IMPLICATION OF ALTERNATIVE LAND USE POLICIES IN THE NORTH CENTRAL REGION*

Earl O. Heady and Brent W. Spaulding**

A long-expressed concern of the public, and especially of agriculturists, has been the conversion of prime agricultural land into nonfarm uses. This conversion was especially rapid in the postwar years when the domestic population was increasing rapidly, cities were shifting to the land-using suburbs and shopping centers, the nation's interstate highway system was implemented, and increased air travel required large increases in airport space. While agriculture had surplus producing capacity in most of the postwar period and government payments were used to hold land out of production, the concern over reallocation of land from agriculture to nonfarm uses still prevailed (USDA Committee on Land Use, 1975). Concern was especially intense over the use of the more productive agricultural lands for nonfarm uses.

The concern over the shift of prime land to nonagricultural uses became especially high in the mid-1970s when export demand for U. S. farm commodities was high and international activity on behalf of world food problems was intense. During this period, the Midwest Governor's Conference raised questions of alternative uses of prime agricultural lands in the Midwest region of the economy. At their request we initiated a study to explore some of these alternatives. The Midwest Governor's Conference includes North and South Dakota, Nebraska, Kansas, Oklahoma, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Kentucky, Michigan, Indiana, Ohio, and West Virginia. Since it covered most of the Midwest, the North Central Region Agricultural Experiment Station Directors Organization was asked to finance the study on behalf of the respective state governments. Since they belonged to other regional experiment station organizations, Oklahoma, Kentucky and West Virginia could not be included. Consequently, the study refers only to the North Central Region of the U. S.

In addition to its concern with diversion of prime agricultural land to nonagricultural uses, the Midwest Governor's Conference was also concerned with the preservation of fragile lands, protection of the soil from erosion and the possibility of improved recreational use. These dimensions were incorporated into the study.

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**Curtiss Distinguished Professor and Director of the Center for Agricultural and Rural Development, Iowa State University and Assistant Professor, University of Arkansas, respectively.

Objectives of Study

A major objective of this study was to analyze the potential impact if prime land in the North Central Region were used only for agricultural purposes. What impact would this restriction have on the interregional distribution of food production, the supply and export capacity of U. S. agriculture, on regional and national resource use and on the supply prices of agricultural commodities? This analysis was made by means of a national and interregional linear programming model. However, since there are other facets of preserving the services of land, the impacts of alternative policies were also analyzed. These policies include (a) returning fragile lands to pasture, forestry or natural habitat; (b) allocation of more land to direct human uses such as parks and green belts; and (c) protecting land productivity by reducing soil erosion.

The 48 contiguous states in the U. S. were delineated into 105 producing areas or regions, each an aggregation of contiguous counties, consistent with the U. S. Water Resources Councils [8], aggregated subarea (ASA) boundaries as defined for the 1975 National Water Assessment. The producing areas containing the North Central Region states were further delineated into 85 producing areas within the region. These spatial entities were used to allow the comparative advantage of each to be expressed so that interested state personnel could develop land use planning and educational programs at substate levels. Summaries also were made by states of the region and for the North Central Region in total. Land use possibilities cannot be evaluated properly for the North Central Region without reference to the rest of the nation. Therefore, to allow expression of comparative advantage relating to soil productivity, climate and water supplies, the land area of states outside the North Central Region also was disaggregated into producing areas consistent with the ASA boundaries. These spatial disaggregations allowed the North Central Region and its "community components" to be analyzed in the framework of the nation's land inventory.

Alternatives Analyzed

As a basis for comparison of alternative land use futures in the North Central Region, a "Base Solution" was first analyzed. It is based on a projection of ongoing trends to the year 2000.

Base Solution. The Base Solution provides an indication of the magnitude and direction of change that might be experienced if effort is not made to direct the agricultural sector aside from influences already in operation as ongoing forces continue in current patterns. It provides a base against which the relative advantages or disadvantages of alternative policies can be measured. Land use in the Base Solution is compared with the alternatives explained below. Subject to the constraints of the Base Solution, an optimal land use pattern is computed by the programming model.

