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Supply of potential cropland in Iowa

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CHAPTER I. INTRODUCTION

This study investigates Iowa's supply of potential cropland under alternative assumptions of output prices, input costs, agricultural practices, and soil erosion control measures.

Unlike the total land area of a given region, the quantity of cropland can be either increased or decreased. A decrease in the quantity of cropland results from the conversion of cropland to noncropland, i.e., the so-called "urban sprawl," and has been investigated by Gibson [11] and Lee [19]. The alternative possibility, in which the quantity of cropland is increased through the conversion of noncropland to cropland, is investigated in this study.

The shift from one land use to another constitutes part of the land use process. The change in the quantity of cropland is one activity in this process. An underlying force in the land use process is the economic motive provided by higher returns to more capital intensive land use.

While higher economic returns usually constitute the major goal for the private owner and operator of land, society seeks benefits from the attainment of several goals. The United States Water Resources Council [45] has stated four goals within the societal context. They are i) enhancement of economic growth and development of the nation, ii) the enhancement of the quality of the environment, iii) regional development, and iv) social well-being. Lundeen [22, p. 201] pursued this topic further, and in a survey of central Iowa residents, three of the goals were ranked in the following order: first, environmental quality; second, regional economic development; and third, social well-being.

In the context of converting less capital intensive noncropland to more capital intensive cropland, two of these goals are of central importance. Economic growth or a higher Gross National Product (GNP) may result from agricultural production on the increased quantity of cropland. The quality of the natural environment affected by soil erosion, pesticides, fertilizers and the destruction of wildlife habitats, is also important. Conversion of noncropland to cropland usually provides positive impact on the overall welfare of society through increased GNP. But negative impacts on environmental quality may also be produced. This is characteristic of an economic problem whereby a single action produces diverse effects.

Need for Research into Potential Supply of Cropland

Two factors motivate inquiry into the supply of potential cropland. One is the uncertainty surrounding potential increases in agricultural production needed to meet future increases in demand. The other is the possible consequences of increased cropland on quality of the environment.

Agricultural production

Future increases in agricultural production can occur in two major ways, either i) by increasing the yields on the present quantity of cropland, and/or ii) by increasing the total quantity of cropland. The former method is hereafter referred to as intensive agricultural expansion, or expansion on intensive margins of cultivation. The latter method is hereafter referred to as extensive agricultural expansion, or expansion on extensive margins of cultivation. If an increase in agricultural production is needed in the future to satisfy increased demands, and this increase cannot be completely satisfied on the intensive margins, then expansion on the extensive margins will necessarily occur.

Agrigultural production is generally increased on the intensive and extensive margins simultaneously. As crop prices increase there is incentive to increase agricultural production on both the intensive and extensive margins. However, physical or technological constraints might prevent expansion on either margin of production. At the extreme, if all land is used for cropland, then it is physically impossible to convert noncropland to cropland. Alternatively, it is conceivable that the physical limits of intensive expansion could be reached, where additional quantities of inputs on a given quantity of cropland would not increase output, i.e. where the marginal product of inputs equal zero.

This can be explained in terms of crop prices and factor input costs. If there is absolutely no noncropland that could be converted to cropland, then obviously an increase in crop prices would increase agricultural production on the intensive margins but not on the extensive margins. Alternatively, if the marginal product of factor inputs on the intensive margin is zero, then an increase in crop prices would increase agricultural production on the extensive margins but not on the intensive margins.

Both examples cited above are extreme cases, with reality lying somewhere in between, where expansion of agricultural production occurs to some degree on both margins. However, it is argued in the following pages and in Chapter II, that reality lies closer to the latter example, in which the physical limits to increased production on the intensive margin are being approached.

In recent years, concern has arisen whether future increases in the demand for U.S. agricultural products can be satisfied on the intensive margins of production. Four major factors have lead to increases on the intensive margins during and since World War II. These factors may well be limited in the future.

First, the increased use of fertilizer has paralleled the increase in crop yields from 1940 to 1970. Evidence indicates that present fertilizer applications are at or near recommended levels [46]. Further increases in fertilizer applications are not likely to increase yields appreciably but might reduce environmental quality.

Second, the use of pesticides has also aided the increase in crop yields. However, pesticides may be hazardous to animal life, including humans, and due to their persistence in the environment, public agencies are scrutinizing the use of such chemicals. The Environmental Protection Agency (EPA) has already banned several pesticides, and if more are banned, not only will future increases in yields become questionable but maintenance of present yields may become difficult.

Third, the mechanization of U.S. agriculture since World War II has required greater amounts of energy. If petroleum or natural gas resources become more scarce and expensive through depletion and resulting shortages, then U.S. agriculture may not be able to continue current farming techniques and consequently yields might be diminished.[1]

The fourth factor which has contributed to increased crop yields since World War II has been genetic technology in terms of seed and plant varieties. Whether there are any major genetic breakthroughs on the horizon is currently unknown. However, there remains serious question whether future increases in yields resulting from technological innovation can match the rate of growth in crop yields during the three decades following World War II.

The foregoing discussion of potential increases on the intensive margins of agricultural production was not intended as a definitive discussion of the subject, nor a conclusive argument for one position or the other. It was intended to show that sufficient uncertainty exists with respect to agricultural production expansion on the intensive margins that a portion of the future increases in agricultural production might well occur through expansion on the extensive margins of agriculture production in terms of noncropland conversions to cropland. Thus, the question arises regarding how far the U.S. can expand production on the extensive margins of production. Estimates of the potential supply of U.S. cropland range from 15 million acres [20, p. 7] to 264 million acres [13, p. 13] beyond the present quantity of about 450 million acres

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[1]This assumes that product prices and nonenergy input costs remain unchanged. It is possible that rising product prices or falling nonenergy input costs could offset an increase in energy prices.

of cropland [42]. It is not clear, given the range of these estimates, that U.S. agriculture has sufficient capacity on the extensive margins of production to satisfy future demand if the intensive margins of production are constrained. In addition, since potential cropland is generally less productive; a 50% increase in the quantity of cropland does not necessarily imply a 50% increase in agricultural production.

The pressure on extensive expansion due to limited increases in crop yields is compounded by a continual conversion of cropland to nonfarm uses. It has been estimated that 2.5 million acres of cropland in the U.S. are annually converted to urban, highway and other special uses [25, p. 149].[1] This process could continue in the near future. Therefore, if sufficient intensive expansion does not occur, extensive expansion will be necessary in order to satisfy future demands projected at current rates of increase.

It is within the context of potential constraints on increased agricultural production on the intensive margins that this study investigates the extensive margins of agricultural production. Throughout the investigation increases in agricultural production on the intensive margins are assumed to remain unchanged. This approach is justified by i) the need to understand the process underlying expansion of agricultural production on the extensive

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[1] Although the conversion of cropland to urban, highway and other special uses decreases agricultural production in the short run, it might augment production in the long run, by increasing the efficiency of transportation and other infrastructures supplied by urban areas.

margins, and ii) distinct possibility that agricultural production on the intensive margins may be limited in the next few decades.

Environmental quality

Future expansion of U.S. agricultural production on extensive margins can have severe impacts on the quality of the environment. Perhaps the most significant impact results from increased soil erosion. Extensive agricultural expansion appears likely to be accompanied by increased soil erosion due to i) greater quantity of cropland and ii) noncropland converted to cropland is likely to be more highly erosive due to steeper slopes.

Soil erosion decreases environmental quality in two ways: i) suspended silt, entering water cources, increases turbidity of the water: and ii) eroded soil also acts as a transport agent through adsorption and absorption, carrying fertilizers, pesticides and other materials which further deteriorate water quality [4, p. 8; 48, p. 10].

Extensive expansion of agricultural production also results in increased use of fertilizers and pesticides on additional land. These chemicals not only enter water cources with sediment, but also enter groundwater through leaching. Pesticides are usually persistent chemicals and can have a significant effect on the ecology of an area once they enter the food chain.

An additional problem is the destruction of natural wildlife habitats. Some part of the agricultural expansion on the extensive margins will likely include the conversion of forest, brush, meadow and swamp land to cropland. This type of land is the habitat of many wildlife forms, some of which may be near extinction. The destruction of such natural environments can upset the ecology of an area with wide ranging ramifications that may not be apparent or even currently understood.

Objectives of Study

The specific objectives guiding this research are:

1. To estimate the supply of potential cropland under alternative assumptions of output prices, input costs, agricultural practices, and soil erosior control measures;

2. To estimate the costs of converting noncropland to cropland, including initial investment costs and opportunity costs of foregone production;

3. To estimate the net value productivity potential of noncropland after conversion to cropland, under alternative assumption of output prices, input costs, agricultural practices, and soil erosion control measure;

4. To develop a model and methodology that will enable achievement of the three previous objectives and to apply the model to Iowa; and

5. To suggest further research needs for expanding the refining methodologies and results developed in this study.

Procedures Used in Pursuit of Objectives

The five stated objectives are pursued by the development of the theoretical foundations and an analytical model applied to the conversion of noncropland to cropland. The analytical model is applied to Iowa, using data from published and unpublished sources and from original data obtained for this study.

Organization of Report

Information contained in this report is organized into six chapters. Chapter I contains introductory statements of the study, indicating the general problem, study objectives and the motivation behind this research. Chapter II discusses in greater detail expansion of agricultural production on the extensive margins. The theoretical foundations involved in the conversion of noncropland to cropland are outlined in Chapter III. Chapter IV sets forth the analytical model and Chapter V applies this model to Iowa, with a discussion of results. Chapter VI contains a summary of results, conclusions drawn and recommendations for further research prompted by results and experience gained in this study.

CHAPTER II. EXTENSIVE AGRICULTURAL EXPANSION

This chapter develops the nature and ramifications of problems involving expansion of agricultural production on the extensive margins of production. Previous estimates of the potential supply of cropland are examined. Next, recent trends in U.S. and Iowa agriculture are presented, indicating interrelations and trade-offs between extensive and intensive expansions. Next, evidence of limits to future increases in crop yields are presented. Finally, ramifications of soil erosion resulting from agricultural expansion on the extensive margins of production, are examined.

Previous Estimates of Potential Supply of Cropland in the U.S.

In recent years, several estimates of the supply of potential cropland in the U.S. have been published. The range and variability of these estimates lead to considerable uncertainty for the direction public policy should take with respect to this issue. Frey and Otte [10, p. 9], and Heady and Timmons [13, p. 13], using the 1967 National Inventory of Soil and Water Conservation Needs (CNI) [36], have estimated the supply of potential cropland in the U.S. at approximately 265 million acres beyond the current cropland base of 450 million acres.

This estimate of 265 million acres is comprised of all noncropland, i.e., pasture, forest and other land, in Soil Conservation Service (SCS) capability classes I, II and III.[1] Excluded from the estimate are urban land, federally owned noncropland and land in SCS capability classes IV-VIII. Even though class IV land is excluded from this estimate Frey and Otte state:

> Class IV land has much less potential for cultivation but must be considered in any appraisal of potential cropland. With very severe limitations for both choice of crops and for latitude of management, it may be suited to only two or three of the common crops or yields may be low relative to inputs. Some is fit only for intermediate cultivation [10, p. 9].

An estimated 131 million acres of land is in SCS capability class IV.

The 396 million acres in SCS capability classes I-IV according to the Frey and Otte study, represent an upper limit for expansion on the extensive margins of production. All other land excluded from the estimated 396 million acres has extremely low potential for cropland. For example, all urban land would require considerable investment cost under existing technology and would likely be unprofitable for any foreseeable economic conditions. Federally owned noncropland has slight potential for cropland because its conversion to cropland would require direct government intervention. The scope of this study is limited to the conversion of noncropland to cropland due to changes in crop prices. Classes V through VIII, as Frey and Otte state: ". . . are generally unsuited for cultivation [10, p. 8]," even though some class V-VIII land

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[1]Throughout this chapter the phrase "the supply of potential cropland" is used to refer to noncropland that could be converted to cropland. It does not include the present quantity of cropland, nor cropland beyond the 48 contiguous states.

may be suited for crops with unique requirements, such as rice.

Cotner, Skold and Krause subdivide the 265 million acres in capability classes I-III into a hierarchy of potential cropland:

> Estimates of high, medium or low conversion-to-crop land potential were obtained by combining the physical capability characteristics provided by the CNI with the regional economic problems and trends as revealed by cropland trend data. We were able to stratify the 265 million potential cropland acres according to feasibility for reclamation after introducing some economic considerations [6, p. 11].

This hierarchy of potential cropland is presented in Table 2.1. High and medium potential land was disaggregated into short run, which could be converted in a year and long run which would require larger investments and thus require a longer time for conversion.

A more recent (1975) survey by the Soil Conservation Service (SCS) of the USDA refined the 1967 CNI estimates of potential cropland. The Potential Cropland Survey (PCS) [37] also ranked potential cropland as either high, medium or low, but based on different criteria. Lee summarizes the criteria as follows:

> A sample point was to be classified as high potential land if based on 1974 price-cost relationships, the probability of conversion to cropland in the foreseeable future (10-15 years) was high. This decision was to be based on evidence that similar land had been converted to cropland in the county within the last three years. Zero potential land was to include desert, mountains, and land preempted for other uses. Low potential land was to include land having one or more very serious obstacles to development. Medium potential land was the residual category having neither high potential for development nor serious development problems [20, p. 9].

Table 2.1. Estimates of the potential supply of cropland in the U.S., Cotner, Skold and Krause[a]

Time for conversion	Potential				
	High (Million acres)	Medium (Million acres)	Subtotal High and Medium (Million acres)	Low[b] (Million acres)	Total High, Medium and Low (Million acres)
Short run[c]	68.2	29.2	97.4	--	--
Long run[d]	27.5	27.8	55.3	--	--
Total	95.7	57.0	152.7	111.8	264.5

[a]Source: [6, p. 12].

[b]Low potential land was not classified as short run or long run.

[c]Noncropland convertible to cropland within a period of one year.

[d]Noncropland convertible to cropland in a period greater than one year.

The 1975 (PCS) study estimated 78 million acres of land with high potential for cropland and 33 million acres of medium potential. An additional 905 million acres were classified as either low or zero potential for cropland. When developmental problems associated with conversion and quality of land are taken into consideration, only 15 million acres of potential cropland had no limitations [20, p. iii].

It is evident from the preceding discussion that there exists no single absolute estimate of the potential supply of cropland for the U.S. Table 2.2 summarizes estimates cited above, plus additional disaggregations to illustrate the range and nature of the supply of potential cropland. The first entry in category A of 10.6 million acres is based on the 1967 CNI, and is all land contained in capability class I. It is land, under the SCS classification system, well suited for cropland without any limitations. The second entry in category A is the estimate made by Lee based on the 1975 PCS. Like the first entry, this is an estimate of the quantity of cropland that could be added to the present supply of cropland with virtually no improvement expenses. For this reason these estimates are grouped together in category A. This category contains noncropland most likely to be converted to cropland if expansion occurs on extensive margin.

Table 2.2. Alternate estimates of the potential supply of cropland in the U.S.

Category		Description of noncropland	Original source of estimate	Potential cropland[a] (million acres)
A	1.	SCS Class I[b]	1967 CNI	10.6
	2.	High potential - No problems[c]	1975 PCS	15.0
B	3.	High potential - Short run[d]	1967 CNI	68.2
	4.	High potential[c]	1975 PCS	78.0
C	5.	High potential - Total[d]	1967 CNI	95.7
	6.	Short run[d]	1967 CNI	97.4
	7.	SCS classes I, II[b]	1967 CNI	110.5
	8.	High and medium potential[c]	1975 PCS	111.0
D	9.	High and medium potential[d]	1967 CNI	152.7
E	10.	SCS classes I,II,III[b]	1967 CNI	264.5
F	11.	SCS classes I,II,III IV[b]	1967 CNI	396.2

[a]The entries in Table 2.2 are cumulative. The estimates in the lower categories contain estimates in the previous categories from the respective source. That is Entry 11 in Category F from the 1967 CNI of 396.2 million acres, contains 264.5 million acres in entry 10 in Category E, which contains 110.5 million acres in entry 7 in Category C, etc.

[b]Source: [10, p. 9].

[c]Source: [20, p. iii].

[d]Source: [6 , p. 12].

Category B potential cropland consists of, i) 68.2 million acres, estimated by Cotner, Skold and Krause from the 1967 CNI as high potential land that could be converted within a year, and ii) Lee's estimate from the 1975 PCS of 78 million acres of high potential land. This category of land, although of high potential for cropland, has minor problems, which would require some improvement expenses.

Category C, in Table 2.2 contains, i) 95.7 million acres of high potential noncropland that could be converted in both the short run and long run, and ii) 97.4 million acres of noncropland of high and medium potential that could be converted in the short run. The first of these estimates views the potentiality of the noncropland in terms of feasibility of conversion to cropland based on economic considerations. The second estimate takes into consideration only the length of time for conversion. The final two entries in the third column are 110.5 million acres in SCS capability classes I and II from the 1967 CNI, and 111 million acres of high and medium potential land from the 1975 PCS. Like the other entries in the category E these estimates contain noncropland which would require moderate improvements before conversion to cropland.

D, E and F categories in Table 2.2 are extensions of the previous estimates containing noncropland which has lower potential. Category D is the total estimate of high and medium potential, 152.7 million acres, by Cotner et al. Categories E and F include 264.5 million acres in SCS capability classes I through III, and 396.2 million acres in SCS classes I through IV, respectively.

Table 2.2 illustrates the heterogeneous nature of noncropland with respect to its potential for cropland. While the 1975 PCS and Cotner, et al. estimates took into consideration current economic conditions in classifying land as either high, medium or low potential, all of the estimates in Table 2.2 lack an explicit price variable. If the economic conditions assumed in the 1975 PCS or by Cotner et al. change, then in all likelihood quantities of noncropland estimated as high or medium potential would also change. For example, with an unfavorable change in economic conditions from the farmers' point of view, a portion of high potential noncropland might become medium potential. It is also conceivable that some of the noncropland would reverse its order with a change in economic conditions, a portion of high potential noncropland might become medium potential, and a portion of medium potential might become high potential. This can be illustrated with two types of noncropland, pasture and forest. Under one set of economic conditions, taking into consideration potential crop yields, cost of improving land and crop prices, pasture land would have greater potential than forest land. But suppose economic conditions change, making improvement costs, e.g., the clearing of trees, relatively less expensive than before. It is feasible that the forest noncropland would be considered higher potential cropland than the pasture land. Without explicit economic variables, estimates of the supply of cropland are not able to remain valid under changing economic conditions.

Davis, in a study of the lower Mississippi and Southeast part of the U.S., attempts to incorporate an explicit economic variable [8]. The lower Mississippi Valley and the Southeast study area was divided into 15 land resource areas. In each land resource area the noncropland was classified by land capability class and subclass.[1] For each land capability class and subclass in a land resource area the most profitable crop was identified. The minimum price required to make this land profitable for conversion was calculated by dividing the total production costs per acre, including the land conversion costs, by the product yield per acre. This minimum product price was compared with the existing 1970 price to determine whether land could be profitably converted to cropland. Davis summarizes these estimates as follows:

> In the lower Mississippi Valley and the Southeast, 49 million acres--37 million from woodland and 12 million from pasture--could profitably be converted to cropland at 1970 costs and product prices. ...if there were a future need for it a total of 98.7 million acres in the region could be converted [8, p. iv).

It is evident that a single estimate of the supply of potential cropland can not be made without reservations, but like the supply of any resource or commodity, it depends on the state of technology and conditions of supply and demand. If crop prices and input costs are favorable to the farmer, then noncropland previously considered as low potential could be converted to cropland.

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[1]The SCS capability subclasses indicates the major hazards to production. They are: e--risk of erosion; w--wetness, drainage or overflow; s--limitations within the rooting zone; and c--climate limitations. For a complete explanation see [34, p. 2].

Recent Agricultural Trends

Future expansion of agricultural production can occur in two ways.[1] One way is by more intensely using the present quantity of cropland, and consequently increasing average yields. This mode of expansion dominated U.S. agriculture from 1950 to 1970. The other way is by increasing the quantity of planted cropland. From about 1970 to 1977, this second method of expansion was evident.

Recent trends in U.S. agriculture

Between 1949 and 1969 the quantity of planted cropland steadily declined, from 365 million acres in 1949 to 291 million acres in 1969 (Table 2.3). Also, during this same period yields steadily increased (Figure 2.1). Between 1970 and 1977, cropland planted increased from 293 million acres in 1970 to 343 million acres in 1977. Yields showed no clear trend during this period, and were approximately the same in 1977 as in 1970.

Based on these data, U.S. agriculture, since 1949 can be divided into two periods. From 1949 to 1969, increases in total agricultural production occurred predominantly on intensive margins with no significant increases in planted cropland acres. From 1970 to 1977, increases in agricultural production resulted, in some degree by increases in planted cropland acres.

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[1]Agricultural production also expands by a combination of the two ways.

Table 2.3. U.S. cropland planted and harvested, U.S. average corn yields, for selected years 1949-1977[a]

	1949	1960	1965	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
						(Millions of acres)							
Cropland													
Harvested	352	316	291	290	281	283	295	283	310	316	324	326	331
Planted	365	324	304	299	291	293	306	295	319	326	332	336	343
Yield						(Bushels per acre)							
Corn	38.9	54.7	62.9	79.5	85.9	72.4	88.1	97.0	91.3	71.9	86.3	87.9	90.8
Soybean	22.4	23.6	24.2	26.8	27.5	26.7	27.5	27.8	27.8	23.2	28.2	25.6	30.6

[a]Source: [40].

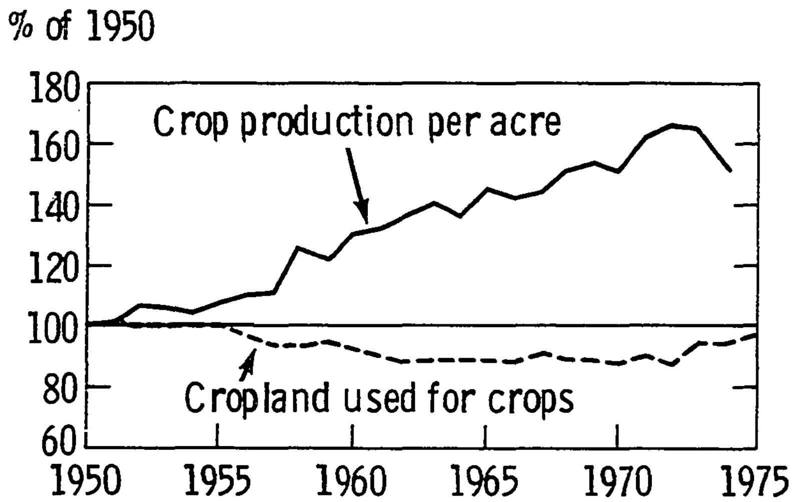

Figure 2.1. U.S. crop production per acre and cropland used for crops [6, p.6]

Increases in planted acres in the U.S. since 1970 can be attributed to two related factors. First, "free market" policies of the USDA to eliminate stocks and remove planting restrictions, encouraged farmers to increase agricultural production. Second, increased world demands for food, feed grains and soybean resulting from increased population and increased per capita income coupled with adverse weather conditions, led to increases in exports of U.S. agricultural products. Table 2.4 presents data for selected years from 1950-51 to 1977-78 of total U.S. grain exports.[1] These data indicate that in 1972-73, U.S. exports of grains increased dramatically, nearly doubling exports in the previous year. From 1972 to 1978, U.S. exports of grains remained higher than a simple extrapolation of historical trends from 1965 to 1972. During the period after 1972, U.S. share of total world grain exports increased to approximately one-half from the pre-1972 share of about one-third.

It is not surprising that crop prices began rising in 1973 in response to these increases in exports. Price indices for "All Crops", "Food Grains" and "Feed Grains and Hay" from 1965 to 1976 are presented in Table 2.5. All three indices remained relatively stable, showing a slight downward trend, between 1965 and 1971. Extreme values for this period were 88 and 108 (1967=100). In 1972 there was no noticeable change in the trend, how-

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[1]Total grains are defined to include wheat, wheat flour, corn, barley, oats, sorghum and rye excluding products [41].

Table 2.4. U.S. exports of total grains 1950-51 to 1977-78, selected years[a]

Year beginning July 1	Total U.S. grains exported[b] (Million metric tons)	(Percent of world export)
1950-51	15.8	38.7
1960-61	28.9	42.8
1965-66	48.7	44.9
1966-67	40.9	40.4
1967-68	39.9	41.4
1968-69	30.7	33.7
1969-70	35.7	36.2
1970-71	39.2	35.6
1971-72	37.7	33.1
1972-73	68.0	49.3
1973-74	75.6	56.7
1974-75	62.4	48.9
1975-76	77.9	54.6
1976-77	76.3	52.9
1977-78[c]	81.0	53.6

[a]Source [41].

[b]Wheat, wheat flour, corn, barley, oats, sorghum and rye excluding products.

[c]Preliminary.

Table 2.5. Various crop price indices for the U.S., 1965 to 1978[a] (1967=100)

Year	Index of prices received by farmers: All crops (1)	Index of prices received by farmers: Food grains (2)	Index of prices received by farmers: Feed grains and hay (3)	Index of prices received to prices paid, interest taxes and wage rates (4)
1965	103	93	100	104
1966	106	105	104	107
1967	100	100	100	100
1968	100	91	90	99
1969	97	88	96	100
1970	100	92	103	98
1971	108	95	108	96
1972	114	109	104	101
1973	175	215	163	124
1974	224	300	243	117
1975	201	242	230	103
1976	197	201	218	97
1977	192	156	181	91
1978	203	191	184	95

[a]Source [39].

ever in 1973 all three indices increased. For "All Crops", "Food Grains" and "Feed Grains and Hay" indices were 175, 215 and 163, respectively. In 1974, indices had increased to double or triple the 1967 level. Clearly, increased exports placed upward pressure on crop prices, increasing profitability of agricultural production. This increased profitability is reflected by column (4) of Table 2.5. Index of prices received by farmers to prices paid, interest, taxes and wage rates, rose from a pre-1972 average of approximately 100 (1967=100) to a high of 124 in 1973.

