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# The Role of Irrigated Agriculture in a Changing Export Market

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## ABSTRACT

Irrigated acreage in the United States would increase by 5.5 million acres if export demand for agricultural products increased by 90 percent, according to analytical research projections reported here. Ground water use would increase by 42 percent. This analysis of the effect of increased export demand for agriculture commodities on irrigated agriculture also projects substantial increases in ground water pumping costs for the Mountain and Northern Plains regions.

## AUTHORS

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## INTRODUCTION

Export demand for agricultural commodities can change substantially depending on world weather conditions, prices, incomes, exchange rates, and the political environment. Domestic production of principal export commodities is affected by the weather conditions, government commodity programs, off-farm input prices, and the amount and quality of labor and natural resources available. Knowing the effect of changes in the demand for export commodities on resource use can assist the Federal Government in short- and long-run resource planning.

This paper examines the current role of irrigation in the production of principal U.S. agricultural commodities and projects how dryland and irrigated cropping patterns could change under alternative export demand scenarios.

A spatial equilibrium mathematical programming model was used in this study which assumes perfectly competitive product and factor markets. The U.S. Mathematical Programming (USMP) model was acquired from the National Economics Division of the Economic Research Service, USDA.[1] The original model was initiated at Purdue University as a computerized model of the U.S. agricultural sector. [2] In the model, national crop and livestock commodity production was specified for 10 regions and commodity use was specified for national domestic, stock, and export market demands. Agricultural labor, crop, and pasture land were specified as price elastic factor supply activities.

The model was modified by including irrigated cropping activities and water supply functions, and by replacing the risk specification with a quadratic cost term that accounts for all unspecified production costs and returns. This modification allows the model to reproduce a base cropping pattern without the use of constraints placed on acreages. The price sensitive labor supply activity was respecified with average regional wage rates.

The original specification of the USMP did not separate dryland and irrigated crop production, or specify water as an explicit resource input. By including both production technologies and the supply of irrigation water as nonlinear regional activities in the national model, better estimates of irrigated agriculture production response and resource use can be made.

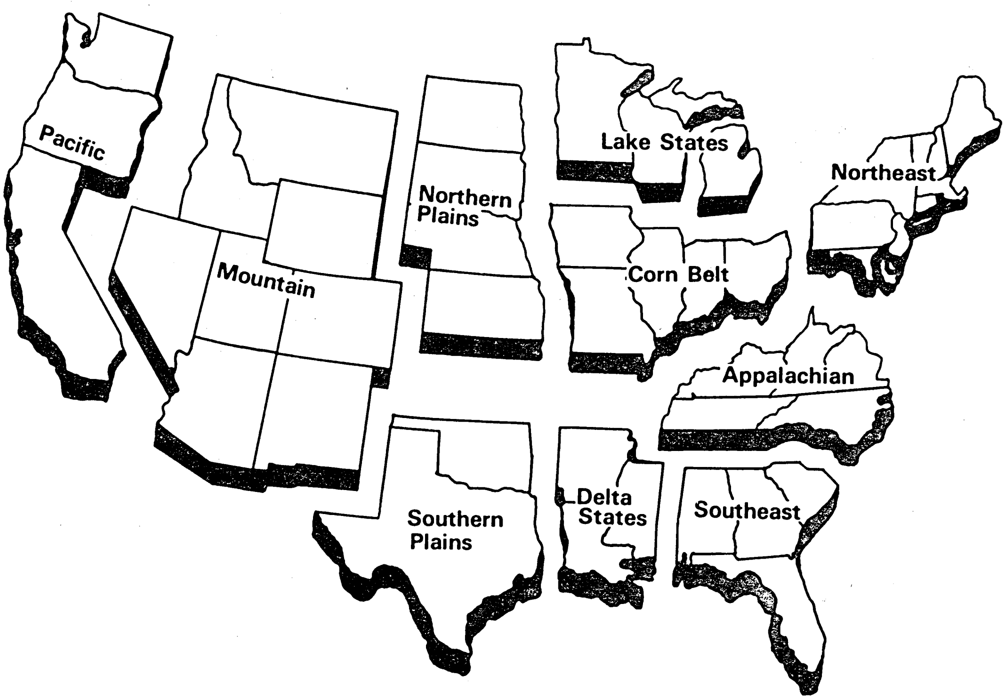
## THE USMP MODEL SPECIFICATION

The USMP optimizes the net social payoff of national agricultural production. This is equal to the area under the demand functions less the area under the supply functions which is commonly defined in the economic literature as consumers' plus producers' surplus. The problem was specified as a quadratic programming model and solved using Minos.[3]

Three final demands were specified at the national level: domestic, export, and stocks. Commodity supply sources specified at the national level were imports, beginning commercial inventories, and government stock release. Crop and livestock production, labor, and land resource supply functions were specified for the 10 USDA crop production regions (fig. 1).

Figure 1.

**Farm Production Regions**




Source: U.S. Department of Agriculture

## Primary and Secondary Commodity Activities

The USMP contained 36 of the major agricultural commodities produced in the United States. These commodities were divided into two categories: primary and secondary products. Primary commodities were defined as those produced on the farm and include the following:

| Crops | Livestock |
|---|---|
| cotton | fed beef for slaughter |
| corn | nonfed beef for slaughter |
| soybeans | beef calves for slaughter |
| wheat | beef feeder yearlings |
| sorghum | beef feeder calves |
| rice | cull beef cows |
| barley | cull dairy cows |
| oats | cull dairy calves |
| silage | milk |
| hay | hogs for slaughter |
| | cull sows for slaughter |
| | feeder pigs |
| | poultry |
| | other livestock |

There were 143 primary commodity production activities specified at the regional level. Elasticities of demand for the crops included in the model are the same elasticities used in the USMP. These elasticities were estimated by the Food and Agricultural Policy Branch, National Economics Division, Economic Research Service, USDA. The elasticities by commodity are as follows

| | Elasticities of demand | | |
|---|---|---|---|
| Crop | Domestic | Stocks | Exports |
| Cotton | -0.22 | -1.96 | -0.18 |
| Corn | -.23 | -3.25 | -.33 |
| Soybeans(oil) | -.14 | -2.01 | -.80 |
| Wheat | -.07 | -.90 | -.35 |
| Sorghum | -.01 | -1.52 | -.82 |
| Barley | -.30 | -.70 | (1) |
| Oats | -.11 | -1.30 | (1) |
| Rice | -.09 | -.63 | -.46 |

(1)Not exported.

Secondary commodity production activities represent the processing of primary commodities into intermediate products or products that have an observable final demand. The following secondary commodity production activities were specified at the national level.

| Crops | Livestock |
|---|---|
| soybean meal | fed beef |
| soybean oil | nonfed beef |
| livestock feed grain | veal |
| dairy protein supplement | pork |
| low protein swine feed | |
| high protein swine feed | |
| low protein cattle feed | |
| high protein cattle feed | |

## Factor Input Activities

The USMP model regionally specified the supply of land, labor, and miscellaneous factor inputs. Cropland and pasture land were specified with price-responsive supply functions. The supply elasticities of land used in this study were estimated to be 0.3 for cropland and 0.6 for pasture. These estimates were done in the original formulation of the model at Purdue University and no attempt was made to estimate regional elasticities.

Family labor was specified with perfectly elastic supply functions and constrained to 1978 levels. Hired labor was specified with price-responsive supply functions. Miscellaneous factor inputs were supplied in perfectly elastic national markets at fixed national prices without constraints.

## Model Modifications

The USMP was modified to include regional irrigated crop production activities, ground and surface water supply functions, and a subroutine to eliminate the need for regional production constraints.

### Irrigated Production Activities

With the exception of rice and cotton, most principal U.S. agricultural crops are not irrigated (table 1). The 31 million irrigated acres represent about 11 percent of the total acreage of those crops. However increased production of export commodities in response to a change in demand can come from irrigated areas. Increases in export demand relative to other irrigated crops would shift resource use from nonexport to export crops. The extent of the changes in cropping patterns would depend on the value of growing the export crops relative to other crops, and the flexibility of farmers to irrigate both export and other crops.

The original USMP model specified one crop production activity for each crop in a region. This specification incorporates both nonirrigated and irrigated cropping technologies into a single activity. By forming an additional activity to represent the irrigated technology, a more accurate commodity supply response to changes in commodity demand scenarios can be projected. Most of the U.S. irrigated crop production takes place in the four Western regions, the Mississippi River Delta, and Florida (table 1). About 50 percent of the principal crop acreage in the Pacific region and 42 percent of the Mountain region is irrigated. In 1978, most of the irrigated cotton was grown in the Southern Plains, Arizona (Mountain region), and California (Pacific region).

Table 1--Dryland and irrigated crop acreage by USDA crop reporting regions, USMP base solution, 1978

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Million acres | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 0.183 | | 0.275 | 0.547 | 2.344 | 4.701 | | | 8.050 |
| Irrigated | | | | | | | .128 | 2.343 | 0.694 | 1.521 | 4.686 |
| Total | | | .183 | | .275 | .547 | 2.472 | 7.044 | .694 | 1.521 | 12.736 |
| Corn: | | | | | | | | | | | |
| Dryland | 2.674 | 11.184 | 35.740 | 5.559 | 4.205 | 2.644 | | .414 | .040 | .007 | 62.466 |
| Irrigated | | | | 5.640 | | .234 | | .932 | .911 | .365 | 8.082 |
| Total | 2.674 | 11.184 | 35.740 | 11.199 | 4.205 | 2.878 | | 1.346 | .951 | .372 | 70.548 |
| Soybeans: | | | | | | | | | | | |
| Dryland | .926 | 4.864 | 21.596 | 3.043 | 3.495 | 4.944 | 10.697 | .916 | | | 50.481 |
| Irrigated | | | | .220 | | .078 | .591 | .187 | | | 1.076 |
| Total | .926 | 4.864 | 21.596 | 3.263 | 3.495 | 5.022 | 11.288 | 1.103 | | | 51.557 |
| Wheat: | | | | | | | | | | | |
| Dryland | .372 | 2.908 | 3.249 | 24.234 | .581 | .228 | .312 | 7.642 | 8.546 | 4.086 | 52.160 |
| Irrigated | | | | .531 | | | | .149 | 1.111 | .511 | 2.302 |
| Total | .372 | 2.908 | 3.249 | 24.765 | .581 | .228 | .312 | 7.791 | 9.657 | 4.597 | 54.462 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | .923 | 5.198 | | | .206 | 3.983 | .110 | .004 | 10.424 |
| Irrigated | | | | .647 | | | | 1.050 | .219 | .104 | 2.020 |
| Total | | | .923 | 5.845 | | | .206 | 5.033 | .329 | .108 | 12.444 |
| Barley: | | | | | | | | | | | |
| Dryland | .208 | 1.009 | | 3.063 | | | | | 1.597 | .827 | 6.704 |
| Irrigated | | | | | | | | | 1.286 | .641 | 1.927 |
| Total | .208 | 1.009 | | 3.063 | | | | | 2.883 | 1.468 | 8.631 |
| Oats: | | | | | | | | | | | |
| Dryland | .788 | 3.839 | 2.993 | 4.638 | | | | | | | 12.258 |
| Irrigated | | | | | | | | | | | 0 |
| Total | .788 | 3.839 | 2.993 | 4.638 | | | | | | | 12.258 |
| Hay: | | | | | | | | | | | |
| Dryland | 4.434 | 6.949 | 6.676 | 8.704 | 3.332 | 1.128 | 1.397 | 3.333 | 1.771 | .818 | 38.542 |
| Irrigated | | | | .556 | | .023 | | .267 | 4.164 | 1.674 | 6.684 |
| Total | 4.434 | 6.949 | 6.676 | 9.260 | 3.332 | 1.151 | 1.397 | 3.600 | 5.935 | 2.492 | 45.226 |
| Silage: | | | | | | | | | | | |
| Dryland | 1.305 | 1.732 | 1.236 | 1.000 | .614 | .189 | .068 | .031 | .023 | | 6.198 |
| Irrigated | | | | .324 | | .015 | .003 | .097 | .485 | .204 | 1.128 |
| Total | 1.305 | 1.732 | 1.236 | 1.324 | .614 | .204 | .071 | .128 | .508 | .204 | 7.326 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | .025 | | | | 1.895 | .598 | | .485 | 3.003 |
| Total: | | | | | | | | | | | |
| Dryland | 10.707 | 32.485 | 72.596 | 55.439 | 12.502 | 9.680 | 15.024 | 21.020 | 12.087 | 5.742 | 247.282 |
| Irrigated | 0 | 0 | .025 | 7.918 | 0 | .350 | 2.617 | 5.623 | 8.870 | 5.505 | 30.908 |
| Cropland | 10.707 | 32.485 | 72.621 | 63.357 | 12.502 | 10.030 | 17.641 | 26.643 | 20.957 | 11.247 | 278.190 |