The following alternatives are compared with the Base Solution for the year 2000:

Prime Lands Alternative. This alternative represents a prime lands retention program. Lands in the North Central Region (only) most suited for agricultural

use, classes I and II of the Soil Conservation Service, Klingebiel and Montgomery [3], are required under this scenario to be maintained in agricultural uses. Nonagricultural development is shifted to lands less suited for agricultural purposes.

The North Central Region contains more than 55 percent of the nation's total cropland and more than 64 percent of its prime cropland as defined in this study. More than 61 percent of the North Central Region's total land falls in the prime land category and 76 percent of the latter is in crops.

Fragile Lands Alternative. In this alternative lands generally considered unsuitable for agriculture in the North Central Region (only) are diverted away from cultivated production activities. This policy returns these lands to pasture, forests, or natural habitat; thereby increasing open lands both in agricultural areas and near urban areas. These fragile lands are not used to a great extent in cultivated agriculture except in some areas of the Great Plains susceptible to wind erosion. Fragile lands, those susceptible to water or wind erosion, include classes V through VIII, Klingebiel and Montgomery [3], class IVe.

The Environmental Corridor Alternative. This alternative requires land to be diverted into nonagricultural uses in the North Central Region only. These uses are for increased recreational and open space areas such as parks and nature preserves within or near populated areas.

Soil Loss Abatement Alternative. In parts of the North Central Region, rainfall and the agricultural production patterns together cause excessive soil erosion. The Soil Loss Abatement Alternative entails shifts in production methods and regional production patterns to lessen erosion and maintain land productivity in the North Central Region only. Land of each class in each producing area is restrained to a soil loss level to maintain its yield and productivity over time. The Universal Soil Loss Equation, Wischmeier and Smith [9], is used in calculating soil loss rates according to soil type, degree of slope, length of slope and climatic factors.

Land Classification and Delineation

Numerous definitions of prime lands prevail. A quantitative proxy for prime land was necessary for this study. Other land classes also had to be designated. Throughout the paper reference is made to various classes of land or land characteristics. These classes are based on the Soil Conservation Service's (SCS) land capability classes and subclasses, Klingebiel and Montgomery [3]. The nine land classes (I through VIII including IVe) used in this study reflect aggregations of the numerous capability classes and subclasses of the SCS, Nicol and Heady [5]. For reporting purposes, these nine land classes are then aggregated into five classifications. The classifications and terminology used are: Prime lands are capability classes I and II of the SCS. Fragile lands are all of capability classes V, VI, VII, and VIII of SCS with subclass IVe included when susceptible to wind erosion. Lands suited to agriculture are

capability classes I, II, III and IV. Lands not generally suited to agriculture are capability classes V, VI, VII, and VIII. Erosion susceptible lands are capability subclasses designated by e.

Model Summary

The national programming model included the 105 producing areas as explained previously. The nine land classes of the SCS are used as restraints in each of these 105 producing areas. Water supplies for irrigated lands were defined in producing areas in the western states to serve as restraints on production within the producing areas. The 105 producing areas were aggregated into 28 commodity market regions. The national demand quantities (the amounts of crops to be produced), were determined exogenously and inserted in the programming model and were defined for each of the commodity market regions as constraints to be met. The demand quantities are based on a set of econometrically estimated demand functions, Nicol and Heady [5]. Commodity supply prices are determined endogenously. A transportation submodel connects the market regions and allows interregional competition to prevail. A "central city" is selected for each region and rail transportation costs are charged between each pair of "central cities." Transshipment also is allowed.

Land for nonagricultural uses to the year 2000 is determined by a land use adjustment submodel, Spaulding and Heady [7]. The amount of land thus determined is subtracted from the existing supply of agricultural land. Land used for agricultural purposes is then determined endogenously within the programming model for each producing area.

The basic model has a set of constraint equations for each producing area, water supply region, and market region. Also, quantity or constraint equations at the national level are specified for cotton and sugar beets. To summarize these equations, we select a typical producing area in the North Central Region which has irrigation, a water supply region, and a commodity market region.