To what degree the causal relationship described above was operating in the early 1970's is not known. However, the apparent correlation between prices and exports is convincing. Increased world demand for agricultural products, led to large increases in crop prices, which induced farmers to expand production. Land use data in Table 2.3, and yields in Figure 2.1 indicate some of the expanded production resulted from increasing planted cropland acres in the U.S.

Recent trends in Iowa agriculture

The trend in U.S. agriculture discussed above can be expanded upon by examining trends in Iowa agriculture. Between 1969 to 1977 planted cropland acres in the U.S. showed an increasing trend. However, the crucial question to this study is the source of the additional planted cropland. The indications from Iowa data are that the increases did not come predominantly from noncropland, but from cropland previously set aside under Agricultural Stabilization and Conservation Service programs.

Table 2.6 presents relevant data for Iowa. Harvested cropland[1] in Iowa, shows a trend similar to the U.S. Prior to 1972 harvested cropland averaged about 21 million acres. After 1973, harvested cropland increased to over 24 million acres. Cropland set aside in ASCS programs are also given in Table 2.6. Total Cropland harvested and set aside as a measure of the cropland base indicates a different story than harvested cropland alone. For the entire period shown, 1964 to 1977, the "cropland base" is about 24 million acres, reaching a slight peak in 1972, at 24.9 million acres.

These data indicate that increases in harvested cropland, and probably planted cropland, in the early 1970's was primarily from ASCS set aside cropland and not from noncropland. However, the important point of this discussion is that increases in crop prices induced increases in planted cropland. In Iowa planted cropland increases were from set aside cropland, which was probably easier and less expensive to bring back into production than the conversion of noncropland to cropland. This activity is not precisely expansion of agricultural production on extensive margins as it has been used in this study. Therefore, the scope of this study is limited exclusively to investigating expansion on the extensive margins by converting noncropland to cropland. The cropland base, including planted acres and any idled cropland are not included in the analysis. It is important to remember that the results of this study are qualified if

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[1]Harvested cropland is used in place of planted cropland due to incomplete data on the latter category.

Table 2.6. Cropland harvested and set aside in Iowa, 1964 to 1977

Year	Harvested[a]	Set Aside[b]	Combined Set Aside and Harvested
		(million acres)	
1964	20.3	3.6	23.9
1965	20.5	3.5	24.0
1966	20.7	3.4	24.1
1967	21.8	2.0	23.8
1968	20.4	3.7	24.1
1969	19.7	3.9	23.6
1970	20.7	3.6	24.3
1971	21.8	2.5	24.3
1972	20.8	4.0	24.9
1973	23.6	0.9	24.5
1974	24.1	0.0	24.1
1975	24.3	0.0	24.3
1976	24.3	0.0	24.3
1977	24.3	0.0	24.3

[a]Source: [40].

[b]Source: Gene Johnson, U. S. Department of Agriculture, Agriculture Stabilization and Conservation Service, Des Moines, Iowa, private communication, March 26, 1979.

there is set aside cropland that would be brought back into production probably before any noncropland is converted to cropland.

Preliminary estimates of the supply of potential cropland in Iowa, using a methodology analogous to Frey and Otte, and Heady and Timmons estimates for the U.S., can be made from 1967 CNI data given in Table 2.7. The summary of estimates is presented in Table 2.8. Depending on the general quality of the noncropland, as indicated by the SCS land capability class, the supply of potential cropland in Iowa ranges from 0.4 to 5.2 million acres.

Potential for Future Intensive Expansion of Production

The quantity of noncropland converted to cropland depends on the interrelationship between expansion of production on extensive and intensive margins. An increase in crop prices may induce expansion of agricultural production on the extensive margins, but not on the intensive margins, due to relative factor costs or physical limits. This section investigates the uncertainty surrounding expansion of agricultural production on the intensive margins in the next few decades.

Yield trends with normal weather conditions[1] for corn and soybeans in the U.S. corn belt, indicate yield increases due to technology may be leveling off since 1970. (See Figures 2.2 and 2.3). A continuing study by Thompson [30, 31 and 32] of weather variability and climate on grain production indicates removal of weather patterns results in a leveling

[1]Normal weather conditions are the average conditions existing for the 30 year period from 1941-1970 [44].

Table 2.7. Iowa land use by capability class, 1967[a]

Land capability class	Land Use						
				Forest			
	Cropland (acres)	Pasture (acres)	Range (acres)	Nongrazed (acres)	Grazed (acres)	Other land (acres)	Total Inventory (acres)
1	3.636.934	184,364	1,012	100,785	45,570	118,861	4,063,463
1E	205	0	0	0	0	0	205
2E	6,105,982	379,937	1,012	85,546	47,036	289,765	6,886,159
3E	6,927,588	1,101,877	1,062	240,494	134,608	241,525	8,542,604
4E	1,277,397	660,361	3,586	171,385	94,522	36,033	2,153,281
6E	530,162	478,085	2,284	227,832	138,810	19,478	1,265,606
7E	166,312	395,254	20,496	363,386	230,439	27,295	976,403
2W	6,064,570	855,155	3,853	124,014	63,435	106,116	7,175,329
3W	874,034	91,250	202	47,186	14,494	18,148	1,039,546
4W	71,829	21,907	0	837	837	1,503	96,947
5W	135,017	259,786	639	235,464	120,000	22,428	659,513
7W	6,716	4,162	0	992	0	792	24,087
2S	270,440	28,116	202	7,124	4,741	10,932	320,275
3S	93,327	6,371	202	2,049	202	2,856	106,465
4S	195,104	33,702	0	31,095	17,162	7,768	274,427
6S	31,734	18,515	0	11,058	6,759	1,804	63,111
7S	24,131	95,085	204	293,661	170,440	5,709	422,355
All Classes	26,411,482	4,613,927	34,754	1,942,908	1,089,055	911,013	34,069,808

[a]Source: [28].

Table 2.8. Alternative estimates of the potential supply of cropland in Iowa[a]

Description of noncropland	Potential supply of cropland (millions of acres)
1. SCS class I	0.4
2. SCS class I, II	2.4
3. SCS class I, II, III	4.2
4. SCS class I, II, III, IV	5.2

[a]Source: [28].

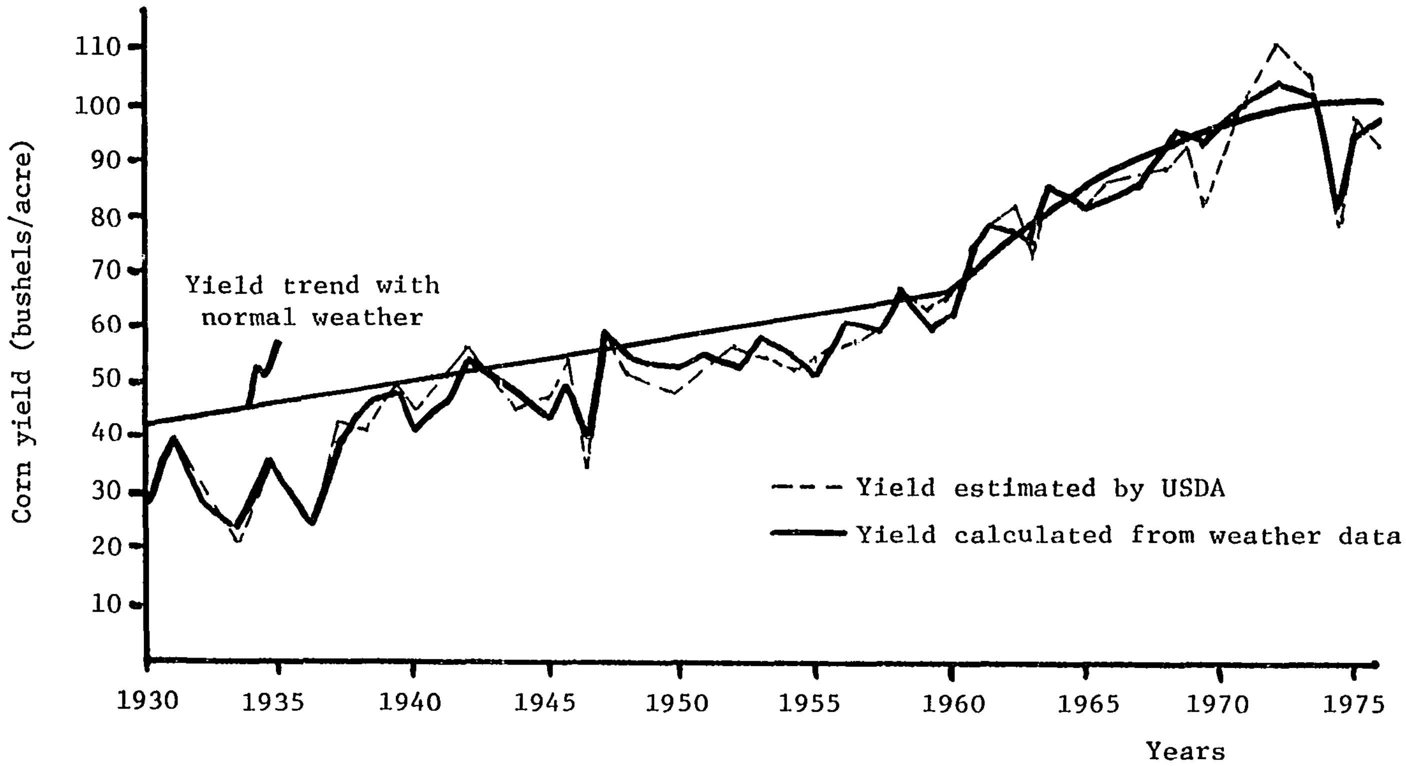

Figure 2.2. U.S. corn belt corn yields, 1930 to 1975 [33]

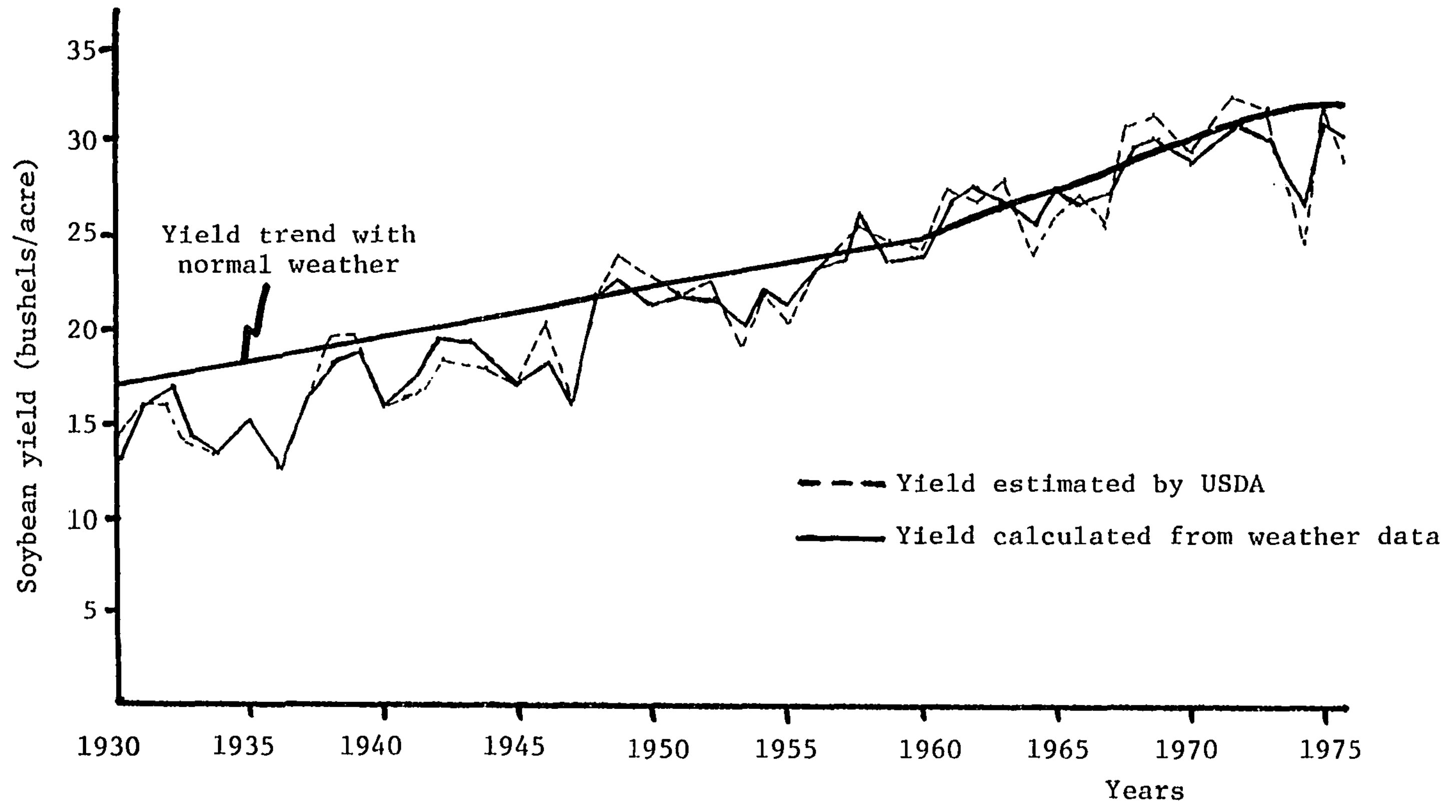

Figure 2.3. U.S. corn belt soybean yields, 1930 to 1975 [33]

off of soybean and corn yields. If this trend continues, and intensive expansion is limited then extensive expansion will be required to meet increases in demand for agricultural products.

Shrader [29] has questioned whether there are further yield increases achievable through technological innovation. Figure 2.4 depicts corn yields for Iowa experimental plots and state averages. While the experimental yields have shown no upward trend, fluctuating around 120 bushels per acre, state average yields have steadily increased from about 70 bushels per acre in the late 1950's to 110 bushels per acre in 1972. This convergence is due to implementation of known technology by farmers. As Shrader states:

> Grain yields, especially corn, have increased steadily for the past century and have been increasing at a rapid rate the past decade. This increase cannot continue indefinitely [29, p. 205].

He later adds:

> Unless a major breakthrough in technology occurs, it is unlikely that the enormous increases in corn production that have occurred in this region (the 13 north central states) in the past decade will continue at the same rate in the future [29, p. 214].

Nitrogen application data shown in Figure 2.5 indicate from where much of the corn yield increases originated. Up to 1960 the quantity of nitrogen applied to corn in the five states shown--Illinois, Indiana, Iowa, Missouri and Ohio--was less than 40 pounds per acre. From 1960 to 1975 application rates triple to approximately 120 pounds per acre. According to Voss [46], the recommended application rate of nitrogen on corn is between 100 and 180 pounds per acre depending on soil

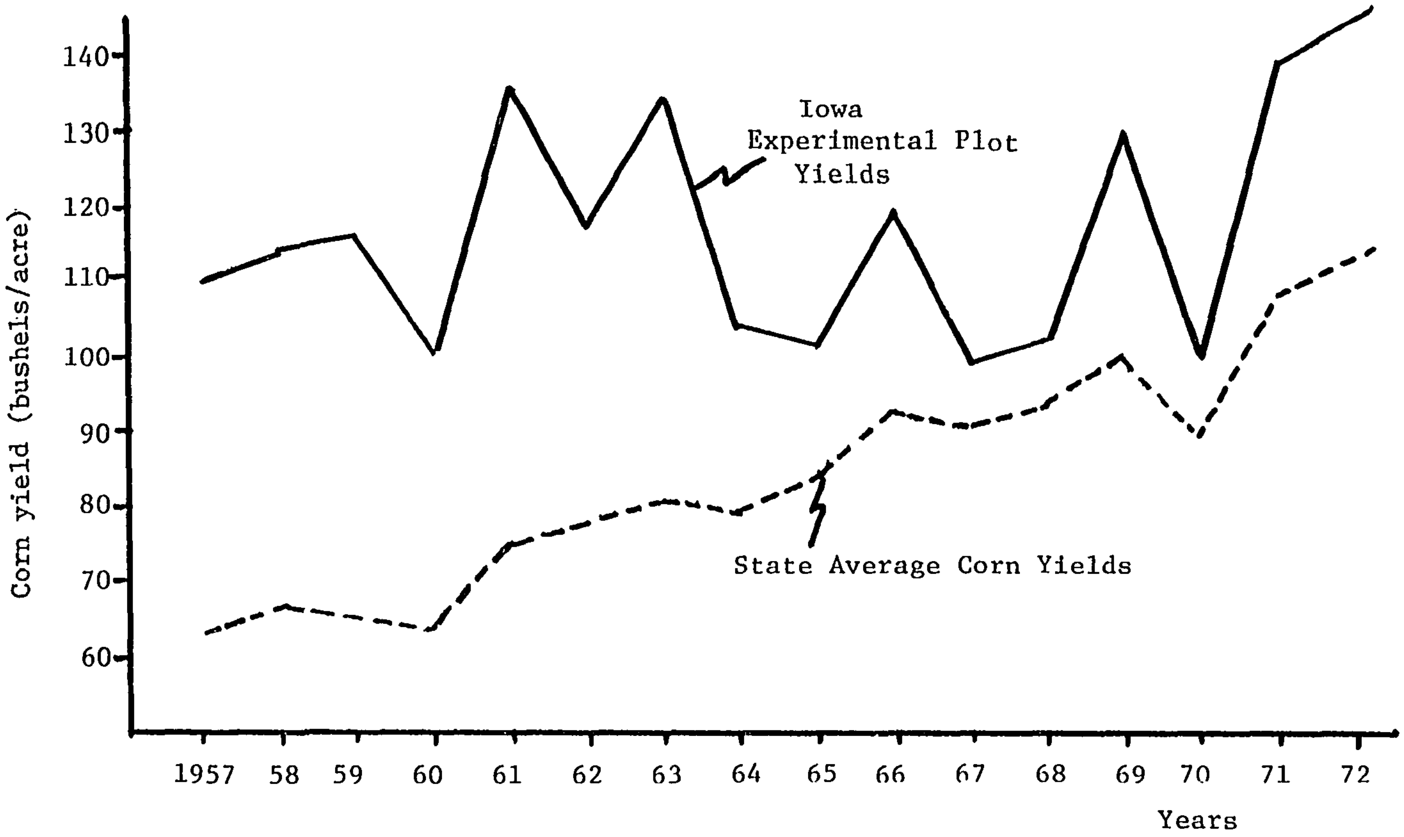

Figure 2.4. Average corn yields from 7 experimental sites compared to state average corn yields in Iowa, 1957 to 1972 [29, p.206]

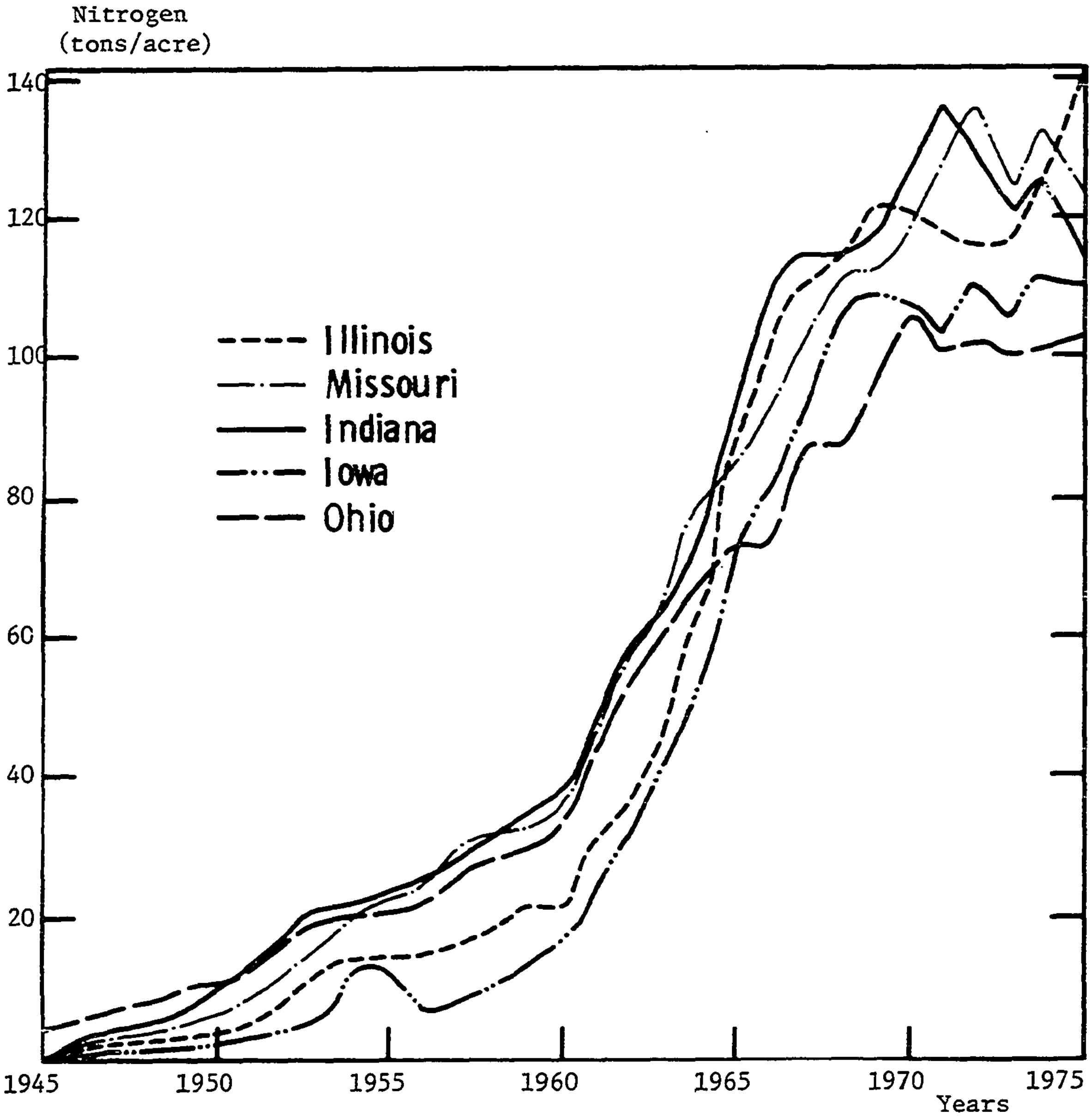

Figure 2.5. Nitrogen application on corn in five midwestern states - 1945 to 1975 [33]

type. Additional nitrogen cannot be absorbed by plants. Increases in yields in the near future due to increased fertilizer application are not likely to occur at historical rates without additional technological breakthroughs.

Concern also arises from the fact that much fertilizer is produced from petroleum. Cotner, Skold and Krause state:

> ...anhydrous ammonia averaged less than $80 per ton for five years prior to 1974; 1974 prices nearly doubled [6, p. 8].

Concern is growing that future prices may follow suit. At the 1978 National Fertilizer Conference, Edwin Wheeler, the president of the Fertilizer Institute was credited with the following scenario [9, p. F2].

Petroleum producing nations with large natural gas reserves could enter production of anhydrous ammonia, making it available in the U.S. at a price forcing domestic producers out of business, after which, prices could be raised to higher than previous levels. While this possibility might appear somewhat paranoid, it does indicate that product-factor relationship between fertilizer and petroleum is highly interdependent on the actions and resulting prices within the petroleum industry. The rapid increase in fertilizer prices, such as exemplified by anhydrous ammonia in 1974, is a distinct possibility, in light of present world economic and political conditions.

The unavailability of pesticides in the future could seriously curtail increases in agricultural production on intensive margins. Since the Environmental Protection Agency (EPA) was formed under the National

Environmental Protection Act in 1969, the use of 45 pesticides have been curtailed either in part or completely. In addition, EPA is currently investigating 60 pesticides, some or all of which could be withdrawn from the market.[1]

Even without the removal of pesticides from the market, continual use could have a negative impact on future crop yields. As Campbell and Whitley state:

> A problem closely related to biological magnification of chloridated hydrocarbons is the development of resistance to pesticides by organisms. The development of resistance is a well-known obstacle in the control of insect pests with pesticides [2, p. 333].

As insects become resistant to pesticides fewer alternatives are available to farmers for pest control. Therefore, there is a tendency for greater crop damage to result, with detrimental impacts on crop yields.

Whether future expansion of agricultural output on the intensive margins will or will not happen is not a major concern of this study. What is important, and what has been indicated in this section, is the possibility future yields might not increase sufficiently to keep pace with world demand for U.S. agricultural products. As Cotner, Skold and Krause aptly summarized:

> With technology now in the pipeline and with oncoming developments, productivity levels of agricultural land could continue to increase. On the other hand, higher costs of inputs and environmental constraints will undoubtedly slow the growth in productivity. The U.S. Department of Agriculture's current projections indicate that yields will

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[1]Poindexter, C. E. Environmental Protection Agency, Kansas City, Missouri. Private communication, January 26, 1979.

> increase but at a dampened rate. At best, productivity per acre is not expected to exceed the rates of increase of the last three decades [6, p. 8].

If this be the case, and a divergence between supply and demand for agricultural products appears evident, then slack can only be filled by extensive expansion of agricultural production. The same question is once more reiterated: Is there an adequate supply of potential cropland to fill the gap?

Environmental Impacts

Increasing the supply of agricultural production on extensive margins has serious implications for the quality of the environment. Estimates of the supply of potential cropland in the U.S. and Iowa are comprised of land not currently cropland because there is either a lack of demand for agricultural products, or it is marginal land with lower productivity and higher susceptibility to soil erosion. Even if economic conditions change to the extent that marginal land becomes profitable for farmers, the high erodibility of land still remains.

Of the 265 million acres of potential cropland identified by Frey and Otte, 155 million acres is in land capability class III. As Frey and Otte state:

> Limitations of class III are the results of ... the following conditons: 1) moderately steep slopes, and (2) high susceptibility to water or wind erosion ... [10, p. 9].

