases, the rate of export growth must slow down to a rate which approximates increased production capabilities in the United States from cultivation of additional land and principally from increasing yields.

There is considerable evidence that the interrelated forces of farm structure, enhanced exports, high commodity prices and inflating land values, have encouraged agriculture to become increasingly exploitive in nature. High levels of exports may be causing the depletion of nonrenewable resources necessary for the American farm sector to maintain productivity.

The running down of groundwater stocks in the gigantic Ogallala Aquifer in the High Plains, and smaller aquifers in parts of Central Arizona and California has paralleled the growth in exports both through

Public Law 480 and market forces over the last 25 years. Already the drawdown of the water table has caused some farmers to shift back to dryland farming in parts of Texas and New Mexico, forced the development of the Central Arizona Project and led to widespread concern in many regions. Export growth will not solve the adjustment and income problems of these farmers in the future.

Perhaps of still greater long-run importance is the major complex of issues involving exports, soil loss and related environmental problems. High crop prices induced by high export levels and other factors is capitalized into land values making it difficult to make mortgage payments for land out of current income [Heady, 1982]. The need for high levels of current income forces farmers to shift to larger acreages of row crops and near-monoculture rotation patterns. The continued increase in land values makes increased land purchases a popular way to increase wealth and provides existing farmers with the equity they need to grow rapidly. The increase in farm size further increased the need for high cash returns for debt service because of the mammoth outlays required for huge tractor and machine units which also cannot be readily used with terraces and contours.

While some progress has been made in conservation tillage methods and conventional conservation practices, there also has been an accentuated shift to crop specialization such as the corn-soybean patterns of the Cornbelt on both level and hilly land. Studies at different times in Iowa show large increases in soil loss [Blase and Timmons, Hauser, Larson]. Timmons reports an increase of nearly 25 percent in erosion rates per crop acre for Ida-Monona-Hamburg soils in Iowa in less than 20 years and projects large increases over the Cornbelt [Timmons, 1979a].

The incorporation of set-aside land into the cropland base the early 70s, as exports exhausted surplus stocks and negated the need for grain supply controls, also has contributed to greater erosion. This set-aside land was somewhat marginal land. Some of the best agricultural land has been converted to urban and other higher valued uses. But the land base for crop production has remained relatively constant because of the conversion of forest, pasture and rangeland to cropland. The converted forest pasture and rangeland again is typically more marginal and fragile than the land lost.

Concern over the erosion problem has caused a number of public bodies and institutions to analyze the process. Included are the activities of the National Academy of Science (National Research Foundation), the Office of Technology Assessment, Resources for the Future, the Conservation Foundation, the North Central Regional Research Committee-III, the U.S. Department of Agriculture through its monitoring and analysis work of the Resources Conservation Act (RCA) and a consortium of Land Grant Universities, the U.S. Department of Agriculture and most of the professional societies representing agriculture [Hauser]. More empirical evidence needs to be gathered. However, it is possible to delineate now the extent of the problem and scope for policy intervention with a set of models and data which have been operational at the Center for Agricultural and Rural Development (CARD) over a number of years [Daines and Heady, English and Heady, Larson et al., Meister and Nicol, Nicol and Heady, Timmons 1979a].

Purpose of study

The purpose of this study is to study potential relationships between soil loss and export levels when different amounts of land can be transferred into the cropland base. The study is not an attempt to determine the extent to which soil erosion increased as agricultural production was intensified under growing exports and favorable prices after 1972. Instead it examines whether increased soil loss in different regions of the United States must increase at various future levels of exports. It is possible that under larger exports and higher commodity prices, it might be profitable for farmers to use sufficient conservation prices to hold soil erosion in cheek. That is, soil erosion may not be a required condition of higher export levels. The study, therefore, also studies the cropping or land use system, the conservation practices and tillage methods which might arise if various export levels were attained in the future.

The study is made with a CARD linear programming model at the national, regional, and interregional level. A base solution of the model at a modest level of exports and a given cropland base is first made. The base solution serves as a basis for comparison for solutions made for higher export levels and cases in which additional land can be converted into the cropland base. The nature of the model and its alternative solutions for varying export and land conversion will be explained later.

II. NATURE OF MODEL AND ALTERNATIVES ANALYZED

Because the CARD models are documented elsewhere [English], the report summarizes the general features indicating where specific assumptions are made for this study. The model used is a spatial linear programming model, national and interregional in nature with 105 producing areas (PAs) and 28 market regions (MRs) and a linking transportation submodel (Figure 1). Each producing region has five separate land classes with differential erodibility and soil loss; irrigated regions have an additional five land classes for both irrigated and dryland crop possibilities. Results in this report are by major zones which in turn are aggregations of market regions: the North Atlantic consists of MRs 1-3; South Atlantic of MRs 4-8; the North Central of MRs 9-14; Great Plains of MRs 10-18; the South Central of MRs 19-23; the Northwest of MR 24; and the Southwest of MRs 25-28.

The objective of the model is to select a production and resource use plan which will minimize the costs of producing and transporting a predetermined vector of commodities at the market region level:

$$\text{Min.} \sum_{rtclp} DR_{rtclp} DL_{rtclp} + \sum_{rtclu} IL_{rtceu} + \sum_{lp} CL_{lp} LC_{lp}$$

$$+ \sum_{lu} CD_{lu} ID_{lu} + \sum_{su} CI_{su} WI_{su} + \sum_{ur} CW_{uv} WT_{uv} + \sum_{imn} CT_{imn} TC_{imn}$$

$$+ \Sigma CN_m NB_m \qquad (1)$$

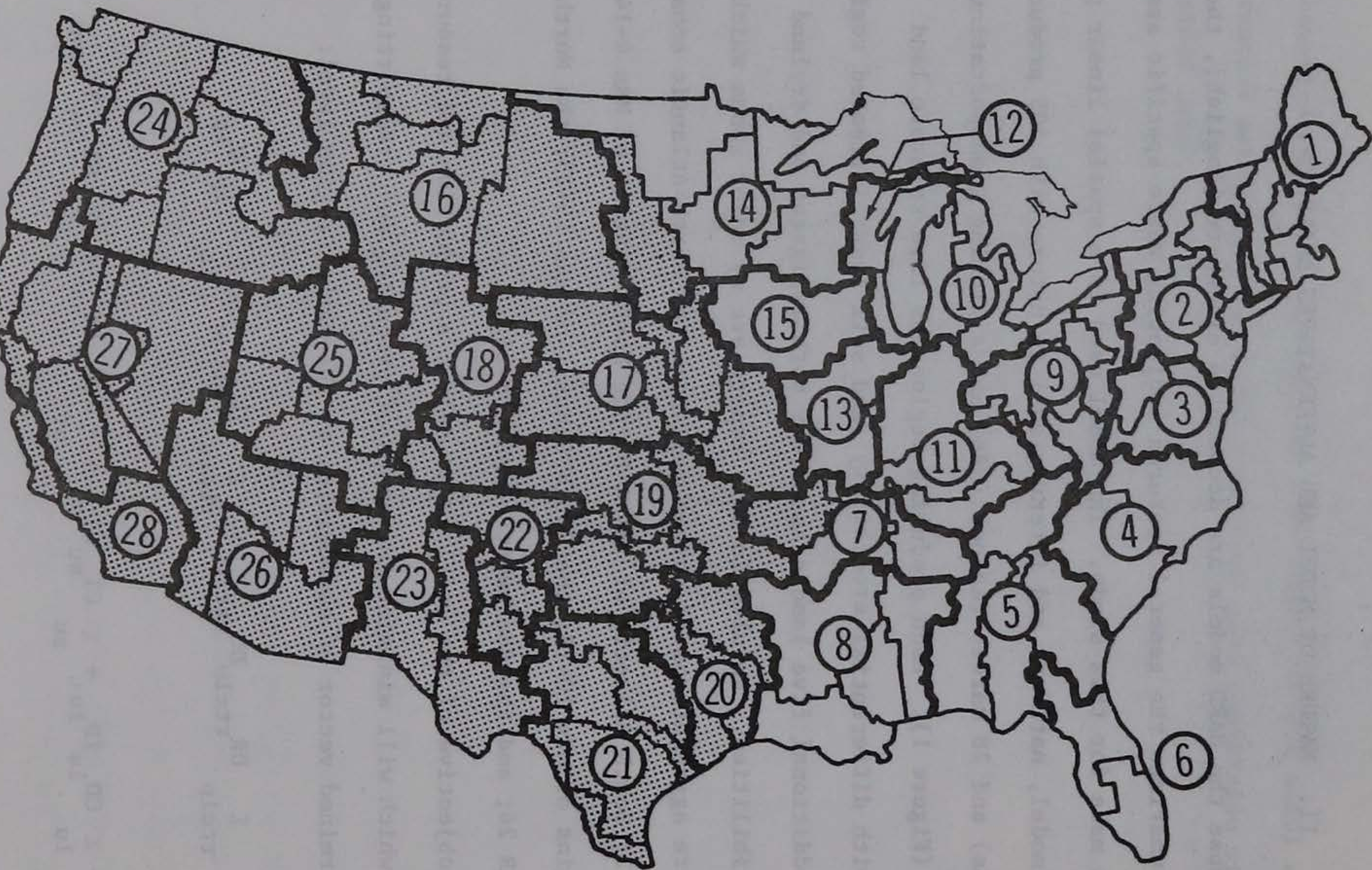

Figure 1. The 28 market regions encompassing the 105 producing areas with producing areas which serve as water resource regions shaded

r = 1, 2, ..., 358 for the rotation,

t = 1, 2, 3 for the tillage practice,

c = 1, 2, 3, 4, for the conservation practice,

e = 1, 2, ..., 5 for the land class,

p = 1, 2, ..., 105 for PA,

u, v = 48, 49, ..., 105 for the irrigated PA,

s = 1, 2 for the water source (1 for surface water, 2 for groundwater)

i = 1, 2, ..., 6 for the transferable commodities,

m, n = 1, 2,..., 28 for market regions,

where:

DR is the dryland rotation cost per acre

DL is the number of acres selected

IR is the irrigated rotation cost per acre,

IL is the number of irrigated acres selected,

CL is the cost of conversion of pasture or forestland to cropland,

LC is the number of acres selected for conversion,

CD is the cost of converting dryland to irrigable land,

ID is the number of acres selected for conversion,

CI is cost of irrigation water,

WI is amount of irrigation water utilized,

CW is the cost of artificial transfer of water between regions,

WT is the amount of water selected for artificial transfer,

CT is the commodity transfer between regions,

TC is the number of units of crops transferred between regions, CN is the cost of nitrogen fertilizer, and

NB is the amount of purchased nitrogen utilized.

Thus, the objective function minimizes the cost of crop production costs (net of land, nitrogen and water costs), are annualized cost of improving land productivity either by conversion of noncropland to cropland or by making cropland irrigable, the costs of purchased nitrogen, and irrigation, and the costs of transferring water and commodities. Actually, the model assumes and simulates a competitive equilibrium wherein all resources, except land and water, receive their market rate of return. Returns to land and water are determined endogenously.

More than 29,400 of the 32,840 activities in the model are rotations representing combinations used in the production of eleven endogenous crops: corn grain, barley, oats, sorghum grain, wheat, soybeans, corn silage, sorghum silage, legume hay, nonlegume hay, and cotton. Differential yields, costs, and soil loss coefficients are specified for each PA and land group by crop or rotation and by conservation practice (contour plowing, terracing, strip crop, conventional), and tillage method (moldboard plowing, conservation tillage, no till). Fertilizer requirements and, in the case of irrigated crops, water requirements are determined together with appropriate yields. The remaining activities represent either commodity and, in the case of water, resource transfers between regions or activities representing resource development such as the land conversion and nitrogen-purchasing activities. Costs are minimized subject to constraints principally on amount of land available at the PA level and commodity production at the MR level. A competitive equilibrium is assumed where resources, except those endogenously determined are given market rates of return.

Land restraints and conversions

The land restraints take the form:

$$\sum_{rtc} DL_{rtclp} - LC_{1p} + ID_{1u} \leq L_{1p}, \text{ or} \tag{2a}$$

$$\sum_{rtc} IL_{rtclu} - ID_{1u} \leq I_{1p} \tag{2b}$$

where: L is dry cropland available by land class and PA,

I is irrigated cropland availability, land class and PA, and the subscripts and other variables are as defined in Equation (1).

Thus there are as many as 525 dryland constraints and 290 irrigated land constraints although in practice a small number of these are deleted because there is no land in a particular land class in specific producing areas. The model endogenously determines the marginal value of an extra unit of land for each of these constraints which incorporates this value into costs of production for the commodities. Total cropland available is based upon the 1977 National Resource Inventory. Of the 403 million acres of cropland estimated available in the survey, 26 million are projected to be converted to nonagricultural uses by 2000 and 24 million required by exogenous crops leaving a land base of 353 million acres for endogenous crops. The amount of land aggregated by zone is presented in Table 2. Land constraints in each PA

Table 2. Projected 2000 crop land base for endogenous crops and potential cropland by zone

Item	Region-							
	North Atlantic	South Atlantic	North Central	Great Plains	South Central	Northwest	Southwest	Total
				(1000 acres)				
Endogenous Cropland:								
Land Class 1	1,613	6,459	32,831	7,963	7,421	1,090	2,372	59,749
Land Class 2	6,764	27,775	81,444	31,830	30,333	5,253	3,652	187,052
Land Class 3	1,879	3,463	16,773	25,939	15,292	6,088	795	70,228
Land Class 4	694	1,177	4,846	9,361	5,213	2,138	1,191	24,620
Land Class 5	431	1,118	2,939	4,015	1,808	796	423	11,530
Total	11,380	39,993	138,834	79,108	60,067	15,364	8,434	353,180
High Potential Cropland:								
Land Class 1	56	597	572	245	528	21	12	2,031
Land Class 2	705	8,756	5,577	3,071	4,342	604	472	23,527
Land Class 3	112	1,074	1,462	2,553	1,969	309	99	7,578
Land Class 4	45	227	370	728	209	103	89	1,771
Land Class 5	81	298	180	551	171	397	1,108	2,696
Total	999	10,952	8,161	7,148	7,219	1,434	1,690	37,603
Moderate Potential Cropland:								
Land Class 1	94	360	360	132	316	5	8	1,269
Land Class 2	2,214	14,963	8,989	5,006	8,375	993	1,155	41,695
Land Class 3	736	4,517	3,770	7,144	7,423	649	363	24,602
Land Class 4	308	1,748	1,794	3,536	2,486	543	717	11,132
Land Class 5	500	2,281	1,212	3,548	1,109	968	1,781	11,399
Total	3,852	23,869	16,125	19,366	19,703	3,158	4,024	90,097

are by land class which are selected so that a range of erosion rates and farming practices to control them can be represented in the model: prime agricultural levels are included in land classes 1 and 2, erosive but otherwise suitable lands in land classes 3 and 4 and the most marginal lands in land class 5.

The range, pasture, forest, and other lands with high and moderate potential for conversion to cropland as determined by the Natural Resource Inventory are incorporated as bounded activities with appropriate conversion costs in the objective function. As shown in Table 2 a total of 90.1 million acres of moderate potential and 37.6 million acres of high potential land could possibly by converted to cropland by 2000. Both Amos and Timmons, and Shulstad and May have suggested that only a fraction of the 127.7 million acres could realistically be converted to cropland by 2000 so we have duplicated our analysis with a "High and Moderate Potential Land Scenario" and a "High Potential Land Only Scenario."

There have also been doubts raised about the feasibility of yields to grow at historical rates. Consequently, we also have included a scenario where yields grow at half the historical rates; in effect 1990 yields are assumed with resources available as they would be in 2000. This is the most pessimistic of possibilities with only the 37.6 million acres of high potential land available for conversion to cropland. This situation is identified in the results on the "Reduced Yields Scenario."