Sources: U.S. Dept. Agr., Agricultural Statistics, 1981, and U.S. Dept. Commerce, Bureau of the Census, 1978 Census of Agriculture, "Irrigation," Vol. 4, Feb. 1982.

Rice production was limited to Texas (Southern Plains), California (Pacific), and the Delta States. There is substantial acreage of dryland wheat and barley acreage in the Mountain and Pacific regions. These crops are usually grown as winter crops in the West where most of the rainfall occurs during the winter and, in some areas, no irrigation water is applied.

## Surface Water Supply Functions

The USMP, as modified, requires the specification of a surface water supply function. Such a function must contain the amount of water that can be used on export crops and the price changes that will occur if the amount of water use changes.

About 54 percent of the total water used for irrigation in the United States is diverted from surface watercourses.[4] The remainder is pumped from ground water aquifers. Where surface water occurs in the arid West, agricultural development has, for the most part, thrived because of low capital investment requirements of the farmer and stable irrigation costs.

The pattern of water allocation in the West is based on court-determined arbitrary rights originating from the Riparian Doctrine and the Doctrine of Prior Appropriation. This means that a low probability of reallocating water from low-value agricultural uses to higher value agricultural and non-agricultural uses exists. Also, physical water requirements that are determined under the assumption of a lower than market determined water price will exceed existing supplies.

The U.S. Constitution delegated to the Congress the paramount authority to control the use of the Nation's navigable surface waters. Most Western States have declared that natural streamflow is the property of the public and therefore the property of the State in trust for the people. However this is subject to the authority of the U.S. Congress. As a result of rigid surface water allocation in the West, the surface water supply functions were specified in the USMP with a perfectly elastic price for each region. Quantities of surface water available for use were constrained by the amount of surface water applied in 1978 to the crops that were included in the model. The amount of surface water applied to crops included in this analysis and their average costs by region in 1978 were:

| Region | Surface water use | Average cost |
|---|---|---|
| | Million acre-feet | $/AF |
| Northern Plains | 1.738 | 4.78 |
| Southeast | .113 | 4.45 |
| Delta States | 1.309 | 4.37 |
| Southern Plains | 2.217 | 8.18 |
| Mountain | 14.462 | 4.27 |
| Pacific | 13.126 | 9.46 |

## Ground Water Supply Functions

Ground water has also played an important role in the irrigation of the West. With the development of the high-volume turbine pump, water could be economically pumped from depths up to 700 feet for irrigating agricultural crops. Vast amounts of ground water are available in some areas of the United States that could be developed for irrigation. The following citation from a recent U.S. Geological Survey report supports the possibility of using greater amounts of ground water.

> "The pumpage of fresh ground water in the United States in 1980 is estimated as approximately 88 billion gallons per day, which is on the order of 10 percent of the estimated natural flow through the Nation's ground water systems. From the national perspective, therefore, the resource is not overdeveloped; locally, however, the situation can vary widely, and a number of problems exist." -U.S. Geological Survey, Water-Supply Paper 2250, page 37.

Ground water aquifers, geological formations that have accumulated water over millions of years, are usually recharged naturally as water is removed. However the rate of pumping is sometimes greater than the rate of recharge and a temporary overdraft exists in several areas.

Ground water comprises about 46 percent of the total water used for irrigation in the Nation.[5] In 1978, about 29 million acres were irrigated with ground water. Overdrafting occurs in 11 of the major irrigated States and it directly affects agricultural production on 15 million acres.[6] Overdrafting is a rational procedure on the part of society if the financial returns from pumping are greater than the current costs of pumping plus the present value of future changes in pumping costs and environmental costs (user costs).[7] For example, benefits from pumping do exceed the pumping cost plus user costs for some aquifers in the San Joaquin Valley of California.[8] But, in other areas, the benefits from pumping are less than the pumping cost plus user costs. But overdrafting still occurs, however, as long as the user costs are not borne directly by the pumper. This is the case because ground water is a common property resource without exclusive rights being assigned to any one individual. Therefore future pumping and environmental costs are distributed among all of the users.

Some States have attempted to internalize user costs to the pumper by limiting the number or spacing of wells. For example, these policies slow the rate of extraction and bring private benefits and costs closer to presumed social benefits and costs. In areas of the country that have large ground water aquifers, overdraft could become a substantial but temporary source of irrigation water given stable energy costs and rising commodity prices.[9]

To accommodate the cost structure of ground water pumping in the USMP, we specified ground water supplies as price-responsive activities for each production region. The responsiveness of quantity supplied to changes in an output price sufficient to induce that level of output is referred to as the elasticity of supply of the product. Elasticity figures reflect the relative ease with which resources can be drawn into the production process. Supply is said to be inelastic (less than 1.0) if additional quantities are produced only at much higher costs (quantity is relatively unresponsive to output price). Conversely, supply is elastic (greater than 1.0) if more output produced is associated with very small cost increases (quantity is relatively responsive to output price). Time is a crucial element of supply elasticity: resources are much more mobile in the long run than in the short run and therefore supply functions become more elastic over a longer time period.

The concept of supply elasticity as relates to water for irrigated agriculture applies in cases for which water production costs per unit rise. The most common example of increasing unit costs is that of water pumped from an overdrafted aquifer. Annual drawdown represents the magnitude of the decline in the water table for a given amount of overdraft (amount by which water withdrawals exceed recharge). Irrigators use pumps and irrigation equipment (fixed factors) and labor and energy (variable factors) to produce water for their own use in a vertically structured production process. Irrigators can be viewed as a suppliers of water because, in the absence of institutional barriers, irrigators would be able to sell the water to users who would be willing and able to pay the most for it.

Each additional acre-foot of water pumped from the aquifer results in cost increasing conditions brought about by the drawdown: water must be pumped a greater distance and well yields are decreased. In this analysis, energy prices, labor wages, and fixed costs are assumed constant so that water cost increases are associated with movements upward and along rather than leftward shifts in the water supply curve. Thus, for a given drawdown, input costs, and quantity of overdraft, an elasticity of ground water supply can be estimated. The following ground water supply cost and elasticities were developed from State-level information gathered by U.S. Geological Survey,[10] Farm and Ranch Irrigation Survey[11] and expert opinion.[12]

| Region | Ground water use | Average cost | Supply elasticity |
|---|---|---|---|
| | Million acre-feet | $/AF | |
| Northern Plains | 8.077 | 12.77 | 0.6 |
| Southeast | .423 | 14.39 | 1.5 |
| Delta States | 3.747 | 11.04 | 1.5 |
| Southern Plains | 5.624 | 18.74 | .4 |
| Mountain | 2.735 | 16.54 | .8 |
| Pacific | 2.192 | 18.99 | .85 |

## Positive Quadratic Programming

Duplicating actual regional cropping patterns with an unconstrained regional programming model is difficult to accomplish. The cause of this difficulty arises from the inability to estimate all costs and benefits from growing a particular crop. Economists have employed techniques to make regional programming models generate results closer to observed acreages. Day[13] and McCarl[14] have suggested procedures to estimate the magnitude of upper and lower bounds on regional crop acreages. One major deficiency of these approaches is the lack of data needed to implement these techniques in a national model.

Howitt and Mean[15] proposed an alternative to estimating the amount of "flexibility" in upper and lower bounds:

> "This paper proposes a method to amend normative linear microeconomic models by a positive measure of the nonlinear part of

the cost function based on the actual action of the farmers. Using this positive approach the linear model can be exactly calibrated to observed outputs for a single year or calibrated with a least-squares criterion if actual crop acreages for several years are known. The resulting optimization problem incorporates a quadratic cost term for each regional crop grown and is constrained only by those fixed input constraints that can be empirically justified. The problem is solved as a quadratic programming problem, and being only moderately constrained, the model reaction to policy changes is a smooth trade-off based on changed comparative advantage."

The Positive Quadratic Programming (PQP) technique was originally applied to only nonmarginal crops (underspecialized crops)[16] in a model[17] and existing regional resource constraints limited the acreage of the marginal crops. The implementation of PQP in the USMP was different in that both underspecialized and overspecialized cropping activities were specified to base-year levels and regional resources were specified as cost-responsive supply functions.

One assumption underlying the USMP is that firms act as profit maximizers within perfectly competitive markets. Economic theory indicates that firms will succeed if they can equate their marginal cost of production with the price they receive for their output. This relationship can be expressed as:

$$P = MC \qquad (1)$$

where P is the unit price of the output and MC is the marginal cost of production.

The production processes within the USMP model are described as Leontief production functions exhibiting constant returns to scale. That is, each unit of output requires fixed levels of inputs. Given these assumptions, the total cost of production for a specific region and crop can be expressed as a linear function of the form:

$$TC = cQ + C \qquad (2)$$

where TC is the total cost of production, c is the variable cost per unit produced, Q is units of output, and C is the fixed cost of production.