High erodibility of class III land leads to deterioration of water quality and future productivity of the soil. As Shrader indicates, soil erosion can have serious implications for society:

One of the most obvious examples of damage from offsite erosion in Iowa occurs in the Missouri River flood plain in western Iowa. Large dredges are almost constantly employed because sediment from neighboring hills is deposited in drainage ditches and must be removed if the bottomlands are to be used. Other easily observed results of off-site effects of erosion include numerous lakes that have been silted full after only a few years of use. These types of damages are in addition to the much more general and diffuse losses that occur downstream and result in such things as reduced fish population and increased costs of water purification for cities [29, p. 210].

Johnson and Moldenhauer also explain:

Sediment reduces water quality and often degrades deposition areas. Sediment pollutes when it occupies space in reservoirs, lakes, and ponds; restricts streams and drainageways; reduces crop yields in a given year; alters aquatic life in streams; reduces the recreational and consumptive use value of water through turbidity; and increases water treatment costs. Sediment also carries other water pollutants such as plant nutrients, chemicals, radioactive materials and pathogens [17, p. 3].

That sediment acts as a transport agent for plant nutrients is elaborated by Holt, Dowdy and Timmons:

The two elements most closely associated with these noxious growths [of aquatic plant life] are nitrogen and phosphorous. These elements are also closely associated with agriculture, for they occur in all plant life. Since these chemicals are most apt to be in insufficient supply for crop growth, they are the nutrients most frequently supplied as fertilizers. Fertilizers are applied to the surface of soils and thus are quite vulnerable to removal by erosion. It is the eroded topsoil which makes up the bulk of the sediment being fed into surface water supplies [14, p. 21].

Sediment acts as a transport agent for other agricultural chemicals. Pesticides which can enter the ecosystem in different ways often do so by eroded soil. Nicholson explains as follows:

> Runoff from the land is probably the most widespread single source of low level surface water contamination by pesticides and has been demonstrated repeatedly. Runoff may be more or less continuous throughout the year at levels generally less than 1 ppb [part per billion] or may occur sporadically. Transport from land to water may occur while the pesticide is absorbed on eroded particulate material, while in solution in runoff water, or by both means. It has been shown that sodium numate, a common soil constituent, solubilizes DDT in water. This phenomenon would be expected to facilitate the transport of DDT [24, p. 187-8].

Soil erosion results in the allocation of scarce resources to sediment removal, or opportunity costs of benefits foregone by people.

Implications of increasing agricultural production on extensive margins are serious. Table 2.9 presents results of a study by Cory and Timmons [5] concerning the quantity of acres planted to crops required to meet future increases in demand for U.S. agricultural products.

Two scenarios were used for projections to 1985, i) assuming historical trends of growth in crop yields, farm size and export demand continued to 1985, ii) assuming high export demand characteristics of U.S. agriculture for 1973 to 1975, stimulatory agricultural policy, and increased farm efficiency continued to 1985.

Results of the study indicated planted acreage for the twelve state corn belt region[1] would increase 18.6 percent for the historical trend scenario and, 30.7 percent for the high export demand scenario from the

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[1]The corn belt states as defined by Cory and Timmons [5], are Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

Table 2.9. Estimated soil erosion losses associated with alternative scenarios of planted acres for Corn Belt states in 1985[a]

State	Planted Acres				Change in Planted Acres from Base Period			Change in Soil Loss from Base Period	
	Base Period 1969-1972	1975	1985[b]	1985[c]	1975	1985[b]	1985[c]	1985[b]	1985[c]
	(1,000 acres)				(percent)			(percent)	
Illinois	18,339	21,040	19,259	21,475	14.7	5.0	17.1	13.1	40.1
Indiana	9,482	11,060	10,336	12,086	16.6	9.0	27.5	13.7	61.6
Iowa	19,299	21,930	23,239	24,782	13.6	20.4	28.4	67.6	106.1
Kansas	17,140	19,950	17,087	22,237	16.4	0.3	29.7	7.6	54.9
Michigan	3,122	3,945	4,163	4,669	26.4	33.3	49.6	40.3	61.7
Minnesota	13,166	15,837	16,395	16,792	20.3	24.5	27.5	39.0	47.0
Missouri	7,735	9,210	10,233	10,378	19.1	32.3	34.2	36.7	43.0
Nebraska	9,090	10,930	14,542	14,965	20.2	60.0	64.6	142.7	180.9
N. Dakota	12,456	14,257	16,438	17,085	14.5	32.0	37.2	44.9	55.5
Ohio	7,559	9,230	8,142	10,344	22.1	7.7	36.8	12.4	66.2
S. Dakota	8,671	9,940	9,861	10,266	14.6	13.7	18.4	36.5	50.8
Wisconsin	4,575	4,970	5,170	5,552	8.6	13.0	21.3	46.4	73.2
Corn Belt	130,581	152,299	154,918	170,631	16.6	18.6	30.7	44.2	75.4

[a]Source: Adapted from [5].

[b]Estimates assume that agricultural stabilization programs are continued and that crop yields, farm size and exports continue to grow at historical rates.

[c]Estimates assume increased farm efficiency and productivity, expanded export sales and stimulatory agricultural policy.

1969-1972 base period. Estimated increases in soil erosion in the corn belt, for the two scenarios were 44.2 and 75.4 percent from the base period. The study implies a one percent increase in planted acres would lead to approximately a 2-1/2 percent increase in soil erosion.[1]

The implications of a 2-1/2 percent increase in soil erosion due to a one percent increase in planted acres can be examined in terms of the estimates of potential cropland in Table 2.2. A 2 percent increase in cropland, from 450 to 460.6 million acres indicated by 10.6 million acres of potential cropland, would result in a 5 percent increase in soil erosion. An 88 percent increase in cropland, from 450 to 846.2 million acres indicated by 396.2 million acres of potential cropland, would result in a 220 percent increase in soil erosion.

For Iowa, Cory and Timmons projected planted acres would increase 20.4 percent under the historical trends scenario, with an associated increase in soil erosion of 67.6 percent. Under the high export demand scenario planted acres were estimated to increase 28.4 percent and soil erosion was estimated to increase 106.1 percent.

Summary

The discussion in this chapter has attempted to put forth the following argument. If demand for U.S. agricultural products increases in the near future, incentive will exist for farmers to increase production. An increase in production can only occur in two ways,

[1]For the first scenario an 18.6 percent increase in planted acres leads to a 44.2 percent increase in soil erosion, or 44.2/18.6 = 2.37. For the second scenario the result is 2.46.

i) intensive expansion and/or ii) extensive expansion. Recent evidence of fertilizer use and crop yields, suggest that U.S. agriculture may be reaching a plateau on the intensive margins of expansion. If this is the case future expansion of agricultural production would likely occur on extensive margins. Expansion of production on the extensive margins will lead to increased soil erosion, resulting in a deterioration of environmental quality and destruction of future productivity of cropland.

Recent studies estimating the supply of potential cropland have failed to incorporate all three relevant factors with respect to the supply of potential cropland, i) a price variable, ii) quantity of potential cropland, and iii) soil erosion. Estimates cited in this chapter have been predominantly concerned with the physical supply of potential cropland. The only study incorporating an explicit price variable was conducted by Davis for the southern part of the U.S. While many studies, uncited in this chapter, have studied soil erosion, most have been on the level of the firm or watershed, few have examined the consequences of expanding the aggregate supply of cropland on soil erosion.

CHAPTER III. THEORETICAL FOUNDATIONS OF EXTENSIVE AGRICULTURAL EXPANSION

This chapter will briefly discuss three theoretical topics underlying and explaining conversion of noncropland to cropland. These topics are i) supply of a heterogeneous resource, ii) theory of investment in a productive resource and iii) environmental externalities. Initially, an introductory discussion of the actual process involving conversion of noncropland to cropland should facilitate an appreciation of the significance of these theories to this study.

The Process of Converting Noncropland to Cropland

Conversion of noncropland to cropland may be regarded as the production of cropland from several inputs, one of which is noncropland. Other inputs typically involved in this production process are labor, machinery, fuel, and construction materials.

Two major types of noncropland are generally used in Iowa as inputs; pastureland and forestland. Initial steps of the process are obvious for each type of noncropland. First, the surface of the land is cleared of trees, brush and other vegetation. Obviously, greater costs may be expected in clearing a stand of trees from forestland than clearing brush from pastureland. The possibility exists that trees cleared from forestland could be marketed as lumber. However, in Iowa the proximity of lumber mills and low quality of the timber prevents such action from being generally undertaken.[1] Thus trees and brush are typically piled and burned.

Once the land is cleared of surface vegetation, the physical characteristics particular to the land indicate need for other activities. Most common activity is installation of subsurface agricultural drainage tiles or other methods of drainage on land limited in use by excess water or poor natural drainage. Subsurface tiles are installed between two and four feet in depth, at a spacing of about 100 feet between tiles, depending on permeability of the soil. Conduit tiles are connected to a larger lateral main, which removes water into an open drainage ditch or other outlets.

Other activities particular to the physcial characteristics of land are filling in channels or small gulleys created by past water runoff, and general land forming. On land with slope between 2 and 18 percent, soil erosion control terraces might be constructed.

The Supply of a Heterogeneous Resource

The supply of cropland, like the supply of many natural resources and unlike the supply of manufactured goods, is heterogeneous in nature. A necessary and often overlooked assumption used in the construction of supply curves in economic theory is the homogeneity of the commodity.

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[1]Private communications with Paul Rosenberry, USDA collaborator, Iowa State University, Ames, Iowa, August 9, 1978, and Fred Hopkins, Forestry Economist, Iowa State University, Ames, Iowa, November 17, 1978.

Thus one unit of the commodity becomes a perfect substitute for any other unit. When total land is viewed as a resource input into the production of agricultural products it is, by nature, heterogeneous. Land varies from location to location, by soil fertility, climate, slope, water retention capacity, erodibility, etc., and consequently, physical productivity also varies.

Not only is land heterogeous, as a whole, but typically there are segments which are relatively homogeneous. Thus a particular amount of land may posses similar characteristics of soil fertility, erodibility, etc, which can be considered, for all practical purposes, homogeneous. Figure 3.1 is a graphical representation of a resource which is overall heterogeneous, but is available in homogeneous "lumps".

Such a graph is called a "kinked supply curve." Letting Figure 3.1 represent the supply of cropland, each segment A, B, C, etc., represents land with different soil fertility and consequently productivity. The question of what "quantity" on the horizontal axis actually measures, must be answered. If A and B represent the same quantity of land, but A is twice as productive, and if B is added to the cropland base, then is there twice as much cropland, or only half again as much? If the relative productivities of the two types of land are the same for all crops, then no major problem exists, as long as the quantity axis is indexed by the productivity, or the results are appropriately qualified. However, if two or more crops are grown on land types A and B, but relative physical productivities are different, for example, twice as much corn can be

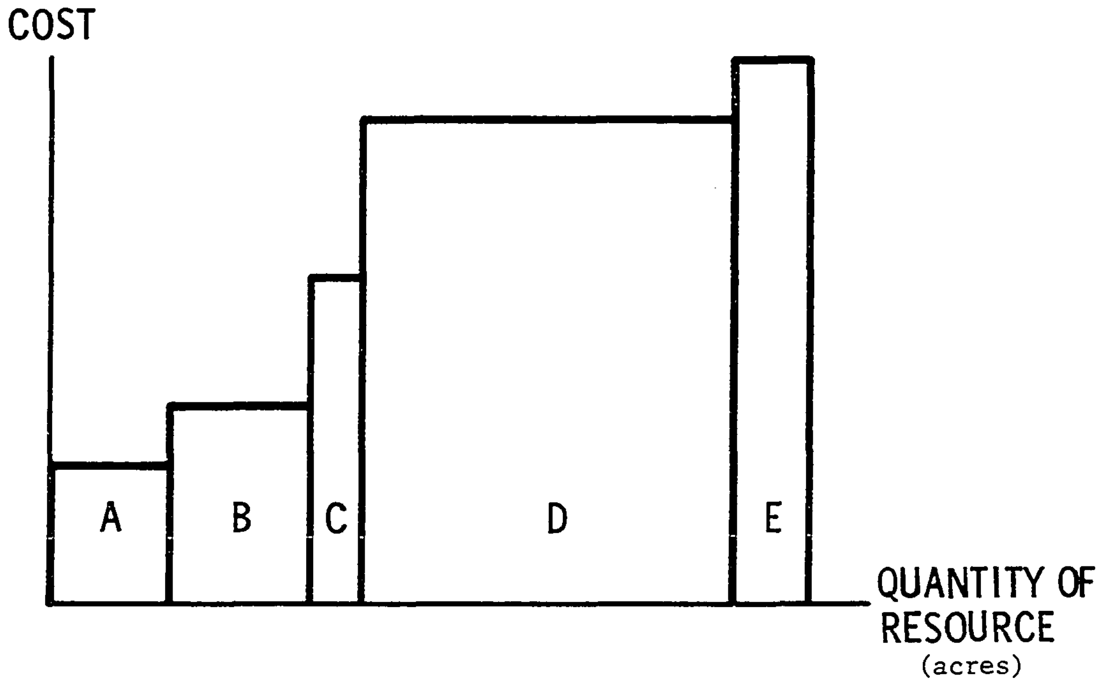

Figure 3.1. Hypothetical kinked supply curve

grown on A with respect to B, but only one-third as many soybeans the measurement unit for the quantity axis becomes ambiguous.

Trade-offs between extensive and intensive increases in output can be illustrated with an extension of the kinked supply curve concept. Thus, Figure 3.2 depicts two resource blocks with different, but constant average costs. If the price, that users of the resource are willing to pay, is P_o, then only the first type of land, block A, will be utilized in the production of crops. If the price should rise above P_o, but less than P_1, block A will still be the only land utilized.[1] However, since the price is above the opportunity costs of bringing the land into production, C_o the owner of land type A is receiving economic rent. The owner is thus encouraged to increase productivity of the land through increases in nonland, capital inputs, such as fertilizer, pesticides or machinery. Consequently, between prices P_o and P_1, intensive expansion is encouraged. However, at price P_1, the second type of land, block B, comes into production, which is expansion on the extensive margins. If the price increased from P_o to P_1, then both extensive and intensive expansion would result simultaneously.

Theory of Investment in a Productive Resource

Cropland investment may be viewed analogously to housing investment. The model used by the Federal Reserve Board and the Massachusetts

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[1]If the price rises above P_o it is possible that block A might be employed in another activity. However, since this study is primarily concerned with extensive expansion no further consideration of this possibility is discussed.

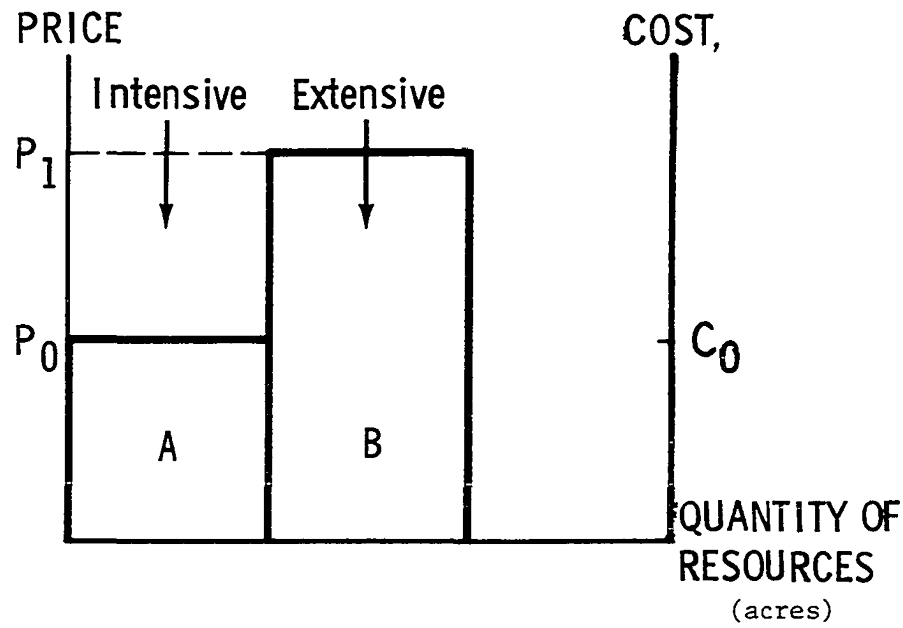

Figure 3.2. Comparison of agricultural expansion on the extensive and intensive margins

Institute of Technology (Fed-MIT) macromodel for housing investment [53] can lend beneficial insights into conversion of noncropland to cropland.[1]

The maximum price a purchaser of a productive resource would be willing to pay is equal to the discounted present value of the expected net revenue stream, over the life of the resource. That is, an investor who desires to purchase an acre of cropland would pay, at most, a price equal to the present discounted value of the net revenue stream expected over the life of the resource. If the investor paid more than this value for the land, he could have received a larger annual return, by investing in bonds at the given rate of return. In a competitive situation he will not likely pay less than this value, since other investors would bid up the price.

Equation (3.1) is the equation for calculating the present discounted value of a productive resource.

$$P = \sum_{t=1}^{n} \frac{(R_t - C_t)}{(1+r)^t} \qquad (3.1)$$

where: R_t = gross revenue in time period t,

C_t = gross operating costs in time period t,

r = the appropriate discount rate,

P = present value of the productive resource,

n = life of the expected stream of income.

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[1]This theory as adapted to this study was supplemented by classnotes from Intermediate Micro-economic Analysis, Fall, 1976, taught by Wallace Huffman and Advanced Economic Theory, Spring, 1978, taught by Dennis Starleaf, both at Iowa State University, Ames, Iowa.

For simplicity it is assumed that the discount rate is constant over time, but there are no major problems involved with a variable discount rate. It is also assumed that the life of the resource is finite. If the life is infinite and R_t and C_t are constant over time, i.e., R_t= R and C_t=C, then equation (1) simplifies to:

$$P = \frac{(R-C)}{r} \qquad (3.2)$$

where: R = annual gross revenue over time,

C = annual gross costs over time,

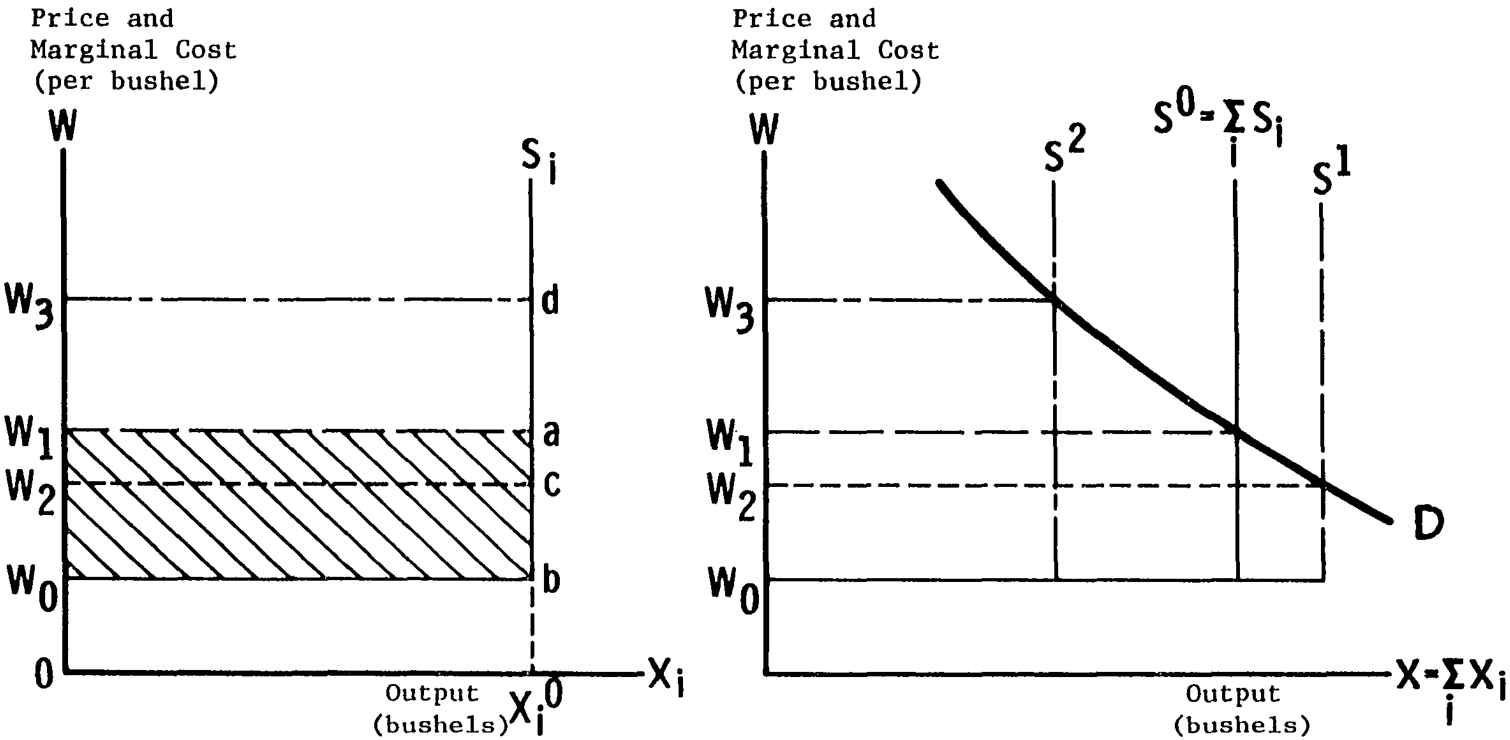
P = present value of the productive resource,

r = the appropriate discount rate.

For a single acre of land, if operating costs (C) are constant and given, then the net revenue stream is also given, since the gross revenue stream (R) is determined in the market for ouput from land.

In Figure 3.3(a) X_i, on the horizontal axis, measures the quantity of output from one acre of land and W, on the vertical axis, measures the price and per unit costs of producing X. The reversed L-shaped curve is the marginal operating costs, or supply curve for output from the one acre of land. At output X_i^o, which represents total utilization of the one acre, the supply curve becomes vertical. At outputs below X_i^o it is assumed that operating costs per unit of output are constant and equal to W_0.

Figure 3.3(b) is the output market, or the aggregation of all single acres of land such as Figure 3.3(a). The horizontal axis in Figure 3.3(b) also measures output, but is the summation of the outputs



(a) Single Acre

(b) Total Market

Figure 3.3. Hypothetical output market

from each acre of land. On the vertical axis W measures gross revenue and costs, on the same scale as Figure 3.3(a). Curve S^o is the horizontal summation of all curves S_i. It is assumed, initially, all land has equal operating costs per unit of output (W_0). Curve D in Figure 3.3(b) is demand for output from land.

In equilibrium the price of the output would be W_1 per unit of output. Gross revenue to a single acre of land would be $OW_1aX_i^o$. Since total gross costs are $OW_0bX_i^o$, net revenue, i.e., gross revenue minus gross costs, would be W_1abW_0. Relating back to equation (3.2), R is $OW_1aX_i^o$ and C is $OW_0bX_i^o$. It is clear, given the demand, D, the present discounted value for the acre of land depicted in Figure 3.3(a), is the shaded area W_1abW_0 divided by the appropriate discount rate.

It is now possible to move from the output market to the market for land. In Figure 3.4, L measures the quantity of land on the horizontal axis and P measures the price of land on the vertical axis. For a given period of time, such as one year, the supply of cropland is fixed for all practical purposes. This is represented by curve S_L, which is vertical at quantity L^o.

The demand curve (D_L) is derived from the analysis in Figure 3.3. As concluded from this analysis the price a buyer of land is willing to pay for land is, at most, equal to the present discounted value of the shaded area W_1abW_0 in Figure 3.3(a). However, the net revenue stream is not independent of the quantity of land in cropland. The aggregate output supply curve in Figure 3.3(b) is drawn for a given

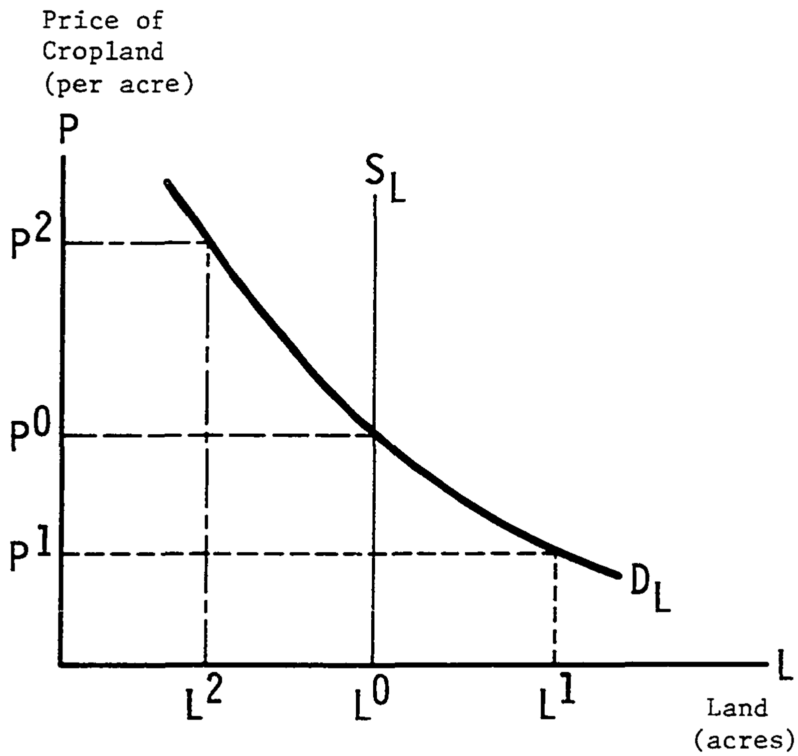


Figure 3.4. Hypothetical land market

quantity of land, say L^o in Figure 3.4. If the supply of cropland is increased to L_1 in Figure 3.4, the supply in Figure 3.3(b) is shifted to S_1. The price of output is reduced to W_2 and consequently, the net revenue is decreased to the rectangular area W_2cbW_0 which is less than the net revenue at price W_1. It is obvious that the present discounted value will also be less, and subsequently, the maximum price a buyer is willing to pay for an acre of land is less. Price P^o corresponds to the net revenue stream with quantity of land L^o, supply of output S^o and price of output W_1. Price P^1, however, corresponds to land quantity L^1, supply curve S^1 and price of output W_2. an analogous procedure can be used to derive price P^2 in Figure 3.4, corresponding to L^2, S^2 and W_3.