Producing Area. Each producing area has constraints for land availability by the nine dry and irrigated land classes, land constraints controlling the level of producing of eight crops, and a constraint to balance water supply and use in the appropriate areas. The equations for the ith producing area are:

Dryland restraint by land class

$$(1)\quad \sum_{k}\sum_{m} X_{ijkm}\, AD_{ijkm} + LD_{i}\, LDP_{ij} \leq DA_{ij}$$

$i = 1, \ldots, 105$ for the producing areas,

$j = 1, \ldots, 9$ for the land classes in the producing area,

$k = 1, \ldots, 330$ for the defined crop rotations (cropping systems), and

$m = 1, \ldots, 12$ for the conservation-tillage alternatives (practices such as contouring, terracing, strip cropping, conventional tillage and minimum tillage which affect the rate of soil erosion).

Irrigated land restraint by land class

$$(2)\quad \sum_{k}\sum_{m} X_{ijkm}\, AI_{ijkm} \leq IA_{ij}$$

$i = 48, \ldots, 105$ for the producing areas, and

$j = 10, \ldots, 18$ for the land classes in the producing area.

Crop acreage restraints

$$(3)\quad MINA_{iu} \leq \sum_{j}\sum_{k}\sum_{m} X_{ijkm}\, W_{ijkmu} \leq MAXA_{ij}$$

$i = 1, \ldots, 105$ for the producing areas,

$j = 1, \ldots, 18$ for the land classes in the producing area, and

$u = 2, 3, 4, 11, 12, 13, 14, 15$ for the crops.[1]

Hay acreage restraint (transferred to the market region for areas outside the North Central Region)

$$(4)\quad \sum_{j}\sum_{k}\sum_{m} X_{ijkm}\, W_{ijkm5} \leq HR_{i} \sum_{j}\sum_{k}\sum_{m} X_{ijkm}\, W_{ijkm6}$$

$$+ \sum_{j}\sum_{k}\sum_{m} X_{ijkm}\, W_{ijkm6}$$

$i = 1, \ldots, 105$ for the producing areas, and

$j = 1, \ldots, 18$ for the land classes in the producing areas

where

X_{ijkm} is the level of rotation k using conservation-tillage method m on land class j in producing area i;

AD_{ijkm} is the acres of dryland used per unit of rotation k using conservation-tillage method m on land class j in producing area i;

AI_{ijkm} is the acres of irrigated land used per unit of rotation k using conservation-tillage method m on land class j in producing area i;

DA_{ij} is the acres of dryland available on land class j in producing area i;

IA_{ij} is the acres of irrigated land available on land class j in producing area i;

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[1]The crops restrained include corn, corn silage, cotton, sorghum, sorghum silage, soybeans, sugar beets and wheat. Barley, oats, and nonlegume hay are restrained at the market region level to help reduce the side of the model. (There are only 28 market regions as compared to 105 producing areas.)

LD_i is the level of land drainage in producing area i;

LDP_{ij} is the proportion of the land drainage in producing area i which is on land class j;

W_{ijkmu} is the rotation weight for crop u in rotation k using conservation-tillage method m on land class j in producing area i;

$MINA_{iu}$ is the minimum acreage of crop u required in producing area i;

$MAXA_{iu}$ is the maximum acreage of crop u allowed in producing area i; and

HR_i is the proportion of all hay which can be legume hay in producing area i.

Water supplies and irrigation activities are defined in producing areas 48-105. Respective equations (not explained here) control the allocation of water to the endogenously determined (i.e., determined within the model) agricultural uses, Nicol and Heady [5].

Commodity Market Regions. Each commodity market region has a set of equations as in (5) to balance the supply and demand of the commodities. Demands are estimated from the population and per capita incomes of the regions.