The marginal cost of production is determined by differentiating the total cost function with respect to the quantity produced which in this case is:

$$MC = c \qquad (3)$$

The price that producers receive for the commodities they produce is determined by a demand function for each commodity. The USMP assumes, for simplicity, that the industry faces a linear demand function of the following form:

$$P = a + bQ \qquad (4)$$

where a is an intercept term and b is a slope coefficient.

The equilibrium condition for the production of each crop is determined by substituting equations (3) and (4) into (1) to obtain:

$$a + bQ = c \qquad (5)$$

Rewriting the equation yields:

$$a + bQ - c = 0 \qquad (6)$$

If the USMP is constrained to base period crop production levels, the constraints will be binding and take on a positive or negative dual value. A dual value indicates that the marginal costs of production estimated were not equal to the actual marginal costs of production that existed in the base year. Thus, the existence of dual values on these constraints indicates a violation of the basic assumption described by equation (6).

A positive dual value in the constrained run indicates that overspecialization of that crop occurred[18] and some of the costs associated with producing the crop were not measured. These unmeasured costs could be actual out-of-pocket costs such as transportation and insurance costs or costs not explicitly accounted for within the firm, such as risk.

A negative dual value in the constrained run indicates an underspecialization and that production costs were overestimated. Resource costs that could be overestimated are land rents and management costs. Positive externalities, such as the value of a crop in a rotational scheme, could also be present and would cause a negative dual value on a crop constraint.

The actual cost producers face can be defined as:

$$MCA = c + f(Q^*) \qquad (7)$$

where $f(Q^*)$ is the negative of the dual value of a base-year level constraint on the respective crop activity. The value of $f(Q^*)$ also represents the unmeasured or overestimated marginal cost of producing that crop in the original normative USMP model.

Assuming that the unknown marginal cost function $f(Q)$ takes a linear form, then:

$$f(Q) = e + gQ \qquad (8)$$

where e is an intercept term. When $Q^*$ is equal to the base-year crop acreage levels, and

$$e + gQ^* = - RDG \qquad (9)$$

with RDG representing the reduced gradient or dual value of the the base-year constraint on the crop-activity level in the quadratic programming model.

The g coefficients of the unknown marginal costs are always negative. Costs increase with quantity produced. Therefore, for crop production activities that are overspecialized (positive dual value on acreage constraint), the unknown marginal cost function would be calculated as:

$$e = 0, \text{ and} \quad (10)$$

$$g = - (RDG/Q^*) \quad (11)$$

Unknown marginal cost functions for underspecialized crop activities (negative dual values in the constrained run) will take the following form:

$$e = -2(RDG), \text{ and} \quad (12)$$

$$g = RDG/Q^* \quad (13)$$

Forming the total cost function yields the objective function for all crop activities

$$TC = (c + e + gQ)Q \quad (14)$$

that is quadratic in form and can be solved using the Minos optimization program.

The inclusion of the PQP technique in the USMP model will allow the model to duplicate base-year acreage levels without constraining the acreage levels. When policy changes or demand scenarios are introduced into the model, changes in the regional cropping pattern are determined entirely by the economic condition for general equilibrium which is that price equals marginal cost.

## ALTERNATIVE EXPORT DEMAND LEVEL SIMULATIONS

The objective of this analysis was to determine the supply response of irrigated and dryland agriculture to changing export demand levels for agricultural commodities. This analysis was based on simulations made with the modified USMP.

Crops included in this study and their 1978 production and quantity exported are listed in table 2. Large proportions of the 1978 cotton, soybeans, wheat and

Table 2--Production and exports of major U.S. agricultural commodities, 1978

| Crop | Production | Exported | Percentage exported |
|---|---|---|---|
| | | | Pct. |
| Cotton (1,000 bales) | 10,478 | 5,850 | 56 |
| Corn (million bu.) | 7,268 | 2,133 | 29 |
| Soybeans (million bu.) | 1,869 | 753 | 40 |
| Wheat (million bu.) | 1,776 | 1,194 | 67 |
| Sorghum (million bu.) | 731 | 207 | 28 |
| Barley (million bu.) | 455 | 26 | 6 |
| Oats (million bu.) | 582 | 13 | 2 |
| Hay (million tons) | 144 | 0 | 0 |
| Silage (million tons) | 118 | 0 | 0 |
| Rice (million cwt) | 133 | 76 | 57 |

Source: U.S. Dept. of Ag., Agricultural Statistics, 1981.

rice crops were exported. Barley, oats, hay and silage were grown mainly for domestic consumption.

The alternative export demand levels selected for analysis were a reduction of 30 percent, and increases of 30, 60, and 90 percent. The range of export levels were chosen to cover possible declines and increases that may be possible in the 1980's.[19] It is assumed that these changes represent shifts in the export demand functions rather than changes in 1978 export demand elasticities.

The effects of changes in export demand levels were examined with respect to commodity production and price changes, regional cropping shifts, regional water use changes, and dryland and irrigated acreage changes.

## Commodity Production and Prices

As one would expect, production of principal export commodities varied directly with changes in the export demand level (table 3). Variations in production levels as a result of a constant export demand level changes depended on the proportion of the crop that went into the export market, the elasticities of demand in the domestic and export markets, technical coefficients, stock of carryover, and the amount of and competition for land and water resources.

A decrease of 30 percent in export demand did not cause a serious decline in corn production (-7 percent) while sorghum, barley, oats, hay, and silage production increased due to increased use as livestock feed. Cotton, soybeans, wheat, and rice production declined significantly under this scenario.

Rice, cotton, and wheat production increased substantially more than corn or sorghum production under a 60- or 90-percent increase in export demand. Over half of the total U.S. production of wheat, rice, and cotton was exported in 1978. Therefore with a 90-percent increase in export demand, a large increase in production could be expected. Feed grains produced for domestic consumption decreased as land and water resources would be bid away by export crops.

## Regional Cropping Shifts

A 90-percent increase in export demand caused U.S. cotton production to increase by 37 percent. Most of this increase was projected to occur in the Mountain States (1.9 million bales) and the Delta States (1.78 million bales) (table 4). A relatively small increase (120,000 bales) in cotton production was expected in California because water costs increased with additional water use as production expanded. This caused the region to lose its cost advantage over other regions growing dryland cotton. Cotton in the Pacific region was also grown in direct competition with rice production.

U.S. corn production increased by 18 percent under the 90-percent demand increase scenario. A substantial amount of that increase was projected for the Corn Belt (572 million bushels) and the Northern Plains (260 million bushels). A 61-percent increase was projected in corn production for Appalachia; slight decreases were projected in the Mountain and Pacific regions. Irrigated corn production was expected to decline in this type of scenario because of corn's high water requirement relative to other export crops.

Table 3--Effects of alternative demand levels on commodity production and prices

| Crop and scenario | Price | Percentage change | Production | Percentage change |
|---|---|---|---|---|
| | Per unit | Pct. | Unit | Pct. |
| Cotton: | | | | |
| 1978 base | 280.23 | | 10.7 | |
| Minus 30 percent | 267.33 | -5 | 9.3 | -13 |
| Plus 30 percent | 294.00 | 5 | 12.1 | 13 |
| Plus 60 percent | 307.32 | 10 | 13.4 | 25 |
| Plus 90 percent | 319.83 | 14 | 14.7 | 37 |
| Corn: | | | | |
| 1978 base | 2.22 | | 6848.2 | |
| Minus 30 percent | 2.10 | -5 | 6363.8 | -7 |
| Plus 30 percent | 2.35 | 6 | 7321.0 | 7 |
| Plus 60 percent | 2.48 | 12 | 7691.8 | 12 |
| Plus 90 percent | 2.59 | 17 | 8062.4 | 18 |
| Soybeans: | | | | |
| 1978 base | 6.74 | | 1732.8 | |
| Minus 30 percent | 6.04 | -10 | 1492.4 | -14 |
| Plus 30 percent | 7.41 | 10 | 1939.9 | 12 |
| Plus 60 percent | 7.99 | 19 | 2109.5 | 22 |
| Plus 90 percent | 8.52 | 26 | 2256.2 | 30 |
| Wheat: | | | | |
| 1978 base | 3.03 | | 1613.2 | |
| Minus 30 percent | 2.75 | -9 | 1398.9 | -13 |
| Plus 30 percent | 3.31 | 9 | 1793.0 | 11 |
| Plus 60 percent | 3.62 | 19 | 1992.3 | 23 |
| Plus 90 percent | 3.90 | 29 | 2172.9 | 35 |
| Sorghum: | | | | |
| 1978 base | 2.00 | | 656.7 | |
| Minus 30 percent | 1.88 | -6 | 803.9 | 22 |
| Plus 30 percent | 2.15 | 8 | 710.4 | 8 |
| Plus 60 percent | 2.30 | 15 | 730.5 | 11 |
| Plus 90 percent | 2.44 | 22 | 740.6 | 13 |
| Barley: | | | | |
| 1978 base | 1.92 | | 413.5 | |
| Minus 30 percent | 1.78 | -7 | 455.0 | 10 |
| Plus 30 percent | 2.07 | 8 | 361.2 | -13 |
| Plus 60 percent | 2.24 | 17 | 348.9 | -16 |
| Plus 90 percent | 2.40 | 25 | 337.1 | -18 |
| Oats: | | | | |
| 1978 base | 1.23 | | 600.0 | |
| Minus 30 percent | 1.16 | -6 | 703.2 | 17 |
| Plus 30 percent | 1.34 | | 523.6 | |
| Plus 60 percent | 1.49 | | 506.3 | |
| Plus 90 percent | 1.64 | | 486.5 | |
| Hay: | | | | |
| 1978 base | 61.02 | | 98.1 | |
| Minus 30 percent | 56.95 | -7 | 99.0 | 1 |
| Plus 30 percent | 65.58 | 7 | 97.4 | -1 |
| Plus 60 percent | 69.96 | 15 | 97.0 | -1 |
| Plus 90 percent | 73.90 | 21 | 96.7 | -1 |
| Silage: | | | | |
| 1978 base | 34.60 | | 98.5 | |
| Minus 30 percent | 34.14 | -1 | 99.3 | 1 |
| Plus 30 percent | 35.15 | 2 | 97.7 | -1 |
| Plus 60 percent | 35.76 | 3 | 97.2 | -1 |
| Plus 90 percent | 36.31 | 5 | 96.8 | -2 |
| Rice: | | | | |
| 1978 base | 8.16 | | 133.7 | |
| Minus 30 percent | 7.71 | -6 | 115.1 | -14 |
| Plus 30 percent | 8.62 | 6 | 153.3 | 15 |
| Plus 60 percent | 9.06 | 11 | 170.9 | 28 |
| Plus 90 percent | 9.48 | 16 | 187.5 | 40 |

Units are: cotton, 1,000 bales; corn, soybeans, wheat, sorghum, barley, and oats, million bushels; hay and silage, million tons; and rice, million hundredweight.