The conclusion drawn from this analysis is, given a downward sloping demand curve for output of cropland, the demand curve for cropland must also be downward sloping.

The fourth aspect of the theory of investment in a productive resource is the supply function for the production of cropland.

Figure 3.5(a) is Figure 3.4 reproduced. In Figure 3.5(b) the vertical axis is the same units as the vertical axis in Figure 3.5(a), the price of land and the costs of producing more acres of land. The horizontal axis also measures quantity of land, but per unit of time. In Figure 3.5(a) land is measured as a stock variable, in 3.5(b) it is a flow variable, S_A is the marginal costs of producing new cropland.

Investment in "new" cropland is determined by demand for "existing" cropland, which determines the price, given a fixed quantity of existing cropland. With the higher price for existing cropland,

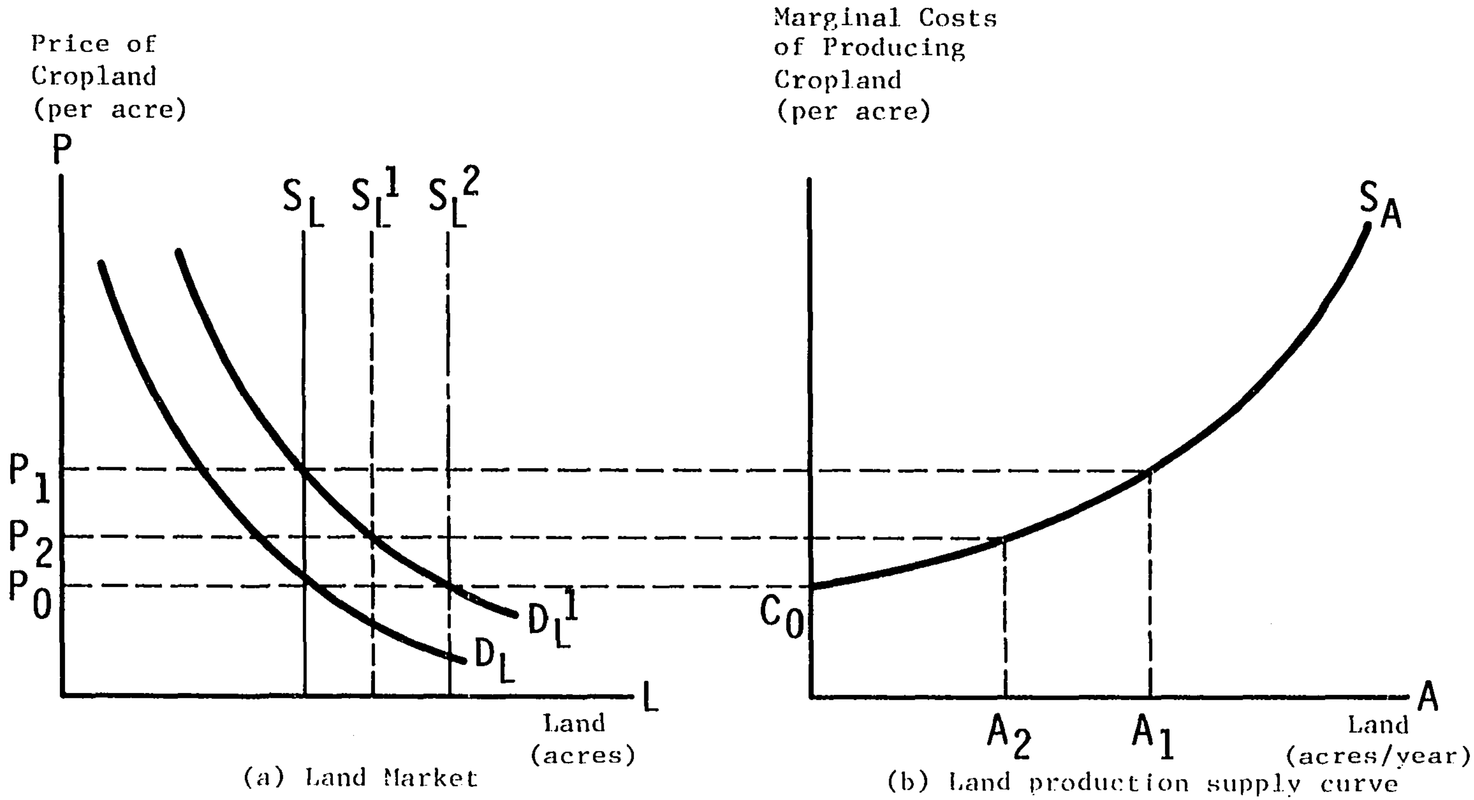


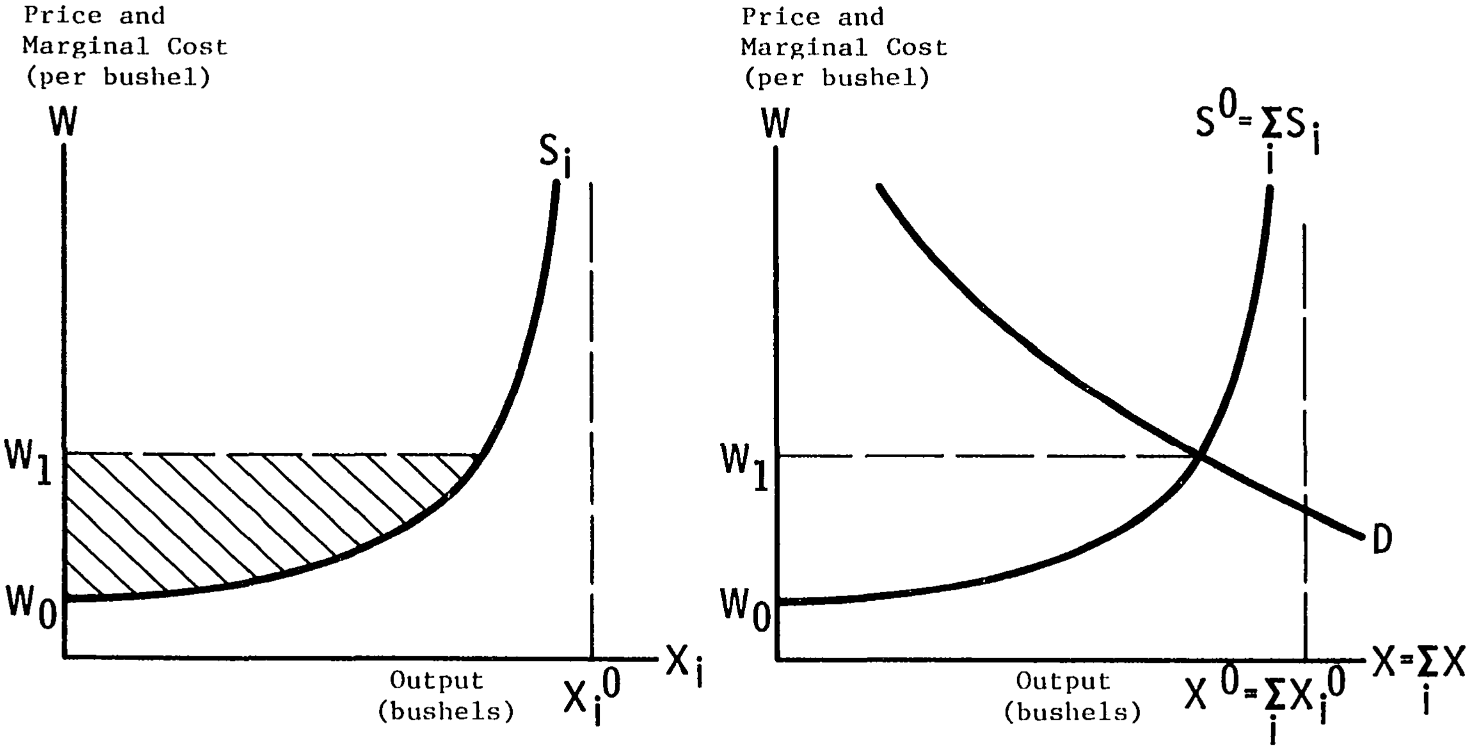
Figure 3.5. Hypothetical land market and land production supply curve

producers of new cropland are induced to produce more cropland. This occurs by conversion of pastureland, forestland or other land uses to cropland.

If demand for cropland is increased to D_L^1, due to a change in the discount rate, demand for output from land or some other factor, then the equilibrium price in the "existing" cropland market will increase to P_1. This will induce producers of cropland to convert A_1 acres of non-cropland per unit of time. This increase in the quantity, or stock of cropland, will shift the supply of existing cropland to S_L^1, in the following period. With the new stock of cropland the equilibrium price in the 3.5(a) will be P_2, this will induce an increase of A_2 of new cropland in the subsequent period. The sequence will continue until the price falls to P_0, the initial price, which is equal to the minimum costs of producing new cropland, and the stock of cropland equal to S_L^2.

Two assumptions used in this theory are unrealistic when applied to cropland and may appear to invalidate the conclusions. The first is the assumption of constant operating costs up to the capacity of land, or the L-shaped supply curve for output. The second is the assumption that all land is homogeneous, which apparently contradicts the preceding discussion on heterogeneous resources.

The assumption of constant marginal operating cost is not crucial to the analysis, but is used only for simplification. If operating costs are an increasing function of output then Figure 3.3(a) would look like Figure 3.6(a). In this case, while operating costs are not



(a) Single Acre (b) Total Market

Figure 3.6. Hypothetical output market

constant, it still seems plausible that a capacity is reached, for a given acre of land, in a single year. That is, with fixed technology, there is a maximum output producible on a single acre of land, at which point (X_i^o) the supply curve turns vertical.

Relaxing the assumption of constant marginal costs would not alter the basic conclusions. Figure 3.3(b), the output market would look like Figure 3.6(b), if the assumption is relaxed. The aggregate output supply curve is the horizontal summation of each individual supply curve and is thus upward sloping, reaching a capacity constraint at X^o equal to the summation of all individual capacity constraints.

The only difference between Figures 3.3 and 3.6 is the calculation of the net revenue value. In Figure 3.6(a) the net revenue is the shaded area, analogous to Figure 3.3(a), however it is not simply the price of the output times the quantity less per unit operating costs times the quantity of output. Regardless of how the net revenue stream is calculated, derivation of the demand curve in Figure 3.4 and analysis of Figure 3.5 remains unchanged.

The second assumption of homogeneous cropland, in light of the emphasis previously placed on the heterogeneity of land, may seem more serious. Relaxation of this assumption, also, need not affect the analysis.

Using equation (3.2) the maximum price a buyer would be willing to pay for an acre of land, with a given quality is:

$$P_i = \frac{R_i - C_i}{r} \qquad (3.3)$$

Where all variables are as defined above, except that the subscript i denotes a homogeneous block of land with a given quality. If the costs of converting this particular quality of land is set equal to K_i, i.e. the vertical distance of the curve S_A in Figure 3.5(b), then this quality of land will be brought into production if $K_i \leq P_i$ or:

$$K_i \leq \frac{R_i - C_i}{r} \qquad (3.4)$$

It is important to note that the quality of cropland is significant only in its effect on either gross revenue R_i, gross costs C_i or investment costs K_i. If $R_i = R_j$, $C_i = C_j$ and $K_i = K_j$ for two types of land i and j, then they are the same quality of land. Dividing both sides by $\frac{R_i - C_i}{r}$ gives:

$$\frac{K_i}{\frac{R_i - C_i}{r}} < 1 \qquad (3.5)$$

Thus for a given quality of land if the left hand side of inequality (3.5) is less than 1 the land should be converted to cropland.[1]

The numerator of the expression is investment costs. The denominator is the present discounted value of the net revenue stream. In Figure 3.5(b) this is equivalent to dividing P by discounted net revenue. The effect of this procedure is to index the price axis, or the price of

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[1]It is also necessary that equation (3.5) be greater than zero. If (3.5) is less than zero then either $K_i < 0$ or $(R_i - C_i)/r < 0$, the former being unrealistic and the latter indicating the land is unprofitable.

land by net productivity of quality of land. It is possible to compare any two qualities of land based upon the expression in inequality (3.5), without distorting the quantity of cropland.

This procedure also has the effect of incorporating the demand for cropland into the supply function, that is Figures 3.5(a) and 3.5(b) are combined together if P on the vertical axis is replaced by $\frac{K}{\frac{R-C}{r}}$. Figure 3.7 depicts this adjustment.

In Figure 3.5 with the initial shift of the demand curve to D_L^1, investment in cropland is A_1. This is also depicted in Figure 3.7, where the shift in the demand curve shifts the cropland supply function from F_0 to F_1. At F_1 the quantity of noncropland converted to cropland is A_1, equivalent to A_1 in Figure 3.5(b).

The procedure of adjusting price by productivity eliminates problems of heterogeneous cropland, and presents a convenient expression for determining whether noncropland is converted to cropland.

Separation of noncropland into several homogeneous classes or types enables the conversion of each type to be analyzed in a benefit-cost framework. For each type of noncropland costs of producing cropland (K) is compared to the present discounted value of the net revenue stream $(\frac{R-C}{r})$. If the latter is at least as great as the former, than at the margin this homogeneous type of noncropland is feasible for conversion to cropland. This is the essence conveyed by equation (3.4). Viewing each homogeneous type of noncropland as an investment project is consistent with the analysis presented in this section, but provides greater insight into the cropland conversion process.

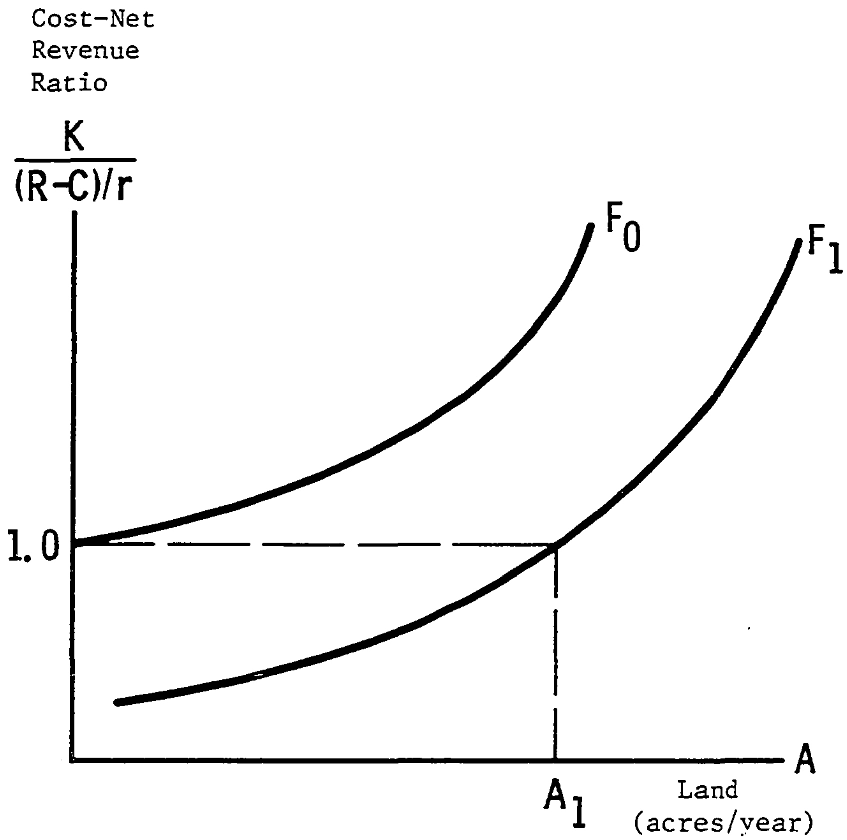

Figure 3.7. Potential cropland supply function

In Figure 3.5(a), at price P_1, consumers' surplus for curve $D_L^{\ 1}$ is the triangular shaped area below $D_L^{\ 1}$ and above the dashed line at P_1. In Figure 3.5(b) producers' surplus is the triangular shaped area above curve S_A and below the uppermost dashed line. The sum of the consumers' and producers' surplus can be identified in Figure 3.7. Curve F_1 was previously identified as the potential cropland supply function corresponding with demand curve $D_L^{\ 1}$, price P_1, and land production supply curve S_A. In Figures 3.5(b) and 3.7, both A_1's represent the same investment. The sum of producers' and consumers' surplus in Figure 3.7 is represented by the area bounded by curve S_A and the dashed line at 1.0.

Environmental Externalities

Conversion of noncropland to cropland, as discussed in the first two chapters, has serious impacts on the quality of the environment. Degradation of water quality due to eroded soil and agricultural chemicals transported by the soil are examples of external diseconomies. An external diseconomy,[1] is present when private costs incurred by an individual or firm diverge from the total resource costs borne by society. Costs beyond those borne by the individual or firm are shifted to other individuals or to society in general.

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[1]This definition of an external diseconomy can be generalized to include an external economy, in which the benefits incurred by an individual or firm are less then the total benefits to society. Since this study is concerned only with external diseconomies no further discussion of external economies are presented in this section.

Soil erosion, by reducing the quality of the environment, or forcing the use of scarce resources to remove sediment from streams, reservoirs, etc., imposes real resource costs on society not borne by the individual or firm engaged in agricultural production. There exists, for this reason, a divergence between private costs incurred in the production process and social costs incurred by society.

Pigou, in 1932, [26] identified externalities as essentially a failure of the market to allocate resources efficiently. Since that time, a large body of literature has been developed to expand the theory of externalities. Coase [3] pointed out that externalities must necessarily involve two parties, a generator of the externality and an affected party. Mishan [23] qualified this by indicating multiple optima exist depending on which party is required to alleviate the externality, due to an income effect. Buchanan and Stubblebine [1] developed a graphical framework for analysis of externalities.

The relevance of the theoretical advancements stated above to this study, is the divergence of social and private costs in the presence of an externality. Analysis in the previous section implicitly assumed that no external diseconomies were present, and all costs incurred were private. In equation (3.5) and Figure 3.7, investment costs (K) and operating costs (C) represent only privately incurred costs. If an external diseconomy is present in the process of converting noncropland to cropland, social investment costs (K^s) will be greater than private investment costs (K), i.e. $K^s > K$. If an external diseconomy is associated with the production of crops after the land is converted, then social operating costs (C^s) will be greater than private operating costs (C), i.e. $C^s > C$.

The impact on equation (3.5) and Figure 3.7 are the same whether $K^s > K$, $C^s > C$ or both. Assuming $C^s = C$, and if $K^s > K$, then including the social component of investment costs in equation (3.5) has the same impact as an increase in investment costs. Clearly if the left hand side of equation (3.5) was equal to 1.0 prior to an increase in K, then afterwards it will be greater than 1.0. Thus for land types which are at the margin of being converted from noncropland to cropland, with only private investment costs included in the analysis, inclusion of social costs will show that the land is socially undesirable for conversion from noncropland to cropland.

Although this is not as evident if social operating costs are greater than private operating costs $C^s > C$, the same conclusion is obtained. If the left hand side of equation 3.5 is equal to 1.0 with private operating costs, then inclusion of social operating costs will decrease the denominator $[(R_i - C_i)/r]$, thus increasing the entire expression. Land of marginal quality will be socially undesirable for conversion from noncropland to cropland due to the inclusion of the external diseconomy. Whether the external diseconomy affects the conversion process, the crop production process or both, the effect on equation (3.5) is the same.

Because external diseconomies are beyond the market place they are not easily valued. This prevents curve F_s in Figure 3.8 from being

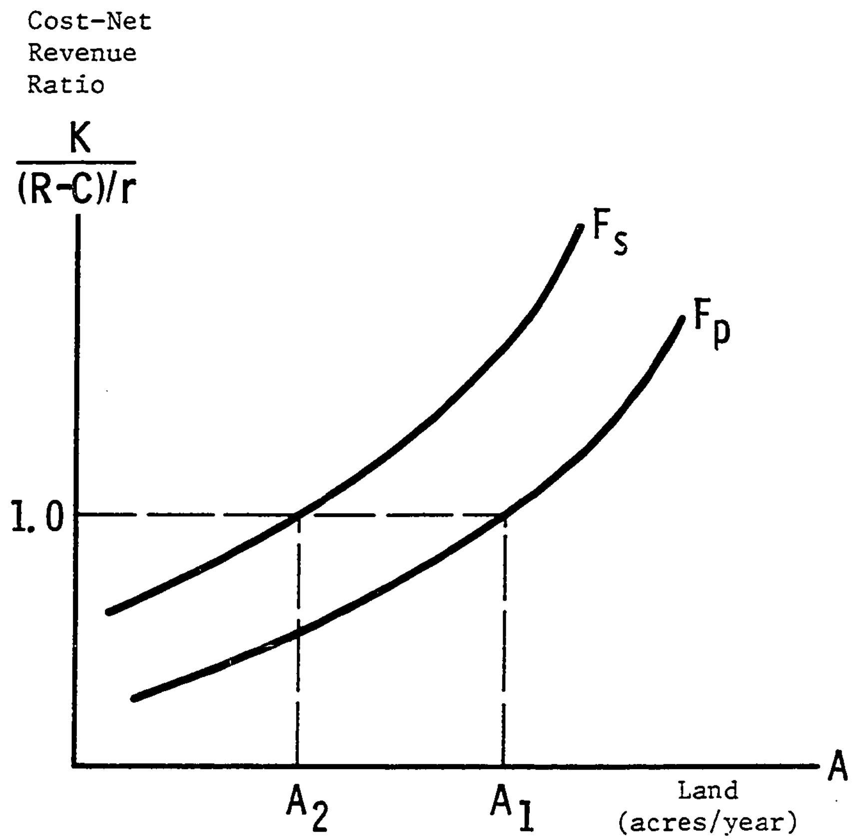

Figure 3.8. Potential cropland supply function with private and social cost

explicitly estimated, unlike curve F_p. However, a methodology for estimating a proxy of the F_s curve has been developed in other studies.[1] The proxy is estimated by placing a constraint on the maximum amount of soil erosion per acre per year, and estimating costs of achieving this limit by altering agricultural practices.

This method has several qualifications which should be noted. First, explicitly setting a constraint on soil erosion implies that the socially optimum quantity is known. That is, if E tons per acre per year of soil erosion is set as the limit, then this implies that at the margin, social benefits equals social costs at E tons per acre per year. Since costs of soil erosion are not generally known, there is no way of pinpointing the precise value which E should assume. Secondly constraining soil erosion to a particular value of E assumes that all soil erosion is homogeneous with respect to its external costs. That is, it assumes that the soil erosion from land type A causes the same damage to the quality of the environment as soil erosion from land type B. If A is adjacent to a stream which supplies water to a major city, and B is several miles from the nearest river, with no major uses of water drawn from the river, then, in all likelihood a ton of soil erosion from A will have greater costs to society than a ton of soil erosion from B.

Figure 3.8 shows a potential cropland supply function in which A_1 quantity of noncropland is feasible for conversion to cropland. F_p is based solely on private investment and/or operating costs. If all land types are affected by an external diseconomy, than a social potential

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[1] See for example, Webb [49], Walker [48], and Seay [28].

cropland supply function can be drawn. The social potential cropland supply function (F_s) would lie above and to the left of the private function. A_1 is the quantity of noncropland converted to cropland based on private costs. A_2 is the quantity of noncropland that would be converted to cropland if all external costs were internalized.

Thirdly, as emphasized throughout this study land is available in distinct qualities, especially in terms of soil erosion. Flat land with no slope has virtually no soil erosion. Steep land, with a slope between 10 and 15 percent, is more susceptible to soil erosion. If a soil erosion constraint is mandated by society, flatter land with no erosion would become relatively more valuable than steeper sloped land. Thus owners of the flatter land would, in essence, receive a windfall gain. This is a situation similar to the construction of a highway. Owners of land near an interchange suddenly find their land is worth many times more than before. Whether windfall gains to owners of land less susceptible to soil erosion is desirable or not is for society to decide. It is important to recognize this as an impact of imposing a constraint on soil erosion. However, this problem does not affect the use of a theoretical constraint as a means of estimating the social potential cropland function.

CHAPTER IV. POTENTIAL CROPLAND SUPPLY MODEL

This chapter develops the potential cropland supply model used in this study. The first section elaborates the model and presents an overview of its principal components. The second section presents and defines structural equations of the model. The third section depicts the model in graphical form which is more readily adaptable to the analysis. The final section of this chapter subjects the graphical form of the model to comparative statics, indicating expected changes in the supply of potential cropland resulting from changes in parameters of the model.

Summary of Model

The analytical model used in this study estimates the quantity of noncropland that could be converted to cropland under alternative assumptions of output prices, factor costs, agricultural technologies and practices, discount rates, and soil erosion control policies. The model is an application of the "Theory of Investment in a Productive Resource" discussed in Chapter III. Working under the assumption that noncropland can be classified into a finite number of homogeneous land types, the model examines each land type in a benefit-cost framework. If benefits exceed costs for a land type then it is considered feasible for conversion from noncropland to cropland under the assumed set of output prices, factor costs, agricultural practices, land use patterns, discount rate, and technology. The model computes the total number of acres of cropland that can be feasibly converted to noncropland and the total quantity of soil erosion that would result from the identified noncropland if it were converted to cropland.

Three output variables are estimated i) potential cropland,[1] ii) gross soil loss and iii) average soil loss.[2] First, they are estimated based only on the criterion that benefits exceed costs. Second, they are estimated based on two criteria (1) benefits exceed costs and (2) average soil loss on each quality of land does not exceed a specified limit.

Figure 4.1 depicts the Potential Cropland Supply Model schematically. The boxes number 1 through 9 represent the components of the model. Arrows labeled (a) through (k) represent interactions between components. Box 1, Technology and Agricultural Practices, symbolizes the current state of the art with respect to farming. As discussed in Chapter II, a main motivation of this study, and a major assumption underlying the model, is that technology will not increase significantly in the next decade, thus requiring the expansion of agricultural production on the extensive margins.