Demand restraints and export levels

Commodity demands in each of the 28 market regions force the model to produce these amounts. Transfer activities between regions are specified for the farm feed grains, wheat and soybeans with commodity constraints in the form:

$$\sum_{irtclp} DY_{irtclp} DL_{rtclp} + \sum_{imn} TC_{imn} \leq D_{im} \qquad (3a)$$

where: DY is the yield by crop rotation, tillage method, conservation practice, land class and PA,

D is the required commodity. Availability by MR, and subscripts and other variables are as defined in Equation (1).

A single silage constraint and both nonlegume hay and legume hay restraints are included for each market region:

$$\sum_{jrtclp} DY_{jrtclp} \leq D_{jm} \qquad (3b)$$

J = 1, 2, 3 for the nontransferable crops.

A single national constraint is used for cotton production. The model determines the cost of producing an additional unit of each crop in each market region and nationally for cotton, incorporating both the production costs in the objective function, the costs of nitrogen and water and the endogenously determined rental value of land. The marginal cost then of each crop is the endogenously determined rental value of land. The marginal cost then of each crop is the endogenously determined crop price.

The constraints at market region levels can also be interpreted as regional demands. Total demand for each market region is the sum of domestic demand and export demand. Domestic demand is projected for direct consumption, for livestock feeds, and other (industrial) uses. Direct consumption by market region is determined by multiplying assumed per capita consumption of each commodity by the projected population for the market region.[1] Per capita consumption by commodity and demand for the entire contiguous states is given in Table 3 while a more detailed description of the determination of market region demand is found in Appendix 1.

Livestock feed demands and industrial demands are also presented in Table 3. Industrial demands are distributed to market region by a set of weights developed from previous industrial demand projections by MR made by Boggess.[2] The predictions for industrial demands at the national level are taken from the NIRAP projections made for the Soil Conservation Service (SCS) in 1978 (High Scenario). Livestock feed demands are taken from the projection made by Boggess.

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[1]It is assumed the population for the contiguous states will be 258.1 million in 2000 (Bureau of Census).

[2]William G. Boggess, Department of Resource and Food Economics, University of Florida, Gainesville.

Table 3. Domestic demand for all commodities in the contiguous states

Commodity	Units	Per Capita	Direct Consumption	Livestock Feed	Industrial	Total
			(millions)			
Corn	bushels	2.248	580.28	4127.40	414.40	5122.08
Barley	"	0.050	12.91	301.30	345.70	659.91
Oats	"	0.244	62.98	839.06	80.90	982.94
Sorghum	"	0.0	0.0	838.22	21.60	859.82
Wheat	"	2.738	706.77	199.53	126.80	1033.10
Soybeans	"	0.0008	0.21	923.44	1394.08	2317.73
Cotton	bales	0.030	7.74	-	8.70	16.44
Legume Hay	tons	-	-	82.19	-	82.19
Nonlegume Hay	"	-	-	59.85	-	59.85
Silage	"	-	-	109.40	-	109.40

[a]Included here are demands for cottonseed. Cottonseed is a minor component of total demand and are therefore treated as a perfect substitute with soybeans.

[b]There are hay requirements for endogenous cropland only. As pasture is converted to cropland demands are automatically increased so that total hay production on endogenous and exogenous land remains the same.

Industrial demands do not include a component of grain for gasohol production nor is a biomass crop implied in the base level. The overall effect of a significant "energy from agriculture program" would be similar in effect to increased exports but different in detail. The regional distribution of production and soil loss may be somewhat different. There is obviously also a tradeoff in terms of exports and energy crops in the sense that the environmental consequences of any given level of exports would be more severe with a given biomass program in place.

Domestic demands are relatively easy to estimate because they depend especially on population and per capita consumption which change in a relatively regular fashion with time. The same level of domestic demands is used for all solutions to the model. But export demands are much less predictable and stable. They depend in part on such factors as government policy, not only in the U.S. but also in potential importing and other potential exporting countries. In the 1970s, an abrupt change in policy was made towards food imports in the East Block countries as the U.S. government has both encouraged and embargoed exports of food to these countries. Food import policy in the EEC and Japan is currently restrictive, but that could easily change. Exports to less developed countries are also subject to great uncertainty, not only with respect to policy in these countries, but also because with respect to the populations in these countries are more difficult to predict, their ability to pay for more food imports and the U.S. government's willingness to subsidize these transactions are also uncertain. Moreover, it is difficult to judge how able these countries will be to feed themselves through expanded production on the extensive margin and increased productivity by "green revolution" and other new technologies. Consequently, seven different export levels are used in this study. The export levels represent a range of possible export levels that may occur in 2000.

The seven export levels are given in Table 4. Export level III is a medium or base level of exports. This level is a close approximation of most recent export projections made by the NIRAP model.[1]

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[1]Leroy Quonce and David Watt, International Economics Division, Economics and Statistics Service, USDA, Washington, D.C. and East Lansing, Michigan.

Table 4. Export levels used in alternate solutions

Export	Crop						
	Corn	Sorghum	Oats	Barley	Wheat	Soybeans	Cotton
	- - - - - - - - - - (million bushels) - - - - - - -						(million bales)
I	2775.00	225.00	15.00	67.50	1575.00	1170.00	3.50
II	3238.00	262.50	17.50	78.75	1838.00	1365.00	4.00
III	3700.00	300.00	20.00	90.00	2100.00	1560.00	4.60
IV	4162.00	337.50	22.50	101.25	2362.00	1755.00	5.20
V	4625,00	375.00	25.00	112.50	2625.00	1950.00	5.80
VI	5088.00	412.50	27.50	123.75	2888.00	2145.00	6.30
VII	6013.00	487.50	32.50	146.25	3412.00	2535.00	7.50

Export levels I and II are across the board reductions in Export Level III of 25 and 12.5 percent respectively. Export Levels IV-VII are across the board increases in these export levels of 12.5, 25, 37.5, and 62.5 percent respectively.

Not all export levels are feasible with all scenarios (i.e. resource levels do not allow their attainment) but results are presented for a range of feasible exports for each scenario. For the scenario with both moderate and high potential land available for conversion to cropland, all export levels are feasible and results are presented for Export Levels II, IV, VI, and VII. Export Level VII is getting near the upper bound of feasibility of the model so crop prices and land values are high. For the scenario with only high potential land available for conversion to cropland, Export Level V is not feasible so results are presented for Export Levels I, II, III, and IV. For the scenario with reduced yields only Export Levels I and II are feasible.

Soil loss restraints

Soil loss per acre is not constrained in the base model but is calculated by:

$$\Sigma DS_{rtclp} Dl_{rtclp} + \Sigma IS_{rtclu} IL_{rtclu} \quad (5)$$

where: DS is gross soil loss per acre for a specific dryland rotation, tillage method, conservation practice, and land class;

IS is gross soil loss per acre for a specific irrigated rotation, tillage method, conservation practice, land class and other variables and subscripts are as defined in Equation (1).

The summation can be made across all rotations, tillage methods, etc., to give total soil loss at the national level or any particular subset such as land class and region. The soil loss coefficients (DS and IS) are estimated using the Universal Soil Loss Equation (USLE). The parameters of the USLE [Weishmeir and Smith] include factors for rainfall, soil erodibility, slope length and gradient, a management factor reflecting tillage method rotation, and conservation practice. The rainfall and soil erodibility factor are dependent upon producing area and necessarily represent PA averages which may in actuality vary considerably. The length and gradient factors depend primarily on land class.

Each land class is in part determined by a range of these factors. All parameters for the USLE equation are derived from data collected by the Soil Conservation Service. The coefficients reflect only erosion caused by rainfall; in the mid-continental portions of the U.S. where wind is an important factor in total soil loss an important environment interaction with exports is not estimated.

A number of restraints are introduced into the model to control rotations which give rise to very high levels of soil loss. These restraints are related to the tolerance of "t-levels" of soil loss. The generation of soil is a slow, but continuous naturally occurring process as is the improvement of subsoils. An amount of soil loss can be tolerated without loss of productivity if it does not exceed the "t-levels." Although what the t-levels should be is subject to dispute, t-levels have been established by PA and land class by the SCS. They generally fall somewhere in the range of 3-5 tons of soil loss per acre.

The constraints for soil loss per acre per year can take the form

$$\sum_{rtclp} DL^*_{rtclp} + \sum_{rtclu} IL^*_{rtclu} \leq 0 \qquad (6)$$

where: DL* and IL* are the acres of a specific rotation, tillage method, conservation practice, land class, and PA that produces soil loss exceeding by some factor the "t-levels" for the specific land class and PA, and subscripts are as defined in Equation (1).

This constraint is not imposed for the initial set of solutions which are reported in the following chapter. The results, for these solutions, project the soil loss that would be generated in the absence of any form of controls or regulations. Results are reported in Chapter 3 for a set of solutions with the "t-level" constraints imposed intitally where the factor exceeding "t-level" is one; all rotations which produce soil loss greater than the "t-levels" are not allowed to come into the solution. This set of solutions then is used to project the effect of a "perfect" but unspecified or explicitly simulated policy not only on soil loss but also on such variables as yields, prices, production, and income by region.

III. EXPORTS AND SOIL LOSS WITHOUT POLICY INTERVENTION

Results in this chapter are presented for model solutions where no constraints were placed on soil loss. They thus relate unrestrained soil loss to export levels. Effects of increased exports which are invariant with zone are described first. Results are then presented for each zone describing first the response in the region to increased exports, the means by which production is increased and the effects on on soil erosion. The results for the zones are presented individually because the effects of increased exports on each is quite different.

Crop prices tend to increase with exports levels in a very regular fashion. This is not surprising since prices are partly determined by production costs on marginal rotations selected and the most efficient rotations are selected with lower levels of production. Returns to assets, chiefly land, increase with each increase in price.

Prices in the second scenario (High Potential Land Only) are much higher than prices in the first for the same level of exports; and prices in the third scenario (Reduced Yields) are much higher than those in the second scenario for the same level of exports. A similar pattern of course emerges for the returns to assets. This is not surprising because scenarios two and three have increasingly more restrictive assumptions built into them making it possible to satisfy production constraints only by including more marginally profitable production methods.

Greater use is made of soil conserving tillage methods and conservation practices in all solutions and scenarios than are currently practiced. Minimum till is practiced on between 50 and 60 percent of the land in all solutions and residue is not removed on most of the remaining land. Approximately 70 percent of the cropland is also selected for some conservation practice. Contour plowing is the most important and accounts for 50-55 percent of total cropland. Strip cropping is relatively insignificant, covering around 4 percent of the land in nearly all solutions. Terracing is used on 10 to 15 percent of the cropland with the amount of terracing increasing with exports. Hence, while no restraints are placed on soil loss in this section, minimum till and the leaving of residue become economic practices in attaining specified demand and export levels.

Even with increased use of conservation practices and tillage methods, soil loss is an important national concern, even at existing levels of exports. In this analysis, soil loss exceeds tolerance levels when 47.2 million additional acreas are used in the High and Moderate Potential Land Scenario, 41.4 million additional acres are used in the High Potential Land Only Scenario, and 33.2 million additional acres are used in the Reduced Yield Scenario (with the lowest levels of exports in each case). These acreages all exceed the 26 million acres of cropland projected to be converted to urban and other high valued uses by the year 2000.

Although soil loss generally increases and becomes a more critical issue with higher exports, it does not increase as much as anticipated when conservation tillage practices are widely used. Neither does the relationship between soil loss and exports necessarily become an ubiquitous problem. Soil loss even declines in some zones as exports are increased from a low level to a moderate level relative to productive capacity. The principal reason for the decline is a rise in crop prices which make additional yields possible with conservation practicies and tillage methods which are more profitable even under somewhat higher costs. When exports approach productive capacity however, soil loss increases sharply. This condition is a particularly important factor on Land Class 3 where soil loss levels tend to be very high at low levels of exports but soil loss levels drop below tolerance levels when exports and crop prices increase and cause conservation practices to be profitable.

North Atlantic Zone

The North Atlantic Zone (Figure 2) is an aggregation of 13 PAs and three market regions, centering on Boston, New York, and Baltimore. It has only minor exports. The region encompasses all of the New England states, New Jersy, Delaware, and Maryland; nearly all of New York and Virginia, all but the western third of Pennsylvania but the eastern counties of West Virginia.

Most of the drainage in the region is through river systems flowing into the Atlantic such as the Hudson, Delaware, Susquehanna and

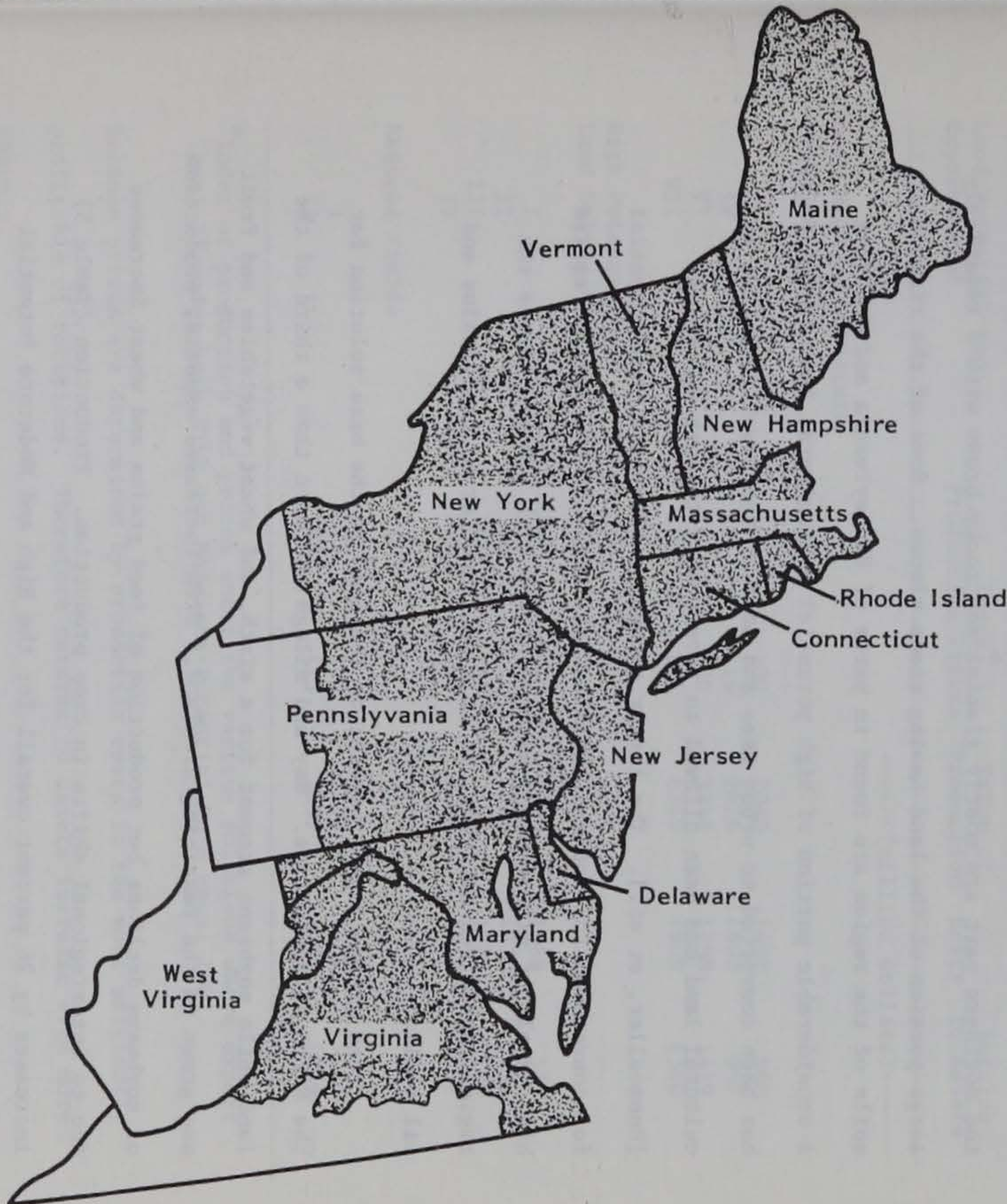

Figure 2. The North Atlantic Zone with political boundaries.