Table 4--Effects of alternative export demand levels on regional commodity production in the United States, 1978

| Region & export level | Cotton | Corn | Soybeans | Wheat | Sorghum | Barley | Oats | Hay | Silage | Rice |
|---|---|---|---|---|---|---|---|---|---|---|
| | Percent change from base production | | | | | | | | | |
| Northeast: | | | | | | | | | | |
| Base production1/ | 0 | 248.9 | 27.5 | 12.5 | 0 | 9.5 | 40.7 | 8.9 | 18.7 | 0 |
| Minus 30 percent | - | -7.8 | -12.7 | -87.2 | - | 5.3 | 11.3 | -3.4 | .0 | - |
| Plus 30 percent | - | 8.6 | 11.6 | 77.6 | - | -9.5 | -7.1 | 4.5 | .2 | - |
| Plus 60 percent | - | 15.3 | 20.7 | 172.8 | - | -3.2 | -4.9 | 6.7 | .5 | - |
| Plus 90 percent | - | 21.6 | 28.7 | 266.4 | - | 3.2 | -3.4 | 9.0 | .8 | - |
| Lake States: | | | | | | | | | | |
| Base production1/ | 0 | 1,050.2 | 151.3 | 97.7 | 0 | 48.7 | 196.3 | 18.1 | 20.6 | 0 |
| Minus 30 percent | - | -5.6 | -12.0 | -26.6 | - | 9.4 | 16.0 | -5.5 | 0.8 | - |
| Plus 30 percent | - | 6.3 | 10.6 | 21.6 | - | -11.3 | -11.6 | 6.6 | - .7 | - |
| Plus 60 percent | - | 10.6 | 18.8 | 47.5 | - | -13.3 | -14.4 | 11.6 | -1.2 | - |
| Plus 90 percent | - | 14.7 | 26.0 | 73.8 | - | -14.8 | -17.6 | 15.5 | -1.8 | - |
| Corn Belt: | | | | | | | | | | |
| Base production1/ | 0.2 | 3,760.0 | 969.7 | 118.9 | 67.1 | 0 | 151.7 | 15.4 | 18.7 | 1.0 |
| Minus 30 percent | -58.6 | -6.5 | -12.5 | -1.9 | 171.2 | - | 10.3 | 7.8 | .5 | -20.0 |
| Plus 30 percent | 44.2 | 5.5 | 10.7 | -5.3 | 43.7 | - | -10.3 | -16.9 | -1.1 | 10.0 |
| Plus 60 percent | 91.7 | 10.3 | 19.8 | -3.0 | 68.9 | - | -15.2 | -30.5 | -1.6 | 20.0 |
| Plus 90 percent | 142.0 | 15.2 | 27.8 | .8 | 85.5 | - | -19.7 | -44.8 | -2.1 | 30.0 |
| Northern Plains: | | | | | | | | | | |
| Base production1/ | 0 | 1,054.2 | 79.2 | 676.6 | 323.4 | 130.2 | 211.3 | 17.1 | 13.2 | 0 |
| Minus 30 percent | - | -9.4 | -13.3 | -11.5 | 1.5 | 13.4 | 24.3 | -4.7 | 1.6 | - |
| Plus 30 percent | - | 10.4 | 11.4 | 8.4 | 8.0 | -19.1 | -16.7 | 6.4 | -1.4 | - |
| Plus 60 percent | - | 17.8 | 19.8 | 17.6 | 10.7 | -18.4 | -19.1 | 8.8 | -2.8 | - |
| Plus 90 percent | - | 24.7 | 27.0 | 27.2 | 12.2 | -17.3 | -22.6 | 9.9 | -4.0 | - |
| Appalachia: | | | | | | | | | | |
| Base production1/ | .3 | 328.1 | 134.6 | 20.1 | 0 | 0 | 0 | 5.7 | 9.1 | 0 |
| Minus 30 percent | -20.2 | -22.6 | -13.2 | -100.0 | - | - | - | 42.1 | 0 | - |
| Plus 30 percent | 20.6 | 22.4 | 11.7 | 158.7 | - | - | - | -49.1 | .1 | - |
| Plus 60 percent | 40.8 | 41.4 | 21.7 | 158.7 | - | - | - | -64.9 | .6 | - |
| Plus 90 percent | 60.3 | 61.2 | 30.7 | 158.7 | - | - | - | -82.5 | 1.1 | - |
| Southeast: | | | | | | | | | | |
| Base production1/ | 0.5 | 146.6 | 95.8 | 6.9 | 2.7 | 0 | 0 | 2.2 | 2.3 | 0 |
| Minus 30 percent | -7.7 | 13.2 | -32.2 | 62.3 | 0 | - | - | 9.1 | 2.1 | - |
| Plus 30 percent | 10.2 | -10.5 | 27.9 | -43.5 | 0 | - | - | 0 | -1.5 | - |
| Plus 60 percent | 21.4 | -20.0 | 49.4 | -2.9 | 0 | - | - | -4.5 | -2.4 | - |
| Plus 90 percent | 32.6 | -28.1 | 67.9 | 50.7 | 0 | - | - | -4.5 | -3.1 | - |
| Delta States: | | | | | | | | | | |
| Base production1/ | 2.5 | 0 | 253.7 | 11.1 | 11.4 | 0 | 0 | 2.2 | .8 | 79.6 |
| Minus 30 percent | -21.2 | - | -13.1 | -6.3 | 10.5 | - | - | 59.1 | 0 | -13.3 |
| Plus 30 percent | 24.3 | - | 11.0 | 5.4 | -2.6 | - | - | -45.5 | 0 | 14.3 |
| Plus 60 percent | 49.6 | - | 20.0 | 18.9 | -3.5 | - | - | -86.4 | 0 | 27.5 |
| Plus 90 percent | 71.2 | - | 26.7 | 29.7 | -7.9 | - | - | -100.0 | 0 | 39.7 |
| Southern Plains: | | | | | | | | | | |
| Base production1/ | 4.1 | 119.5 | 21.2 | 180.8 | 223.2 | 0 | 0 | 6.1 | 1.9 | 27.8 |
| Minus 30 percent | .5 | -10.2 | -24.1 | -4.0 | 11.2 | - | - | -49.2 | 1.0 | 24.8 |
| Plus 30 percent | -4.0 | 11.4 | 20.3 | .3 | - .9 | - | - | 57.4 | - .8 | 26.6 |
| Plus 60 percent | -7.0 | 17.3 | 36.8 | 6.0 | -3.1 | - | - | 106.6 | -1.2 | 49.6 |
| Plus 90 percent | -7.9 | 22.8 | 51.4 | 12.6 | -5.4 | - | - | 145.9 | -1.6 | 71.9 |
| Mountain: | | | | | | | | | | |
| Base production1/ | 1.3 | 98.4 | 0 | 287.3 | 21.5 | 149.8 | 0 | 14.0 | 8.9 | 0 |
| Minus 30 percent | -51.1 | 2.3 | - | -15.7 | 3.2 | 8.5 | - | 9.3 | 1.6 | - |
| Plus 30 percent | 52.5 | -2.1 | - | 14.0 | 4.2 | -9.5 | - | -7.1 | -1.5 | - |
| Plus 60 percent | 99.6 | -5.9 | - | 31.5 | 6.0 | -15.1 | - | -17.1 | -2.6 | - |
| Plus 90 percent | 146.4 | -9.8 | - | 41.1 | 4.7 | -21.3 | - | -20.0 | -3.8 | - |
| Pacific: | | | | | | | | | | |
| Base production1/ | 1.9 | 42.3 | 0 | 201.3 | 7.5 | 75.3 | 0 | 8.4 | 4.3 | 25.3 |
| Minus 30 percent | -2.9 | 1.9 | - | -14.2 | 6.7 | 8.2 | - | -3.6 | 1.7 | -3.6 |
| Plus 30 percent | 2.8 | -1.7 | - | 14.1 | -6.7 | -9.0 | - | 6.0 | -1.5 | 3.2 |
| Plus 60 percent | 4.3 | -4.5 | - | 29.8 | -12.0 | -14.9 | - | 10.7 | -2.7 | 4.7 |
| Plus 90 percent | 6.3 | -7.1 | - | 44.6 | -17.3 | -20.2 | - | 13.1 | -3.8 | 7.1 |

1/ Units are: cotton, 1,000 bales; corn, soybeans, wheat, sorghum, barley, and oats, million bushels; hay and silage, million tons; and rice, million hundredweight.

The projected increase in national soybean production of 30 percent was evenly distributed among the regions except the Southeast (68 percent) and the Southern Plains (51 percent). Most of the increase was projected for the Corn Belt (241 million bushels) where a substantial amount of soybean production currently exists. Moderate increases were projected for other soybean producing regions with the exception of the 68-percent increase in the Southeast and the 51-percent increase in the Southern Plains.

Increases in regional wheat production resulting from the 90-percent increase in export demand varied considerably. Large percentage increases occurred in the Northeast and Appalachia but relatively small increases were projected for the Corn Belt and the Southern Plains. Substantial increases in wheat production were projected for the Pacific and Mountain regions because of the crop's low water requirement relative to other irrigated crops.

The regional increase in sorghum production was even more diverse than the increase in wheat production. Production actually decreased in the Pacific region, Southern Plains, and the Delta States because of high water requirements and/or low returns to land and competition from other crops. A large part of the total increase was projected for dryland conditions in the Corn Belt and the Northern Plains.

As stated before, production of the non export feedstuffs declined under the export demand scenarios. With the exception of hay production, most of the decreases were fairly uniform across regions. Hay production declined substantially in the Corn Belt, Appalachia, and the Delta States. This was countered by an increase of 8.9 million tons in the Mountain region's hay production and smaller increases in the Lake States and Northern Plains.

Total rice production was projected to increase by 40 percent as a result of the 90-percent increase in export demand. Texas rice production (Southern Plains) was projected to almost double. California production increased only 9 percent due to the crop's high water requirement and the higher opportunity cost for water in competing export crops.

## Regional Water Use

As stated before, regional surface water supplies were constrained to the amount of water from surface sources that was applied to the crops included in the study in 1978. Surface water applied to other agricultural crops was not included in the water supply because of the problem of physically reallocating surface water from other crops and because the crops not included in the model are usually higher valued crops.

The weighted average regional costs of surface water were substantially less than average ground water costs in all irrigated regions, but the use of surface water was constrained to 1978 levels and, as a result, changes in export demand levels did not change the use of surface water. However increases in export demand levels caused significant increases in the amount of ground water pumped and the per unit cost (table 5). Under a 90-percent increase in export demand, total ground water pumped increased over 42 percent from 22.8 million acre-feet to 32.5 million acre-feet.