Box 2, Economic Conditions, symbolizes economic forces acting through output prices and input costs. Box 3, Investment Costs, represents costs incurred in converstion of noncropland to cropland. Box 4, Net Revenue, is the present discounted value of the net revenue stream

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[1]While potential cropland was used earlier in this report, and in other studies to mean any noncropland that potentially could be cropland, it is used in a more restricted sense in the remainder of this report. It is defined as any noncropland, that under the given assumptions of the model could be profitably converted to cropland, i.e., it meets the criteria outlined for the model.

[2]Gross soil loss is the total soil loss from all potential cropland identified in the model. Average soil loss is gross soil loss divided by potential cropland. Average soil loss for each estimation of the model is different from average soil loss for each land type.

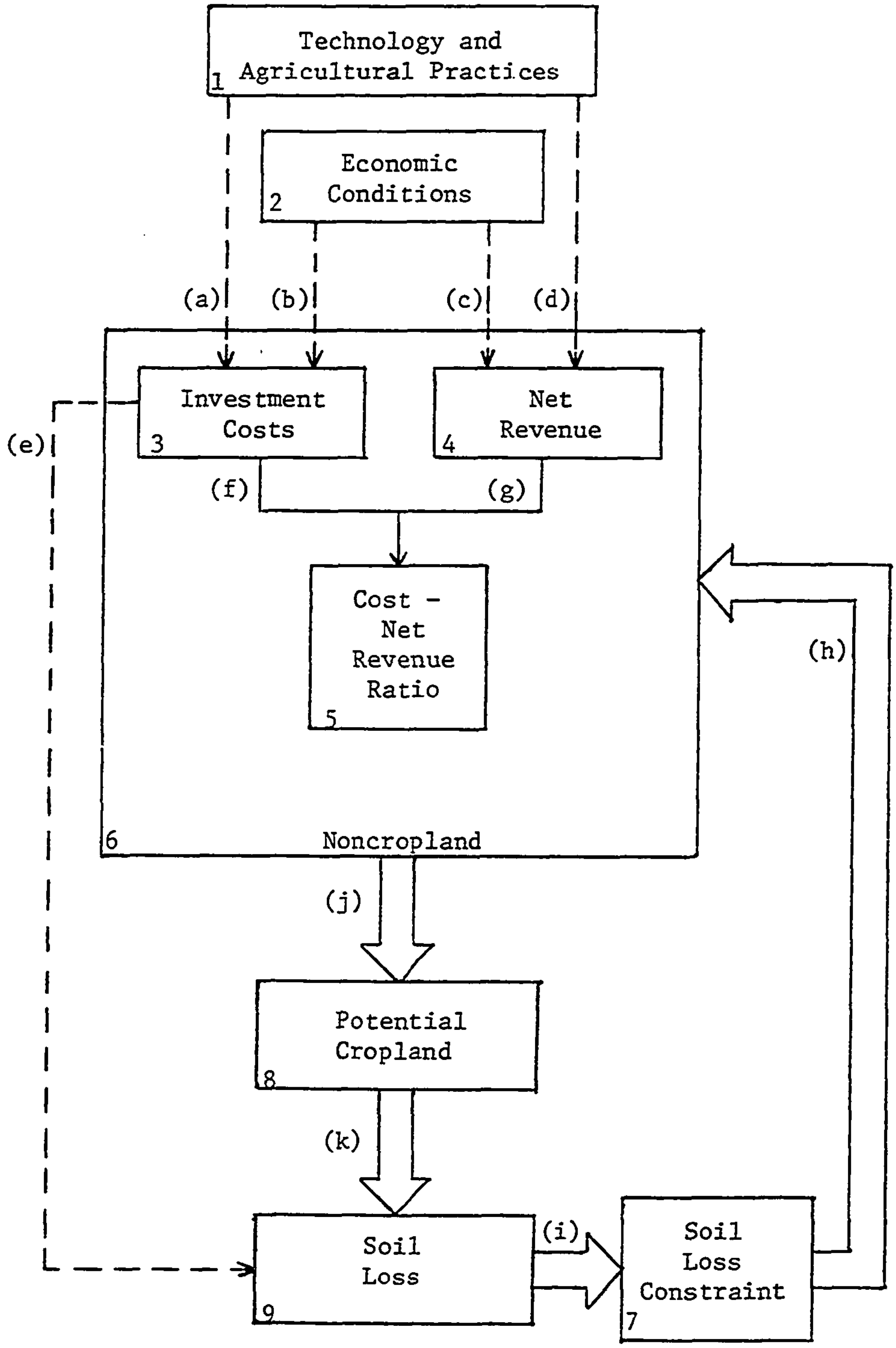

Figure 4.1. Potential cropland supply model

resulting from the production of crops after the land is converted from noncropland to cropland. Box 5, the Cost-Net Revenue ratio, is the ratio of box 3 to box 4, and is the essence conveyed by equation (3.5). Box 6, Noncropland, represents the input of noncropland into the conversion process. Box 6 contains boxes 3, 4, and 5, indicating that the Cost-Net Revenue ratio reflects the feasibility of converting noncropland to cropland. The dashed arrows in Figure 4.1 indicate interactions of the Cost-Net Revenue ratio (i.e., boxes 3, 4 and 5) with other parts of the model. The solid arrows, except (f) and (g), show interactions between noncropland and other parts of the model. Box 5 is the single decision criterion used in the estimation of the model without the social costs of soil erosion. Box 7, Soil Loss Constraint, is combined with box 5 when the model is estimated with the social costs of soil erosion included. Boxes 8 and 9, Potential Cropland and Soil Loss, respectively, are the two output variables of the model. Input variables are reflected through Investment Costs and Net Revenue, as influenced by boxes 1 and 2.

Mechanics of the model are represented by the arrows connecting the boxes. Arrows (a) and (d) represent the impact of Technology and Agricultural practices on Investment Costs and Net Revenue, respectively. The level of technology is assumed to remain constant. However, alternative agricultural practices are available, as represented by arrows (a) and (d). Arrows (b) and (c) represent the impact economic conditions, through output prices, input costs and the discount rate, have on Investment Costs and Net Revenue, respectively. Arrows (f) and

(g) indicate the Cost-Net Revenue ratio is merely the combination of Investment Costs and Net Revenue. Arrow (e) indicates that Soil Loss resulting from conversion of noncropland to cropland can be affected by the investment costs incurred in the conversion process.

Arrows (h) and (i) are relevant only when the model is estimated with the social costs of soil erosion included, otherwise box 7 is not used. When the soil loss constraint is used the model has a three step procedure. First the model estimates which land types have benefits greater than costs, the sole criterion if the social costs of soil erosion are not included. Each land type that satisfies the first criterion is subjected to the soil loss constraint criteria. For all land types passing the second criterion, they are reevaluated in terms of the first criterion again. If all three steps are passed by the land type then it is considered feasible for conversion from noncropland to cropland.

Arrow (j) indicates the quantity of noncropland that is feasible for conversion to cropland after passing one or both of the criteria. Arrow (k) indicates the soil erosion which results from the converted cropland.

The model can be further examined in terms of i) assumptions and structural parameters which do not change, ii) input variables which are adjusted under alternative scenarios, and iii) output variables which are the primary concern of the study.

Assumptions and structural parameters

Since this model is an application of the "Theory of Investment in a Productive Resource," the entire discussion in that section of Chapter III is assumed for this model. In addition the model includes the discussion of "The Supply of a Heterogeneous Resource" in Chapter III. The model also holds constant the level of technology, particularly increases in agricultural production on intensive margins. This also includes, as noted above, availability of alternative agricultural practices. Only those agricultural practices currently available are assumed to be used in crop production. It is also assumed that patterns of land use do not change beyond what is indicated in the results of this study. That is, the current supply of cropland is assumed to remain constant. This is a simplifying assumption used to examine the expansion of agricultural production on extensive margins without the effect on crop prices of a shrinking cropland base.

Input variables

The input variables of greatest importance in this study are crop prices, which reflect the incentive to increase agricultural production. Other input variables are the discount rate, investment costs, production costs and crop yields. The input variables are changed in various combinations to either test the sensitivity of the model or project alternative future scenarios.

Output variables

Two variables produced as outputs of the model are i) noncropland feasible for conversion to cropland i.e., potential cropland and ii) gross soil loss resulting from the potential cropland. Average soil loss is calculated from potential cropland and gross soil loss.

Structural Equations of Model

Equations (4.1) through (4.8) depict the model illustrated in Figure 4.1.

$$K_i = CC_i + \frac{AOC_i}{r} \tag{4.1}$$

where: K_i = the total investment costs incurred in the conversion of noncropland type i to cropland,

CC_i = the construction costs component of investment costs, consisting of the costs of installing drainage systems, the costs of clearing the land, the costs of constructing terraces and the costs of restructuring the terrain,

AOC_i = the annual net revenue forgone from noncropland type i after it is converted to cropland,

r = the discount rate,

$$NR_i = \frac{R_i - C_i}{r} \tag{4.2}$$

where: NR_i = the present discounted value of the net revenue stream received after noncropland type i is converted to cropland,

R_i = the annual gross revenue stream received after noncropland type i is converted to cropland,

C_i = the annual operating cost incurred in receipt of the annual gross revenue stream (R_i) after noncropland type i is converted to cropland,

$$CNR_i = \frac{K_i}{NR_i} \tag{4.3}$$

where: CNR_i = the ratio of the investment costs of converting noncropland type i to cropland to the present discounted value of the net revenue stream after noncropland type i is converted to cropland, termed the Cost-Net Revenue ratio,

$$(CNR, a, sl)_i \tag{4.4}$$

where: a_i = the quantity of land classified as noncropland type i,

sl_i = the annual, per acre, soil loss from noncropland type i after it is converted to cropland,

$$A^1 = \sum_{i=1}^{n} a_i \tag{4.5}$$

where: A^1 = the total quantity of noncropland that is economically feasible for conversion to cropland, for all land types, i = 1, ... n, which satisfy the criterion $0 < CNR_i \leq 1$,

$$SL^1 = \sum_{i=1}^{n} a_i sl_i \tag{4.6}$$

where: SL^1 = the gross soil loss resulting from A^1 acres of noncropland after it is converted to cropland.

$$A^2 = \sum_{j=1}^{m} a_j \tag{4.7}$$

where: A^2 = the total quantity of noncropland that is economically feasible for conversion to cropland, which satisfy the criterion, $sl_j \leq SLC$ (a specified constraint on annual per acre soil loss) and $0 < CNR_j \leq 1$,

$$SL^2 = \sum_{j=1}^{m} a_j sl_j \tag{4.8}$$

where: SL^2 = the gross soil loss resulting from A^2 acres of noncropland after it is converted to cropland.[1]

The Potential Cropland Supply Function

The model presented above can be depicted graphically. Using Equation (4.4), and ignoring soil loss, it is possible to rank all types of noncropland (i) by the Cost-Net Revenue ratio (CNR_i) from lowest to highest. Each cropland type can be represented by a point in (CNR, a) space. Figure 4.2 illustrates two such points. The two points are labeled (1) and (2), respectively. Point (1) is assumed to be that type of cropland which had the lowest Cost-Net Revenue ratio. It is plotted in (CNR, a) space using the following coordinates (CNR_1, a_1). The second point, labeled (2) is assumed to be the noncropland type with the second lowest Cost-Net Revenue ratio. It is plotted in (CNR, a) space in a slightly different manner than point (1). While the y-axis (CNR-axis) uses the coordinate CNR_2, which is the Cost-Net Revenue ratio for land type 2, the x-axis (a-axis) uses the coordinate ($a_1 + a_2$), where a_2 is the quantity of type 2 land and a_1 is the quantity

[1]Average soil loss (ASL) for a single estimation of the model is gross soil loss (SL) divided by potential cropland (A), i.e., ASL=SL/A, with and without the soil loss constraint.

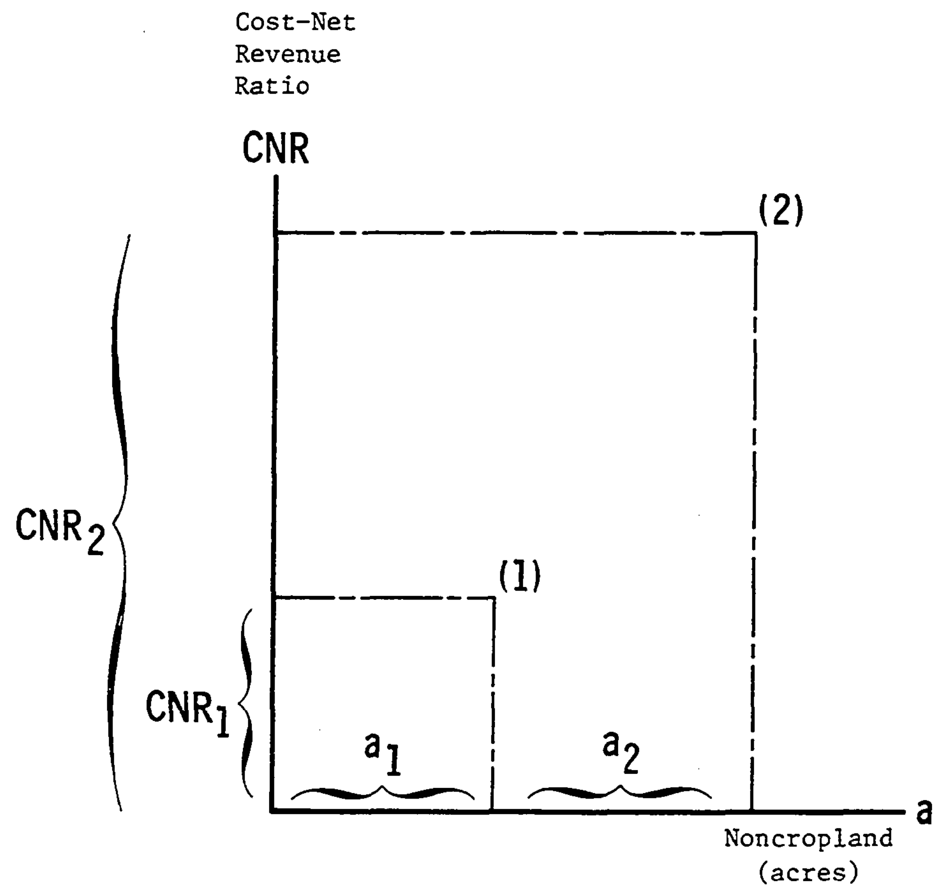

Figure 4.2. Construction of potential cropland supply function

of type 1 land. By extension a third point could be plotted where the y-coordinate is CNR_3 and the x-coordinate is $(a_1 + a_2 + a_3)$.

By plotting all land types in this manner a diagram similar to Figure 4.3 can be constructed. It is no coincidence that Figure 4.3 resembles Figure 3.7 in Chapter III. These graphs are derived from two different perspectives but depict the same relationship. Figure 4.3 was constructed in such a way that the total quantity of noncropland feasible for conversion to cropland could be read off the horizontal axis. Thus, for a CNR ratio less than 1.0 in Figure 4.3 the quantity of noncropland feasible for conversion to cropland is A_1. Note the manner in which Figure 4.3 was constructed appears to assume the land type with a lower CNR ratio would be converted before land with a higher CNR ratio. This is not necessarily the case since Figure 4.3 is a static diagram without a time dimension, although such an assumption would seem reasonable. It is not important whether the lowest CNR ratio is converted before the next lowest, etc. Figure 4.3 merely states that all noncropland with a CNR $\leq$ 1.0 will be converted to cropland.

As discussed in Chapter III, the triangular area in Figure 4.3, above the potential cropland supply function, and below the dashed line at 1.0, is a representation of consumer surplus. A measure of this area can be calculated from the model. From the view point of the farmer involved in converting noncropland to cropland his (her) per acre net income (Ni_i) would be the excess of the presented discounted value of the net revenue stream (NR_i) over the total investment costs (K_i):

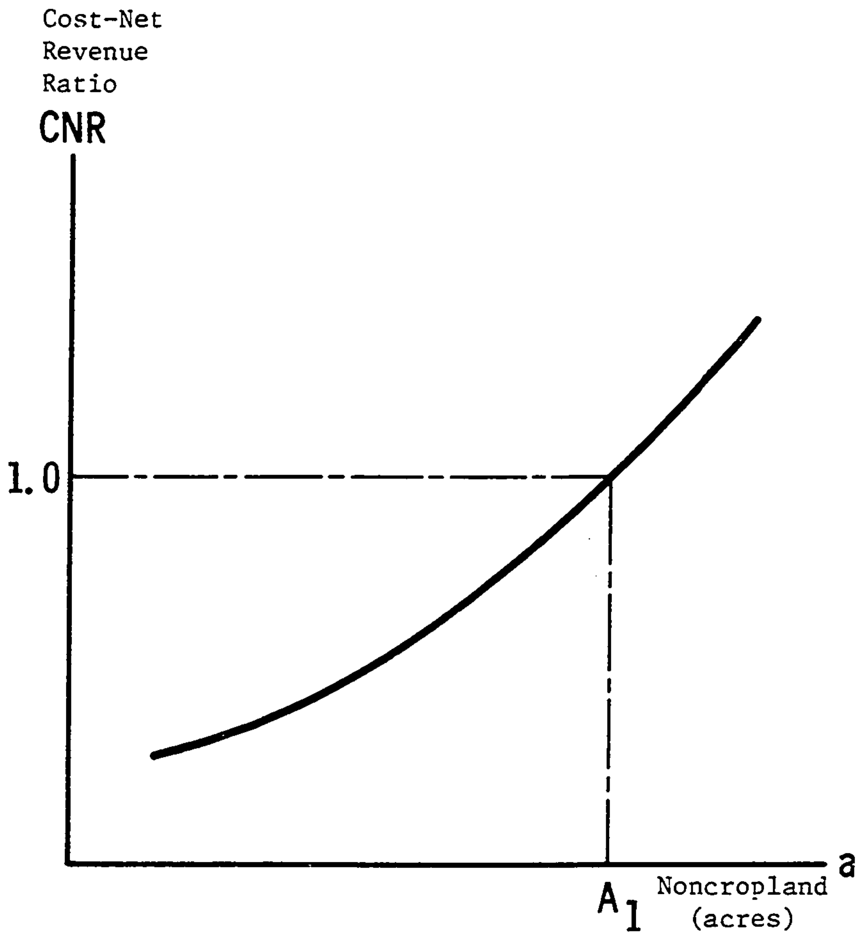

Figure 4.3. Potential cropland supply function

$$Ni_i = NR_i - K_i \tag{4.9}$$

where: Ni_i = per acre net income or profit for land type i and other variables are as defined above.

The total net income for A_i acres of land type i converted to cropland is:

$$NI_i = A_i(NR_i - K_i) \tag{4.10}$$

where: NI_i = total net income for land type i.

For all potential cropland meeting the criterion $0 < CNR_i \leq 1.0$, the net income is expressed as:

$$NI = \sum_{i=1}^{n} A_i(NR_i - K_i) \tag{4.11}$$

where: NI = total net income of all land types meeting the criterion $0 < CNR_i \leq 1.0$.

The measure of net income, NI, can be used to compare potential cropland supply functions produced by alternative assumptions of output prices, factor cost and soil erosion control measures.

Comparative Statics of Model

Figure 4.3 can be used to analyze the effect of changes in different parameters of the model which could result from changes in input variables. Five major classes of comparative static shifts are examined in this section (i) a change in the price of crops, (ii) a change in productivity or yields of the cropland, (iii) a change in production costs, (iv) a change in the discount rate, and (v) imposition of a soil loss constraint.

Curve LM in Figure 4.4 illustrates a situation in which extensive margins of production are in equilibrium under existing conditions, i.e., there is no quantity of noncropland which is economically feasible for conversion to cropland under current economic conditions. Thus curve LM lies everywhere above the 1.0 CNR line, or at the margin equal to 1.0.

Under this equilibrium situation if the price of crops were to increase, the CNR ratio for every type of land would be less than the initial situation. Therefore, curve NP would become the relevant potential cropland supply function, with A_1 quantity of noncropland feasible for conversion to cropland.

A similar shift in the cropland supply function would result if the yields of each type of land were to increase. Note in this discussion that it may not be the case that all land types are in the same order after, as they are before, the shift in the potential cropland supply function. That is, prior to the shift land type A may have the lowest CNR ratio, type B the next lowest, type C the third, etc., but after the shift the ranking of land types by CNR ratio might be B, C, A. This will in no way affect analysis or results of this study.

An increase in production costs would have an opposite effect of an increase in either yields or crop prices. For each type of noncropland the estimated net revenue stream, NR_i, would decrease due to

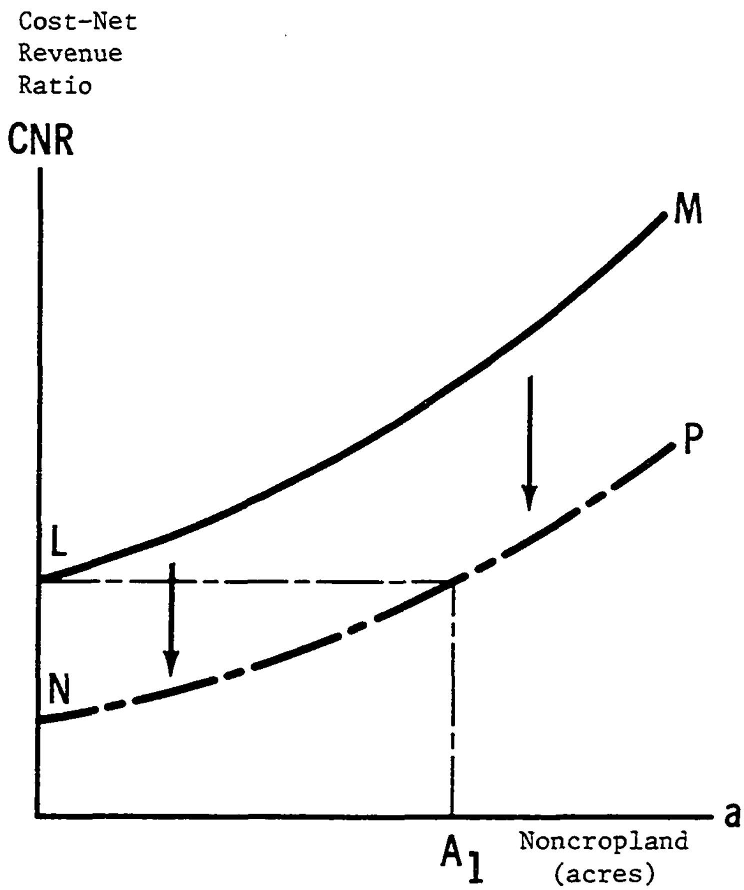

Figure 4.4. Downward shift in potential cropland supply function

increased production costs. This would shift up the potential cropland supply function. If curve NP in Figure 4.5 were the initial situation (perhaps after an increase in crop prices) then an increase in production costs would shift the curve to QR, with quantity of noncropland feasible for conversion to cropland, A_2, less than before, A_1.

The effect of a change in the discount rate is not as obvious as changes in other input variables, since the discount rate appears in numerator and denominator of the CNR ratio. Substituting equations (4.1) and (4.2) into (4.3) gives:

$$CNR_i = \frac{DC_i + CC_i + \frac{AOC_i}{r}}{\frac{R_i - C_i}{r}} \tag{4.12}$$

where: all variables are as defined above.

Multiplying numerator and denominator by r gives:

$$CNR_i = \frac{rDC_i + r\,CC_i + AOC_i}{R_i - C_i} \tag{4.13}$$

In equation (4.12) it is not clear what effect an increase in r has upon the CNR ratio. However in equation (4.13) it is evident that an increase in r would increase CNR through its effect on the numerator alone, causing the potential cropland supply function to shift upward as in Figure 4.5.

The imposition of a constraint on soil loss would either increase costs, or decrease yields. Both alternative impacts would result in a

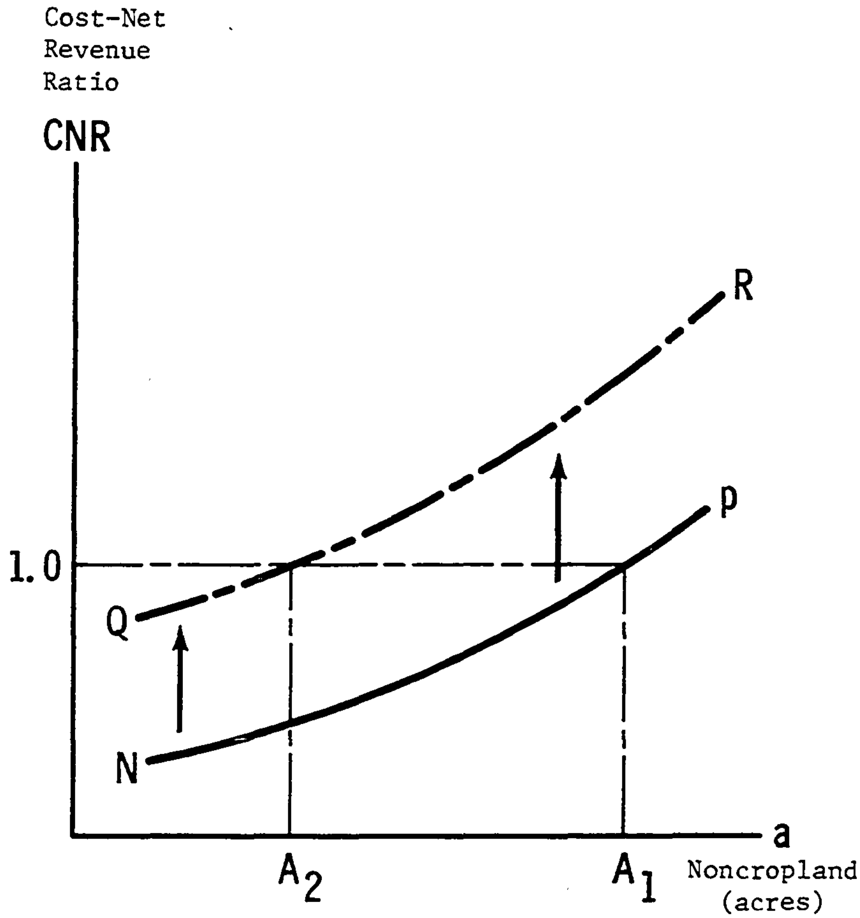

Figure 4.5. Upward shift in potential cropland supply function

decrease in the Cost-Net Revenue ratio for a given type of noncropland.[1] The potential cropland supply function would shift upward as in Figure 4.5, resulting in a decrease in the quantity of noncropland feasible for conversion to cropland.