Potomac flowing through highly industrialized areas. River systems on the northern fringe flow north into the St. Lawrence. The soils in the northern part are mostly glacial and rocky brown with a relatively large portion of the land having steep slopes. Some of the richest soils of the region are found in parts of Pennsylvania and New York. A considerable portion of high potential agricultural land in the region has been converted to urban uses and some of the lower potential agricultural land has been allowed to revert back to bush and forest [Huemoeller, et al.]. The latter category, of course, has potential for conversion to cropland again but all soils in the region require high levels of nitrogen and management for high yields. Since the region emphasizes dairying, it is a net importer of feed grains and oil meals.

Feed grains use 38 percent of the land in the base solution for the North Atlantic Zone. Hay and silage use more than a third of the land while soybeans account for a sixth, and wheat vegetables and fruit are grown on the remaining cropland. With increased exports, production of soybeans declines but production of feed grains and wheat increases due to interregional shifts in crop production. Production (Table 5) increases by 26 percent overall for the High and Moderate Potential Land Scenario, nine percent for the scenario with only High Potential Land Available, and three percent for the Reduced Yields Scenario comparing the lowest export level with the highest possible level of exports in each case. Prices, of course, increase by more than production

Table 5. Changes in production, value of production, and costs returns to assets with increased exports in the North Atlantic Zone

Land Potential and Export Level	Index[a] Production	Index[a] Prices	Value of Production	Costs	Returns to Assets
			------(million dollars)-------		
Both High and Moderate Potential Land					
II	100	100	2040	1472	568
IV	111	116	2626	1692	997
VI	121	130	3217	1798	1419
VII	126	244	6249	1909	4340
High Potential Land Only					
I	94	103	1970	1389	571
II	96	116	2285	1430	855
III	99	131	2652	1473	1179
IV	103	164	3435	1548	1887
Reduced Yields					
I	93	137	2586	1468	1118
II	96	173	3391	1542	1849

[a]Index of production and prices under the various solutions where export level II under both High and Moderate Potential Land equal 100.

because prices are determined by production costs in the most marginally profitable of rotations. Therefore returns to assets increase even more sharply.

The main method of increased production in the North Atlantic Zone is by increasing land use. The increased production very closely parallels the increase in total land use, one percentage point in all solutions (Table 6). Nearly all of available Land Class 1 is used in the

Table 6. Increases in land use in the North Atlantic resulting from various export levels

Land Potential and Export Level	Increase on Land Class: 1	2	3	4	5	Total Increases
	(1000 Acres)					
Both High and Moderate Potential Land						
II	1686	7807	2123	717	0	12333
IV	1714	8634	2475	860	0	13683
VI	1714	9465	2538	987	60	14764
VII	1714	9519	2670	1015	649	15567
High Potential Land Only						
I	1624	7228	1966	713	34	11566
II	1624	7469	1991	738	62	11885
III	1624	7469	1991	738	134	11957
IV	1624	7469	1991	738	446	12269
Reduced Yields						
I	1624	7469	1991	738	75	11897
II	1624	7469	1991	738	446	12269

solutions with the lowest export levels. Nearly all land in classes 1-4 is used in all solutions for scenarios with only high potential land available for conversion. The only means of increasing the land base is by increasing the use of the most marginal land in Class 5. However, even then production increases in the North Atlantic Zone are much smaller than in other zones.

The use of nitrogen increases with each level of production in terms of total nitrogen, nitrogen per acre and also in terms of nitrogen per unit of production (Table 7). There are two reasons why nitrogen use increases sharply: the mix of crops produced changes to crops which require more fertilizer and the land brought into production is inherently less fertile. Energy use increases as well, mainly because of the increase in use of nitrogen fertilizer.

Table 7. Changes in nitrogen and energy use in the North Atlantic as a result of increased returns

Land Potential Export Level	Nitrogen			Energy		
	Total	Per acre	Per unit of Production[a]	Total	Per acre	Per unit of Production[a]
	(Million pounds)	(Pounds/ acre)		(Million of BTU's)	(M BTU/ acre)	
Both Moderate and High Potential Land						
II	459	37.2	100	40973	3.32	100
IV	542	39.6	107	45807	3.35	101
VI	685	46.4	123	51882	3.51	105
VII	810	52.1	140	56625	3.64	110
High Potential Land Only						
I	429	37.1	99	38672	3.34	100
II	460	38.7	104	40086	3.73	101
III	520	43.5	114	42049	3.52	104
IV	626	51.0	133	45573	3.71	108
Reduced Yields						
I	499	42.0	117	41435	3.48	109
II	587	47.8	133	44749	3.65	114

[a]Index based on Export Level II with high and moderate potential land available for conversion.

There is not, however, a clear relationship between soil loss and exports in the North Atlantic Zone (Table 8). Average soil loss per acre remains roughly consistent on land classes 1 and 2 but declines on land class 3 with increased export levels. The decline in soil loss per acre results because it becomes profitable to use more conservation practices (chiefly contour plowing and terraces on land class 3) as crop prices increase at the higher export levels. Soil loss per acre on

Table 8. Number of acres exceeding "t-level" of soil loss in the North Atlantic Zone by export level.

Land Potential and Export Level	Total Acres Exceeding				Soil loss on land exceeding "t-levels"	Total soil loss
	10T	4T	2T	T		
	(1000 Acres)				(1000 tons)	
Both High and Moderate Potential Land						
II	0	557	900	1301	13977	24468
IV	0	665	1262	1789	18642	30093
VI	0	416	762	1732	10935	23284
VIII	0	276	1062	1261	13360	26053
High Potential Land Only						
I	0	527	844	1178	13114	23108
II	0	529	1060	1408	15142	24644
III	0	310	575	967	8922	18599
IV	0	137	703	865	8724	18254
Reduced Yields						
I	0	333	766	826	9354	19711
II	0	188	65	772	8483	17642

land class 4 is high averaging well above t-levels in all solutions. Soil loss on land class 5 is high and tends to increase with export levels but management practices on land class three tend to offset changes in soil loss on the other two land classes. A major explanation for the differences in the patterns in total soil loss between scenarios is the fact that nearly all land in land classes 1-4 is used in the second two scenarios. Increased production can be achieved only by bringing into use relatively small amounts of land class 5 and by imporved management on land class 3. Only a small increase in production results from these changes in the zone.

South Atlantic Zone

The South Atlantic zone is an aggregation of 15 PAs and 5 market regions. The market regions center on Charleston, Atlanta, Miami, Memphis, and New Orleans. New Orleans is the major port for export of a large portion of the feed grains and soybeans produced in the North Central zone with Atlanta and Charleston serving as minor export points. Politically, the zone encompasses all (Figure 3) of Florida, Georgia, South Carolina, Alabama, and Mississippi; nearly all of North Carolina, Louisana, Arkansas and Tennessee; the southern fringes of Missouri and Virginia; and six southwestern Kentucky counties.

The drainage in the western part of the zone is into the Tennessee and Lower Mississippi Rivers. The eastern part of the zone is characterized by smaller river systems draining directly into the Atlantic Ocean and the

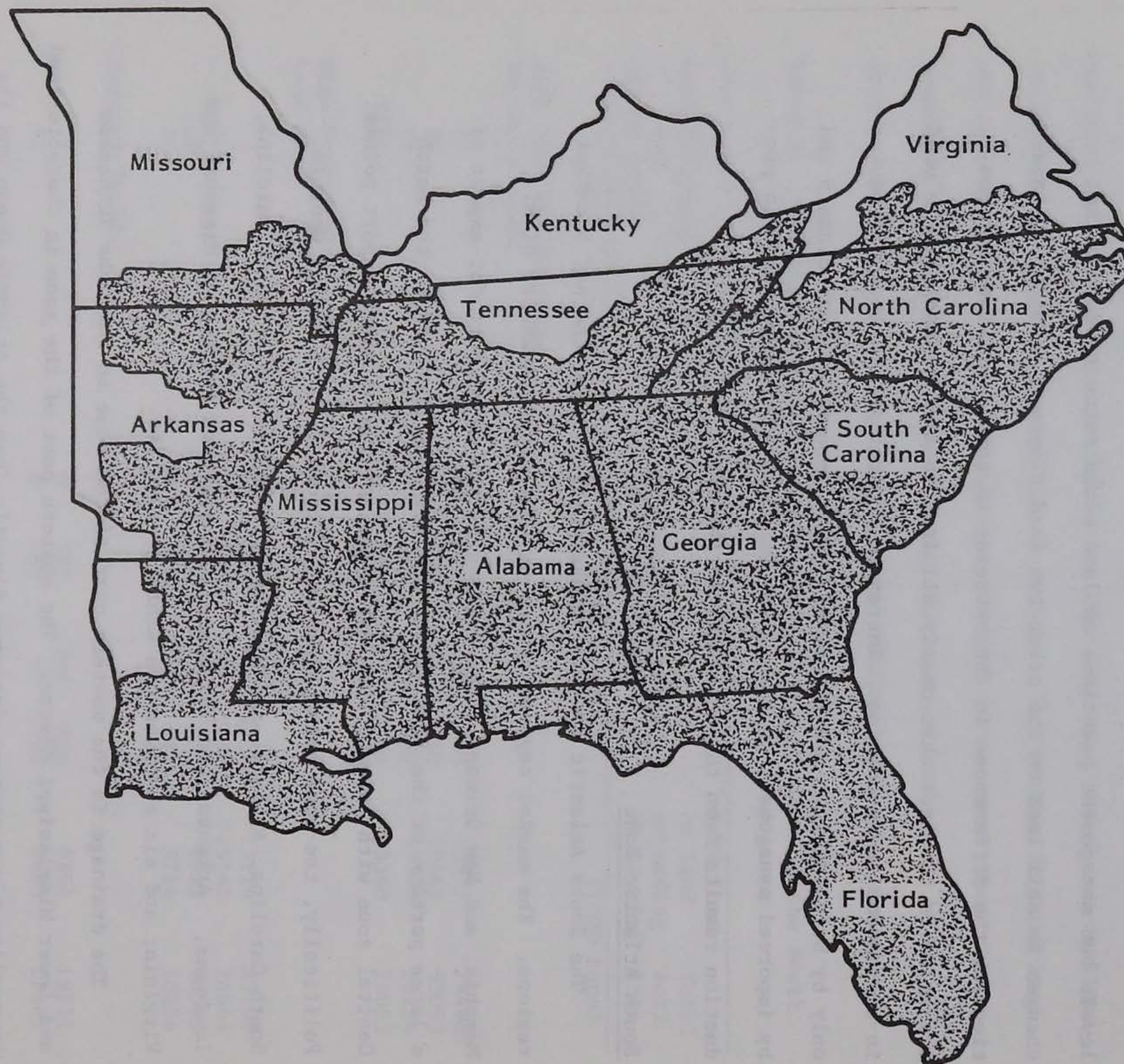

Figure 3. The South Atlantic Zone with political boundaries.

Gulf of Mexico. The Piedmont formation cuts diagonally through the center of the zone separating the direction of flow of runoff. The soils in the zone tend to be shallow, highly leached and lacking in great inherent productivity with the major exception of the heavy alleuvial soils in the Mississippi and other flood plains. A major problem with soil loss in the region, aside from the fragility of the soils, is the high delivery ratios characteristic of the zone; a high proportion of soil loss ends up as suspended sediment in the rivers so the externalities and environmental consequences are more pronounced [Wade and Heady]. Major exogenous crops in the region include citrus in Florida and peanuts and tobacco elsewhere. Exogenous soil loss from these crops, especially peanuts, may contribute significantly to soil loss. In addition, the region is a major timber producer and soil loss from forest lands adds significantly to the total sediment in the river system.

A very large portion of the potential agricultural land base is located in the South Atlantic Zone (Table 2). Eleven percent of the endogenous cropland is in the South Atlantic Zone. However, more than 29 percent of the high protential land and more than 26 percent of the moderate potential land is in the zone. With low levels of exports, it is not economic to convert a large portion of the potential cropland base; total land use is around 40 million acres in the base solution. There is some conversion of potential land in classes 1 and 2 but no class 5 land is used. Wheat and soybeans are the most important endogenous crops, using 47 and 31 percent of the land respectively. Hay and silages are also important and require 11 percent of the land. Feed grains and cotton use approximately the same amount of the remaining land. When exports are increased, production of all crops but feed grains increases.

Production in the zone increases sharply with greater exports (Table 9): the increase in production with increased exports is larger in relative terms than in all other zones. The absolute increases in production also are very large relative to all other zones except the North Central. Production in the South Atlantic Zone also is a higher share of national production in both of the more restrictive scenarios.

Similar to the North Atlantic Zone, the main means of increasing production is by increasing the land used to produce endogenous crops (Table 10). Production increases by a slightly smaller proportion than the increase in land use. A large proportion of the increased land use is in land class 2. While production increases somewhat on land class 1, use of land classes 3-5 increases by a larger relative amount as exports increase. Soil loss increases sharply in the South Atlantic Zone with each increase in export level (Table 11). Average soil loss per acre exceeds "t-levels" for land classes 3-5 in nearly all solutions. It also exceeds "t-levels" for large amounts of land classes 1 and 2. Soil loss per acre is roughly constant on land classes 1 and 2, declining only fractionally with increases exports. Average soil loss on land class 3 starts out at more than 9 tons per acre for all scenarios, but

Table 9. Changes in production, value of production, and costs and returns to assets with increased exports in the South Atlantic Zone

Land Potential and Export Level	Index[a] Production	Index[a] Prices	Value of Production	Costs	Returns to Assets
			-----(million dollars)------		
Both High and Moderate Potential Land					
II	100	100	5,038	3,772	1,266
IV	119	121	7,279	4,490	2,789
VI	151	139	10,591	5,752	4,839
VII	178	291	26,053	6,940	19,113
High Potential Land Only					
I	98	100	4,922	3,693	1,229
II	110	117	6,470	4,159	2,311
III	123	135	8,356	4,725	3,631
IV	124	178	11,170	4,819	6,351
Reduced Yields					
I	106	139	7,483	4,443	3,040
II	113	183	10,392	4,758	5,634

[a]Production is measured with a Laspeyres Index, prices with a Paasche Index based on Export Level II with High and Moderate Potential Land.

declines with increased exports although the average generally remains well above 5 tons per acre. Soil loss per acre is even higher on land classes 4 and 5. It averages as high as 96.5 tons per acre on land class 5 in some solutions.

Table 10. Increase in land use in the South Atlantic Zone as a result of increased exports

Land Potential and Export Level	Land Class 1	2	3	4	5	Total
	(1000 acres)					
High and Moderate Potential Land						
II	6,816	29,275	3,840	626	0	40,558
IV	7,272	35,032	5,064	1,318	135	48,822
VI	7,372	44,298	6,383	1,572	380	60,005
VII	7,391	51,494	9,054	3,145	2,783	73,357
High Potential Land Only						
I	6,838	29,007	3,570	626	0	40,041
II	6,948	32,741	3,918	1,218	135	44,961
III	7,031	36,346	4,537	1,239	380	49,533
IV	7,031	36,531	4,537	1,397	1,138	50,634
Reduced Yields						
I	7,031	34,799	4,131	1,232	236	47,429
II	7,031	36,531	4,537	1,348	1,084	50,531

Soil loss above t-levels is severely aggregated by increased exports. Soil loss exceeds ten times the tolerance levels on 58 thousand acres in the base solution and 1.6 million acres in the solution with Export Level VIII. The total area with soil losses beyond t-levels is nearly seven million acres in all solutions. Soil loss is a major problem in this zone even with low export levels, the area with soil losses above t-levels increases to more than 11 million acres under Export Level VII. The amount of land with losses this large is more than 15 percent of all land in the region in nearly all solutions.