Table 5--Effects of alternative export demand levels on regional ground water pumping and costs in the United States, 1978

| Region & export level | Quantity pumped | Percentage change | Cost per Acre-foot | Percentage change |
|---|---|---|---|---|
| | Mil. acre-ft. | Pct. | Dollars | Pct. |
| Northern Plains: | | | | |
| 1978 base | 8.081 | | 12.76 | |
| Minus 30 percent | 6.981 | -13.6 | 9.86 | -22.7 |
| Plus 30 percent | 9.277 | 14.8 | 15.91 | 24.7 |
| Plus 60 percent | 10.305 | 27.5 | 18.62 | 45.9 |
| Plus 90 percent | 11.258 | 39.3 | 21.13 | 65.6 |
| Southeast: | | | | |
| 1978 base | .429 | | 14.26 | |
| Minus 30 percent | .393 | -8.4 | 13.46 | -5.6 |
| Plus 30 percent | .469 | 9.3 | 15.15 | 6.2 |
| Plus 60 percent | .504 | 17.5 | 15.93 | 11.7 |
| Plus 90 percent | .536 | 24.9 | 16.66 | 16.8 |
| Delta States: | | | | |
| 1978 base | 3.754 | | 11.03 | |
| Minus 30 percent | 2.913 | -22.4 | 9.38 | -15.0 |
| Plus 30 percent | 4.661 | 24.2 | 12.81 | 16.1 |
| Plus 60 percent | 5.530 | 47.3 | 14.51 | 31.6 |
| Plus 90 percent | 6.317 | 68.3 | 16.05 | 45.5 |
| Southern Plains: | | | | |
| 1978 base | 5.632 | | 18.67 | |
| Minus 30 percent | 5.215 | -7.4 | 15.20 | -18.6 |
| Plus 30 percent | 6.055 | 7.5 | 22.19 | 18.9 |
| Plus 60 percent | 6.460 | 14.7 | 25.56 | 36.9 |
| Plus 90 percent | 6.800 | 20.7 | 28.87 | 54.6 |
| Mountain: | | | | |
| 1978 base | 2.744 | | 16.47 | |
| Minus 30 percent | 2.165 | -21.1 | 12.11 | -26.5 |
| Plus 30 percent | 3.371 | 22.8 | 21.20 | 28.7 |
| Plus 60 percent | 3.970 | 44.7 | 25.71 | 56.1 |
| Plus 90 percent | 4.502 | 64.1 | 29.72 | 80.4 |
| Pacific: | | | | |
| 1978 base | 2.202 | | 18.88 | |
| Minus 30 percent | 1.901 | -13.7 | 15.83 | -16.2 |
| Plus 30 percent | 2.535 | 15.1 | 22.26 | 17.9 |
| Plus 60 percent | 2.841 | 29.0 | 25.37 | 34.4 |
| Plus 90 percent | 3.125 | 41.9 | 28.25 | 49.6 |
| Total: | | | | |
| 1978 base | 22.842 | | | |
| Minus 30 percent | 19.568 | -14.3 | | |
| Plus 30 percent | 26.368 | 15.4 | | |
| Plus 60 percent | 29.610 | 29.6 | | |
| Plus 90 percent | 32.538 | 42.4 | | |

The Northern Plains ground water pumping was projected to increase by 3.2 million acre-feet and the pumping cost to increase from $12.76 to $21.13 per acre-foot. The greatest percentage increase in regional pumping was projected for the Delta States (68 percent); but, due to the relative high elasticity of water supply, pumping cost was projected to increase by only 45.5 percent. Pumping cost for the eight-State Mountain region was projected to increase from $16.47 to almost $30.00 per acre-foot. This projected cost would be comparable to costs projected for the other western regions.

One of the overdraft problem areas is the Southern Plains where a substantial portion of the increase in ground water use (about 1.17 million acre-feet annually) was projected to occur. Southern Plains farmers in the pump most of their water from the Ogallala aquifer. Some areas of this aquifer have experienced substantial annual overdrafting. Increasing the overdraft by over 1 million acre-feet may quickly exhaust the economic water supply in the western part of the Southern Plains. These projections are based on ground water supply functions that existed in 1978; no attempt was made to estimate the change that may occur in those functions as a result of the export demand scenarios. A long-run increase in export demand would certainly change the nature of the water supply functions in critical ground water areas.

## Dryland And Irrigated Production

Tables 6 through 9 present the change in regional dryland and irrigated crop acreages resulting from the four export demand scenarios. The percentage change in dryland and irrigated acreages by scenarios is presented in appendix tables 1-4.

As export demand decreased, total cropland use decreased by 14.7 million acres from 278 million acres (table 6). This decrease was distributed almost proportionately between dryland and irrigated acreage (app. table 1). As exports increased by 30, 60, and 90 percent, total cropland use increased by 15.9, 31.8, and 46.6 million acres (tables 7, 8, and 9). However irrigated acreage increased proportionally more than dryland acreage (app. tables 2, 3, and 4). Since irrigated yields are generally higher than dryland, the production response from irrigated agriculture was greater than dryland agriculture despite the higher ground water prices.

Irrigated wheat acreage was projected to increase by 1.135 million acres or 49 percent under the 90-percent increase in export demand (table 9 and app. table 4). About half of this increase (571,000 acres) was projected for the Northern Plains. This projected increase was expected because 67 percent of the total wheat production was exported in 1978. Dryland wheat acreage was projected to increase by only 32 percent from 54.4 million acres (app. table 4).

Soybean acreage was projected to increase by over 16 million acres under the 90-percent export increase scenario. Almost all of the increase is projected for dryland production because soybeans are not produced easily under irrigated conditions.

Corn acreage was projected to increase by 3 million acres under the high-export demand scenario with the irrigated acreage increasing by 21 percent and the dryland acreage increasing by 17 percent (app. table 4). Almost all of the

Table 6--Change in dryland and irrigated crop acreage due to a 30-percent decrease in exports, by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Million acres | | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | -0.107 | | -0.056 | -0.042 | -0.440 | -0.234 | | | -0.878 |
| Irrigated | | | | | | | - .077 | .183 | -0.354 | -0.044 | - .293 |
| Total | | | - .107 | | - .056 | - .042 | - .517 | - .051 | - .354 | - .044 | -1.171 |
| Corn: | | | | | | | | | | | |
| Dryland | -0.208 | -0.627 | -2.310 | -0.440 | - .948 | .398 | | - .092 | 0 | 0 | -4.227 |
| Irrigated | | | | - .587 | | .002 | | - .072 | .022 | .007 | - .629 |
| Total | - .208 | - .627 | -2.310 | -1.028 | - .948 | .401 | | - .164 | .022 | .007 | -4.856 |
| Soybeans: | | | | | | | | | | | |
| Dryland | - .119 | - .584 | -2.706 | - .381 | - .461 | -1.578 | -1.338 | - .169 | | | -7.336 |
| Irrigated | | | | - .048 | | - .032 | - .120 | - .080 | | | - .280 |
| Total | - .119 | - .584 | -2.706 | - .429 | - .461 | -1.611 | -1.458 | - .249 | | | -7.616 |
| Wheat: | | | | | | | | | | | |
| Dryland | - .326 | - .772 | - .062 | -2.597 | - .580 | .146 | - .019 | - .332 | -1.497 | - .614 | -6.652 |
| Irrigated | | | | - .184 | | | | .012 | - .123 | - .056 | - .351 |
| Total | - .326 | - .772 | - .062 | -2.781 | - .580 | .146 | - .019 | - .320 | -1.620 | - .670 | -7.004 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | 1.578 | .102 | | | .021 | .702 | - .011 | 0 | 2.393 |
| Irrigated | | | | - .006 | | | | - .003 | .020 | .007 | .018 |
| Total | | | 1.578 | .096 | | | .021 | .699 | .009 | .008 | 2.411 |
| Barley: | | | | | | | | | | | |
| Dryland | .012 | .094 | | .412 | | | | | .043 | .044 | .604 |
| Irrigated | | | | | | | | | .154 | .066 | .220 |
| Total | .012 | .094 | | .412 | | | | | .197 | .109 | .824 |
| Oats: | | | | | | | | | | | |
| Dryland | .089 | .616 | .310 | 1.127 | | | | | | | 2.142 |
| Irrigated | | | | | | | | | | | 0 |
| Total | .089 | .616 | .310 | 1.127 | | | | | | | 2.142 |
| Hay: | | | | | | | | | | | |
| Dryland | - .151 | - .366 | .557 | - .259 | 1.410 | .087 | .811 | -1.948 | .880 | .041 | 1.061 |
| Irrigated | | | | - .085 | | - .001 | | - .032 | .100 | - .084 | - .102 |
| Total | - .151 | - .366 | .557 | - .344 | 1.410 | .086 | .811 | -1.980 | .980 | - .043 | .959 |
| Silage: | | | | | | | | | | | |
| Dryland | .001 | .015 | .011 | .013 | 0 | .004 | .001 | 0 | 0 | | .045 |
| Irrigated | | | | .007 | | 0 | 0 | .001 | .008 | .003 | .020 |
| Total | .001 | .015 | .011 | .020 | 0 | .004 | .001 | .001 | .008 | .003 | .065 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | - .006 | | | | - .251 | - .149 | | - .017 | - .423 |
| Regional total: | | | | | | | | | | | |
| Dryland | - .701 | -1.626 | -2.729 | -2.024 | - .634 | - .985 | - .963 | -2.073 | - .585 | - .529 | -12.849 |
| Irrigated | 0 | 0 | - .006 | - .903 | 0 | - .031 | - .448 | - .140 | - .173 | - .118 | - 1.819 |
| Cropland | - .701 | -1.626 | -2.735 | -2.927 | - .634 | -1.016 | -1.411 | -2.214 | - .758 | - .647 | -14.699 |