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[1]The imposition of a soil erosion constraint would not affect noncropland which satisfy the constraint before it is imposed. For these cases the CNR ratio would not change. It is possible, therefore to have a portion of QR in Figure 4.5 coincide with NP, making it possible for A_2 to equal A_1.

CHAPTER V. APPLICATION OF MODEL TO IOWA AND RESULTS

This chapter discusses (1) procedures used to apply the model presented in Chapter IV, and (2) results of the analysis for Iowa. Four major topics are discussed in this chapter: i) concept of land types and classification criteria used for delineating land types, ii) data used to apply the model to Iowa, and sources of the data, iii) a specification of scenarios used to simulate the model for projections to 1985, and iv) empirical results of model application to Iowa.

Land Types

As stated in Chapter III, natural resources are generally composed of "blocks". Each "block" is characterized by a relatively uniform quality, distinguished from other blocks by different qualities, e.g., productivity. Since cropland as a natural resource displays these characteristics, the implementation of the model used in this study requires a system of classifying land into distinct "blocks".

There are three characteristics which are significant in classification of land blocks in this study: i) productivity, ii) investment costs, and iii) soil erosion. A classification system which incorporates these characteristics accounts for variations between qualities of land within the context of the analytical model used in this study.

The USDA Soil Conservation Service (SCS) uses a system of classification called "capability classes".[1]

> The [capability] classes show the location, amount and general suitability of the soils for agricultural use. Only information concerning general limitations in soil use are obtained at the capability class level [34. p. 2].

The Land Capability Class (LCC) system is widely used by the SCS, and consequently data used to apply the Potential Cropland Supply Model are readily available. However, the LCC system does not meet the three fold criteria of homogeneous i) productivity, ii) investment costs and iii) soil erosion, due to great variability within classes.

The LCC system is an aggregation of a much finer land classification system called soil mapping units (SMU). Each SMU is comprised of a specific soil type, slope phase, and erosion class. Land with identical soil type and slope phase would be placed in distinct SMU's if erosion class differed.

The SCS explains:

> A soil mapping unit is a portion of the landscape that has similar characteristics and qualities whose limits are fixed by precise definition. Within the cartographic limitations and considering the purpose for which the map is made, the soil mapping unit is the unit about which the greatest number of precise statements and predictions can be made.
>
> The soil mapping units provide the most detailed soils information. The basic mapping units are the basis for all interpretive groups of soils. They furnish the information needed for developing capability units, forest site groupings, crop suitability ratings, range

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[1]This system was used by Davis [8] and some of its characteristics were discussed in Chapter II.

> site groupings, engineering groupings and other interpretive groupings. The most specific management practices and estimated yield are related to the individual mapping unit [34, p. 2].

Precision with which SMU's are defined enables the greatest homogeneity within each "block" of land currently possible, with one qualification. While each SMU is homogeneous with respect to productivity and soil erosion, it need not be with respect to investment costs. Investment costs are highly dependent on land use, which is not incorporated in the SMU system. The process of converting pasture land to cropland is likely to incur different investment costs than conversion of forest land.

Therefore, in order to obtain a land classification system which identifies land into classes which are homogeneous with respect to productivity, investment costs and soil erosion, it is necessary to combine land use and the SMU system. For the purposes of this study a Land Type is defined as land characterized by soil type, slope phase, erosion class[1] and land use.

Data Needs and Sources

This section discusses kinds and sources of data used to estimate the model. The discussion follows the lines established by the major components of the model: i) investment costs, ii) net revenue, iii) soil erosion, iv) land use and v) discount rates.

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[1]1977 National Erosion Inventory data were not avaiable by erosion class.

Investment costs

Investment costs are examined by further disaggregation into i) conversion costs and ii) opportunity costs.

Conversion costs   There are three basic activities involved in conversion of noncropland to cropland; i) clearing of trees, shrubbery, brush, etc. from the surface of land, ii) installation of drainage systems in areas which suffer wetness problems, and iii) construction of soil erosion control terraces or otherwise restructuring the terrain.

With the exception of subsurface drainage systems, all other components of conversion costs were obtained through two separate random surveys of i) county SCS personnel and ii) land improvement contractors involved in conversion of noncropland to cropland. Results of the surveys are presented in Table 5.1. The SCS did not respond to clearing costs and contractors did not respond to terraces costs.

For clearing costs and terrace costs, the estimate used in the model is the mean value identified in Table 5.1. For channeled land, which had estimates from both contractors and SCS personnel, the variability of the SCS estimate, combined with reservations expressed by the SCS personnel when responding, indicated the most reliable estimate would be from the contractor's survey. The SCS and contractors both responded to the estimate of surface drainage costs, therefore a weighted average of the estimates was used in application of the model.

Table 5.1. Estimated components of Investment Costs

Type of Investment Cost	Contractors[a] Mean	N[c]	Std. Dev.	SCS[b] Mean	N[c]	Std. Dev.
			($/ft.)[d]			
Drainage tiles						
5"	.95	20	.119	.93	16	.116
6"	1.03	20	.098	.98	16	.110
			($/acre)[d]			
Surface Drainage	203.00	20	39.31	190.33	15	26.22
Clearing Cost						
Pasture	88.15	17	17.0	--	--	--
Forest-Grazed	268.62	18	87.34	--	--	--
Forest-Not Grazed	673.40	19	96.25	--	--	--
Terrace Costs						
Slope 2-5%	--	--	--	196.17	12	32.69
5-9%	--	--	--	242.67	12	47.37
9-14%	--	--	--	304.42	12	78.42
14-18%	--	--	--	351.67	12	72.33
18+%	--	--	--	NR[e]		
Channeled land	846.88	16	167.21	1000	3	408.25

[a]Source: Survey of land improvement contractors. Contractors were not able to supply information on terraces. See Table A.1.

[b]Source: Survey of county Soil Conservation Service offices. SCS personnel were unable to furnish data on clearing costs. See Table A.2.

[c]Number of observations.

[d]Drainage tile costs are in dollars per foot installed, all other data are in dollars per acre.

[e]Terraces are not recommended by the SCS on slopes greater than 18%.

The estimation of subsurface drainage systems required data beyond contractors and SCS surveys. Equation (5.1) gives computations used to estimate the costs per acre of installation of subsurface drainage tiles.[1]

$$DC_i = \frac{43,500}{SC_i} \times TP \tag{5.1}$$

where: SC_i = the recommended distance between laterals for land type i,

TP = the price, per foot, of installed subsurface drainage tiles, and

DC_i = estimated costs per acre of installed drainage tiles.

43,500 is the number of square feet per acre, and like TP is constant for all SMU's.

The first part of the expression is the number of square feet per acre divided by the distance between rows of drainage tile. The result is the number of linear feet of drainage tile per acre. When multiplied by the price, per foot, of installed drainage tiles an estimate of cost, per acre, of installed drainage tile is obtained.

SC_i, distance between lateral, in equation (5.1) incorporates the variability of the SMU's. Due to the permeability and porosity of the soil, different SMU's will require different distances between laterals, resulting in different, per acre, installation costs.

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[1]The helpful comments and guidance of Stewart Melvin, Extension Agricultural Engineer at Iowa State University in deriving this equation are gratefully appreciated.

The mean SCS and contractor responses for the price, per foot, of installed drainage tile are given in Table 5.1.[1] In application of the model, a weighted average of the four estimates were used. Estimates of the distance between laterals, for each SMU requiring subsurface drainage were obtained from recommendations compiled by the SCS and Iowa State University [15, p. 9-20].

Opportunity costs   Two types of opportunity costs were estimated for this study. First, opportunity costs of foregone production on pastureland, including grazed forestland, were estimated. Second, opportunity costs of foregone production from forestland were estimated.

The computations made in the estimation of pasture opportunity costs are given in equation (5.2).

$$APOC_i = (AUD_i) \times (GAIN) \times (PRICE) - PMC \tag{5.2}$$

where: $APOC_i$ = the annual pasture opportunity costs for land type i.

AUD_i = the number of days per year land type i can support an animal unit without destroying productivity.

GAIN = the average gain, in pounds per day of one animal unit,

PRICE = the price per animal unit, and

PMC = the costs of maintaining the pasture in an improved state.

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[1]Although other sizes of drainage tile are sometimes used in Iowa, five and six inch diameter tiles are most frequently used and are the only sizes given in Table 5.1.

As indicated by equation (5.2) only AUD_i varies across land types, all other components are constants.

Estimates of AUD_i were obtained from SCS Soil Interpretation Records, Form V, [38]. Estimate of PMC was obtained from Schaller and Edwards [27]. An average gain of 1.5 pounds per day was used. The price per animal unit varies, depending on the scenario used in application of the model.

The annual opportunity costs of nongrazed forestland were calculated in a manner similar to pasture opportunity cost. First estimates of annual productivity of nongrazed forestland were obtained from the SCS Form V's cited above. Productivity was multiplied by the net or stumpage timber price in order to obtain an estimate of annual opportunity costs of foregone production from non-grazed forestland.[1] Stumpage timber price used was obtained from Wray [54].

Each estimate of opportunity cost was capitalized by dividing through by the discount rate. This results in an estimate of the value of pastureland or forestland that is considered for conversion to cropland.

Net revenue

Net revenue is comprised of three components: i) crop yields, ii) crop prices, and iii) crop production or input costs.

Crop yields Two sets of crop yields were used to test the sensitivity of the model and to analyze the possibility that future yields might increase due to the adoption of technology currently available.

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[1]It was assumed that grazed forestland had no timber production, but was only used as grazing land.

The first set of yields was estimated for the period 1968 to 1977, based upon 1974 yields. Four crops are included in the analysis: corn, soybeans, oats and hay. Estimated 1974 yields for all four crops were based upon SCS corn suitability ratings (CSR). Per acre yields for each land type were calculated such that relative ranking of the CSR were unchanged, and the total production for the state did not exceed the actual 1974 production. The 1974 yields were readjusted to reflect the ten year average yields.

Table 5.2 gives the average yields for corn soybeans oats and hay in Iowa from 1968 to 1977. Oats and hay yields for 1974 did not differ significantly from the 1968-1977 average. However, as indicated in Table 5.2 corn and soybean yields did vary considerably from the 10 year state average.

The second set of yields was obtained for SCS Form V's cited above. Yields were estimated, based on the premise that High Level Management practices were employed. The concept of High Level Management is not clearly defined, but generally means everything that is needed to be done for crop production was done at the right time, and to the proper level. For example, fertilizer and pesticides were applied only when most useful and in correct amounts. This set of yields is used to reflect the maximum productivity of the converted land, if currently available technology is fully utilized. HLM technology is not designed to control soil erosion. In general, High Level Management Yields (HLM) are approximately 20% greater than average yields for 1968-1977.

Table 5.2. Average corn and soybean yields, 1968 to 1977, Iowa[a]

Year	Corn	Soybean	Oats	Hay
	(bushels per acre)	(bushels per acre)	(bushels per acre)	(tons per acre)
1968	93.0	32.0	59.0	2.77
1969	98.0	33.9	50.0	2.89
1970	86.0	32.5	55.0	2.77
1971	102.0	32.5	59.0	2.84
1972	114.0	36.0	56.0	3.03
1973	107.0	34.0	51.5	3.00
1974	80.0	28.0	55.0	2.82
1975	90.0	34.0	53.0	2.80
1976	91.0	31.0	59.0	2.82
1977	88.0	34.0	59.0	3.21
Average	94.9	33.7	55.7	2.90

[a]Source: [40].

Crop production costs   Crop production costs were estimated from 1974 USDA budgets for southern Iowa. Budgets were adjusted for slope phase and soil type when applied to each land type. Crop production costs for corn, soybeans, oats and hay were estimated for each land type in associated with respective crops assumed to be grown on the converted land.

The 1974 production costs were adjusted to 1978 dollars using the Consumer Price Index (CPI). The 1978 production costs were further adjusted to correspond to the specific scenario used in application of the model. For scenarios using HLM yields, 1978 production costs were increased by 10% to reflect higher fertilizer and pesticide use.[1] Additionally, for scenarios requiring a 33 percent increase in production costs the necessary adjustment was made.

Crop prices   Three sets of crop prices were used in application of the model. Table 5.3 lists these prices. All prices are expressed in constant 1978 dollars. Projections for the price of hay and cattle for 1985 consistent with the prices of corn, soybeans and oats were not available; thus they were assumed not to vary with respect to the CPI.

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[1]This procedure was employed under the recommendations of Paul Rosenberry, USDA Collaborator, Iowa State University. A more accurate measure of HLM production costs was not available due to the indistinct concept of High Level Management.

Table 5,3, Crop prices used in model in 1978 dollars, Iowa

Crop	1977[a]	1985[b]	1985[b]
Corn ($/Bu.)	2.08	2,52	2.92
Soybeans ($/Bu.)	7.05	5.51	6.24
Oats ($/Bu.)	1,34	2,52	2.92
Hay ($/ton)	56.68	56.68	56.68
Cattle ($/pound)	.373	.373	.373

[a]Source: [39].

[b]Source: [7].

Corn and soybean price projections for 1985 were derived from the USDA Grain-Oilseeds and Livestock Model (GOL).[1] The GOL model contained two extremes: i) baseline and ii) high demand. These assumptions are explained as follows:

Baseline:

> World grain trade prices in real terms are likely to average closer to the low levels of 1969/70-1971/72 base period than the high levels of the 1972/73-1974/75 period.

High demand:

> Real grain prices...would be substantially higher than in the base 1969/70-1971/72 period but still below the levels of 1972/73-1974/75 [7, p. 2].

The GOL model contained prices for only soybean meal and feed grains. The feed-grain price is assumed to apply to corn and oats. Soybean meal price was converted to a price for soybeans based upon the following regression equation:[2]

$$SM_t = 1.45 + .02\ (SB_t) \quad R^2 = .99 \tag{5.3}$$

where: SM_t = price of soybean mean in period t, and

SB_t = price of soybeans in period t.

High demand and baseline price of soybean meal (3.86 and 3.41, respectively) were placed in equation (5.3). Estimated 1985 price of

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[1]The assistance of Pierre Crosson, of Resources for the Future, Inc., in obtaining the 1985 projected prices is gratefully appreciated.

[2]The regression conversion estimates for soybean meal to soybeans were obtained from Robert Schustad, Department of Agricultural Economics, University of Arkansas. This work is gratefully appreciated.

soybeans for each set of assumptions after being adjusted to 1978 dollars is presented in Table 5.3 with other prices.

Soil erosion

Soil erosion was estimated by the Universal Soil Loss Equation [51]. The Universal Soil Loss Equation has been tested on sample plots for the past thirty years. The equation is specified as follows:

$$SL = R \cdot K \cdot L \cdot S \cdot P \cdot C \qquad (5.4)$$

where: SL = average annual gross soil loss from sheet and rill erosion in tons per acre,

R = rainfall intensity factor,

K = soil erodibility factor,

L = slope length factor,

S = slope gradient factor,

P = conservation practice factor, and

C = cropping and management factor.

The rainfall factor (R) is the product of two characteristics, the total kinetic energy of a rainstorm and its maximum thirty minute intensity. The R factor measures the interactive potential of raindrop impact and turbulence of runoff in dislodging and transporting soil particles from the surface.

The soil erodibility factor (K) is the rate of erosion per unit or erosion index from unit plots of soil which are 72.6 feet in length with a slope of 9 percent, in continuous fallow tilled up and down the slope. The K factor accounts for differing characteristics of the soil, such as permeability, depth, texture, soil structure and stability, and organic matter content.

The slope length (L) and slope gradient (S) factors are generally considered together as a single factor. The LS factor is a measure of the effect of slope length and gradient on soil losses, which differ from the unit plot. Longer, steeper slopes result in greater soil loss due to less infiltration of rainfall and higher velocity of runoff.

The conservation practice factor (P) accounts for impact of alternative conservation management practices, such as contouring and terracing. Values for the P-factor range from 0.0 to 1.0. For example, on relatively flat land the soil loss from an acre of land with contoured rows would be 1.0 times the soil loss with straight rows. Alternatively the more effective the conservation practice, as contouring on intermediate slopes, then the lower the P-factor.

The cropping management factor (C) measures the effects of crop cover and management variables on soil loss. Alternative crop rotations, tillage practices and the management of crop residue all affect the C-factor.

Land use

Land use data were obtained from the 1967 Inventory of Soil and Water Conservation Needs [36] and the 1977 National Erosion Inventory [35]. For each SMU, quantity of acres in pasture, forestland grazed and forest-land not grazed were obtained. These data were then recombined into land types, defined earlier as SMU and land use.[1] As noted earlier, cropland was excluded from analysis since this study examines only the expansion on the extensive margins. Noncropland classified as "other" land, consisting of federally owned land, urban, highway, wasteland and other special uses were a priori eliminated from the analysis on the premise that "other" land would require investment costs far exceeding those considered in this study, and are highly unlikely to be converted to cropland in the foreseeable future.

Discount rates

The discount rate used in the model should reflect the opportunity cost of investment capital used in converting noncropland to cropland. However there appears little consensus on what the appropriate discount rate should be. Table 5.4 presents rates of return, in the U.S., for alternative investment opportunities. The rates range from around 4% to over 9%, from 1965 to 1976, respectively. However, Table 5.5 presents the return on investments for Iowa farmland, from 1968 to 1977. The mean value for this period is 4.8% , ranging from 2.7% in 1977 to 7.4% in 1973.

Because one discount rate cannot be pinpointed as the "correct" opportunity cost of investment capital, three discount rates 4, 6 and 8 percent, were used in this study. This also enables the sensitivity of the model to be tested.

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[1]Land type classification for 1977 data was altered due to data availability. While 1967 data were available by SMU, i.e., soil type, soil phase and erosion class, 1977 data were classified only by soil type and slope phase without an erosion class.

Table 5.4. Selected rates of return, 1965 to 1976[a], United States

Year	Federal Intermediate Credit Bank Loans	Government Securities 3-5 years	Corporation Dividend Yields
		(percent)	
1965	4.94	4.22	4.64
1966	5.82	5.16	5.34
1967	5.88	5.07	5.82
1968	6.41	5.59	6.51
1969	7.23	6.85	7.36
1970	8.50	7.37	8.51
1971	6.37	5.77	7.94
1972	6.00	5.85	7.63
1973	7.16	6.92	7.80
1974	8.82	7.81	9.03
1975	8.14	7.55	9.57
1976	7.35	6.94	9.01

[a]Source: [43, p. 92, 101].

Table 5.5. Return on investment, Iowa farmland[a]

Year	Return on Investment
	(percent)
1968	4.2
1969	4.0
1970	4.2
1971	4.4
1972	5.9
1973	7.4
1974	7.0
1975	4.6
1976	4.0
1977	2.7

[a]Source: [21, p.2].

Scenarios

In applying the analytical model developed in Chapter IV to Iowa, alternative assumptions of crop yields, crop prices and crop production costs were used to project possible futures. Sensitivity of the model was tested by varying the discount rate and land use data. Table 5.6 summarizes nine scenarios used in application of the model. In all nine scenarios investment costs are assumed to remain constant. Two crop rotations corn-soybean and continuous corn were assumed, with the model choosing the most profitable. Initially, only conventional tillage was assumed.

Scenario A estimates potential cropland with 1977 land use data, 1977 crop prices, 1974 production costs and average yields from 1968 to 1977. This scenario is used to test the responsiveness of potential cropland to crop prices discussed below.

Scenario B investigates implications of the baseline set of crop prices in 1985, with constant production costs and yields. It is the baseline scenario used for comparison of all other 1985 projections. Scenario E investigates the same situation, except with high crop prices.

Scenarios C and F are identical to Scenarios B and E, respectively, but with HLM yields, reflecting the impacts of the adoption of the best technology currently available. Scenarios D, E, H and I repeat Scenarios B, C, F and G, respectively, except crop production costs are assumed to increase by 33 percent. Eight scenarios projecting to 1985, with three discount rates for each, and two sets of land use data result in 48 estimates of the supply of potential cropland in Iowa under a variety of alternative futures.

Table 5.6. Alternative scenarios used in application of model

Scenario	Prices		Production Costs		Yield	Land Use
A	1977	and	1974	and	1968-1977	1977
B	1985B[a]	and	1974	and	1968-1977	1967 and 1977
C	1985B	and	1974	and	HLM[b]	1967 and 1977
D	1985B	and	1985	and	1968-1977	1967 and 1977
E	1985B	and	1985	and	HLM	1967 and 1977
F	1985H[c]	and	1974	and	1968-1977	1967 and 1977
G	1985H	and	1974	and	HLM	1967 and 1977
H	1985H	and	1985	and	1968-1977	1967 and 1977
I	1985H	and	1985	and	HLM	1967 and 1977

[a]Assumes crop prices resulting from export demand similar to 1969 to 1972 base period.

[b]Assumes high level management technology is used by all farmers.

[c]Assumes crop prices resulting from high export demand.

Price responsiveness

The responsiveness of the supply of potential cropland is investigated by increasing crop prices in discrete steps. Table 5.7 presents prices for corn, soybeans, oats and hay used in this procedure. Twenty set of prices are included, each ten percent higher than the previous price. 1977 was used as the base run with corn, soybean, oats and hay prices of 2.08, 7.05, 1.34, 56.68; respectively. This application of the model allows estimation of i) the responsiveness of potential cropland, and consequently soil erosion to increases in crop prices and ii) potential limits to increases in cropland, where increases in crop prices will not bring in additional cropland.

Soil loss constraint

All scenarios in Table 5.6 are estimated with and without a constraint on the annual soil loss per acre. When the model is estimated within confines of the soil loss constraint, additional agricultural practices are introduced to allow soil loss control. Three additional rotations are possible, i) corn-soybeans-corn-oats-meadow-meadow, ii) corn-oats-meadow-meadow-meadow-meadow and iii) continuous meadow. For each rotation two tillage practices and three plowing methods are possible. Tillage practices are i) conventional moldboard plowing and ii) residue covering. Plowing methods include i) straight row, ii) contouring and iii) terracing. The model chooses the combination of rotation, tillage practice and plowing method which meets the soil loss constraint of 5 tons/acre/year, recommended by the Soil Conservation Service, and has a cost-net revenue ratio less than 1.0 [50].

Table 5.7. Crop prices used to test responsiveness of potential cropland

Step number	Corn	Soybeans	Oats	Hay
	($/bu.)	($/bu.)	($/bu.)	($/ton)
1[a]	2.08	7.05	1.34	56.68
2	2.29	7.76	1.47	62.35
3	2.52	8.53	1.62	68.58
4	2.77	9.38	1.78	75.44
5	3.05	10.32	1.96	82.99
6	3.35	11.35	2.16	91.28
7	3.68	12.49	2.37	100.41
8	4.05	13.74	2.61	110.45
9	4.46	15.11	2.87	121.50
10	4.90	16.62	3.16	133.65
11	5.39	18.29	3.48	147.01
12	5.93	20.11	3.82	161.71
13	6.53	22.13	4.20	177.89
14	7.18	24.34	4.63	195.67
15	7.90	26.77	5.09	215.24
16	8.69	29.49	5.60	236.77
17	9.56	32.39	6.16	260.44
18	10.51	35.63	6.77	286.49
19	11.56	39.20	7.45	315.14
20	12.72	43.12	8.20	346.65

[a]Step number 1 is 1977 crop prices taken from table 5.3.

Estimated yields from residue tillage were obtained by taking 95 percent of the yields for the average period from 1968-1977.[1] Established estimates of residue tillage crop yields were not available within the land type classification base used in this study.

Results

Analysis of results from application of the model developed in Chapter IV is separated into two discussions. First, projections of the supply of potential cropland are made to 1985 using eight scenarios (B through I) shown in Table 5.6. Second, the sensitivity of potential cropland to increases in crop prices is analyzed, using scenario A as a base.

1985 projections

Alternative assumptions of crop prices, production costs and crop yields were combined in eight scenarios reflecting possible 1985 conditions. Each scenario was used with three discount rates: 4 %, 6 % and 8 %; and two sets of land use data: 1967 Conservation Needs Inventory and 1977 National Erosion Inventory. Eight scenarios, three discount rates and two sets of land use data enabled 48 estimates of potential cropland, soil loss and net income. The 48 estimates were reevaluated with a 5 ton/acre/year constraint on soil loss.

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[1]Based on recommendations from Paul Rosenberry, USDA Collaborator, Iowa State University, Ames, Iowa.

This section analyzes all 96 estimates of potential cropland. First, the eight price/cost/yield scenarios are discussed separately. Second, the overall implications derived from all eight scenarios are further examined.

Analysis of scenarios Scenarios B through I in Table 5.6 were used to estimate potential cropland by 1985. Two sets of crop prices, production costs and yields were used to construct the scenarios. Results of applying the model to Iowa using each scenario is discussed separately. Each scenario is evaluated in terms of potential cropland, gross and average soil loss, net income, slope of the land and relative portion in pasture and forest. The impact on these variables of the soil loss constraint, the discount rate and the two sets of land use data are also examined.

Scenario B Baseline crop prices, 1974 production costs and average crop yields from 1968 to 1977 were assumed in scenario B. This was the baseline scenario depicting the situation if export demand continues the trend establish in the pre-1972 period, production costs do not increase due to energy shortages and yields do not increase through technological innovation.