Table 11. Number of acres exceeding tolerance levels (t-level) of soil loss in the South Atlantic Zone by export level

Land Potential and Export Level	Exceeding 10T	4T	2T	T	Soil loss on land exceeding "t-levels"	Total soil loss
	(1000 Acres)				(1000 Tons)	
Both High and Moderate Potential Land						
II	58	2,038	3,533	6,885	94,474	162,769
IV	237	2,383	4,303	8,809	119,419	198,124
VI	416	2,645	5,435	9,790	140,571	210,721
VII	1,599	2,298	2,775	11,085	160,198	251,577
High Potential Land Only						
I	58	2,038	3,533	6,848	87,976	155,189
II	194	2,332	3,986	7,688	110,704	180,476
III	366	2,502	4,506	8,000	124,282	185,005
IV	759	2,939	4,567	8,124	146,286	210,508
Reduced Yields						
I	294	2,576	4,657	8,217	134,072	195,482
II	705	3,289	4,467	7,952	148,192	211,955

North Central Zone

The North Central Zone (Figure 4) is large and encompasses 21 PAs and seven market regions. The zone is trisected by two major river systems: the Northern Mississippi running from north to south and the Ohio flowing west. Most of the zone drains into these two systems although the western fringe drains into the Missouri and the northern fringe into the Great Lakes. A large amount of the best and deepest soils in America are

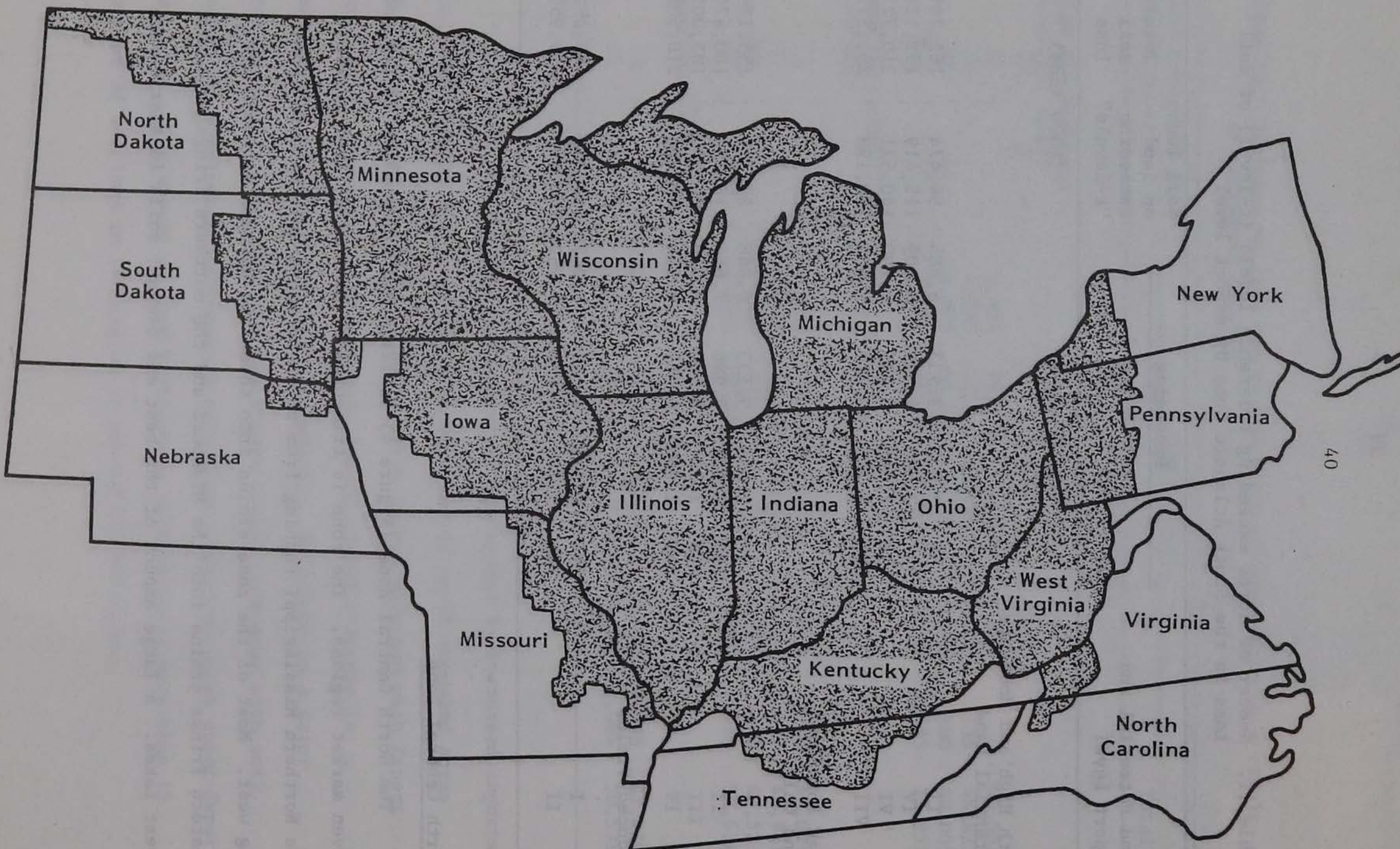

Figure 4. The North Central Zone with political boundaries.

found in this zone. However, it also includes a large area of hilly soils subject to water erosion. Rainfall is generally plentiful throughout the zone although less so in the western fringe.

The zone includes all of the Corn Belt and Great Lake states and is the most important zone in the production of the endogenous crops especially feed grains (other than sorghum) soybeans, hays and silages.

The region responds to higher export demands by increased specialization. Feed grain production increases substantially while production of soybeans remains relatively constant. Wheat production also remains roughly constant over a range of export levels, but declines by 50 percent at the highest export level.

Overall production increases by only 19 percent in the base solution to that with the highest level of exports (Table 12). The change in production is small in relative terms, but large in absolute terms because of the quantities produced in this zone in the base solution. Most of the land in the zone is used with low levels of exports; land use increases only 12 percent for the solution with the highest export levels compared to the base solution (Table 13). Irrigation increases slightly.

Nitrogen and energy use increase sharply. Comparing the base solution with the solution for Export Level VII, nitrogen per acre increases 51 percent while nitrogen per unit of production increases 42 percent. This change results because more nitrogen is used in response to higher crop prices and a shift of production mix to relatively more fertilizer-

Table 12. Changes in production, value of production, and costs and returns to assets with increased exports in the North Central Zone

Land Potential and Export Level	Index[a] Production	Prices	Value of Production	Costs	Returns to Assets
			-------(million dollars)------		
Both High and Moderate Potential Land					
II	100	100	19,219	14,016	5,203
IV	109	121	25,336	15,386	9,950
VI	113	141	30,681	16,171	14,510
VII	119	281	64,342	17,425	46,917
High Potential Land Only					
I	97	100	18,649	13,589	5,060
II	100	117	22,474	14,089	8,385
III	103	136	26,901	14,573	12,428
IV	106	177	36,008	15,247	20,761
Reduced Yields					
I	93	143	25,504	14,349	11,155
II	95	186	34,154	14,932	19,222

[a]Production is measured with a Laspeyres Index, prices with a Paashe Index based on Export Level II with High and Moderate Potential Land.

intensive feed grains. The increased energy mainly in the energy component of nitrogen fertilizer.

Soil loss per acre is relatively low on land classes 1 and 2 in the base solution and changes very little with the level of exports (Table 14). All of land class 2 is contour plowed and most employs one of the soil-conserving tillage practices. Soil loss on land class

Table 13. Increase in land use in the North Central Zone as a result of measured exports

Land Potential and Export Level	Land Class 1	2	3	4	5	Total
	(1000 Acres)					
Both High and Moderate Potential Land						
II	33,703	89,234	18,870	3,835	0	145,643
IV	33,764	94,138	21,553	5,680	805	155,941
VI	33,764	95,378	21,932	6,612	1,409	159,094
VII	33,764	96,011	22,003	7,010	4,192	162,980
High Potential Land Only						
I	33,403	85,731	17,509	3,772	0	140,415
II	33,403	86,901	18,234	4,974	805	144,328
III	33,404	87,022	18,233	5,171	1,386	145,215
IV	33,404	87,022	18,277	5,216	2,722	146,597
Reduced Yields						
I	33,404	87,022	18,233	5,163	1,386	145,207
II	33,404	87,022	18,233	5,193	2,702	146,554

3 is high and averaged 7.4 tons/acre in the base solution. Most of this land does not have a conservation practice in the base solution but as exports increase conservation practices become economic on land class 3 and soil loss per acre drops sharply.

Soil loss per acre exceeds tolerance levels on land classes 4 and 5 at all levels of exports. With higher exports soil loss per acre increases slightly on land class 4 and by a large amount on land class 5.

Table 14. Number of acres exceeding "t-level" of soil loss in the North Central Zone by export level

Land Potential and Export Level	Exceeding 10T	4T	2T	T	Soil loss on land exceeding "t-levels"	Total soil loss
	(1000 Acres)					
Both High and Moderate Potential Land						
II	413	3,603	6,010	13,034	153,692	299,648
IV	108	3,597	5,196	12,951	125,096	284,156
VI	970	3,563	6,117	8,719	127,131	296,611
VII	1,227	3,669	3,935	7,197	149,758	319,100
High Potential Land Only						
I	1,716	4,800	5,847	11,965	190,457	329,298
II	108	3,111	4,395	12,088	113,034	259,316
III	948	2,745	3,716	7,986	102,131	255,629
IV	883	2,703	4,833	7,025	109,759	265,008
Reduced Yields						
I	7,994	3,797	6,315	9,043	120,803	271,381
II	1,307	2,795	4,603	8,077	123,105	279,238

Because there is more class 3 land than class 4 and 5 land, the number of acres with soil loss exceeding t-levels tends to decline with increased exports until the highest export level is reached (Table 14).

South Central Zone

The South Central Zone (Figure 5) is an aggregation of five MRs centering on El Paso, Amarillo, Okalahoma City, San Antonio, and Houston.

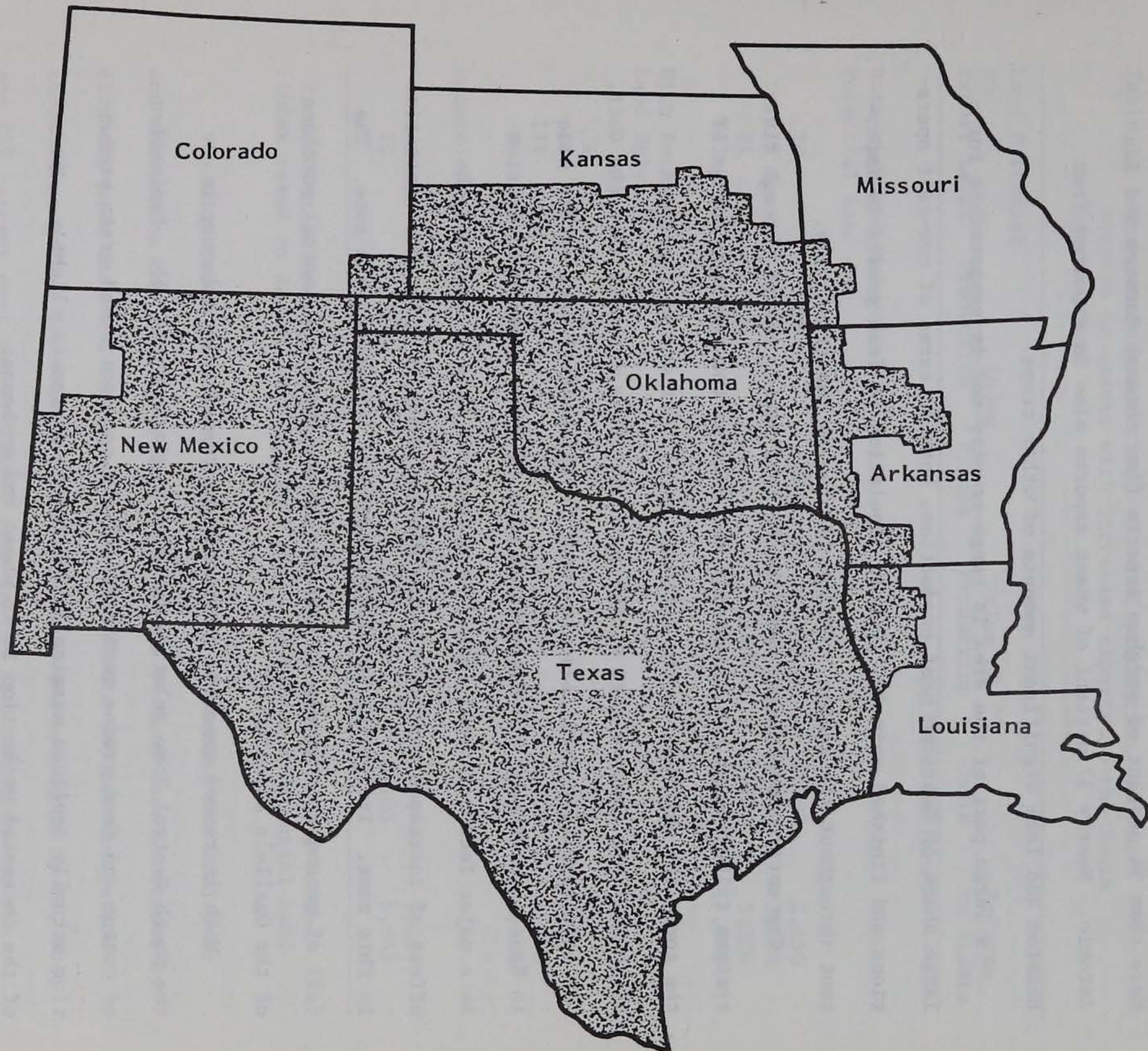

Figure 5. The South Central Zone with political boundaries.

More than 94 percent of sorghum exports flow through Houston and San Antonio. Nearly 37 percent of wheat exports also is exported from Houston and less significant amounts of other crops.

A large part of the area is range country and is responsible for a large share of American beef production, both in terms of cow-calf operations and finished animals. Hence, population of feed grains is important throughout the region. Cotton is also an important crop.

The entire zone drains into the Gulf of Mexico either through river systems tributory to the Rio Grande which forms the southern border of the zone, the Arkansas on the northern border, or one of the small systems in the central part of the zone that flow directly into the Gulf. The most naturally fertile soils occur in the central part of the zone in Kansas, Oklahoma, and High Plains area of Texas where wind erosion is a major factor in soil loss. No attempt is made to evaluate the effect of increased exports on wind erosion which is a serious limitation in this zone. Irrigation is widely practiced throughout the zone. The fall of groundwater levels is greatest in the south and central portions of the Ogallala Acquifer.

With increased exports, production increases only modestly in the South Central Zone relative to other regions (Table 15). Production of cotton and feed grains remain relatively constant; feed grain production actually declines marginally and cotton increases slightly. Most of the increased production is in wheat and soybeans.