Table 7--Change in dryland and irrigated crop acreage due to a 30-percent increase in exports, by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Million acres | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 0.082 | | 0.056 | 0.057 | 0.500 | 0.157 | | | 0.851 |
| Irrigated | | | | | | | .090 | - .322 | 0.364 | 0.042 | .175 |
| Total | | | .082 | | .056 | .057 | .590 | - .165 | .364 | .042 | 1.026 |
| Corn: | | | | | | | | | | | |
| Dryland | 0.228 | 0.701 | 1.973 | 0.488 | .941 | - .325 | | .062 | 0 | 0 | 4.068 |
| Irrigated | | | | 0.645 | | .002 | | .099 | - .020 | - .007 | .720 |
| Total | .228 | .701 | 1.973 | 1.132 | .941 | - .322 | | .161 | - .020 | - .007 | 4.788 |
| Soybeans: | | | | | | | | | | | |
| Dryland | .106 | .518 | 2.315 | .333 | .411 | 1.369 | 1.116 | .137 | | | 6.304 |
| Irrigated | | | | .038 | | .028 | .113 | .074 | | | .253 |
| Total | .106 | .518 | 2.315 | .371 | .411 | 1.397 | 1.228 | .211 | | | 6.557 |
| Wheat: | | | | | | | | | | | |
| Dryland | .288 | .628 | - .173 | 1.866 | .920 | - .099 | .017 | .074 | 1.299 | .616 | 5.436 |
| Irrigated | | | | .148 | | | | - .035 | .123 | .054 | .289 |
| Total | .288 | .628 | - .173 | 2.014 | .920 | - .099 | .017 | .038 | 1.422 | .670 | 5.725 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | .402 | .408 | | | - .004 | - .330 | .029 | 0 | .505 |
| Irrigated | | | | .059 | | | | .132 | - .011 | - .006 | .173 |
| Total | | | .402 | .467 | | | - .004 | - .199 | .018 | - .006 | .679 |
| Barley: | | | | | | | | | | | |
| Dryland | - .018 | - .115 | | - .585 | | | | | - .047 | - .044 | - .809 |
| Irrigated | | | | | | | | | - .172 | - .074 | - .246 |
| Total | - .018 | - .115 | | - .585 | | | | | - .219 | - .118 | -1.055 |
| Oats: | | | | | | | | | | | |
| Dryland | - .056 | - .445 | - .308 | - .774 | | | | | | | -1.582 |
| Irrigated | | | | | | | | | | | 0 |
| Total | - .056 | - .445 | - .308 | - .774 | | | | | | | -1.582 |
| Hay: | | | | | | | | | | | |
| Dryland | .203 | .461 | -1.113 | .436 | -1.619 | - .030 | - .650 | 2.216 | - .683 | - .036 | - .814 |
| Irrigated | | | | .101 | | .001 | | .041 | - .077 | .111 | .176 |
| Total | .203 | .461 | -1.113 | .537 | -1.619 | - .029 | - .650 | 2.257 | - .760 | .075 | - .638 |
| Silage: | | | | | | | | | | | |
| Dryland | .002 | - .011 | - .012 | - .011 | .001 | - .003 | - .001 | 0 | 0 | | - .036 |
| Irrigated | | | | - .007 | | 0 | 0 | - .001 | - .007 | - .003 | - .018 |
| Total | .002 | - .011 | - .012 | - .018 | .001 | - .003 | - .001 | - .001 | - .007 | - .003 | - .054 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | .003 | | | | .271 | .158 | | .015 | .446 |
| Regional total: | | | | | | | | | | | |
| Dryland | .753 | 1.736 | 3.167 | 2.161 | .710 | .969 | .977 | 2.315 | .599 | .537 | 13.923 |
| Irrigated | 0 | 0 | .003 | .984 | 0 | .032 | .474 | .146 | .199 | .132 | 1.969 |
| Cropland | .753 | 1.736 | 3.169 | 3.144 | .710 | 1.000 | 1.451 | 2.461 | .798 | .669 | 15.892 |

Table 8--Change in dryland and irrigated crop acreage due to a 60-percent increase in export demand, by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Million acres | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 0.168 | | 0.111 | 0.117 | 1.016 | 0.305 | | | 1.717 |
| Irrigated | | | | | | | .190 | -.584 | 0.692 | 0.066 | .363 |
| Total | | | .168 | | .111 | .117 | 1.206 | -.279 | .692 | .066 | 2.080 |
| Corn: | | | | | | | | | | | |
| Dryland | 0.407 | 1.187 | 3.680 | 0.785 | 1.742 | -.620 | | .075 | 0 | 0 | 7.256 |
| Irrigated | | | | 1.137 | | .006 | | .160 | -.054 | -.017 | 1.232 |
| Total | .407 | 1.187 | 3.680 | 1.922 | 1.742 | -.615 | | .235 | -.054 | -.017 | 8.488 |
| Soybeans: | | | | | | | | | | | |
| Dryland | .191 | .915 | 4.270 | .577 | .761 | 2.422 | 2.006 | .245 | | | 11.388 |
| Irrigated | | | | .066 | | .052 | .211 | .137 | | | .466 |
| Total | .191 | .915 | 4.270 | .643 | .761 | 2.474 | 2.218 | .382 | | | 11.854 |
| Wheat: | | | | | | | | | | | |
| Dryland | .639 | 1.382 | -.098 | 3.862 | .920 | -.005 | .061 | .497 | 2.973 | 1.287 | 11.517 |
| Irrigated | | | | .361 | | | | -.019 | .261 | .119 | .722 |
| Total | .639 | 1.382 | -.098 | 4.223 | .920 | -.005 | .061 | .478 | 3.233 | 1.406 | 12.239 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | .634 | .505 | | | -.007 | -.713 | .052 | 0 | .471 |
| Irrigated | | | | .102 | | | | .246 | -.025 | -.012 | .311 |
| Total | | | .634 | .607 | | | -.007 | -.467 | .027 | -.012 | .781 |
| Barley: | | | | | | | | | | | |
| Dryland | -.006 | -.135 | | -.565 | | | | | -.047 | -.076 | -.829 |
| Irrigated | | | | | | | | | -.287 | -.119 | -.405 |
| Total | -.006 | -.135 | | -.565 | | | | | -.333 | -.194 | -1.234 |
| Oats: | | | | | | | | | | | |
| Dryland | -.040 | -.553 | -.454 | -.887 | | | | | | | -1.933 |
| Irrigated | | | | | | | | | | | 0 |
| Total | -.040 | -.553 | -.454 | -.887 | | | | | | | -1.933 |
| Hay: | | | | | | | | | | | |
| Dryland | .337 | .802 | -2.007 | .446 | -2.144 | -.042 | -1.193 | 4.114 | -1.744 | -.083 | -1.514 |
| Irrigated | | | | .193 | | .002 | | .080 | -.174 | .206 | .307 |
| Total | .337 | .802 | -2.007 | .638 | -2.144 | -.040 | -1.193 | 4.194 | -1.918 | -.123 | -1.207 |
| Silage: | | | | | | | | | | | |
| Dryland | .006 | -.022 | -.019 | -.022 | .004 | -.005 | -.002 | 0 | 0 | | -.060 |
| Irrigated | | | | -.013 | | 0 | 0 | -.001 | -.013 | -.006 | -.033 |
| Total | .006 | -.022 | -.019 | -.035 | .004 | -.005 | -.002 | -.001 | -.013 | -.006 | -.092 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | .005 | | | | .521 | .297 | | .024 | .847 |
| Regional total: | | | | | | | | | | | |
| Dryland | 1.535 | 3.577 | 6.175 | 4.700 | 1.394 | 1.868 | 1.881 | 4.522 | 1.234 | 1.128 | 28.013 |
| Irrigated | 0 | 0 | .005 | 1.846 | 0 | .059 | .922 | .317 | .400 | .261 | 3.809 |
| Cropland | 1.535 | 3.577 | 6.180 | 6.546 | 1.394 | 1.927 | 2.803 | 4.839 | 1.633 | 1.389 | 31.822 |

Table 9—Change in dryland and irrigated crop acreage due to a 90-percent increase in export demand, by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | *Million acres* | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 0.260 | | 0.165 | 0.178 | 1.459 | 0.508 | | | 2.571 |
| Irrigated | | | | | | | .274 | -.773 | 1.016 | 0.095 | .612 |
| Total | | | .260 | | .165 | .178 | 1.733 | -.265 | 1.016 | .095 | 3.183 |
| Corn: | | | | | | | | | | | |
| Dryland | 0.577 | 1.648 | 5.427 | 1.064 | 2.574 | -.875 | | .116 | -.001 | -.001 | 10.530 |
| Irrigated | | | | 1.600 | | .009 | | .203 | -.090 | -.026 | 1.695 |
| Total | .577 | 1.648 | 5.427 | 2.664 | 2.574 | -.866 | | .319 | -.092 | -.027 | 12.225 |
| Soybeans: | | | | | | | | | | | |
| Dryland | .265 | 1.263 | 6.009 | .788 | 1.075 | 3.328 | 2.657 | .340 | | | 15.726 |
| Irrigated | | | | .088 | | .072 | .300 | .192 | | | .652 |
| Total | .265 | 1.263 | 6.009 | .887 | 1.075 | 3.400 | 2.958 | .532 | | | 16.378 |
| Wheat: | | | | | | | | | | | |
| Dryland | .986 | 2.146 | .028 | 5.924 | .920 | .119 | .094 | .993 | 3.734 | 1.922 | 16.865 |
| Irrigated | | | | .571 | | | | -.002 | .386 | .180 | 1.135 |
| Total | .986 | 2.146 | .028 | 6.494 | .920 | .119 | .094 | .991 | 4.119 | 2.102 | 18.000 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | .789 | .548 | | | -.016 | -1.051 | .065 | 0 | .335 |
| Irrigated | | | | .136 | | | | .339 | -.040 | -.018 | .417 |
| Total | | | .789 | .684 | | | -.016 | -.712 | .025 | -.018 | .752 |
| Barley: | | | | | | | | | | | |
| Dryland | .008 | -.149 | | -.528 | | | | | -.085 | -.016 | -.860 |
| Irrigated | | | | | | | | | -.396 | -.160 | -.557 |
| Total | .008 | -.149 | | -.528 | | | | | -.481 | -.266 | -1.417 |
| Oats: | | | | | | | | | | | |
| Dryland | -.028 | -.675 | -.589 | -1.048 | | | | | | | -2.340 |
| Irrigated | | | | | | | | | | | 0 |
| Total | -.028 | -.675 | -.589 | -1.048 | | | | | | | -2.340 |
| Hay: | | | | | | | | | | | |
| Dryland | .438 | 1.079 | -2.986 | .342 | -2.734 | -.058 | -1.397 | 5.583 | -1.771 | -.131 | -1.635 |
| Irrigated | | | | .270 | | .003 | | .111 | -.300 | .279 | .364 |
| Total | .438 | 1.079 | -2.986 | .612 | -2.734 | -.055 | -1.397 | 5.695 | -2.071 | .149 | -1.270 |
| Silage: | | | | | | | | | | | |
| Dryland | .010 | -.031 | -.024 | -.033 | .007 | -.008 | -.002 | 0 | 0 | | -.083 |
| Irrigated | | | | -.018 | | 0 | 0 | -.002 | -.019 | -.008 | -.047 |
| Total | .010 | -.031 | -.024 | -.051 | .007 | -.008 | -.003 | -.002 | -.019 | -.008 | -.129 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | .007 | | | | .754 | .431 | | .035 | 1.227 |
| Regional total: | | | | | | | | | | | |
| Dryland | 2.255 | 5.280 | 8.914 | 7.057 | 2.007 | 2.684 | 2.795 | 6.490 | 1.941 | 1.684 | 41.110 |
| Irrigated | 0 | 0 | .007 | 2.647 | 0 | .084 | 1.328 | .499 | .556 | .377 | 5.499 |
| Cropland | 2.555 | 5.280 | 8.921 | 9.705 | 2.007 | 2.769 | 4.123 | 6.990 | 2.498 | 2.062 | 46.609 |

increase in irrigated acreage, 1.6 million acres, was projected for the Northern Plains where ground water cost was relatively low and other high-value crops such as rice and cotton were not competing for water.