Table 5.8 presents results of the model run under scenario B. Estimates of potential cropland without the soil loss constraint range from 71,000 acres to 313,000 acres. Using 1967 data and 6% discount rate estimated potential cropland was 232,900 acres. With 1977 data the estimate was 87,000 acres. Without exception 1977 data resulted in estimates of potential cropland lower than 1967 data.

Table 5.8. 1985 projections under scenario B, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land use						
Pasture	15.3	12.4	10.8	5.5	4.9	3.7
Forest	298.0	220.5	61.6	217.5	159.2	25.9
Slope Phase						
0-2%	88.1	75.0	9.0	78.6	70.3	4.9
2-5%	80.1	50.7	23.9	65.0	48.0	19.8
5-9%	50.2	46.8	36.2	47.9	45.4	4.9
9-14%	64.5	57.9	0.8	31.6	0.4	0.0
14-18%	26.6	0.0	0.0	0.0	0.0	0.0
18-30%	1.4	1.4	1.4	0.0	0.0	0.0
30+%	1.4	0.0	0.0	0.0	0.0	0.0
Total Acres	313.3	232.9	72.4	223.0	164.1	29.6
	(1000 tons/year)					
Gross Soil Loss	21,011.6	10,571.4	4,263.2	369.5	273.3	53.8
	(tons/acre/year)					
Ave. Soil Loss	67.1	45.4	58.9	1.7	1.7	1.8
	(million dollars)					
Net Income	188.9	55.6	19.1	120.5	28.4	4.0

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
14.0	14.0	14.0	0.0	0.0	0.0
148.0	73.0	57.0	111.0	59.0	14.0
67.0	15.0	7.0	67.0	15.0	7.0
7.0	7.0	7.0	7.0	7.0	7.0
37.0	37.0	29.0	37.0	37.0	0.0
23.0	0.0	0.0	0.0	0.0	0.0
28.0	28.0	28.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
162.0	87.0	71.0	111.0	59.0	14.0
(1000 tons/year)					
8,300.0	6,080.0	5,765.5	152.8	152.8	8.9
(tons/acre/year)					
51.2	69.9	81.2	1.4	2.6	0.6
(million dollars)					
122.8	48.4	26.2	59.1	10.9	2.5

Average soil loss, without the soil loss constraint ranged from 45.4 to 81.2 tons/acre/year. The majority, from 80% to 90%, of potential cropland regardless of land use data came from forestland. The vast majority of the potential cropland had slopes less than 9%. With 1977 data between 60% and 70% of the potential cropland had slopes greater than 9%, with or without the soil loss constraint. With 1967 data over 70% of the potential cropland was in slope phase less than 9% without the soil loss constraint.

The soil loss constraint had a predictable effect on potential cropland, gross and average soil loss and net income. Potential cropland was reduced about 50% for both 1967 and 1977 data, gross soil loss was reduced 98% and net income was reduced 63%. Average soil loss was decreased from around 62 tons/acre/year to about 2 tons/acre/year. The soil loss constraint also decreased the relative share of potential cropland in the steeper slope phases. Without the soil loss constraint slopes less than 9% accounted for a little more than 60% of the potential cropland. However with the soil loss constraint 85% to 100% of potential cropland was in slopes less than 9%.

Scenario C The only difference between scenarios B and C is scenario C assumed high level management (HLM) technology and associated yields. Crop prices and production costs, with only slight modification are the same as scenario B. Production costs were increased 10% to adjust for HLM technology. HLM yields can be interpreted two ways. First, HLM is literally technology currently available. The use of HLM yields can be interpreted as the adoption by farmers of present technology. Second, HLM yields can be used as a proxy for higher yields due to technological innovation.

Table 5.9 presents the results under scenario C. Estimates of potential cropland ranged from 1,380,000 to 826,000 acres, with the soil loss constraint, considerably more than scenario B. For 4%, 6% and 8% discount rates the 1967 and 1977 estimates were 1,380,000/988,000; 1,133,500/891,000 and 878,900/826,000; acres respectively.

Average soil loss was about 40 tons/acre/year, ranging from 35.7 to 43.4 tons/acre/year without the soil loss constraint. Both 1967 and 1977 data sets indicated three fourths of potential cropland had a slope less than 9% without the soil loss constraint. 1967 data had about half of the potential cropland in pasture and half in forest, whereas the 1977 data had 75% in pasture.

The 5 ton/acre/year soil loss constraint reduced potential cropland 33%, gross soil loss 97% and net income 20%. The portion of land in pasture was smaller for both 1967 and 1977 data with the soil loss constraint, 35% and 60% respectively. Average soil loss was under 2 tons/acre/year with the soil loss constraint. The relative share of potential cropland with slopes less than 9% increased to 85% with the soil loss constraint.

Scenario D Production costs are increased by one-third to reflect scarce energy and fertilizer inputs in scenario D. Crop prices and yields are identical to scenario B. This scenario portrays the most pessimistic of all eight conditions faced by farmers in this study.

Table 5.9. 1985 projections under scenario C, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land Use						
Pasture	623.6	530.9	421.0	364.8	294.7	218.8
Forest	756.3	602.6	457.9	706.3	540.0	366.8
Slope Phase						
0-2%	363.7	248.7	171.6	363.4	246.7	171.1
2-5%	359.6	335.2	301.2	386.8	256.2	204.2
5-9%	302.6	272.6	172.2	213.9	184.7	119.0
9-14%	223.5	196.0	171.0	105.5	89.7	82.1
14-18%	84.0	59.5	58.7	61.5	54.9	7.1
18-30%	45.6	50.7	3.6	39.3	1.7	1.3
30+%	1.0	0.8	0.8	0.8	0.8	0.8
Total Acres	1,380.0	1,133.5	878.9	1,071.1	834.7	585.5
	(1000 tons/year)					
Gross Soil Loss	59,924.7	45,853.6	34,631.1	1,786.6	1,449.2	966.8
	(tons/acre/year)					
Ave. Soil Loss	43.4	40.4	39.4	1.7	1.7	1.7
	(million dollars)					
Net Income	1,016.7	460.8	225.1	866.3	377.7	180.8

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
701.0	663.0	634.0	370.0	334.0	283.0
287.0	228.0	192.0	273.0	206.0	163.0
303.0	228.0	229.0	303.0	258.0	229.0
187.0	172.0	172.0	113.0	113.0	113.0
226.0	226.0	212.0	117.0	103.0	67.0
228.0	181.0	191.0	66.0	44.0	37.0
22.0	22.0	22.0	22.0	22.0	0.0
22.0	22.0	0.0	22.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
988.0	891.0	826.0	643.0	540.0	446.0
(1000 tons/year)					
39,554.8	36,206.0	29,507.4	885.0	702.9	481.1
(tons/acre/year)					
40.0	40.6	35.7	1.4	1.3	1.1
(million dollars)					
524.3	281.4	151.0	445.4	208.0	105.8

Table 5.10 presents results under scenario D. 1977 land use data projected only 7,000 acres potential cropland under scenario D-14% discount rate, and only 4,500 to 41,600 acres of potential cropland were estimated with 1967 data. Therefore the discussion in this section deals only with results from 1967 data. Average soil loss without the soil loss constraint was about 25 tons/acre/year ranging from 15 to 33 tons/acre/year. Between 70% and 90% of the potential cropland had slopes less than 9%. The portion of potential cropland in pasture fluctuated from 12% to over 90%. The interesting point is the absolute quantity of pastureland remained constant for all three discount rates at about 4,000 acres. The large fluctuation in shares was due to the change in forestland. At a 4% discount rate 36,800 acres, or 88%, was in forestland. At an 8% discount rate only 400 acres, or less than 10%, was in forestland.

The soil loss constraint reduced potential cropland by 68%, gross soil loss by 96% and net income 90%. All potential cropland estimated with the soil loss constraint was in slopes less than 5% for all three discount rates. And as with the unconstrained estimates the portion in pasture fluctuated, due to the absolute change in forestland.

This indicates that virtually no potential cropland exists under the assumptions of scenario D. In contrast to scenario B, the one-third increase on production costs decreased potential cropland an average by 95%.

Table 5.10. 1985 projections under scenario D, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land Use						
Pasture	4.9	4.1	4.1	1.6	0.8	0.4
Forest	36.8	3.2	0.4	13.7	2.8	0.0
Slope Phase						
0-2%	3.2	0.8	0.8	2.8	0.4	0.4
2-5%	13.5	4.1	1.2	12.4	3.2	0.0
5-9%	2.2	0.0	0.0	0.0	0.0	0.0
9-14%	0.4	0.0	0.0	0.0	0.0	0.0
14-18%	0.0	0.0	0.0	0.0	0.0	0.0
18-30%	1.4	1.4	1.4	0.0	0.0	0.0
30+%	0.0	0.0	0.0	0.0	0.0	0.0
Total Acres	41.6	7.3	4.5	15.3	3.6	0.4
	(1000 tons/year)					
Gross Soil Loss	1,394.5	112.4	107.1	25.7	8.0	1.3
	(tons/acre/year)					
Ave. Soil Loss	33.5	15.4	23.8	1.7	2.2	3.3
	(million dollars)					
Net Income	15.4	7.3	5.1	3.6	0.4	0.2

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	7.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	7.0	0.0	0.0
(1000 tons/year)					
0.0	0.0	0.0	0.0	0.0	0.0
(tons/acre/year)					
0.0	0.0	0.0	0.0	0.0	0.0
(million dollars)					
1.1	0.0	0.0	1.1	0.0	0.0

Scenario E   HLM yields and higher production costs are both assumed with baseline prices for scenario E. This scenario analyzed the consequences of both higher production costs, due to scarcer inputs, and increased yields, from either technological innovation or implementation of technology currently available.

Table 5.11 presents results under scenario E. Potential cropland estimates, without the soil loss constraint, are between 89,000 and 404,200 acres. As might be expected scenario E potential cropland estimates are greater than scenario D, with only higher production costs; and lower than scenario C, with only higher yields. As in all scenarios, estimates of potential cropland with 1977 data are consistently lower than estimates with 1967 data.

Average soil loss ranged from 29 to 50 tons/acre/year. The majority of potential cropland was in forestland. For 1967 data about 95% of potential cropland was in forest, and for 1977 data all was in forest. About 75% of the potential cropland was in slopes less than 9%, without the soil loss constraint.

The soil loss constraint had very little effect on all but soil loss. Potential cropland decreased 2%, net income decreased 6% and gross soil loss decreased 95%. The relative shares of potential cropland in forest and slopes less than 9% remained unchanged by the soil loss constraint. However average soil loss decreased to around 2 tons/acre/year with the constraint.

Table 5.11. 1985 projections under scenario E, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land Use						
Pasture	13.5	13.1	11.7	13.3	12.9	11.5
Forest	390.7	269.6	141.7	368.2	267.6	138.8
Slope Phase						
0-2%	129.8	111.0	31.5	127.4	110.6	31.2
2-5%	109.6	56.9	45.0	108.4	56.5	44.6
5-9%	88.9	51.7	45.0	69.9	51.7	45.0
9-14%	69.5	62.3	31.7	69.5	61.3	29.2
14-18%	5.2	0.6	0.2	5.3	0.2	0.2
18-30%	0.8	0.0	0.0	0.8	0.0	0.0
30+%	0.2	0.2	0.0	0.2	0.2	0.0
Total Acres	404.2	282.7	153.4	381.5	280.5	150.3
	(1000 tons/year)					
Gross Soil Loss	11,888.4	8,402.4	5,052.7	505.9	392.2	289.9
	(tons/acre/year)					
Ave. Soil Loss	29.4	29.7	32.9	1.3	1.4	1.9
	(million dollars)					
Net Income	343.7	128.4	53.5	340.4	127.6	50.4

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
0.0	0.0	0.0	0.0	0.0	0.0
162.0	148.0	89.0	155.0	148.0	89.0
67.0	67.0	15.0	67.0	67.0	15.9
14.0	7.0	7.0	14.0	7.0	7.0
44.0	37.0	37.0	37.0	37.0	37.0
37.0	37.0	30.0	37.0	37.0	30.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
162.0	148.0	89.0	155.0	148.0	89.0
(1000 tons/year)					
5,536.9	5,096.8	4,512.3	206.8	198.3	186.7
(tons/acre/year)					
34.2	34.4	50.7	1.3	1.3	2.1
(million dollars)					
166.3	64.8	26.7	156.6	58.2	22.7

Two points are apparent in analysis of scenario E with the other scenarios. First, in contrast to scenario D, which is identical except scenario E has HLM yields, potential cropland is substantially increased from less than 50,000 to around 200,000 acres. Second, potential cropland estimates with 1977 data are consistently less than with 1967 data.

Scenario F   Crop prices resulting from high export demand are assumed in scenario F. Production costs and crop yields are the same as assumed in scenario B. This scenario depicts the situation if historical trends generally continue, but export demand increases, driving crop prices up.

Table 5.12 presents the results under scenario F. Potential cropland estimates, without the soil loss constraint, ranged from 209,000 to 588,000 acres. As in all scenarios previously discussed, potential cropland estimates with 1977 data are consistently lower than with 1967 data. Average soil loss ranged from 30 to 60 tons/acre/year. With 1977 data average soil loss was about 35 tons/acre/year, and with 1967 data they were about 55 tons/acre/year. About three-fourths of potential cropland estimated with 1967 data was in forest. With 1977 data about 63% is in forestland. With 1967 and 1977 data 75% of the potential cropland has slope less than 9%.

With the soil loss constraint potential cropland is decreased by 36%, gross soil loss by 98% and net income by 67%. Average soil loss is less than 2 tons/acre/year, with the soil loss constraint. Between 90% and 100% of potential cropland has slope less than 9% under the soil loss constraint.

Table 5.12. 1985 projections under scenario F, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land Use						
Pasture	136.2	130.3	77.7	62.6	54.4	17.1
Forest	451.8	333.6	292.2	320.5	194.8	174.4
Slope Phase						
0-2%	177.4	142.3	100.3	165.1	131.2	92.9
0-5%	146.1	128.3	103.9	84.1	63.1	51.7
5-9%	112.5	80.0	59.0	70.8	52.7	47.0
9-14%	85.5	72.8	67.0	63.0	2.2	0.0
14-18%	53.3	27.4	26.6	0.0	0.0	0.0
18-30%	1.6	1.6	1.6	0.0	0.0	0.0
30+%	10.5	10.5	10.5	0.0	0.0	0.0
Total Acres	588.0	463.9	369.9	383.0	249.3	191.6
	(1000 tons/year)					
Gross Soil Loss	32,301.3	25,756.6	22,282.9	734.2	342.3	300.7
	(tons/acre/year)					
Ave. Soil Loss	54.9	55.5	60.2	1.9	1.4	1.6
	(million dollars)					
Net Income	519.8	225.0	104.1	284.4	106.3	39.4

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
127.0	111.0	75.0	91.0	83.0	61.0
228.0	169.0	134.0	133.0	111.0	97.0
173.0	150.0	114.0	173.0	150.0	114.0
28.0	21.0	7.0	14.0	7.0	7.0
59.0	44.0	37.0	37.0	37.0	37.0
45.0	37.0	23.0	0.0	0.0	0.0
0.0	28.0	28.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
355.0	280.0	209.0	224.0	194.0	158.0
(1000 tons/year)					
13,873.4	9,138.0	7,655.1	162.3	152.8	152.8
(tons/acre/year)					
39.1	32.6	36.6	0.7	0.8	1.0
(million dollars)					
297.1	134.5	71.0	102.4	62.5	22.4

Comparison of scenarios F and B show the effect of higher crop prices. Scenario B estimated potential cropland around 200,000 acres, scenario B was near 400,000 acres. On average scenario F estimates were 174% of scenario B estimates. That the impact of crop prices is not as great as crop yields is due to, primarily, the relative magnitudes. HLM yields are about 20% greater than average yields for 1968 to 1977, whereas high export prices are about 15% greater than baseline prices.

Scenario G   The assumptions of high crop prices, HLM yields and 1974 production costs make scenario G the most optimistic of the eight scenarios, from the farmers viewpoint. This scenario analyzes the results if both crop prices and yields increase. However, care should be taken to avoid misinterpreting the scenario. The scenario does not say that, if crop prices increase causing crop yields to increase, what are the consequences? Obviously if yields increase for all cropland there will be a downward pressure on crop prices. This scenario only assumes that crop prices and yields are at a specific level. Table 5.13 presents the results under scenario G.

Without the soil loss constraint potential cropland was estimated between 2.46 and 3.86 million acres. This was by far the largest group of potential cropland estimates of all eight scenarios. Potential cropland estimates with 1967 and 1977 data were very similar. Using 4%, 6% and 8% discount rates the estimates were 3.86/3.76; 3.14/3.02 and 2.58/2.46 million acres for 1967/1977 data, respectively.

Table 5.13. 1985 projections under scenario G, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land use						
Pasture	2,769.0	2,233.0	1,796.6	1,507.5	1,059.5	813.0
Forest	1,094.3	907.7	780.7	789.9	703.8	543.6
Slope Phase						
0-2%	907.4	663.7	444.3	904.2	657.4	439.1
2-5%	717.7	621.3	513.8	609.7	490.4	400.9
5-9%	731.0	583.4	563.7	531.4	433.6	397.2
9-14%	658.8	598.0	454.8	144.4	120.2	106.3
14-18%	482.0	459.6	407.5	64.9	58.4	10.2
18-30%	342.3	193.9	183.3	40.7	2.5	2.1
30+%	24.1	20.8	9.8	2.2	0.8	0.8
Total Acres	3,863.3	3,140.7	2,577.3	2,297.6	1,763.2	1,356.6
	(1000 tons/year)					
Gross Soil Loss	266,895.4	207,384.9	180,513.6	3,716.1	2,936.9	2,424.7
	(tons/acre/year)					
Ave. Soil Loss	69.1	66.0	70.0	1.6	1.7	1.8
	(million dollars)					
Net Income	3,135.8	1,576.5	890.0	1,960.4	926.7	492.0

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
3,101.0	2,496.0	2,078.0	1,878.0	1,094.0	742.0
663.0	525.0	384.0	443.0	316.0	235.0
672.0	509.0	396.0	672.0	509.0	396.0
873.0	695.0	487.0	667.0	329.0	215.0
668.0	445.0	416.0	452.0	336.0	314.0
820.0	769.0	656.0	383.0	206.0	52.0
476.0	380.0	284.0	75.0	30.0	0.0
255.0	223.0	223.0	22.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
3,764.0	3,021.0	2,462.0	2,271.0	1,410.0	977.0
(1000 tons/acre)					
243,661.5	204,042.9	179,215.0	4,685.6	2,585.8	1,607.7
(tons/acre/year)					
64.7	67.5	72.8	2.0	1.8	1.6
(million dollars)					
2,704.2	1,362.7	797.2	1,583.5	615.7	354.7

Average soil loss was about 68 tons/acre/year, ranging from 65 to 73 tons/acre/year. About three-fourths of the potential cropland was in pasture, and one-half with slopes less then 9%, without the soil loss constraint imposed on the model.

The soil loss constraint led to a decrease in potential cropland of 48%, gross soil loss of 99% and net income of 46%. Over 90% of the potential cropland had slopes less than 9% and the share in pasture remained the same with the soil loss constraint.

Scenario G, as with all previous scenarios, shows estimates of potential cropland with 1977 data are consistently lower than 1967 data estimates. The combination of high prices and HLM yields have resulted in the largest estimates of potential cropland. In conjunction with the approximate 3 million acres of potential cropland, are the highest estimates of average soil loss. While it will be investigated more fully in the section on price responsiveness there appears to be a trend between potential cropland and average soil loss. The trend indicates that greater quantities of potential cropland are associated with greater average soil loss.

Scenario H High crop prices are combined with high production cost and average yields for 1968 to 1977 for scenario H. This scenario analyzes the impact of a combined increase in crop prices and production costs.

Table 5.14 presents the results under scenario H. Estimates of potential cropland range from 7,000 to 213,700 acres. Estimates of potential cropland with 4%, 6% and 8% discount rates were 213,700/97,000;

Table 5.14. 1985 projections under scenario H, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land Use						
Pasture	11.0	9.8	9.6	2.8	2.2	1.8
Forest	202.7	72.7	39.8	162.1	35.2	12.9
Slope Phase						
0-2%	77.7	19.3	6.3	72.4	14.1	2.6
2-5%	57.8	24.4	14.7	47.4	20.8	11.9
5-9%	46.6	36.0	25.5	45.2	2.5	0.2
9-14%	29.1	0.4	0.4	0.0	0.0	0.0
14-18%	0.0	0.0	0.0	0.0	0.0	0.0
18-30%	1.4	1.4	1.4	0.0	0.0	0.0
30+%	0.0	0.0	0.0	0.0	0.0	0.0
Total Acres	213.7	82.5	49.4	165.0	37.4	14.7
	(1000 tons/year)					
Gross Soil Loss	7,833.9	4,286.0	3,291.3	267.6	42.7	22.7
	(tons/acre/year)					
Ave. Soil Loss	36.7	52.0	66.0	1.6	1.1	1.5
	(million dollars)					
Net Income	108.1	28.0	12.0	58.2	4.7	0.8

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
0.0	0.0	0.0	0.0	0.0	0.0
97.0	43.0	7.0	97.0	14.0	7.0
53.0	7.0	7.0	53.0	7.0	7.0
7.0	7.0	0.0	7.0	7.0	0.0
37.0	29.0	0.0	37.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
97.0	43.0	7.0	97.0	14.0	7.0
(1000 tons/year)					
1,780.0	1,465.5	0.0	152.9	8.9	0.0
(tons/acre/year)					
18.4	34.1	0.0	1.6	0.6	0.0
(million dollars)					
38.8	12.1	0.8	23.9	3.4	0.8

82,500/43,000 and 49,400/7,000 for 1967/1977 data respectively. Average soil loss was between 36.7 and 66.0 tons/acre/year for 1967 and 0.0 and 34.1 tons/acre/year for all 1977 data estimates. The relative share of potential cropland in pasture was less than 20%, for 1967 data. No land was in pasture for 1977 data. For 1977 all potential cropland has slopes less than 9%. For 1967 data over 85% had slopes less than 9%.

The soil loss constraint decreased potential cropland 35%, gross soil loss 97% and net income 55%. With the soil loss constraint all potential cropland had slopes less than 9% and less than 5% was in pasture. Average soil loss, with the soil loss constraint, was less than 2 tons/acre/year.

The constrictive consequences of higher production costs are evident in scenario H. Potential cropland is reduced from around 400,000 acres in scenario F, with 1974 production costs, to around 100,000 acres with a one-third increase in production costs.

Scenario I High prices, high production costs and HLM yields are combined in scenario I. This scenario, examines the effect of changes in all three variables.

Table 5.15 presents results under scenario I. Estimates of potential cropland ranges from 506,000 to 1,131,600 acres. For 4%, 6% and 8% discount rates estimates of potential cropland were 1,131,600/1,004,000; 901,000/694,000 and 618,800/506,000 for 1967/1977 data, respectively. As with all other scenarios 1977 data estimates of potential cropland are consistently lower than 1967 data estimates.

Table 5.15. 1985 projections under scenario I, Iowa

	1967 Land Use Data					
	Unconstrained			Constrained		
Discount rate	4%	6%	8%	4%	6%	8%
	(1000 acres)					
Land Use						
Pasture	466.3	358.8	249.8	209.1	125.8	61.0
Forest	665.3	542.2	369.0	548.9	426.4	277.4
Slope Phase						
0-2%	366.4	235.5	159.9	358.2	221.7	146.4
2-5%	343.8	312.2	257.2	181.0	161.3	91.1
5-9%	214.8	197.3	111.6	136.4	93.8	67.5
9-14%	131.5	97.7	82.7	75.1	72.6	32.1
14-18%	54.8	54.3	5.7	5.7	1.8	0.8
18-30%	19.6	3.2	0.8	0.8	0.2	0.2
30+%	0.8	0.8	0.8	0.8	0.8	0.2
Total Acres	1,131.6	901.0	618.8	758.0	552.3	338.3
	(1000 tons/year)					
Gross Soil Loss	37,845.3	29,269.3	15,252.1	1,165.0	772.5	483.9
	(tons/acre/year)					
Ave. Soil Loss	33.4	32.5	24.6	1.5	1.4	1.4
	(million dollars)					
Net Income	900.9	406.0	199.2	658.5	297.4	130.5

1977 Land Use Data					
Unconstrained			Constrained		
4%	6%	8%	4%	6%	8%
(1000 acres)					
754.0	488.0	358.0	258.0	206.0	169.0
250.0	206.0	148.0	192.0	170.0	141.0
287.0	251.0	222.0	287.0	251.0	222.0
256.0	172.0	157.0	67.0	44.0	14.0
226.0	205.0	90.0	59.0	44.0	44.0
191.0	44.0	37.0	37.0	37.0	0.0
22.0	22.0	0.0	0.0	0.0	0.0
22.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
1,004.0	694.0	506.0	540.0	376.0	310.0
(1000 tons/year)					
37,079.7	17,892.5	8,953.1	480.3	308.3	251.6
(tons/acre/year)					
36.9	25.8	17.7	1.1	0.8	0.8
(million dollars)					
479.3	229.8	119.7	334.1	152.0	74.2

Average soil loss ranged from 18 to 37 tons/acre/year without the soil loss constraint. 40% of potential cropland was in pasture using 1967 data, but 70% using 1977 data, without the soil loss constraint. In addition, about 80% of potential cropland had slopes less than 9%.

The soil loss constraint reduced potential cropland 43%, gross soil loss 97% and net income 32%. The relative share of potential cropland in slopes less than 9% went up to about 90%. The portion of pasture and forest remain about the same as without the soil loss constraint.

In contrast to scenario G higher production costs reduces potential cropland about 75%. In contrast to scenario E higher crop prices increases potential cropland about 3 1/2 times.

Implications of scenarios Three topics relevant to the scenarios discussed above require elaboration. The topics are, i) the overall impact of individual variables, crop prices, production cost, yields and the discount rate on estimates of potential cropland; ii) the impact of the soil loss constraint on potential cropland, gross soil loss and net income; iii) the consistency between 1967 and 1977 data in estimating potential cropland.