Table 15. Changes in production, value of production, and cost returns to assets with increased exports in the South Central Zone

Land Potential and Export Level	Index Production	Index Prices	Value of Production	Costs	Returns to Assets
			--------(million dollars)----------		
Both High and Moderate Potential Land					
II	100	100	6,549	4,399	2,150
IV	111	121	8,836	5,098	3,738
VI	116	160	11,108	5,784	5,324
VII	124	296	24,014	6,452	17,562
High Potential Land Only					
I	90	97	5,725	3,895	1,830
II	91	117	6,986	4,255	2,731
III	99	131	8,520	4,740	3,780
IV	104	171	11,662	5,276	6,386
Reduced Yields					
I	89	132	7,845	4,447	3,398
II	95	173	10,768	5,103	5,665

Production is measured with a Laspeyres Index, prices with a Paashe Index based on Export Level II with High and Moderate Potential Land

The additional production is achieved by increasing the land base and increasing the area irrigated. The amount of land used increases by slightly more than the increased production (Table 16) but irrigation shows large gains; for example, the irrigated area increases by 61, 154, and 229 percent over the irrigated area in the base solution for the three alternative export levels in the scenario with high and moderate

Table 16. Increase in land use in the South Central as a result of increased exports

Land Potential and Export Level	Land Class 1	2	3	4	5	Total
	(1000 Acres)					
Both High and Moderate Potential Land						
II	8,742	37,945	16,159	3,671	9	66,530
IV	8,803	40,229	18,166	4,952	490	72,640
VI	8,805	40,505	20,771	6,217	1,144	77,443
VIII	8,841	40,716	21,117	6,914	2,509	80,097
High Potential Land Only						
I	8,450	32,481	13,378	3,672	2	57,983
II	8,485	33,487	13,906	4,048	51	59,980
III	8,490	33,899	16,005	4,109	935	63,439
IV	8,527	33,926	16,110	4,635	1,409	64,607
Reduced Yields						
I	8,490	33,609	15,887	4,133	760	62,879
II	8,527	33,927	16,111	4,636	1,233	64,432

potential land available for conversion as shown in Table 17. The land converted to cropland at high exports is less productive than the land used at low levels of exports. Hence, production per acre is maintained constant by increased irrigation.

Nitrogen use per acre remains fairly constant. Additional nitrogen on the greater irrigated are is offset by the shift to more soybeans. Energy use increases sharply because of the increased use of irrigation under high export levels.

Table 17. Increased irrigation in the South Central zone with increased export levels

Land Potential and Export Level	Irrigated Land	Surface Water	Ground Water	Groundwaters in Ogallala Area
	(1000 Acres)	-------(1000 Acre Feet)	-------------	-------------
Both Moderate and High Potential Land				
II	3,663	643	6,366	1,510
IV	5,901	674	10,551	3,489
VI	9,300	674	16,298	6,734
VIII	12,053	674	27,703	9,524
High Potential Land Only				
I	3,753	643	6,115	1,782
II	5,310	643	9,101	3,003
III	7,731	674	13,410	5,373
IV	10,789	674	18,765	8,394
Reduced Yields				
I	5,854	674	10,494	3,581
II	9,727	674	17,430	7,514

Soil loss due to sheet erosion is less of a problem in the South Central Zone than in other zones because of less rain. Soil loss on land classes 1 and 2 averages around 4 tons/acre and 3 tons/acre respectively. Soil loss on land class 3 and 4 does not exceed the tolerance levels in most PAs in any solution. Soil loss per acre tends to decline with increased exports as more conservation practices are used. Lower rainfall in the zone causes conservation practices to be economic at lower crop prices over a large area of the South Central Zone.

Total soil loss (Table 18) increases with increased export levels mainly because of the increased acreage in crops. The increase in irrigation tends to lower soil loss; soil loss per acre on irrigated land is generally less than that on nonirrigated land. The area of land with soil loss greater than t-levels declines with increased export levels in all three scenarios.

Table 18. Number of acres exceeding "t-level" of soil loss in the South Central Zone by export level

Land Potential and Export Level	Exceeding				Total soil loss
	10T	4T	2T	T	
	(1000 Acres)				(1000 tons)
Both High and Moderate Potential Land					
II	29	168	2,480	14,455	205,554
IV	39	627	3,122	12,240	215,795
VI	266	1,577	3,061	10,822	226,333
VIII	210	2,020	3,002	9,604	221,783
Moderate Potential Land Only					
I	271	405	1,718	11,144	178,281
II	116	204	1,675	9,666	171,072
III	203	999	1,968	8,409	178,925
IV	221	1,303	1,832	8,530	180,578
Reduced Yields					
I	459	1,068	2,793	8,614	188,429
II	159	1,330	2,233	8,433	178,861

Great Plains

The Great Plains Zone (Figure 6) is an aggregation of 13 PAs and three market regions in the mid-continental region of the U.S. No states are completely within the Great Plains Zone but the zone encompasses the main agricultural regions of Montana, Wyoming, Colorado, as well as western North Dakota, South Dakota, and Iowa, nearly all of Nebraska, the northern half of Kansas, and northwestern Missouri.

The zone closely approximates the boundaries of the Water Resource Council's "Missouri Region." The Missouri River runs along the eastern edge of the zone with tributary rivers such as the Yellowstone and Platte flowing eastwards throughout the zone. The exceptions are two PAs in southern Colorado which are part of the Arkansas and Rio Grande basins. Wind erosion is a serious problem throughout the zone. However, the impact of exports on wind erosion is not included in this study. The region is dry and irrigation is an important factor in crop production. Most of the cropland in the zone is engaged in the production of the endogenous crops (except cotton) but there also are large acreages of hayland and pasture.

Production of all export crops increases in the Great PLains Zone at higher export levels. Wheat increases proportionately the most. It increases nearly 50 percent when the solution for Export Level VII is compared with the bases solution for the High and Moderate Potential Land Scenario. However, production of other crops also increases by substantial amounts. As shown in Table 19 overall production increases

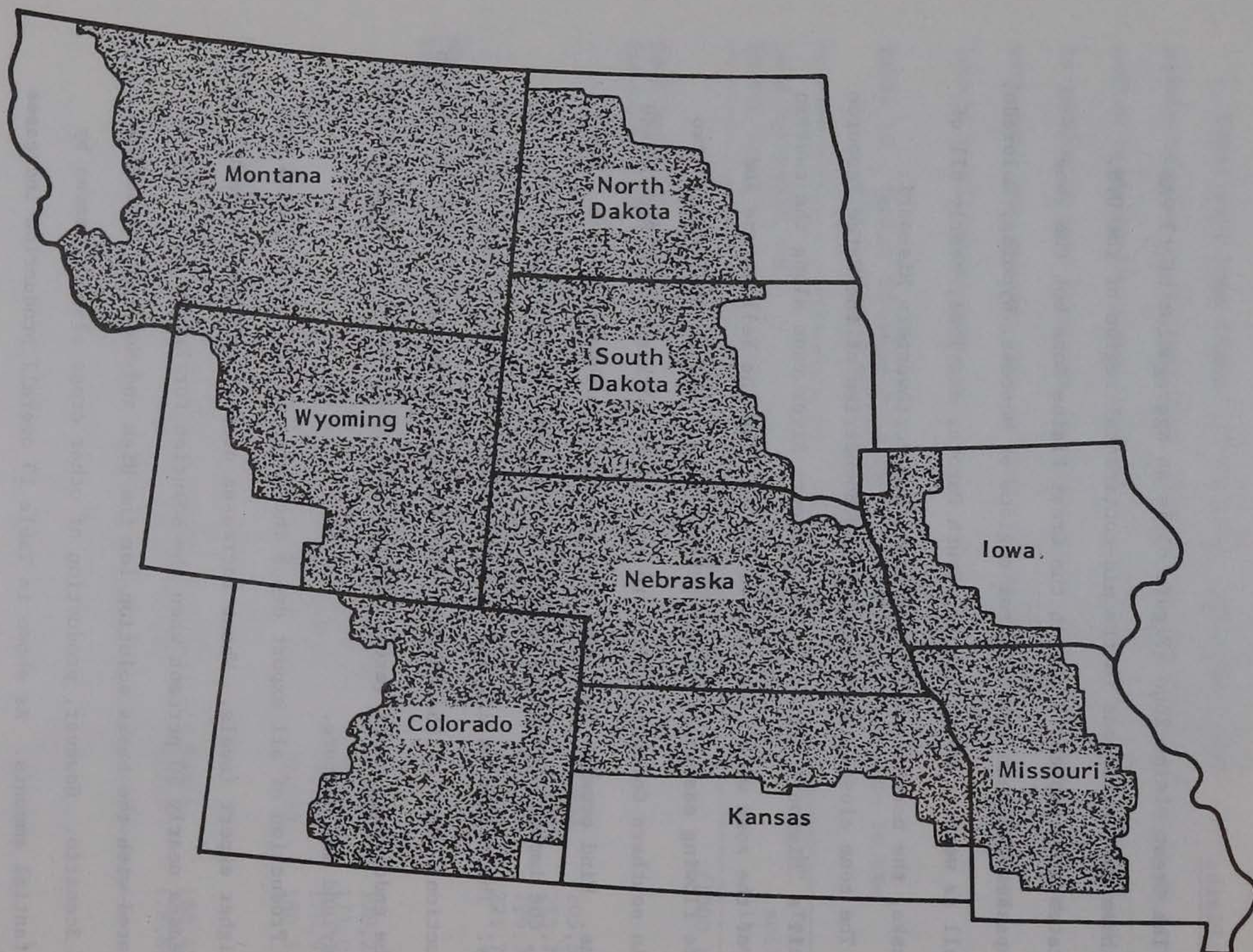

Figure 6. The Great Plains Zone with political boundaries.

Table 19. Changes in production, value of production, and costs returns to assets with increased exports in the Great Plains zone

Land Potential and Export Level	Index Production	Index Prices	Value Production	Costs	Returns to Assets
			--------(million dollars)-----		
Both High and Moderate Potential Land					
II	100	100	7,678	5,170	2,508
IV	100	128	9,852	5,714	4,138
VI	118	138	12,516	6,476	6,040
VIII	127	299	29,147	7,539	21,608
High Potential Land Only					
I	91	101	7,084	4,747	2,337
II	97	117	8,654	5,131	3,523
III	101	135	10,432	5,472	4,960
IV	107	181	14,968	6,203	8,765
Reduced Yields					
I	93	140	10,027	5,443	4,584
II	101	188	14,401	6,185	8,316

Production is measured with a Laspeyres Index, prices with a Paashe Index based on Export Level II with High and Moderate Poential Land.

by 27 percent between these two solutions. The pattern of changes in prices, value of production, costs and returns to assets is similar to that of other regions as exports move to higher levels.

Increased production comes from use of more land and by increased irrigation. Land use increases by 20 percent and irrigated land increases by 130 percent between the base solution and the solution with

Export Level VII. Nitrogen and energy use increase by proportionately greater amounts than the increase in production. The additional production of the Great Plains Zone is relatively more energy intensive because of increased irrigation. Relatively more nitrogen is required because of the disproportionate increase in wheat production.

Nearly all of the increase in land is by expansion of the erosive lands in land class 3-5 (Table 20). Nearly all of land class I land is used at the lowest export levels in all scenarios and most of land

Table 20. Increase in land use in the Great Plains as a result of measured exports

Land Potential and Export Level	Land Class					Total
	1	2	3	4	5	
			(1000 Acres)			
Both High and Moderate Potential Land						
II	8,793	38,543	30,713	4,314	0	81,759
IV	8,819	39,601	32,077	8,393	539	89,377
VI	8,819	39,813	34,880	10,338	1,640	95,491
VII	8,819	39,840	35,240	12,948	6,230	103,437
High Potential Land Only						
I	8,624	34,881	26,676	4,043	0	74,286
II	8,686	34,882	27,513	7,827	243	79,151
III	8,686	34,882	28,028	9,336	827	81,858
IV	8,686	34,882	28,104	9,735	3,156	84,562
Reduced Yields						
I	8,686	34,882	27,827	8,920	853	81,168
II	8,686	34,882	28,104	9,735	2,916	84,324

class 2. Land use increases in roughly the same amounts in absolute terms for land classes 3-5 but proportionately by much greater amounts for land classes 4 and 5.

Increased exports have a negligible effect on soil loss per acre on land classes 1 and 2 (Table 21). Average soil loss is relatively high on land classes 3 and 4 with low exports levels but decreases with increased exports. The decrease is primarily due to use of more terracing as high prices encourage the practice at high export levels.

Table 21. Soil loss per acre in Great Plains as a result of increased exports

Land Potential and Export Level	Land Class				
	1	2	3	4	5
	(Tons/Acre)				
Both High and Moderate Potential Land					
II	2.6	1.6	4.5	-	-
IV	2.7	1.6	3.9	5.8	14.7
VI	2.8	1.6	1.1	4.4	31.8
VII	2.8	1.6	0.8	1.0	27.9
High Potential Land Only					
I	2.6	1.6	4.5	4.1	-
II	2.7	1.6	4.0	5.8	-
III	2.8	1.6	1.4	4.6	25.3
IV	2.8	1.6	0.9	4.7	22.7
Reduced Yields					
I	2.8	1.6	1.4	5.2	25.3
II	2.8	1.6	1.0	4.7	24.4

Average soil loss per acre on land class 5 is at very high levels even with low export levels. It tends to decrease slightly at high exports as it becomes profitable to use more conservation practices.

Aggregate soil loss is not clearly related to the export level in any consistent fashion (Table 22). Aggregate soil loss increases with exports initially, declines and then increases again. The same pattern holds for the number of acres exceeding tolerance levels. The erratic results for the zone are mainly due to land use in land class 3 and 4 in

Table 22. Number of acres exceeding "t-level" of soil loss in the Great Plains by export level

Land Potential and Export Level	Exceeding 10T	4T	2T	T	Total soil loss
					(1000 tons)
Both High and Moderate Potential Land					
II	0	4,592	5,105	9,349	234,507
IV	0	5,570	5,784	9,712	260,169
VI	733	2,466	2,680	3,703	209, 746
VII	1,461	3,894	5,156	5,163	282,892
Moderate Potential Land Only					
I	0	4,076	5,296	8,209	212,434
II	0	5,054	5,054	7,967	230,541
III	190	1,420	1,634	4,234	170,556
IV	441	2,683	3,850	3,850	208,278
Reduced Yields					
I	190	1,420	1,444	3,633	173,145
II	441	2,646	3,755	3,755	207,177

western Iowa. The land is selected for use in row crop production but terracing is marginally viable or not viable in all solutions depending upon crop prices. However, the land is subject to high erosion rates in the absence of terracing.

Wind erosion was not included in this study. Hence, the erosion rates related to water are lower than total erosion (wind and water) would be.

Northwest Zone

The Northwest Zone (Figure 7) is relatively small made up of only seven PAs and one MR. Seattle, the central city in the MR, is also a major port for barley and wheat exports. The zone spans all of Washington, most of Oregon and Idaho, and small parts of northeast Wyoming and Montana.

The entire zone is mountainous. It produces mostly wheat and barley and oats of the endogenous crops. However, potatoes, sugar beets, apples, and beef production also are important within the zone. Soil loss from the exogenous crops, as well as soil loss originating in extensive forest harvesting activities, may also be important. The area is also characterized by relatively high sediment delivery ratios; a high proportion of the soil loss becomes suspended sediment in the Columbia and other river systems within the zone [Wade and Heady].