About 2.5 of the 3.2 million acres of cotton projected to increase as a result of the high-export scenario were dryland. This increase is much more than the projected increase in irrigated cotton acreage of 13 percent. Most of the increase is projected for the Delta States. A switch from irrigated to dryland cotton is projected for about 500,000 acres in the Southern Plains.

The projected rice acreage increase of 1.2 million acres under the 90-percent export increase scenario was unevenly distributed among the rice producing areas (table 9). The largest projected regional increase was 431,000 acres (72 percent) in the Southern Plains. This is contrasted to the relatively low projected increase of 7 percent for the Pacific region (app. table 4). The regional differential in projected rice acreage can be explained in terms of the comparative advantage the Southern Plains has in growing rice due to lower water costs. Crops with high water requirements generally did not increase significantly in those regions with high water costs and high ground water supply elasticities.

With the exception of sorghum, feed grains grown mainly for domestic consumption declined under the increased export scenarios. The largest acreage decline was projected for oats (2.3 million acres). Hay, silage, and barley acreages were also projected to decline.

Irrigated agricultural production is projected to increase proportionality more than dryland production under the 90-percent increased export demand scenario. Some projected changes in regional irrigated and dryland acreages were also significant under this scenario. As one might expect, regions that had large cropland acreages in 1978 would have large projected increases in acreages. For example, total cropland acreage was projected to increase in the Northern Plains by 9.7 million acres of which 2.6 million acres would be irrigated (table 9). The projected increase in Northern Plains irrigated acreage was 33 percent (app. table 4). However, the largest projected percentage increase in irrigated acreage was 51 percent for the Delta States, a region with a relatively low ground water cost and a high elasticity of ground water supply. The largest projected increase in regional dryland acreage under the highest export demand scenario was 8.9 million acres in the Corn Belt.

## SUMMARY AND CONCLUSIONS

Using a modified version of the USMP model that included irrigated cropping activities and water supply functions, we projected commodity production and regional cropping shifts under four export demand scenarios. Production of export commodities in irrigated regions would play a significant role in an expansion of export commodity demand. Under a 90-percent increase in export demand, irrigated acreage is projected to increase by 1.3 million acres or 51 percent in the Delta States. The Northern Plains can expect an increase of 2.6 million acres of irrigated land.

Ground water use was projected to increase by 42 percent under the 90 percent export demand increase scenario. Water use and costs were changed significantly in some regions. Ground water pumping increased by 68 percent in the Delta States and 64 percent in the Mountain region. Water costs increased by 80 percent in the Mountain region to over $28.00 per acre foot and by 66 percent in the Northern Plains to over $21.00 per acre foot.

The results of this study are limited by the level of aggregation. In formulating a 10-region national model, one must make substantial aggregations in estimating production coefficients and specifying water supply functions. A good example is the Mountain region that includes such diverse agricultural areas as Montana and Arizona. Attempting to construct an irrigated wheat activity that would adequately represent the production of wheat from the Mountain region under various demand conditions is very difficult. The USMP model was developed to estimate national changes in income and agricultural production from changes in national policies. It serves that purpose very well. However, attempting to estimate regional changes in resource use as a result of those same policies needs to be done at a less aggregated level. A 48-state version of the USMP model is expected to be completed soon.

FOOTNOTES

1. Robert M. House, "USMP: A Mathematical Programming Model for Agriculture Sector Policy Analysis," forthcoming, U.S. Dept. Agr. Econ. Res. Serv.

2. Barbara L. Chattin, Bruce A. McCarl, and Harry Stephen Baumes, Jr. User's Guide and Documentation For A Partial Equilibrium Sector Model of U.S. Agriculture, Bulletin No. 414, Purdue Univ., Agr. Exp. Stat., Apr. 1983.

3. Bruce A. Murtagh and Michael A. Saunders, Minos 5.0 User's Guide, Tech. Rept. SOL 83-20, Systems Optimization Laboratory, Dept. of Operations Research. Stanford Univ., Dec. 1983.

4. Gordon Sloggett, Prospects For Ground water Irrigation: Declining Levels and Rising Energy Costs, AER-478, U.S. Dept. Agr., Econ. Res. Serv., Dec. 1981.

5. Sloggett, op.cit.

6. Sloggett, op. cit.

7. These costs are referred to as user costs in the economic literature

8. Richard E. Howitt, Is Overdraft Always Bad?, Proceedings of the Twelfth Biennial Conference on Ground Water, Sacramento, Calif., Nov. 1979, Univ. of Calif., Water Resources Center, pp. 50-61.

9. Optimal periods of overdraft can be determined quite easily. See Charles V. Moore, Ground water Overdraft Management: Some Suggested Guidelines, Giannini Foundation, Info. Series No. 84-1, Feb. 1984.

10. U.S. Geological Survey, Water Supply Paper 2250, 1984.

11. U.S. Bureau of the Census, 1978 Census of Agriculture, 1979 Farm and Ranch Irrigation Survey, Vol. 5, Special Reports, Part 8, 1980.

12. Oral communications with Gordon Sloggett, agricultural economist, U.S. Dept. Agr., Econ. Res. Serv., Oklahoma State Univ.

13. Richard H. Day, "Recursive Programming and the Production of Supply," Agricultural Supply Functions, Heady et al., Iowa State University Press, 1961.

14. Bruce A. McCarl, "Cropping Activities in Agricultural Sector Models: A Methodological Proposal," American Journal of Agricultural Economics 64:768-772, 1982.

15. Richard E. Howitt and Phillippe Mean, "A Positive Approach to Microeconomic Programming Models," Working Paper No. 83-6, Dept. of Agr. Econ., Univ. of Calif., 1983.

16. Nonmarginal or underspecialized crops are those that are "underproduced" in

a programming solution when compared to a base-year production.

17. Howitt and Mean, op. cit., p 16.

18. The cropping activity level in the unconstrained model is greater than the acreage level observed in the base year.

19. Robert M. House, "Agriculture and Uncertainty in the 1980's." unpublished, U.S. Dept. of Agr. Econ. Res. Serv., 1983.

Appendix table 1--Percentage in dryland and irrigated crop acres from 1978 base acreage due to a 30-percent decrease in export demand by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop change |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Percent | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | -58.4 | | -20.3 | -7.6 | -18.8 | -5.0 | | | -10.9 |
| Irrigated | | | | | | | -60.3 | 7.8 | -51.0 | -2.9 | -6.3 |
| Total | | | | | | | | | | | -9.2 |
| Corn: | | | | | | | | | | | |
| Dryland | -7.8 | -5.6 | -6.5 | -7.9 | -22.5 | 15.1 | | -22.3 | -.3 | 2.4 | -6.8 |
| Irrigated | | | | -10.4 | | .9 | | -7.7 | 2.4 | 1.8 | -7.8 |
| Total | | | | | | | | | | | -6.9 |
| Soybeans: | | | | | | | | | | | |
| Dryland | -12.9 | -12.0 | -12.5 | -12.5 | -13.2 | -31.9 | -12.5 | -18.4 | | | -14.5 |
| Irrigated | | | | -21.8 | | -41.7 | -20.2 | -42.8 | | | -26.0 |
| Total | | | | | | | | | | | -14.8 |
| Wheat: | | | | | | | | | | | |
| Dryland | -87.5 | -26.6 | -1.9 | -10.7 | -100.0 | 63.8 | -6.1 | -4.3 | -17.5 | -15.0 | -12.8 |
| Irrigated | | | | -34.7 | | | | 8.0 | -11.1 | -11.0 | -15.2 |
| Total | | | | | | | | | | | -12.9 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | 171.1 | 2.0 | | | 10.4 | 17.6 | -9.8 | 3.0 | 23.0 |
| Irrigated | | | | -1.0 | | | | -.3 | 9.1 | 7.1 | .9 |
| Total | | | | | | | | | | | 19.4 |
| Barley: | | | | | | | | | | | |
| Dryland | 5.9 | 9.3 | | 13.4 | | | | | 2.7 | 5.3 | 9.0 |
| Irrigated | | | | | | | | | 12.0 | 10.2 | 11.4 |
| Total | | | | | | | | | | | 9.5 |
| Oats: | | | | | | | | | | | |
| Dryland | 11.4 | 16.0 | .3 | 24.3 | | | | | | | 17.5 |
| Irrigated | | | | | | | | | | | 0 |
| Total | | | | | | | | | | | 17.5 |
| Hay: | | | | | | | | | | | |
| Dryland | -3.4 | -5.3 | .6 | -3.0 | 42.3 | 7.7 | 58.0 | -58.5 | 49.7 | 5.0 | 2.8 |
| Irrigated | | | | -15.3 | | -2.6 | | -12.2 | 2.4 | -5.0 | -1.5 |
| Total | | | | | | | | | | | 2.1 |
| Silage: | | | | | | | | | | | |
| Dryland | 0 | .8 | .9 | 1.3 | 0 | 0 | 1.9 | .5 | .8 | | .7 |
| Irrigated | | | | 2.3 | | 1.8 | 2.3 | 1.1 | 1.7 | 1.7 | 1.8 |
| Total | | | | | | | | | | | .9 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | -24.4 | | | | -13.3 | -24.9 | | -3.5 | -14.1 |
| Regional change: | | | | | | | | | | | |
| Dryland | -6.5 | -5.0 | -3.8 | -3.7 | -5.1 | -10.2 | -6.4 | -9.9 | -4.8 | -9.2 | -5.2 |
| Irrigated | 0 | 0 | -24.0 | -11.4 | 0 | -8.9 | -17.1 | -2.5 | -2.0 | -2.1 | -5.9 |
| Cropland | -6.5 | -5.0 | -3.8 | -4.6 | -5.1 | -10.1 | -8.0 | -8.3 | -3.6 | -5.8 | -5.3 |