Commodity balance equation

$$(5)\quad \sum_i \sum_j \sum_k \sum_m X_{ijkmn} W_{ijkmu} CY_{ijkmsu} - \Sigma T_{nst} - \Sigma WH_i DA_{is} \leq CD_{ns}$$

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

s = 1, 2, 4, ..., 13, 15 for the commodities balanced at the market region, and

t = 1, ..., 176 for the transportation activities defined.

where

X_{ijkmn} is the level of crop rotation k using conservation-tillage method m on land class j in producing area i which is included in market region n;

W_{ijkmu} is the weight of crop u in rotation k using conservation-tillage method m on land class j in producing area i;

CY_{ijkmsu} is the per acre production of commodity s from crop u in rotation k using conservation-tillage method m on land class j in producing area i;

CD_{ns} is the exogenously determined demand for commodity s in market region n;

T_{nst} is the net export commodity s over transportation route t defined in market region n;

WH_i is the level of irrigated to dryland pasture conversion in producing area i; and

DA_{is} is the reduction in yield of commodities associated with the conversion of an acre of irrigated pasture to dryland pasture in producing area i. $DA_{is} = 0$ for all $s \neq 5$.

As mentioned previously, national equations were used to balance supplies and demand for cotton and sugar beets.

Endogenous Commodities. Endogenous commodities are those whose (a) quantities of production by producing regions, and (b) shadow prices are determined through solution of the model. They include corn, oats, barley, wheat, grain sorghum, corn silage, sorghum silage, all types of tame and wild hay, and summer fallow. Soil loss coefficients are defined for each crop in each land class grown under each of three conservation measures (terracing, contouring and strip cropping) and three tillage practices (conventional tillage, minimum tillage and residue management) which also affect annual soil loss per acre. Exogenous crop commodities, which use less than one percent of the nation's agricultural land include fruits, vegetables, nuts, and miscellaneous crops.

Objective Function. Subject to the constraints outlined, the objective function minimizes the national costs of producing and transporting agricultural commodities. Except for the policies which restrain land use, competitive equilibrium is assumed with resources, except land and water, receiving their market rate of return. Returns to land and water are determined endogenously. Surface irrigation water can be transported from one producing area downstream to another producing area.

No government supply control program is used for the study. The policy which prevents prime lands from being used for nonfarm uses is executed simply by supposing that only agriculture can use this land. Nonagricultural uses must come from other land classes. Similarly, the fragile lands alternative is executed by allowing this land to be used only for pasture, forests or natural habitats. The abatement of soil loss is executed through calculation of soil loss coefficient for each crop and tillage method used in the model. The annual soil loss per acre for each land class in each producing area is set at a level which will not impair soil productivity, Wischmeier and Smith [9].

Programming Results

The United States has such a large supply of cropland relative to domestic demands that it has considerable flexibility in land use and export alternatives. About 16 percent of total agricultural output is exported. Even then, agriculture frequently is in a "surplus" situation and public programs and funds are used to restrict production and to support prices above the market levels. Within this framework the country or any of the major regions and states is faced with trade-offs among alternatives.

Base Solution. Under the Base Solution, which does not have any restrictions on agricultural land use, the North Central Region would lose 6 million acres capable of producing about 600 million bushels of corn to nonagricultural uses by the year 2000. The region and nation would remain large exporters, however. Partially offsetting the loss of this existing cropland, some 8.3 million acres of wetlands not now cropped would be brought into production. Most wetland development would occur in the eastern and northern parts of the region, with the remainder in the lower Mississippi Valley.

Under the trend conditions of the Base Solution, corn production in the region would increase by 32 percent in 2000 while land devoted to corn would decline by nine percent. Greater production from fewer acres in 2000, as compared to the present, would be possible from new technology and an increased concentration of grains within the region in conformance with comparative advantage. (Higher per acre yields are projected exogenously for all alternatives analyzed.) Under the Base Solution, grains would use 87 percent of the total cropland as compared to only 68 percent in the period 1972-76. Inroads on cropland by nonagricultural uses would come mainly at the expense of hay, pasture and miscellaneous crops within the North Central Region.