When exports are increased, the Northwest zone becomes more specialized. Even at low export levels, production on endogenous cropland is dominated by wheat acres with feed grains produced on less

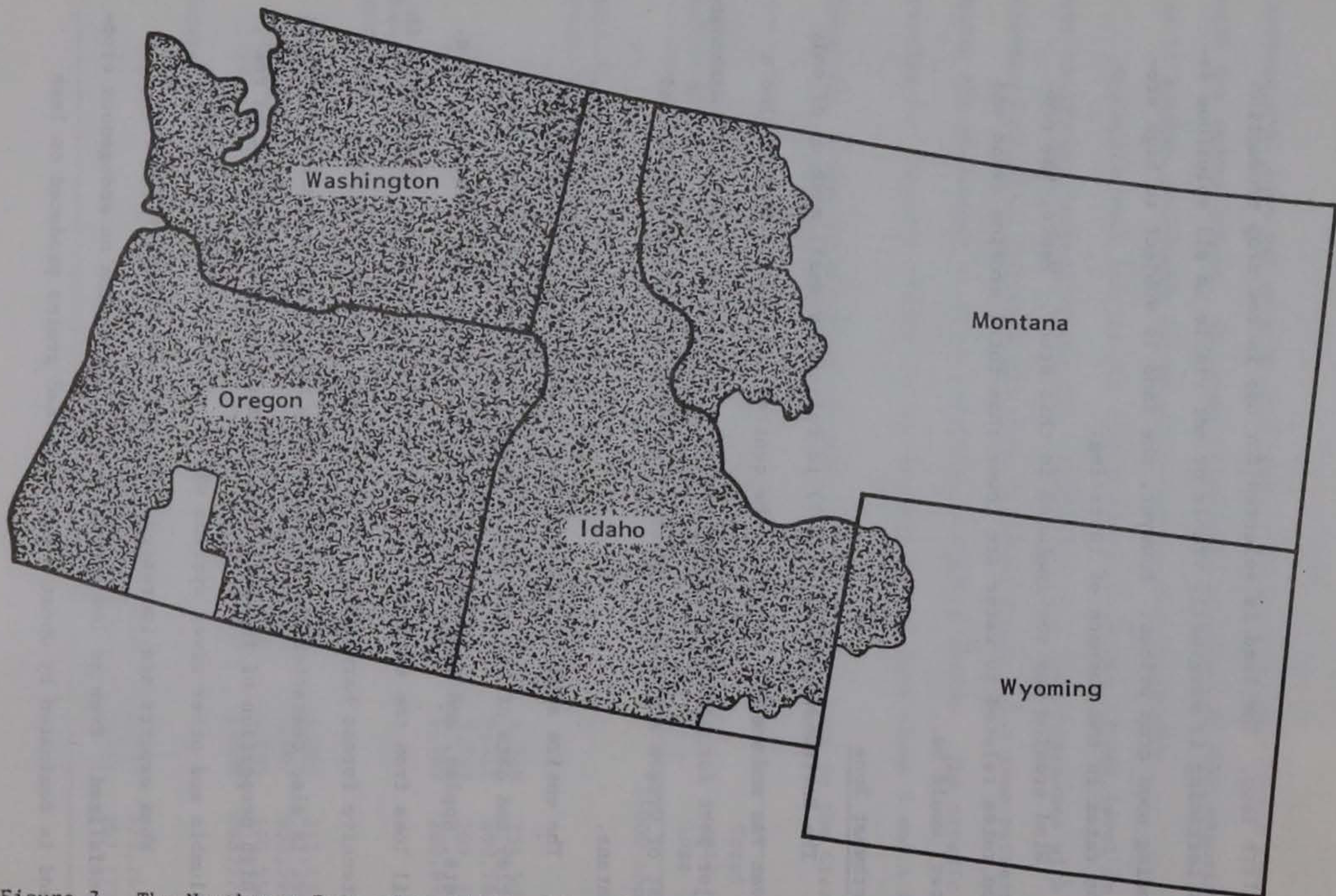

Figure 7. The Northwest Zone with political boundaries.

than half as may acres; silage and endogenous hay production is less important and cotton and soybeans are not produced in the zone. Increased exports raise wheat production while feed grain production declines. Overall production (Table 23) increases sharply in the Northwest Zone by 6 percent, 28 percent, and 44 percent for Export Levels IV, VI, VIII respectively over production in the base solution with both high and moderate potential land for conversion.

Table 23. Changes in production, value of production, and costs and returns to assets with increased exports in the Northwest Zone

Land Potential and Export Level	Index		Value		Returns
	Production	Prices	Production	Costs	to Assets
			-------(million dollars)------		
Both High and Moderate Potential Land					
II	100	100	1,537	1,000	537
IV	106	113	1,839	1,080	759
VI	128	132	2,583	1,490	1,093
VII	144	288	6,367	1,843	4,524
High Potential Land Only					
I	95	101	1,471	958	513
II	99	109	1,653	1,008	645
III	105	126	2,037	1,120	917
IV	128	170	3,336	1,584	1,752
Reduced Yields					
I	103	130	2,048	1,194	854
II	122	174	3,249	1,579	1,670

Production is measured with a Laspeyres Indes, prices with a Paashe Index based on Export Level II with High and Moderate Potential Land.

Expanded production is achieved not only by an increase in the amount of land used but also by a large increase in use of other inputs. Land use (Table 24) increases 31 percent between the base solution and the solution with Export Level VII while production increases 44 percent. Little increase occurs in use of land class 1 land since nearly all of it is used in the solutions at low export levels. Substantial increases occur in land use for the remaining four land classes. Production on substantial areas of land class 2 where land conversion is required is only

Table 24. Land use in the Northwest Zone with various levels of exports

Land Potential and Export Level	Land Class 1	2	3	4	5	Total
	(1000 Acres)					
Both High and Moderate Potential Land						
II	1,110	6,140	6,424	1,023	2	14,588
IV	1,121	6,220	6,769	1,220	267	15,598
VI	1,126	6,522	6,894	2,229	296	17,067
VII	1,162	6,978	6,874	2,754	1,289	19,057
High Potential Land Only						
I	1,111	5,611	6,075	1,016	10	13,825
II	1,121	5,676	6,340	1,081	267	14,486
III	1,121	5,889	6,340	2,135	296	13,781
IV	1,157	5,984	6,225	2,160	748	16,274
Reduced Yields						
I	1,121	5,777	6,340	1,161	296	14,695
II	1,157	5,984	6,225	2,160	564	16,090

feasible at higher crop prices. The pattern in other zones of increasing proportion of land classes 1-5 of utilized as cropland at high export levels also is evident in the Northwest Zone.

Nitrogen and energy use and irrigated land expand more in the Northwest Zone than any other zone as exports move to higher levels. Nitrogen use per acre for example increases by 63 percent between the base solution and the solution with Export Level VIII. Nitrogen use per unit of production increases by 56 percent between the same two solutions. The reason for the increase in nitrogen use are the change in the crop mix produced and the increase in area irrigated. Irrigated land increases by -1, 157, and 380 percent for Export Levels IV, VI, and VIII respectively in the scenario with both high and moderate potential land available for conversion and in a similar fashion in the other scenarios. Energy use also increases by large amounts because of its requirement in irrigation and fertilizer.

Average soil loss per acre (Table 25) is quite low and increases only slightly with exports on land classes 1-3 in the Northwest Zone. A high portion of land class 3 employs contouring and terracing at low export levels. Soil loss per acre on land class 4 and 5, however, is high in all solutions; the average tends to decline on land class 4 (due to conservation practices) and rise on land class 5 with increased exports.

Total soil loss also increases with exports. Total soil loss more than doubles, comparing the solution with the highest and lowest export

Table 25. Soil loss per acre in Northwest with different levels of exports

Land Potential and Export Level	Land Class 1	2	3	4	5
	(Tons/Acre)				
Both High and Moderate Potential Land					
II	0.5	0.8	1.3	8.0	0
IV	0.5	0.7	1.8	7.0	16.6
VI	0.5	0.8	1.8	4.9	15.6
VII	0.7	1.2	1.9	5.0	19.9
High Potential Land Only					
I	0.4	0.7	1.2	8.1	1.1
II	0.5	0.7	1.6	7.8	16.6
III	0.5	0.7	1.8	5.3	15.6
IV	0.6	0.8	2.0	3.9	29.2
Reduced Yields					
I	0.5	0.7	1.7	7.4	15.6
II	0.6	0.8	2.0	3.9	33.1

levels in the first two scenarios. It increases by 48 percent in the scenario with reduced yields (Table 26). A large part of the soil is from the land brought into production with increased exports.

Southwest Zone

The Southwest Zone (Figure 8) is very large spatially but because of the arid conditions, is relatively less important in the production of the endogenous crops. The zone is an aggregation of four MRs which in turn are an aggregation of 17 PAs.

Table 26. Number of acres exceeding tolerance levels ("t-level") of soil loss in the Northwest Zone by export level

Land Potential and Export Level	Exceeding 10T	4T	2T	T	Total Soil Loss
Both High and Moderate Potential Land					
II	0	0	607	609	21,829
IV	0	257	754	851	29,665
VI	0	257	754	902	32,897
VII	13	1073	1736	2362	55,480
High Potential Land Only					
I	0	0	497	499	19,768
II	0	257	754	804	27,488
III	0	257	754	902	31,470
IV	230	695	1065	1233	45,640
Reduced Yields					
I	0	257	754	912	28,782
II	230	511	881	1049	42,545

The zone encompasses the entire Colorado River system, the Great Basin Region in the northern part of the zone where rainfall is balanced by evapo-transpiration and the coastal river systems of California. A number of activities are included in the model to simulate transfers of water by canal mainly within the State of California. The production of exogenous crops, tree fruits and vegetables is important throughout much of the zone.

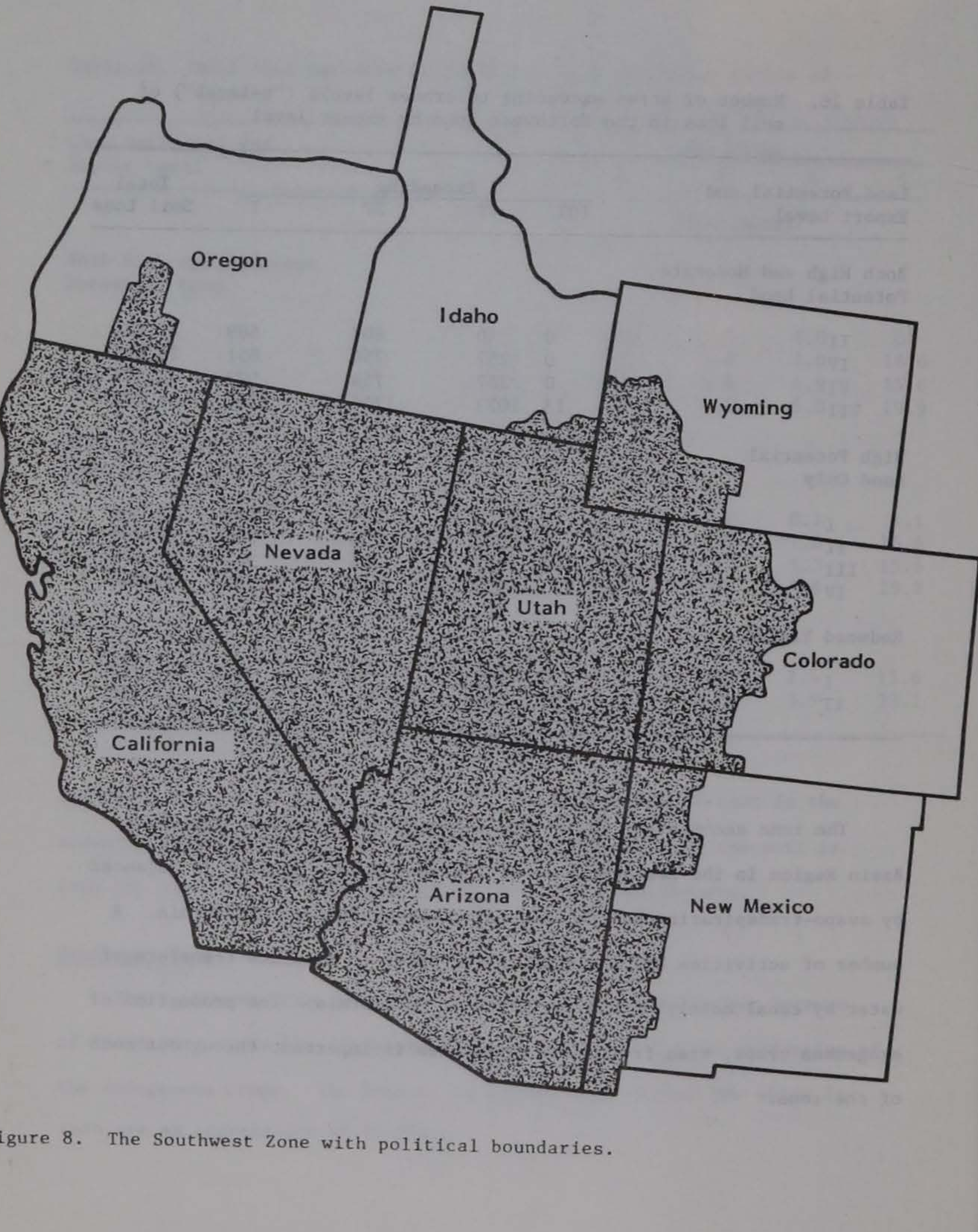

Figure 8. The Southwest Zone with political boundaries.

Production in the Southwest Zone increases substantially with increased exports. A comparison of the base solution with Export Level VII solution shows a 40 percent increase in production measured in constant prices (Table 27). Cotton production triples between these two solutions. Wheat production also increases substantially while feed grain production increases slightly at intermediate export levels and then declines at the highest export levels. Costs increase with each level of production but by less than the value of production so returns to assets rise greatly.

Table 27. Changes in production, value of production, and costs returns to assets with increased exports in the Southwest Zone

Land Potential and Export Level	Index Production	Index Prices	Value of Production	Costs	Returns to Assets
			------(million dollars)------		
Both High and Moderate Potential Land					
II	100	100	1,507	1,151	356
IV	108	109	1,771	1,268	503
VI	118	122	2,187	1,454	733
VII	140	216	4,569	1,965	2,604
High Potential Land Only					
I	97	100	1,464	1,117	457
II	102	107	1,632	1,184	448
III	113	120	2,042	1,389	653
IV	118	145	2,585	1,480	1,105
Reduced Yields					
I	107	124	1,995	1,381	614
II	112	149	2,517	1,467	1,050

Production is measured with a Laspeyres Index, prices with a Paashe Index based on Export level II with High and Moderate Potential Land.

As shown in Table 28, total land cropped increases dramatically with higher exports. The amount of land irrigated also increases with each level of exports but less dramatically because most opportunities for irrigation are exploited at low export levels.

Average soil loss per acre in the Southwest Zone is quite low for land class 1-3. Soil loss on land class 3 increases with exports but, on average, never exceeds 1.8 tons on nonirrigated land and 2.3 tons on irrigated land. Average soil loss on land class 4 is in the 3.8 to 4.5

Table 28. Increase in land use in the Southwest as a result of measured exports

Land Potential and Export level	Land Class 1	2	3	4	5	Total
	(1000 Acres)					
Both High and Moderate Potential Land						
II	1,987	3,492	673	946	59	7,155
IV	2,122	3,578	733	1,486	75	7,993
VI	2,385	3,676	1,013	1,621	177	8,872
VII	2,360	5,247	1,201	1,890	1,037	11,735
High Potential Land Only						
I	1,975	2,987	655	876	5	6,501
II	2,001	3,296	674	1,057	75	7,104
III	2,378	3,461	835	1,057	147	7,896
IV	2,377	3,794	862	1,088	241	8,363
Reduced Yields						
I	2,369	3,456	767	1,075	75	7,741
II	2,377	3,794	862	1,076	241	8,351

tons per acre range but exceeds tolerance levels in a number of PAs. Low levels of rainfall are important in explaining these results. Soil loss on land class 5 exceeds tolerance levels in nearly all PAs in all solutions where this land class is used.