Appendix table 2--Percentage in dryland and irrigated crop acres from 1978 base acreage due to a 30-percent increase in export demand by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop change |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Percent | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 44.6 | | 20.5 | 10.3 | 21.3 | 3.3 | | | 8.7 |
| Irrigated | | | | | | | 70.7 | -13.7 | 52.4 | 2.8 | 7.9 |
| Total | | | | | | | | | | | 8.4 |
| Corn: | | | | | | | | | | | |
| Dryland | 8.5 | 6.3 | 5.5 | 8.8 | 22.4 | -12.3 | | 15.0 | .8 | - .7 | 6.2 |
| Irrigated | | | | 11.4 | | 1.0 | | 10.7 | - 2.2 | - 1.8 | 11.2 |
| Total | | | | | | | | | | | 6.8 |
| Soybeans: | | | | | | | | | | | |
| Dryland | 11.5 | 10.6 | 10.7 | 10.7 | 11.8 | 27.7 | 10.4 | 15.0 | | | 12.5 |
| Irrigated | | | | 17.4 | | 36.5 | 19.0 | 39.6 | | | 24.1 |
| Total | | | | | | | | | | | 12.8 |
| Wheat: | | | | | | | | | | | |
| Dryland | 77.5 | 21.6 | - 5.3 | 7.7 | 158.6 | -43.4 | 5.5 | 1.0 | 15.2 | 15.1 | 10.2 |
| Irrigated | | | | 27.8 | | | | -23.6 | 11.0 | 10.5 | 16.3 |
| Total | | | | | | | | | | | 10.5 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | 43.6 | 7.9 | | | - 2.0 | - 8.3 | 26.7 | - .3 | 4.4 |
| Irrigated | | | | 9.1 | | | | 12.5 | - 5.1 | - 5.7 | 10.2 |
| Total | | | | | | | | | | | 5.3 |
| Barley: | | | | | | | | | | | |
| Dryland | - 8.9 | -11.4 | | -19.1 | | | | | - 2.9 | - 5.3 | -12.6 |
| Irrigated | | | | | | | | | -13.4 | -11.5 | -11.6 |
| Total | | | | | | | | | | | -12.4 |
| Oats: | | | | | | | | | | | |
| Dryland | - 7.1 | -11.6 | - .3 | -16.7 | | | | | | | -12.9 |
| Irrigated | | | | | | | | | | | 0 |
| Total | | | | | | | | | | | -12.9 |
| Hay: | | | | | | | | | | | |
| Dryland | 4.6 | 6.6 | - 1.1 | 5.0 | -48.6 | - 2.7 | - 46.5 | 66.6 | - 38.6 | - 4.3 | - 2.5 |
| Irrigated | | | | 18.1 | | 4.8 | | 15.3 | - 1.9 | 6.6 | 3.4 |
| Total | | | | | | | | | | | - 1.6 |
| Silage: | | | | | | | | | | | |
| Dryland | .2 | - .7 | - 1.0 | - 1.1 | .1 | 0 | - 1.5 | - .4 | - .6 | | - .7 |
| Irrigated | | | | - 2.1 | | - 1.1 | - 2.0 | - .9 | - 1.5 | - 1.5 | - 1.4 |
| Total | | | | | | | | | | | .8 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | 11.0 | | | | 14.3 | 26.4 | | 3.1 | 14.8 |
| Regional change: | | | | | | | | | | | |
| Dryland | 7.0 | 5.3 | 4.3 | 3.5 | 5.6 | 10.0 | 6.8 | 9.3 | 4.5 | 9.2 | 5.4 |
| Irrigated | 0 | 0 | 12.0 | 15.2 | 0 | 8.0 | 15.1 | 9.2 | 2.8 | 2.6 | 8.2 |
| Cropland | 7.0 | 5.3 | 4.3 | 5.0 | 5.6 | 9.9 | 8.0 | 9.2 | 3.8 | 6.0 | 5.7 |

Appendix table 3--Percentage in dryland and irrigated crop acres from 1978 base acreage due to a 60-percent increase in export demand by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop change |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Percent | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 91.8 | | 40.4 | 21.5 | 43.4 | 6.5 | | | 21.3 |
| Irrigated | | | | | | | 148.3 | -24.9 | 99.6 | 4.3 | 7.7 |
| Total | | | | | | | | | | | 16.3 |
| Corn: | | | | | | | | | | | |
| Dryland | 15.2 | 10.6 | 10.3 | 14.1 | 41.4 | -23.5 | | 18.0 | - .3 | - 6.7 | 11.6 |
| Irrigated | | | | 20.2 | | 2.4 | | 17.2 | - 6.0 | - 4.6 | 15.2 |
| Total | | | | | | | | | | | 12.0 |
| Soybeans: | | | | | | | | | | | |
| Dryland | 20.6 | 18.8 | 19.8 | 19.0 | 21.8 | 49.0 | 18.8 | 26.7 | | | 22.6 |
| Irrigated | | | | 29.8 | | 66.3 | 35.8 | 73.4 | | | 43.3 |
| Total | | | | | | | | | | | 23.0 |
| Wheat: | | | | | | | | | | | |
| Dryland | 171.9 | 47.5 | - 3.0 | 15.9 | 158.6 | - 2.1 | 19.4 | 6.5 | 34.8 | 31.5 | 22.1 |
| Irrigated | | | | 68.0 | | | | -12.6 | 23.5 | 23.2 | 31.4 |
| Total | | | | | | | | | | | 22.5 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | 68.8 | 9.7 | | | - 3.6 | -17.9 | 47.1 | - 2.3 | 4.5 |
| Irrigated | | | | 15.7 | | | | 23.4 | -11.3 | -11.7 | 15.4 |
| Total | | | | | | | | | | | 6.3 |
| Barley: | | | | | | | | | | | |
| Dryland | - 2.9 | -13.4 | | -18.5 | | | | | - 2.9 | - 9.2 | -12.4 |
| Irrigated | | | | | | | | | -22.3 | -18.5 | -21.0 |
| Total | | | | | | | | | | | -14.3 |
| Oats: | | | | | | | | | | | |
| Dryland | - 5.0 | -14.4 | - .5 | -19.1 | | | | | | | -15.8 |
| Irrigated | | | | | | | | | | | 0 |
| Total | | | | | | | | | | | -15.8 |
| Hay: | | | | | | | | | | | |
| Dryland | 7.6 | 11.5 | - 2.0 | 5.1 | -64.4 | - 3.7 | - 85.4 | 123.6 | - 98.5 | -10.2 | - 3.9 |
| Irrigated | | | | 34.6 | | 10.1 | | 29.9 | - 4.2 | 12.3 | 4.6 |
| Total | | | | | | | | | | | - 2.7 |
| Silage: | | | | | | | | | | | |
| Dryland | .5 | - 1.2 | - 1.5 | - 2.2 | .6 | 0 | - 2.5 | - .5 | - 1.0 | | 1.0 |
| Irrigated | | | | - 3.9 | | - 1.5 | - 3.3 | - 1.3 | - 2.7 | - 2.7 | - 2.9 |
| Total | | | | | | | | | | | .4 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | 21.1 | | | | 27.5 | 49.7 | | 4.9 | 28.2 |
| Regional change: | | | | | | | | | | | |
| Dryland | 14.3 | 11.0 | 8.5 | 8.5 | 11.2 | 19.3 | 12.5 | 21.5 | 10.2 | 19.6 | 11.3 |
| Irrigated | 0 | 0 | 20.0 | 23.3 | 0 | 16.9 | 35.2 | 5.6 | 4.5 | 4.7 | 12.3 |
| Cropland | 14.3 | 11.0 | 8.5 | 10.3 | 11.2 | 19.2 | 15.9 | 18.2 | 7.8 | 12.3 | 11.4 |

Appendix table 4--Percentage in dryland and irrigated crop acres from 1978 base acreage due to a 90-percent increase in export demand by USDA crop reporting region

| Crop | Northeast | Lake States | Corn Belt | Northern Plains | Appalachia | Southeast | Delta | Southern Plains | Mountain | Pacific | Crop change |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Percent | | | | | |
| Cotton: | | | | | | | | | | | |
| Dryland | | | 142.1 | | 60.2 | 32.6 | 62.2 | 10.8 | | | 31.9 |
| Irrigated | | | | | | | 214.0 | -33.0 | 146.4 | 6.2 | 13.1 |
| Total | | | | | | | | | | | 25.0 |
| Corn: | | | | | | | | | | | |
| Dryland | 21.6 | 14.7 | 15.2 | 19.1 | 61.2 | -33.1 | | 28.1 | - 3.2 | -12.7 | 16.9 |
| Irrigated | | | | 28.4 | | 4.0 | | 21.8 | - 9.9 | - 7.2 | 21.0 |
| Total | | | | | | | | | | | 17.3 |
| Soybeans: | | | | | | | | | | | |
| Dryland | 28.6 | 26.0 | 27.8 | 25.9 | 30.8 | 67.3 | 24.8 | 37.2 | | | 31.2 |
| Irrigated | | | | 40.1 | 92.3 | 50.8 | 102.5 | | | | 60.6 |
| Total | | | | | | | | | | | 31.8 |
| Wheat: | | | | | | | | | | | |
| Dryland | 265.0 | 73.8 | .9 | 24.4 | 158.6 | 52.2 | 30.2 | 13.0 | 43.7 | 47.0 | 32.3 |
| Irrigated | | | | 107.4 | | | | - 1.2 | 34.7 | 35.3 | 49.3 |
| Total | | | | | | | | | | | 33.1 |
| Sorghum: | | | | | | | | | | | |
| Dryland | | | 85.5 | 10.5 | | | - 7.7 | -26.4 | 59.4 | - 4.3 | 3.2 |
| Irrigated | | | | 21.1 | | | | 32.3 | -18.2 | -17.5 | 20.6 |
| Total | | | | | | | | | | | 6.0 |
| Barley: | | | | | | | | | | | |
| Dryland | 3.7 | -14.8 | | -17.2 | | | | | - 5.3 | -12.8 | -12.8 |
| Irrigated | | | | | | | | | -30.8 | -25.0 | -28.9 |
| Total | | | | | | | | | | | -16.4 |
| Oats: | | | | | | | | | | | |
| Dryland | - 3.6 | -17.6 | - .6 | -22.6 | | | | | | | -19.1 |
| Irrigated | | | | | | | | | | | 0 |
| Total | | | | | | | | | | | -19.1 |
| Hay: | | | | | | | | | | | |
| Dryland | 9.9 | 15.5 | - 3.0 | 3.9 | -82.1 | - 5.1 | -100.0 | 167.7 | -100.0 | -16.0 | - 4.2 |
| Irrigated | | | | 48.6 | | 14.7 | | 41.7 | - 7.2 | 16.7 | 5.4 |
| Total | | | | | | | | | | | - 2.8 |
| Silage: | | | | | | | | | | | |
| Dryland | .8 | - 1.8 | - 2.0 | - 3.3 | 1.1 | 0 | - 3.6 | - .5 | - 1.7 | | - 1.3 |
| Irrigated | | | | - 5.5 | | - 1.8 | - 4.7 | - 1.8 | - 3.8 | - 3.8 | - 4.2 |
| Total | | | | | | | | | | | - 1.8 |
| Rice: | | | | | | | | | | | |
| Irrigated | | | 28.0 | | | | 39.8 | 72.1 | | 7.2 | 40.9 |
| Regional change: | | | | | | | | | | | |
| Dryland | 21.1 | 16.3 | 12.3 | 12.7 | 16.1 | 27.7 | 18.6 | 30.9 | 16.1 | 29.3 | 16.6 |
| Irrigated | 0 | 0 | 28.0 | 33.4 | 0 | 24.0 | 50.7 | 8.9 | 6.3 | 6.8 | 17.8 |
| Cropland | 21.1 | 16.3 | 12.3 | 15.3 | 16.1 | 27.6 | 23.4 | 26.2 | 11.9 | 18.3 | 16.8 |