Prime Land Retention. Under the Base Solution the North Central Region would lose 9.3 million acres of cropland to urban uses by 2000, and 3.8 million acres of this would be land capability classes I and II, prime cropland. (These shifts of land to urban uses are projected exogenously based on 1960-75 trends by cities and towns within the North Central Region.) Under the Prime Lands Alternative, this prime land would be retained in agriculture, with less productive land classes converted to nonagricultural use. Hence, projected supply capacity of the North Central Region for 2000 is greater than under the Base Solution. Consequently, supply prices for agricultural commodities are four percent lower under the policy of prime land retention. Income to agriculture in the region in 2000 also is somewhat less under the Prime Lands Alternative than under trend condition of the Base Solution. However, since it retains prime land for agricultural uses, the region's supply capacity remains larger relative to other regions of the nation which do not preserve prime land. Hence, while income of the nation's agriculture declines under the Prime Lands Alternative, the reduction is less in the North Central Region than in other regions. States within the region such as Illinois gain in income relative to states such as South Dakota under the Prime Lands Alternative. (Illinois, Indiana and Ohio have nearly 50 percent of prime lands transferred to nonagricultural uses under the Base Solution.)

Compared to the Base Solution, returns to land (weighted average shadow prices of land) decline by approximately 10 percent for both dryland and irrigated land at the national level under the Prime Lands Alternative as commodity supply prices are reduced. As mentioned previously, supply prices decline since greater supply capacity is retained under the Prime Lands Alternative. Urban uses draw on land classes other than prime in the North Central Region. Declines in land returns are, respectively, 9.9 and 4.7 percent in the North Central Region and 12.5 and 12.0 percent in other regions. The differential prevails because relatively more prime lands are retained in the North Central Region than elsewhere in the nation. Under the Prime Lands Alternative, the North Central Region

is projected to increase its relative share of national agricultural output, farm income and resource values as compared to other regions of the country.

Fragile Land Retention. Whereas the Prime Lands Alternative saves land and productive capacity, the Fragile Lands Alternative withdraws land and reduces agricultural supply power in the North Central Region. As compared to the Base Solution and the Prime Lands Alternative, land is relatively more scarce and both commodity shadow prices and land rents increase accordingly. Grain shadow prices average 5.1 percent higher, both nationally and in the North Central Region, in the Fragile Lands Alternative compared to the Base Solution. Land rents (weighted shadow prices) for the North Central Region increase by 11.4 percent for dryland and 12.1 percent for irrigated land as compared to the Base Solution. Average land rents for the rest of the nation increase by 11.4 and 17.5 percent, respectively, for dryland and irrigated land under the Fragile Lands Alternative even though protection of fragile lands occurs only in the North Central Region.

Environmental Corridor. The Environmental Corridor Alternative also withdraws land from cropping activities of the North Central Region. For the analysis of other alternatives, a survey was made of per capita land use in metropolitan areas of the North Central Region, Spaulding and Heady [7]. These coefficients were then multiplied by the population projected to 2000. For the Environmental Corridor Alternative, however, per capita nonagricultural use for 2000 was increased. The National Recreation and Park Association (NRPA) recommends a minimum of 25 percent of all land in new towns, planned unit developments, and large subdivisions be devoted to parks, recreational lands, and open space, Buechner [1]. The Environmental Corridor Alternative simulates the adoption of the NRPA's recommended 25 percent standard in the North Central Region only.

The alternative assumes a greater withdrawal of land for nonagricultural use than any other alternative. Historically, urban settlements tended to be located on the more productive, level lands. As cities expanded a high proportion of land thus came from quality cropland.

The added use of land per person under the Environmental Corridor Alternative is relatively small and the impact of this alternative is generally small in the entire region. The impact is larger, of course, around cities such as Chicago, St. Louis, Kansas City, Detroit, and Columbus. Under the Environmental Corridor Alternative corn shifts somewhat out of the region because more prime land is diverted to urban uses. More wheat tends to shift into the region because of its relative advantage on land classes III and IV.