Zone comparisons

Increased production is obtained chiefly by converting pasture and forest land to cropland in all regions but each region differs in the details. The North Central Zone responds with an increased intensifi-

Table 29. Number of acres exceeding "t-level" of soil loss in the southwest by export level

Land Potential and Export Level	Exceeding 10T	4T	2T	T	Total Soil Loss
	(1000 Acres)				(1000 Tons)
Both High and Moderate Potential Land					
II	0	96	112	1,610	12,043
IV	0	299	334	1,996	15,743
VI	30	329	391	2,102	20,464
VII	309	772	917	2,683	39,294
High Potential Land Only					
I	0	96	112	1,599	11,342
II	0	96	112	1,741	12,271
III	0	96	131	1,809	14,751
IV	30	169	204	1,481	16,269
Reduced Yields					
I	0	96	131	1,737	14,000
II	30	169	212	1,402	16,032

cation of production practices, while increased irrigation is an important factor in the South Central, Great Plains, and Northwest zones. Increased land use is largely the sole factor in the remaining three zones.

The effect of increased exports on programmed soil loss differs greatly by zone. In three zones (South Atlantic, Northwest, and Southwest) increased exports greatly aggravate soil loss. In the remaining four zones, increased exports make it profitable to improve management practices on classes 3 and 4 land and thus lead to reduced soil loss on these classes. Soil loss and exports at low and intermediate export levels are only weakly related. There is a much stronger relationship between export levels and soil loss at high export levels.

IV. REDUCTION OF SOIL LOSS TO TOLERANCE LEVELS

The effect of reducing soil loss to tolerance (T) levels under various potential export levels is examined in this chapter. This is accomplished in the model by forcing all rotations which generate greater soil loss than the tolerance levels out of the feasible region. No explicit policy is simulated but the effects of a perfectly effective policy (either through incentive, penalty, or regulation) are described. The policy is perfectly effective from the point of view of limiting soil loss to T levels, rather than in reducing the environmental consequences of soil loss, and therefore suspended sediment, would be greatly reduced. The costs of establishing and enforcing such a policy as well as means of implementation, are not examined.

Throughout the chapter comparisons are made between the solutions described in the last chapter where soil loss is not constrained with solutions where the same export levels are attained but soil loss is restrained to various levels and certain assumptions are used on land conversion possibilities. The effect of the policy is examined therefore over the same range of export levels and scenarios described in Chapter 2. There is a major exception; Export Level VI in the High and Moderate Potential Land Scenario is not feasible when land depletion is eliminated so comparisons are impossible for this extreme. This export level restrains productive capacity near the limits without the land depletion constraint (as evidenced by the crop and land prices in this solution). Also Export Level I in the High Potential Land Only scenario is not analyzed. Productive capacity is near its limits with soil loss constrained to T levels at Export Level IV in this scenario.

The effects of limiting aggregate soil loss are described first, followed by a discussion of the practices selected to reduce soil loss. The effects of soil loss limits on water and wind erosion are then discussed. Finally, the potential economic consequences of the limits are described.

Reductions in soil loss by zones

Table 30 shows the reduction in aggregate soil loss by zone and for the United States brought about by limiting soil erosion to T levels.

Table 30. Reduction in aggregate soil loss as a result of reducing soil loss to T levels on all land classes in all producing areas

Land Potential and Export Level	Zone							
	North Atlantic	South Atlantic	North Central	South Central	Great Plains	North west	South west	United States
	(percent)							
Both High and Moderate Potential Land								
II	51	55	44	41	41	39	39	45
IV	54	55	36	37	51	39	37	44
VI	40	59	37	37	38	34	47	42
High Potential Land Only								
II	55	55	35	32	50	42	27	43
III	39	61	35	32	33	38	34	41
IV	44	64	38	36	47	55	27	46
Reduced Yields								
I	45	63	38	38	34	34	33	42
II	41	64	40	36	46	53	38	46

The changes are very large in all zones, in all scenarios, and for all export levels. In all solutions the largest reductions in soil loss are made in the South Atlantic Zone. Very large reductions in aggregate soil loss in some solutions are also made in the North Atlantic, Great Plains, and Northwest zones.

The principal means by which soil loss is reduced in shown in Tables 31 and 32. Data are presented for Export Level VI, High and Moderate

Table 31. Changes in conservation practices and tillage methods in reducing soil loss to T levels for Export Level VI, Both High and Moderate Potential Land Scenario

Conservation Practice: Tillage Method	Land Class 1	2	3	4	5
	(1000 Acres)				
Row Cropped:					
Residue Removed	-129	182	-61	-292	-29
Residue Left	-1882	-3244	-1009	-2533	-2989
Minimum Till	1926	-2530	-4820	-1659	-680
Contouring:					
Residue Removed	-	-411	-	-	-
Residue Left	-	4823	-	-	-
Minimum Till	-	2015	-	-	-
Strip Cropped:					
Residue Removed	-	-	0	0	-
Residue Left	-	-	-1753	-90	-
Minimum Till	-	-	-16	-271	-
Terracing:					
Residue Removed	-	-	-1	0	-
Residue Left	-	-	1948	2233	-
Minimum Till	-	-	6148	2362	-

Table 32. Proportional changes in tillage methods and conservation practice to achieve no land depletion for Export Level VI, Moderate and High Potential Land Available.

Conservation Practice: Tillage method	Land Class 1	2	3	4	5	All land
	(percent)					
Conservation Practice						
Row cropped	-0.1	-45.5	-17.9	-37.6	-70.4	-17.0
Contour Plowing	-	2.8	-	-	-	2.8
Strip Cropped	-	-	-8.1	-10.7	-	-8.5
Terraced	-	-	15.9	33.0	-	19.5
Tillage Method						
Residue Removed	-7.6	-15.4	-13.7	-95.8	-100.0	-18.3
Residue Left	-10.4	1.9	1.6	-3.1	-84.6	-2.5
Minimum Till	4.4	-0.6	3.5	3.7	-40.9	1.0
All Land	-0.1	0.3	0.5	-0.8	-70.4	-1.0

Potential Land Available for conversion for the entire U.S. but the pattern illustrated for this particular case is similar for all zones and export levels.

To attain Export Level VI, Both High and Moderate Potential Land Scenario, some of the most erosive land was withdrawn from crop production. Cropland use of land class 5 declined by 3.7 million acres, or by 70 percent (Table 31). There also were small decreases in the use of land class 1 (where conversion costs plus minimum till are not cost effective) and land class 4 offset by small increases. Land class 5 is largely removed from the cropland base and shifted to permanent pasture or some other use which does not lead to excessive erosion. Improved management is used to reduce soil loss on the remaining four land classes (Table 32). The most erosive land classes, 3 and 4, use management systems which combine terracing with residue left. Soil loss is lowered to T levels on land class 2 by a shift to contouring while the shift is to minimum till on land class 1.

With the exception of the reduction in the use of land class, 5 all of these changes under the policy intervention are relatively small as compared to the programmed optimal distribution of conservation practices and tillage methods with no policy intervention. However, the total change from current practices is probably substantial. The gains in reduction of aggregate soil loss are very large because of the high proportion of soil loss accounted for by the relatively small proportion of land which exceeds the tolerance levels solution without policy intervention. Nine percent of the land accounted for 49 percent of total soil loss in the latter solution.

Shifts among zones and practices

Of course, shifts in tillage methods and production practices and land use patterns vary among zones and export levels. Larger shifts under policy intervention are necessary in the South Atlantic Zone because of its greater relative soil loss in the absence of policy controls. Land use, for example, declines by as much as six percent in the South Atlantic Zone while the decline in the North Central Zone is always less than one half of one percent as shown in Table 33. Land use for the entire United States declines between one and two percent in all comparisons between the intervention and non-intervention solutions. Hence, it appears that the nation could attain or maintain huge export levels by use of appropriate conservation practices without a large net reduction in cropland use.

Table 33. Land use with soil loss eliminated as a percent of land use with no policy controls by zone and export level

Land Potential and Export Level	Zone							
	North Atlantic	South Atlantic	North Central	outh Central	Great Plains	North west	South west	United States
	(percent)							
Both High and Moderate Potential Land								
II	99	95	100	100	99	97	98	99
IV	99	97	100	99	99	96	98	98
VI	100	100	100	98	99	100	96	99
High Potential Land Only								
II	100	95	100	100	99	94	102	99
III	100	96	100	99	100	98	98	99
IV	98	94	100	98	98	98	103	98
Reduced Yields								
I	100	97	100	99	100	103	98	99
II	98	95	100	98	98	98	98	98

As soil loss is reduced to T-levels, interregional and intraregional shifts in crops take place both (a) to allow the reduced soil loss goal to be attained and (b) to allow the prescribed production and export levels to be attained. Tables 34, 35, and 36 indicate the relative magnitudes of interregional shifts. The comparisons are relative to the optimal land use patterns for the indicated export levels and land potentials when soil losses are not restricted to T levels. (They are not compared to land use patterns as they currently exist in agriculture.) Some of the largest shifts among crops occur in the South Atlantic Region where the erosion hazzard is generally high. As noted previously,

Table 34. Production shifts by crop to maintain production and reduce soil loss to T-levels for the High and Moderate Potential Land Scenario

Crop: Export Level	Zone North Atlantic	South Atlantic	North Central	South Central	Great Plains	North west	South west	United States
	(1000 Acres)							
Feed Grains:								
II	160	548	-1,058	-231	-199	6	159	-621
IV	-111	1,817	-1,132	-1,010	-1,092	-81	173	-1,436
VI	-109	1,722	-1,922	-201	-514	-8	354	-678
Soybeans								
II	-30	-2,025	1,655	1,248	-474	0	0	374
IV	46	-2,602	262	416	1,537	0	0	-341
VI	134	-1,681	794	835	2,204	0	0	2,286
Wheat								
II	-93	-1,008	319	-207	456	-200	-61	-794
IV	-49	-1,213	72	1,469	147	-199	-185	42
VI	0	756	197	250	-1,237	-33	-643	-710
Cotton								
II	0	465	0	-319	0	0	-44	102
IV	0	516	0	-752	0	0	-119	-355
VI	0	-18	0	579	0	0	-136	425

Table 35. Production shifts by crop to maintain production and reduce soil loss to T-levels for the High Potential Land Only Scenario

Crop:	Zone							
	North Atlantic	South Atlantic	North Central	South Central	Great Plains	North west	South west	United States
	(1000 Acres)							
Feed Grains:								
II	-107	1,622	-1,045	-581	-512	-152	271	-504
III	-332	1,672	-1,176	-245	-939	8	256	-762
IV	-428	638	330	-827	-874	223	123	-815
Soybeans								
II	17	-3,728	366	664	1,874	0	0	-807
III	233	-3,684	-276	-148	3,493	0	0	-382
IV	-412	-1,685	1,298	16	16	0	0	-767
Wheat								
II	31	-397	141	1,218	-811	-332	-16	-166
III	0	25	629	7	-1,630	574	-386	841
IV	556	-804	-1,509	1,925	1,005	210	-519	864
Cotton								
II	0	516	0	-862	0	0	160	-186
III	0	215	0	73	0	0	-127	161
IV	0	434	0	-800	0	0	584	218

The North Central Zone tends to maintain the area cropped. It also expands the area planted to soybeans while reducing feed grain acreage marginally. With minor differences, most of the other zones show a pattern similar to the North Central Zone. There is a minor reduction in the acreages of feed grains, soybeans, and wheat at the national level while cotton acreage increases slightly. Interregional changes contribute to the reduction in

Table 36. Production shifts by crop to maintain production and reduce soil loss to T-levels for the Reduced Yield Scenario

Crop: Export Level	Zone North Atlantic	South Atlantic	North Central	South Central	Great Plains	North west	South west	United States
	(1000 Acres)							
Feed Grains:								
I	-40	1,096	-1,387	-191	-274	102	-215	-909
II	-213	773	975	-1,940	-567	170	658	-139
Soybeans								
I	-132	-2,820	-251	170	2,033	0	0	-1,101
II	-727	-3,702	-3,371	492	134	0	0	-433
Wheat								
I	131	281	528	0	-1,139	165	-70	-103
II	654	918	-4,002	1,002	2,101	-361	-422	-111
Cotton								
I	0	122	0	67	0	0	70	259
II	0	-176	0	816	0	0	-209	443

soil loss but the changes in management practices by land class within regions are probably the most important factor in total soil loss reduction.

One effect of reductions in soil erosion could be an acceleration of the rate of the exhastion of other national resources. The use of groundwater increases rapidly with exports, especially where soil loss is restricted to T-levels. In the seven producing areas which largely rely on the Ogallala Aquifer for groundwater for example, groundwater use increases by 38, 32, and 13 percent for Export Levels II, IV and VI in the High and Moderate Potential Land Scenario; by 38, 27, and 6 percent for Export Levels II, III, and IV in the High Potential Land Only Scenario; and by 58 and 12 percent for Export Levels I and II in the Reduced Yields Scenario.

Another possible effect of high exports of is acceleration of wind erosion. Production increases in the Great Plains Zone no limits on soil loss from water and thus entails the possibility of additional wind erosion. But with limits on soil loss from water in the model, total land use is somewhat reduced in both the Great Plains and South Central Zones, regions most exposed to wind erosion. Also, there is a considerable shift towards more minimum till in these zones. Residue left on the soil is one of the most important means in reducing wind erosion. While estimates are not made of soil loss by wind erosion, it appears that elimination of soil loss by water is complementary with reduced wind erosion.

Policies and their costs

An important issue relating to alternative policies to control soil loss is what are the costs of each policy and who will bear the costs. There are a number of different components of policy costs and possible groups who may bear the costs including producers, consumers, and taxpayers both nationally and regionally. The costs of policy implementation and enforcement are necessarily born by the taxpayer. There is a good argument to be made for the taxpayer bearing at least these costs from the point of view that clear waters have public good aspects or at least that the "clear water benefits" of changing land use to effect the benefits are not appropriable by the farm sector. However, analysis of these costs and benefits are outside the scope of this study.

But the solutions of the model do provide some insight into the costs of the policy in terms of the producer versus the consumer and producer versus producer. The impact of the policy on crop prices (Table 37) depends upon the level of exports. At low levels of exports

Table 37. Indices of increase in imputed crop shadow prices by crop resulting from policy reducing soil losses to T-levels (comparison is with base solution)

Land Potential and Export Level	Crop						
	Feed grains	Soybeans	Wheat	Cotton	Hay	Silages	All Crops
			(Indices)[a]				
Both High and Moderate Potential Land:							
II	100	100	102	99	101	99	101
IV	99	99	100	106	100	101	100
VI	103	103	104	102	104	103	103
High Potential Land Only:							
II	99	98	99	104	99	99	99
III	101	101	102	103	102	101	101
IV	135	140	143	122	138	132	137
Reduced Yields:							
I	101	100	101	103	101	101	101
II	113	114	117	109	114	112	114

[a]Laspeyres price indices

and high land potentials, a policy of soil loss at T-levels sould have a negligible effect on crop shadow prices. At high export levels and restricted land conversion possibilities, the rise in crop shadow prices would be considerable. The implication is that where exports are pushed near the productive capacity of the agricultural sector, a policy of maintaining soil loss at T-levels would be fairly costly to the ocnsumer.

A policy which restricted soil T-levels over the nation also would cause some shifts in asset values among farmers. Producers with erosive land would have to bear the brunt of changed practices. While their costs of production increase would increase very little, price increases would not compensate for these increases. Too, under restriction of soil losses to T-levels, farmers with land class 5 generally would have to shift from field crops to hay or pasture. There also are a large number of acres in other categories that would have to shift to less profitable practices and rotations. Hence, the form of policy intervention would be important to allow acceptability among all farm groups.

V. SUMMARY

A set of technological and economic factors have interacted to cause increased soil erosion in the last two decades. The technological factors include the development to chemicals to provide fertility and control crop pests. As a result of these changes, farmers have generally eliminated rotations with a meadow crop and have turned increasingly to enterprise specialization. In the Cornbelt particularly but also over much of the nation, crop production has moved towards a monoculture. In the Cornbelt, specialized crop farms produce mainly corn and soybeans, row crops which are more conducive to soil erosion than rotations grown to provide nitrogen and pest control in earlier decades. The growth in the size of tractors and farm machinery are technological factors also serving as obstacles to soil conservation practices such as terracing, contouring and strip cropping.

A major set of economic factors favoring more intensive farming and the use of some marginal lands revolved around the mammoth growth in exports over the last three decades, especially the last decade. The resulting "fence-row-to-fence-row" farming of this period is estimated to have caused large increases in soil erosion. Large exports and high commodity prices over the period also favored high land prices and a high level of farm indebtedness which also required very intensive row crop farming with more concern for the current cash flow than long-term land productivity. Also, as a result of increased export demand, land set-aside programs operated by the government were ceased and most of this land went back into crop production even though some of it was fragile.

Because of the concern that greatly increased exports were associated with increased soil erosion and stream sedimentation, this study has been made to explore certain relationships between these two phenomena. The study examines the extent to which increased soil erosion is necessary to attain higher levels of exports or whether exports can increase while conservation and land management practices can be used which will partly or entirely prevent soil erosion.

The study is made by means of a national and interregional linear programming model. The results are summarized by six major zones of the United States although the basic analysis is made for 105 producing areas each containing five land classes. The study examines results for seven different levels of exports in year 2000. Results also are analyzed when different amounts of land are converted from pasture and other uses to cropland and when the rate of increase in crop yield is reduced over time. A base solution of the model is made at a moderate level of exports and a standard land base. The results of higher export levels and an extended land base are then compared to each other and the land base. In most of the alternative solutions of the model, the conservation practices and levels of soil loss which are optimal under the economic setting determined endogenously. However, in another set of solutions at various export and land conversion levels, soil loss per acre per year is not allowed to exceed T (tolerance) levels on any of the land classes in any of the 105 producing regions.

The results of the study show that if exports are high, prices are at profitable levels and additional land can be brought into the cropland base, the greater production can be attained under a set of conservation and land management practices which do not give rise to large increases in soil losses. The pattern over the major zones analyzed, however, is not uniform. In the North Atlantic Zone total soil loss could be less at high export levels with conversion of land and use of conservation practices. Of course, this region contributes a relatively small amount to the nation's major exports. In the North Central Zone without a restrictive policy, soil loss would be higher under high export levels if large amounts of land (high and moderate potential conversion) could be converted to crops. However, export levels could be high without a greater total soil loss if a more limited amount of land (high potential only) was converted to crop production. High exports and land conversion woudl generally result in higher total erosion in the South Atlantic, South Central, Great Plains, Northwest, and Southwest Zones.

Irrigated land and groundwater use would increase at all higher levels of exports in the South Central and Great Plains Zones. In general, water mining would occur and the supply of water would be depleted sooner (i.e. irrigation would have to reduce to recharge rates). The higher export levels also would cause greater use of chamical fertilizer and energy in all zones. Energy use would increase in all zones for nitrogen fertilizer and especially for pumping water in some regions.

However, if policies were used which required soil loss to be less than T-levels, greater export levels could be attained with reduced erosion in all major zones, although the highest level of exports could not be attained. Soil loss could be reduced by about 45 percent over the nation as a whole. It could be reduced by around 60 percent in the South Atlantic Zone where erosion is large due to open winters and high rainfall. It would be reduced (due to water erosion) by a smaller amount in the Great Plains and Southwest Zones where rainfall is loss and a greater expanse of level land prevails. The reduction in soil loss would result from less Class 5 land, a large amount of reduced tillage and increased terracing on land classes 3 and 4. The amount of land used for crops would remain unchanged in the North Central Zone under policies restricting soil loss to T-levels (as compared to the same export level in the absence of such policies). Reduction in land used for crops would be greatest in the South Atlantic and Northwest Zones which have the highest current soil loss and the greatest loss in the base solution. The location of crop production would shift considerably if higher export levels were attained while soil loss is restrained to T-levels with both high and moderate potential lands converted to crops. The North Central and South Atlantic Zones would shift out of some corn to soybeans. The South Atlantic Zone would shift out of some cotton while the South Central Zone would add more cotton at higher export levels if only high potential land could be convereted to crops. Crop shadow prices would increase only slightly if soil loss were restrained to T-levels and both high and moderate potential lands could be converted to crops under higher exports. However, under conversion of high potential land to crops or a reduced growth in crops yield rate, crop prices would increase considerably.

VI. LIMITATIONS

This study has several potential limitations which should be mentioned. The inability to deal with soil loss and soil erosion caused by wind is a limitation that has already been mentioned. This does not invalidate results obtained from erosion caused by rainfall and runoff but does indicate that total erosion and land depletion is underestimated and makes it impossible to truly evaluate the tradeoffs that may incur in abating only one form of erosion. Efforts are under way now to incorporate wind erosion into the CARD models for the 1985 assessment so this deficiency will be corrected in future studies.

A second limitation is that a number of factors in the interrelated forces leading to soil erosion are not captured. The model does not capture the effect on farm decision impacting on soil loss involving the financial squeeze caused by high debt loads as exports are capitalized into land values requiring larger current returns. The impact of the trend to larger machine sizes as the size of the family farm increases making such things as terraces, strip cropping, and contour plowing less efficient also is not included. These factors may induce more soil erosion and lead to a greater impact of exports on soil erosion than model results indicate.

There is also a complex of behavioral issues which it is not possible to model. One tillage export, Wes Buchele,[1] has described fall plowing

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[1]Privage Communication, Department of Agricultural Engineering, Iowa State University.

(our residue removed tillage practice) as a "recreational" activity because it does not appear to make economic sense. There may be an aesthetic appeal to cleanly plowed fields or perhaps more importantly, an unwillingness to change established methods when the economic consequences are small (unlike a linear programming model). There also may be a problem if the alternatives to conventional practices are not widely known or appreciated. Perhaps more importantly is a risk element on the decision making process; the farmer may prefer to have as much land preparation as possible done ahead of time in case weather proves to provide less than the average amount of time in spring. None of these behavioral aspects are incorporated into the model, but they may all contribute to more soil loss then is seen in model results.

APPENDIX

Four sources of demands are considered in estimating demands for the endogenous commodities. Total demand for each commodity is a point demand estimated by adding point demands for each source of demand at the national level. These are then distributed to total demand in each market region by various sets of weights. The method for calculating national demands and distributing them to the market regions is described in this Appendix.

The four sources of demand for endogenous commodities are domestic direct consumption, livestock feed and other (industrial uses); and foreign demand or exports. The feed grains (corn, barley, oats, and sorghum), wheat, and soybeans are produced for all four uses but cotton demand is used for domestic direct consumption, industrial uses, and to satisfy foreign demand only. The hays (legume and nonlegume) and silages (corn and sorghum) are used only for livestock feed. Cotton seed is also treated as a substitute for soybeans.

The national demands for direct consumption are estimated by multiplying projected per capita demands by projected population. Per capita demands are presented in Table XI for 2000 and also for 1985 and 1990 for comparison. The Bureau of Census' Series II-B (1979) estimated is used as the projected population. Their estimates are 230,899, 251,427, and 258,132 thousand for 1985, 1990, and 2000 respectively(adjusted for contiguous states). The projection for 2000 is used for all solutions in this report.

Table X1. Per capita demands for the endogenous crops

Commodity	Units	Year 1985	1990	2000
Feed grains:				
Corn	Bu/Capita	1.993	2.084	2.246
Barley	"	0.044	0.046	0.048
Oats	"	1.222	0.228	0.234
Sorghum	"	0.000	0.000	0.000
Wheat	"	2.463	2.527	2.632
Soybeans	"	0.002	0.002	0.002
Cotton	Bales/Capita	0.030	0.030	0.029

Source: ERS, USDA NIRAP projection (Moderate Scenario), personal communication.

Direct consumption demands are then projected to market region according to the proportion of total population in each market region. The assumption is made that per capita demands are invariant regionally. The procedure is equivalent to multiplying market region population by per capita demands. Market region population is estimated by

$$MRPOP_{rt} = STPOP_{it} * CTYPOP_{j1979}/STPOP_{j1979} \quad (Y1)$$

$r = 1, 2, \ldots 28$ for the MRs

$i = 1, 2, \ldots 48$ for the contiguous states

$j = 1, 2, \ldots$ for the counties within state i and market region r,

and

$t = 2000$ for the projection year;

where

MRPOP is the market region population

STPOP is the state population, and

CTYPOP is the county population

Projected state populations are taken from the Bureau of the Census (1979) Series II-b projections and all 1979 populations are taken from preliminary data from the 1979 census. The market region population estimated are shown in Table X2 with projections for 1985 and 1990 also given for comparison.

Industrial demands at the national level are shown in Table X3. These are distributed to market regions with weights by commodity derived from previous CARD studies. The weights used for 2000 are given in Table X4. Livestock demands are taken from previous CARD studies by market region and documented by English [1981].

Export demands for each level of export were reported previously. Exports are distributed to market region by a set of port weights by commodity. The port weights, shown in Table X5, are the average proportion of total exports routed through all export points in each market region over the period 1975-79 as reported by USDA, Consumer and Marketing Service (1976, 1977, 1978, 1979, 1980).

Table X2. Projected population by market region

Market Region	Year 1985	1990	2000
	------------	(thousands)	------------
1. Boston	13,195	13,626	14,575
2. New York	32,543	33,003	33,508
3. Baltimore	10,138	10,725	11,731
4. Charleston	9,242	9,850	10,880
5. Atlanta	10,918	11,668	12,937
6. Miami	10,059	11,213	13,207
7. Pittsburgh	17,774	18,062	18,346
8. Detroit	11,532	11,826	12,178
9. Cincinnati	8,504	8,812	9,284
10. Memphis	3,789	3,967	4,257
11. New Orleans	8,351	8,694	9,213
12. Chicago	10,981	11,266	11,656
13. St. Louis	5,061	5,178	5,339
14. Minneapolis	6,548	6,796	7,153
15. Des Moines	4,102	4,215	4,373
16. Billings	1,196	1,255	1,349
17. Kansas City	5,531	5,709	5,982
18. Oklahoma City	5,382	5,645	6,081
19. Houston	8,423	9,028	10,060
20. San Antonio	4,640	4,986	5,579
21. Denver	2,852	3,106	3,533
22. Amarillo	1,179	1,267	1,415
23. El Paso	1,637	1,761	1,968
24. Seattle	7,583	7,991	8,657
25. Salt Lake City	2,121	2,302	2,605
26. Phoenix	3,569	3,961	4,614
27. San Francisco	9,574	10,124	11,022
28. Los Angeles	14,474	15,293	16,631

Table X3. Industrial demands for the endogenous crops

Commodity	Units	Year 1985	1990	2000
		---------(millions)---------		
Feed grains:				
Corn	Bushels	281.1	315.1	377.3
Barley	"	231.2	260.1	319.2
Oats	"	54.3	61.0	74.6
Sofghum	"	14.5	16.3	19.0
Wheat	"	90.2	98.4	114.8
Soybeans	"	551.0	735.7	1111.7
Cotton	Bales	6.9	7.2	7.6

Table X4. Weights for distributing industrial demands by commodity to the market regions

Market Region	Corn	Barley	Oats	Sorghum	Wheat	Soybeans
	Crop					
1. Boston	.0	.0	.0040	.0	.0	.0
2. New York	.0226	.0189	.0477	.0	.0045	.0051
3. Baltimore	.0198	.0265	.0500	.0004	.0044	.0190
4. Charleston	.0279	.0127	.0123	.0064	.0049	.0595
5. Atlanta	.0270	.0027	.0074	.0031	.0037	.0390
6. Miami	.0067	.0	.0003	.0004	.0001	.0009
7. Pittsburgh	.0396	.0044	.0376	.0	.0094	.0325
8. Detroit	.0603	.0020	.0397	.0001	.0218	.0565
9. Cincinnati	.1197	.0072	.0105	.0041	.0288	.0987
10. Memphis	.0117	.0009	.0038	.0125	.0134	.1296
11. New Orleans	.0051	.0001	.0043	.0058	.0056	.0966
12. Chicago	.0221	.0014	.0397	.0001	.0020	.0110
13. St. Louis	.1251	.0010	.0116	.0067	.0225	.1173
14. Minneapolis	.1274	.3144	.4369	.0142	.1590	.0913
15. Des Moines	.1837	.0007	.1119	.0016	.0008	.1192
16. Billings	.0041	.2284	.1099	.0176	.1750	.0002
17. Kansas City	.1553	.0055	.0387	.1927	.1283	.0951
18. Oklahoma City	.0136	.0354	.0120	.1898	.2044	.0246
19. Houston	.0015	.0009	.0110	.0367	.0026	.0028
20. San Antonio	.0073	.0025	.0314	.2272	.0081	.0
21. Denver	.0093	.0423	.0070	.0102	.0380	.0001
22. Amarillo	.0017	.0018	.0004	.2389	.0339	.0011
23. El Paso	.0001	.0014	.0	.0038	.0005	.0
24. Seattle	.0020	.1432	.0	.0	.0987	.0
25. Salt Lake City	.0009	.0258	.0018	.0001	.0095	.0
26. Phoenix	.0002	.0136	.0	.0105	.0040	.0
27. San Francisco	.0052	.0892	.0071	.0143	.0111	.0
28. Los Angeles	.0002	.0172	.0014	.0029	.0052	.0

Table X5. Weights for distributing export demand by commodity to the market regions

Market Region	Corn	Barley	Oats	Sorghum	Wheat	Soybeans
	Crop					
1. Boston	.0	.0	.0	.0	.0	.0
2. New York	.0546	.0004	.0202	.0	.0172	.0149
3. Baltimore	.0	.0	.0	.0	.0	.0
4. Charleston	.1533	.0251	.0488	.0	.0399	.0599
5. Atlanta	.0191	.0	.0021	.0	.0323	.3280
6. Miami	.0	.0	.0	.0	.0	.0
7. Pittsburgh	.0378	.0	.0203	.0	.0047	.0539
8. Detroit	.0031	.0	.0	.0	.0011	.0026
9. Cincinnati	.0	.0	.0	.0	.0	.0
10. Memphis	.0	.0	.0	.0	.0	.0
11. New Orleans	.6006	.0398	.1199	.0299	.1116	.4438
12. Chicago	.0497	.0014	.0009	.0	.0020	.0271
13. St. Louis	.0	.0	.0	.0	.0	.0
14. Minneapolis	.0245	.5129	.7596	.0	.0779	.0018
15. Des Moines	.0	.0	.0	.0	.0	.0
16. Billings	.0	.0	.0	.0	.0	.0
17. Kansas City	.0	.0	.0	.0	.0	.0
18. Oklahoma City	.0	.0	.0	.0	.0	.0
19. Houston	.0536	.0061	.0	.4385	.3699	.0497
20. San Antonio	.0009	.0	.0	.5024	.0375	.0166
21. Denver	.0	.0	.0	.0	.0	.0
22. Amarillo	.0	.0	.0	.0	.0	.0
23. El Paso	.0	.0	.0	.0	.0	.0
24. Seattle	.0003	.4141	.0229	.0002	.2791	.0001
25. Salt Lake City	.0	.0	.0	.0	.0	.0
26. Phoenix	.0	.0	.0	.0	.0	.0
27. San Francisco	.0026	.0	.0052	.0	.0269	.0
28. Los Angeles	.0	.0	.0	.0290	.0	.0016

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