The Environmental Corridor Alternative uses 469,000 acres more of prime land for nonagricultural uses than does the Base Solution. However, the Environmental Corridor Alternative shifts an additional 647,000 acres of land in classes III and IV to crops in the North Central Region. Since the added land required under the Environmental Corridor Alternative is small compared with the Base Solution, supply prices of commodities increase slightly. The increase is so small that it translates into an unnoticeable change in food prices. The shadow prices of land change somewhat more. Weighted average shadow prices for all land

classes increase by 1.9 percent for dryland and 3.1 percent for irrigated land in the United States, as compared to the Base Solution. The corresponding figures are, respectively, 1.7 and 1.6 percent for the North Central Region. Based on agricultural uses only, average weighted shadow prices of land classes III and IV increase by 8.4 percent as compared to only 1.2 percent for classes I and II (prime lands) under the environmental Corridor Alternative as compared to the Base Solution. Relatively, a greater agricultural production burden falls on land classes III and IV than on classes I and II in the region.

Soil Loss Abatement. In contrast to those alternatives which preserve prime or fragile lands in agriculture, the Soil Loss Abatement Alternative preserves land through reduction of soil erosion. It implements the erosion reduction alternative only in the North Central Region. Under this alternative this annual soil loss per acre is limited to each soil's erosion tolerance or t-value, Nicol and Heady [5].

Average annual soil loss per acre in the North Central Region decreases from 4.11 tons per acre under the Base Solution to 2.09 tons under the Soil Loss Abatement Alternative. Annual loss per acre increases slightly on classes I and II but decreases from 7.5 tons to 4.0 tons per year on classes III and IV and from 6.4 to 3.2 on classes V-VIII. As soil loss is restrained on classes III-VIII, more intensive cropping of classes I and II occurs. Reductions in particular states and producing areas of the region are, of course, much larger. For Missouri, the average reduction is from 9.5 to 4.9 tons. On land classes III and IV in Nebraska, the reduction is from 14.3 to 7.8 tons.

The Soil Loss Abatement Alternative has no great effect on the total acres or mix of crops grown in the region. While fewer row crops are grown on the steeper land classes, more corn and soybeans are shifted to land classes I and II while small grains and hays shift from classes I and II to classes III-VIII. To prevent soil loss, straight-row farming decreases by 15 percent, contouring increases by 10 percent and strip cropping increases by 6 percent under the Soil Loss Abatement Alternative as compared to the Base Solution. Minimum tillage farming increases by 7 percent. The shift of crops among land classes dampens somewhat the amount of conservation practices needed to bring soil loss down to restrained levels.

Land shadow prices for the United States increase by 8.3 percent under the Soil Loss Abatement Alternative. They increase in the North Central Region by 7.7 percent and by 9.6 percent outside the region. In the North Central Region, a higher return to land is partially cancelled by the increased production costs in complying with the soil loss restriction. Areas outside the North Central Region benefit by being able to grow higher-valued crops without introducing costly erosion control practices.

General Implications. The North Central Region includes a major proportion of the nation's prime lands and total grain and livestock production. However, the supply of prime and other lands, both in the region and the nation, is so large that numerous regional land use policies could be applied without undue burdens on consumers in the form of increased food costs. Intense competition between "reasonableness" in food costs would occur only in periods of very large

export demands (presumably caused by crop short-falls elsewhere in the world). This possibility has historic verification. Prior to 1972 the government paid farmers to leave land idle from cropping. With crop shortfalls in Russia in 1972 and 1975, all land shifted back to crops, grain prices soared and food costs quickly inflated. But with more nearly normal weather over the world, U. S. grain prices declined markedly in 1977. Consequently, the Secretary of Agriculture proposed that wheat plantings be reduced by 20 percent and feed grain plantings by 10 percent in 1978. Thus, unless export demand pressure burdens U. S. agriculture, the nation at large has no intense land scarcity problem. Hence, endangered food supplies or extremely high real prices for food do not seem likely under ongoing trends (the Base Solution) in use of land in the North Central Region. Diversion of prime land to urban uses at the rate of past trends in the region would still leave the nation with great food supply and exporting capacity.

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