Variable sensitivity The sensitivity of potential cropland to four variables: crop prices, production costs, yields and the discount rate, are discussed in this section.

Table 5.16 presents the twenty-four estimates of potential cropland made with 1977 data and no soil loss constraint. Estimates were

Table 5.16. Responsiveness of potential cropland to crop prices, 1977 data

Scenario-Decrease Rate	1985B[a]	1985H[b]	Percentage Increase
	(1,000 acres)		(Percent)
B-4/F-4	162.0	355.0	119.1
B-6/F-6	87.0	280.0	221.8
B-8/F-8	71.0	209.0	194.4
C-4/G-4	988.0	3,764.0	281.0
C-6/G-6	891.0	3,021.0	239.1
C-8/G-8	826.0	2,462.0	198.1
D-4/H-4	7.0	97.0	1,285.7
D-6/H-6	0.0	43.0	—[c]
D-8/H-8	0.0	7.0	—[c]
E-4/I-4	162.0	1,004.0	519.8
E-6/I-6	148.0	694.0	368.9
E-8/I-8	89.0	506.0	468.5

[a]Assumes baseline crop prices.

[b]Assumes high demand crop prices.

[c]Percentage increases were not calculated due to the inability of dividing by zero.

paired such that the only difference in the assumptions underlying each estimate was crop prices. For example 71,000 acres were estimated assuming 1974 production costs, average yields for 1968 to 1977, 8% discount rate and baseline crop prices (i.e., scenario B-8%). This is compared to 209,000 acres estimated under the assumption of 1974 production costs, average yields for 1968 to 1977, 8% discount rate and high export demand crop prices (i.e., scenario F-8%). All twelve pairs are associated in the same manner.

While there is considerable variation between the percentage increase of each pair, ranging from 119% to 1286%, the higher crop prices produce substantially more potential cropland than the baseline prices. The average increase in potential cropland with high over baseline prices is 390%. This indicates that the higher prices will bring in about 5 times as much potential cropland as baseline prices.

The thirty-three percent increase in production costs decreases potential cropland an average of 85%. As noted above, the increase in production costs virtually stifles the conversion of noncropland to cropland. To facilitate comparison with Table 5.16 it makes more sense to view a decrease in production costs leading to an increase in potential cropland. Table 5.17 is constructed in a manner analogous to Table 5.16 except production costs are varied within each pair of observations and crop prices, yields and the discount rate are held constant. The decrease in production costs leads to an average increase in potential cropland of 875% ranging from 266% to 2886%. This is over twice the effectiveness of crop prices at 390%.

Table 5.17. Responsiveness of potential cropland to production costs, 1977 data

Scenario-Discount Rate	1974[a]	1985[b]	Percentage Increase
	(1,000 acres)		(Percent)
B-4/D-4	162.0	7.0	2,214.3
B-6/D-6	87.0	0.0	—[c]
B-8/D-8	71.0	0.0	—[c]
C-4/E/4	988.0	162.0	509.9
C-6/E-6	891.0	148.0	502.0
C-8/E-8	826.0	89.0	828.1
F-4/H-4	355.0	97.0	266.0
F-6/H-6	280.0	43.0	551.2
F-8/H-8	209.0	7.0	2,885.7
G-4/I-4	3,764.0	1,004.0	274.9
G-6/I-6	3,021.0	694.0	335.3
G-8/I-8	2,462.0	506.0	386.6

[a]Assumes 1974 production costs.

[b]Assumes 1985 production costs.

[c]Percentage increases were not calculated due to the inability of dividing by zero.

The greatest impact on potential cropland by any of the variables is yields. Table 5.18 presents an analysis analogous to Tables 5.16 and 5.17 except yields are changed within each pair of potential cropland estimates. It indicates potential cropland is 1730% greater with HLM yields than with average yields for 1968 to 1977. The range is between 500% and 7130%.

The discount rate also has a noticeable effect on potential cropland. Table 5.19 presents analysis of potential cropland sensitivity. As with the previous Tables, estimates of potential cropland are paired in such a way that only the discount is altered with each pair. Two sets of comparisons are made, 4%/6% and 6%/8% discount rates, indicating the effect of a decrease in the discount rate. With a decrease in the discount rate from 6% to 4% potential cropland increases by about 48% ranging from 9.5% to 125%. From a 8% to 6% discount rate, potential cropland increases about 100%, ranging from 8% to 514%.

The discount rate also has a noticeable effect on the relative share of potential cropland in pasture and forest, without exception, in all eight scenarios, for 1967 and 1977 data and with or without the soil loss constraint, an increase in the discount rate reduced the potential cropland in forest greater then pasture. Apparently this is due to greater investment costs required for clearing trees from forestland. As the discount rate increases, clearing costs, which are not discounted become greater, relative to net revenue and opportunity costs, which are discounted. Therefore, less forestland is economically feasible for conversion to cropland.

Table 5.18. Responsiveness of potential cropland to crop yields, 1977 data

Scenario-Discount Rate	1968-77[a]	HLM[b]	Percentage Increase
	(1,000 acres)		(Percent)
B-4/C-4	162.0	988.0	509.0
B-6/C-6	87.0	891.0	924.1
B-8/C-8	71.0	826.0	1,063.4
D-4/E-4	7.0	162.0	2,214.3
D-6/E-6	0.0	148.0	—[c]
D-8/E-8	0.0	89.0	—[c]
F-4/G-4	355.0	3,764.0	960.3
F-6/G-6	280.0	3,021.0	978.9
F-8/G-8	209.0	2,462.0	1,078.0
H-4/I-4	97.0	1,004.0	935.1
H-6/I-6	43.0	694.0	1,514.0
H-8/I-8	7.0	506.0	7,128.6

[a]Assumes average crop yields from 1968 to 1977.

[b]Assumes crop yields using high level management practices.

[c]Percentage increases were not calculated due to the inability of dividing by zero.

Table 5.19. Responsiveness of potential cropland to discount rate, 1977 data

Discount Rate	4%	6%	8%	Percentage Increase 6%-4%	Percentage Increase 8%-6%
Scenario	(1,000 acres)			(Percent)	
B	162.0	87.0	71.0	86.2	22.5
C	988.0	891.0	826.0	10.9	7.9
D	7.0	0.0	0.0	—[a]	—[a]
E	162.0	148.0	89.0	9.5	66.3
F	355.0	280.0	209.0	26.8	34.0
G	3,764.0	3,462.0	2,462.0	24.6	22.7
H	97.0	7.0	7.0	125.6	514.3
I	1,004.0	506.0	506.0	44.7	37.2

[a]Percentage increase were not calculated due to the inability of dividing by zero.

Soil loss constraint   Two points associated with the soil loss constraint deserve more discussion. First, the fact that average soil loss under the soil loss constraint of 5 tons/acre/year was generally less than 2 tons/acre/year. Second, the average decrease in gross soil loss potential cropland and net income, due to the soil loss constraint.

The 5 ton/acre/year soil loss limit has been used as a norm in many places. The question posed by the results of this study is whether it is appropriate. A 5 ton/acre/year soil loss limit will effectively result in an average soil loss for all potential cropland less than 5 tons/acre/year as shown here. If a goal of exactly 5 tons/acre/year is desired then the soil loss limit should be placed higher than 5. However if the goal is 5 tons/acre/year or less, then there is no problem. The crucial point is whether it is economically efficient to achieve exactly 5 tons/acre/year, (i.e., a goal) or somewhat less (i.e., a maximum).

Table 5.20 presents average percentage decreases in potential cropland, gross soil loss and net income due to the soil loss constraint. Both 1967 and 1977 data are used. Potential cropland, for all eight scenarios, is reduced about 44%, due to the soil loss constraint. The range is from 2.1% to 68.3%. Gross soil loss is reduced 97.5%, ranging from 95.6% to 98.6%. Net income is reduced about 46%, ranging from 6.4% to 89.1%.

Table 5.20 indicates that the 5 ton/acre/year soil loss constraint is effective in reducing gross soil loss and consequently preventing a

Table 5.20. Percentage decrease in potential cropland, gross soil loss and net income due to soil loss constraint

Scenario	Percentage Decrease in		
	Potential Cropland	Gross Soil Loss	Net Income
		(percent)	
B	43.5	98.3	64.0
C	33.7	97.5	20.6
D	68.3	96.6	89.1
E	2.1	95.6	6.4
F	36.9	98.4	58.0
G	47.5	98.6	45.9
H	35.9	97.2	54.1
I	42.8	97.5	32.5

decrease in environmental quality. The opportunity costs to farmers of reducing soil loss is indicated by reducing potential cropland and, consequently, net income. The price farmers pay for meeting the 5 ton/acre/year soil loss constraint is about a 45% reduction in net income, resulting from potential cropland. Since there is no measure available for the benefits received from meeting the soil loss constraint (e.g., better water quality), it is difficult to judge the 5 ton/acre/year limit.

Comparison of estimates from 1967 and 1977 data Throughout the analysis of individual scenarios it was indicated that estimates of potential cropland with 1977 data were consistently less than 1967 data. A casual inspection of Tables 5.8 to 5.15 indicates that 1967 data estimates are about 100,000 acres greater than 1977 data estimates, with or without the soil loss constraint.

Tables 5.21 and 5.22 present estimates of potential cropland with 1967 and 1977 data, without and with the soil loss constraint, respectively. In both tables the difference between 1967 and 1977 estimates were calculated for corresponding scenario-discount rates. The "differences" range from 400 acres for scenario D, discount rate 8%, to 428,100 acres for scenario C, discount rate 4%, both with the soil loss constraint. However, most differences fall between 60,000 and 150,000 acres. The mean value for all 48 differences is 128,700 acres.

The question indicated by these results is whether 1967 data estimates of potential cropland are significantly different than 1977

Table 5.21. Comparison of potential cropland projections with 1967 and 1977 data, no soil loss constraint

	1967 Land Use Data			1977 Land Use Data			Difference		
Discount rate	4%	6%	8%	4%	6%	8%	4%	6%	8%
	(1,000 acres)								
Scenario									
B	313.3	232.4	72.4	162.0	87.0	71.0	151.3	145.9	1.4
C	1,380.0	1,133.5	878.9	988.0	891.0	826.0	392.0	242.5	52.9
D	41.6	7.3	4.5	7.0	0.0	0.0	34.6	7.3	4.5
E	404.2	282.7	153.4	162.0	148.0	89.0	242.2	134.7	64.4
F	588.0	463.9	369.9	355.0	280.0	209.0	233.0	183.9	160.9
G	3,863.3	3,140.7	2,577.3	3,764.0	3,021.0	2,462.0	99.3	119.7	115.3
H	213.7	82.5	49.4	97.0	43.0	7.0	116.7	39.5	42.4
I	1,131.6	901.0	618.8	1,004.0	694.0	506.0	127.6	207.0	112.8

Table 5.22. Comparison of potential cropland projections with 1967 and 1977 data, soil loss constraint

	1967 Land Use Data			1977 Land Use Data			Difference		
Discount rate	4%	6%	8%	4%	6%	8%	4%	6%	8%
	(1,000 acres)								
Scenario									
B	223.0	164.1	29.6	111.0	59.0	59.0	112.0	105.1	15.6
C	1,071.1	834.7	585.5	643.0	540.0	540.0	428.1	294.7	139.5
D	15.3	3.6	0.4	7.0	0.0	0.0	8.3	3.6	0.4
E	381.5	280.5	150.3	155.0	148.0	148.0	226.5	132.5	61.3
F	383.0	249.3	191.6	224.0	194.0	194.0	159.0	55.3	33.6
G	2,297.6	1,763.2	1,356.6	2,271.0	1,410.0	1,410.0	26.6	353.2	379.6
H	165.0	37.4	14.7	97.0	14.0	14.0	68.0	23.4	7.7
I	758.0	552.3	338.3	450.0	376.0	376.0	308.0	176.3	28.3

data estimates. Two confidence intervals were constructed to test the hypothesis that the true population mean (estimated mean $\bar{D}$ = 128,700 acres) is significantly different from zero. The standard deviation for all 48 differences was 113,347 acres. The 95% confidence interval is $Pr(96,000 \leq \delta \leq 161,400) = 95\%$, where δ is the true population mean of of the difference in 1967 and 1977 data estimates. The 99% confidence interval is $Pr(84,500 \leq \delta \leq 172,870) = 99\%$. The hypothesis that the true mean difference of the estimates is equal to zero is rejected.

This analysis indicates that 1977 data estimates of potential cropland are about 130,000 acres less than 1967 data estimates. In Chapter II it was indicated that very little noncropland was converted to cropland between 1967 and 1977, and that most increases in planted cropland came from reuse of previously set aside cropland. These results clarify this conclusion. While harvested cropland, and presumably planted cropland, increased about 2 1/2 million acres in Iowa (see Table 2.6) between 1967 and 1977, only about 130,000 acres came from the conversion of noncropland to cropland. That is, less than 5% of the increase in harvested acres came from noncropland.

Crop price responsiveness of potential cropland

This section analyzes i) the responsiveness of potential cropland to crop prices and ii) the characteristics of the potential cropland that is brought in.

Crop prices, as shown in Table 5.7, were systematically increased in discrete 10% steps from 1977 prices. The model, with average yields from 1968 to 1977, 1974 production costs and 1977 land use data was run with each set of crop prices. As in the previous section investment costs were assumed to remain unchanged. Estimates of potential cropland, gross soil loss and average soil loss, for all 20 runs, are presented in Table 5.23.

The relationship between crop prices[1] and potential cropland, assuming a 4% discount rate,[2] is graphically depicted in Figure 5.1 A clear picture of potential cropland response to crop prices is indicated. Two distinct sections of the curve in Figure 5.1 can be identified. From $2.08 to $4.05 per bushel of corn potential cropland

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[1]Throughout this section the price of corn is used to represent all four crop prices. This enables the crop prices to be put in perspective and helps clarify the presentation by eliminating excess baggage.

[2]Since all three discount rates follow the same general pattern, graphs for only the 4% discount rate are presented.

Table 5.23. Estimated potential cropland, gross soil loss and average soil loss under 20 sets of crop prices

	Potential Cropland			Gross Soil Loss			Average Soil Loss		
Discount Rate	4%	6%	8%	4%	6%	8%	4%	6%	8%
	(1,000 acres)			(100,000 tons/year)			(tons/acre/year)		
Price Step									
1	237.0	148.0	71.0	9.4	6.1	2.9	39.8	41.1	40.9
2	295.0	223.0	171.0	13.1	9.4	8.3	44.4	42.3	48.5
3	535.0	392.0	319.0	27.9	17.1	12.2	52.1	43.7	38.2
4	1,330.0	986.0	861.0	68.5	54.1	51.7	51.5	54.9	60.0
5	2,622.0	2,289.0	1,939.0	150.2	135.2	127.0	57.3	59.0	65.5
6	3,425.0	3,061.0	2,767.0	216.9	182.6	169.4	63.3	59.7	61.2
7	4,391.0	4,090.0	3,534.0	301.5	269.5	221.4	68.7	65.9	62.7
8	5,130.0	4,894.0	4,664.0	412.4	397.0	372.3	80.4	81.1	79.8
9	5,266.0	5,174.0	5,132.0	435.5	422.9	419.7	83.3	81.7	81.8
10	5,359.0	5,280.0	5,179.0	450.3	441.1	426.7	84.0	83.5	82.4
11	5,589.0	5,508.0	5,464.0	505.0	488.3	485.7	90.4	88.7	88.9
12	5,675.0	5,631.0	5,588.0	517.7	513.3	508.6	91.2	89.4	91.0
13	5,873.0	5,800.0	5,713.0	549.8	536.0	523.2	93.6	92.4	91.6
14	5,887.0	5,872.0	5,835.0	555.6	552.8	544.2	94.4	94.1	93.3
15	6,015.0	5,909.0	5,879.0	590.0	560.6	554.4	98.1	94.9	94.3
16	6,015.0	6,015.0	6,015.0	590.0	590.0	590.0	98.1	98.1	98.1
17	6,015.0	6,015.0	6,015.0	590.0	590.0	590.0	98.1	98.1	98.1
18	6,015.0	6,015.0	6,015.0	590.0	590.0	590.0	98.1	98.1	98.1
19	6,015.0	6,015.0	6,015.0	590.0	590.0	590.0	98.1	98.1	98.1
20	6,015.0	6,015.0	6,015.0	590.0	590.0	590.0	98.1	98.1	98.1

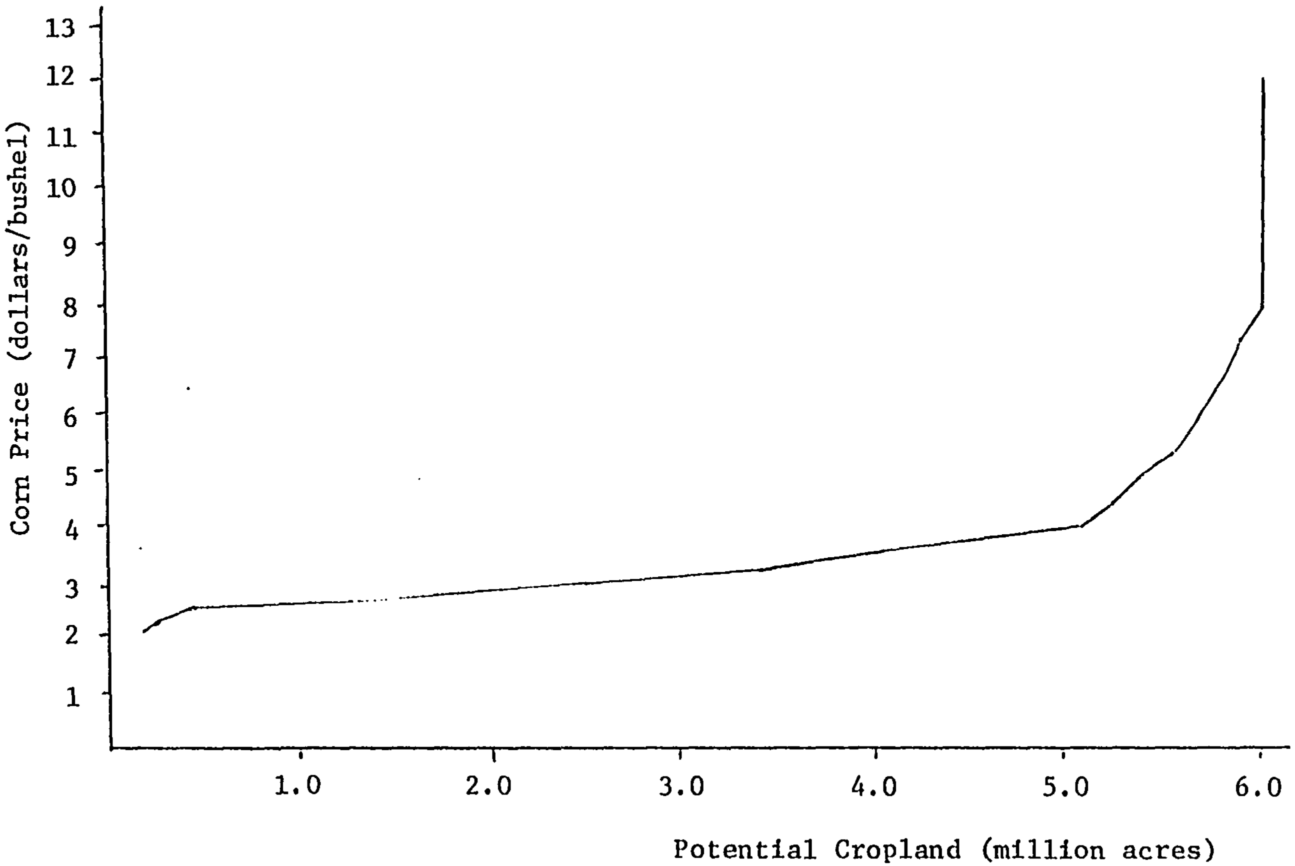

Figure 5.1. Estimates of potential cropland by corn price - 4% discount rate

is very responsive to crop prices. Potential cropland reaches about 5 million acres with slightly more than a doubling of crop prices. The other section, from about $4.00 per bushel on up, potential cropland is much less responsive to crop prices. If crop prices are approximately doubled again, from $4.05 to $7.90 per bushel, potential cropland is increased less than 1.0 million acres, up to 6.015 million acres. As Figure 5.1 clearly indicates potential cropland turns vertical, or completely in inelastic[1] at a corn price of about $ 8 per bushel. Two conclusions can be drawn from this analysis. First, there is a large quantity of pasture and forest (5 million acres) that could be converted to cropland if an adequate demand for agricultural products existed, and consequantly higher crop prices. Second, the additional 1 million acres of pasture and forest would need enormous increases in crop prices before they are feasible for conversion to cropland.

Figure 5.2 graphs potential cropland against gross soil loss, for 4% discount rate, for all 20 price steps, as given in Table 5.23. Clearly gross soil loss is directly related to potential cropland. It also appears, from Figure 5.2, that gross soil loss increases at an increasing rate as potential cropland increase. However, this is not as

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[1]At $ 8.69 for corn all 6,015 million acres of pasture and forest identified by the 1977 NEI survey, and used in this study was feasible for conversion, regardless of discount rate.

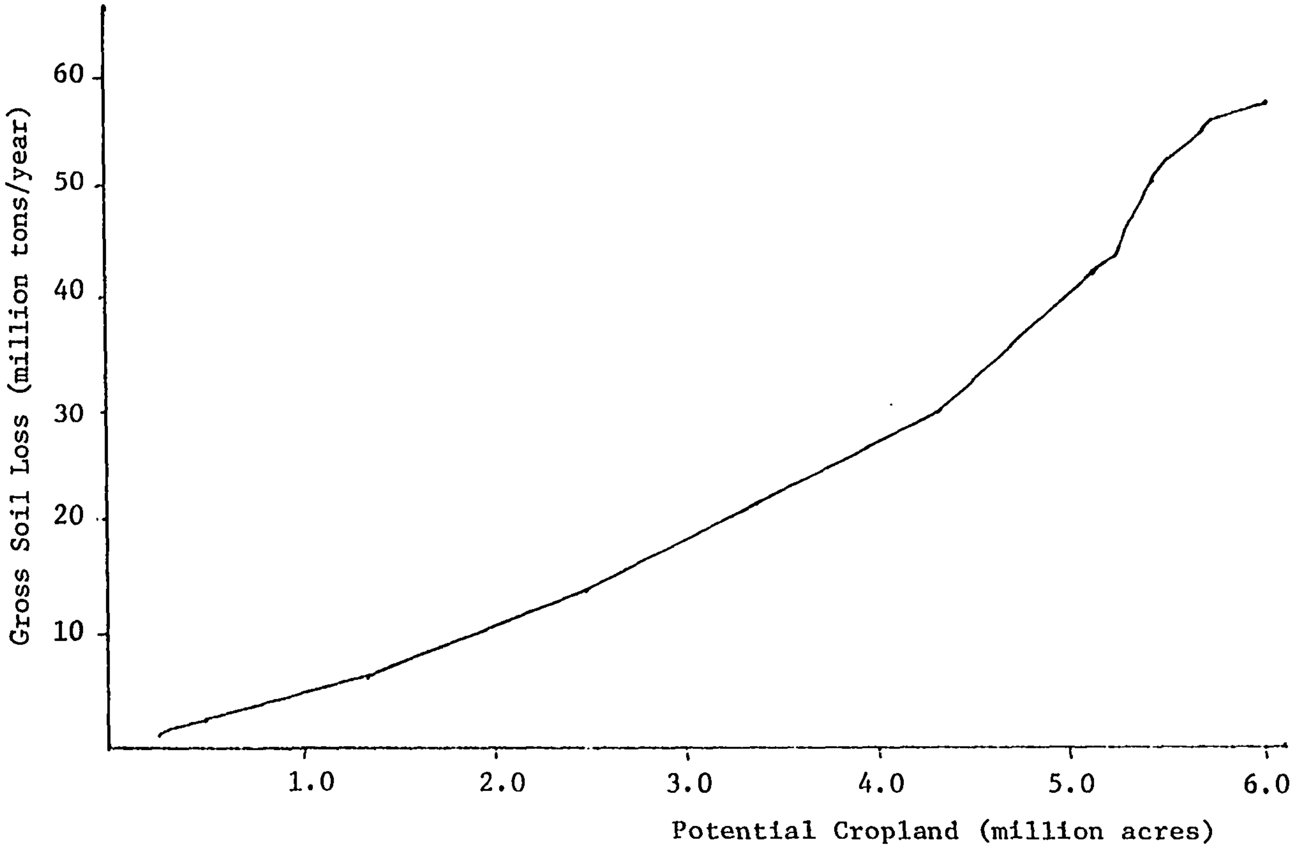

Figure 5.2. Gross soil loss and potential cropland under 20 sets of crop prices - 4% discount rate

evident. Figure 5.3 graphs average soil loss against potential cropland. Figure 5.3 indicates average soil loss and potential cropland are directly related.

In general, if a marginal value of a unit is greater than the average value, the average will increase. For example, if five people have an average height of 6'0" and a sixth person with a height of 6'6" is added to the group, the average height of the group with increase to 6'1". This is the general trend depicted by Figure 5.3. Average soil loss increases as cropland increases therefore the marginal soil loss of each added acre of potential cropland is greater than the average.

Average soil loss for Iowa is estimated at 13.0 tons/acre/year.[1] The average soil loss of potential cropland in Figure 5.3 is substantially greater than 13.0 tons/acre/year. Assuming 24 million acres at 13.0 tons/acre/year soil loss is the existing situation in Iowa, an additional 6 million acres of cropland at 98 tons/acre/year soil loss would raise the average soil loss in Iowa to 30 tons/acre/year. In fact the additional 6 million acres of cropland would have about twice as much gross loss as all 24 million acres of current cropland. While this study has not been directly concerned with the effects of increased soil loss, the implications seem to be severe.

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[1]William Brune, State Conservationists, U.S. Department of Agriculture, Soil Conservation Service, Des Moines, Iowa, private communication, January, 26, 1979.

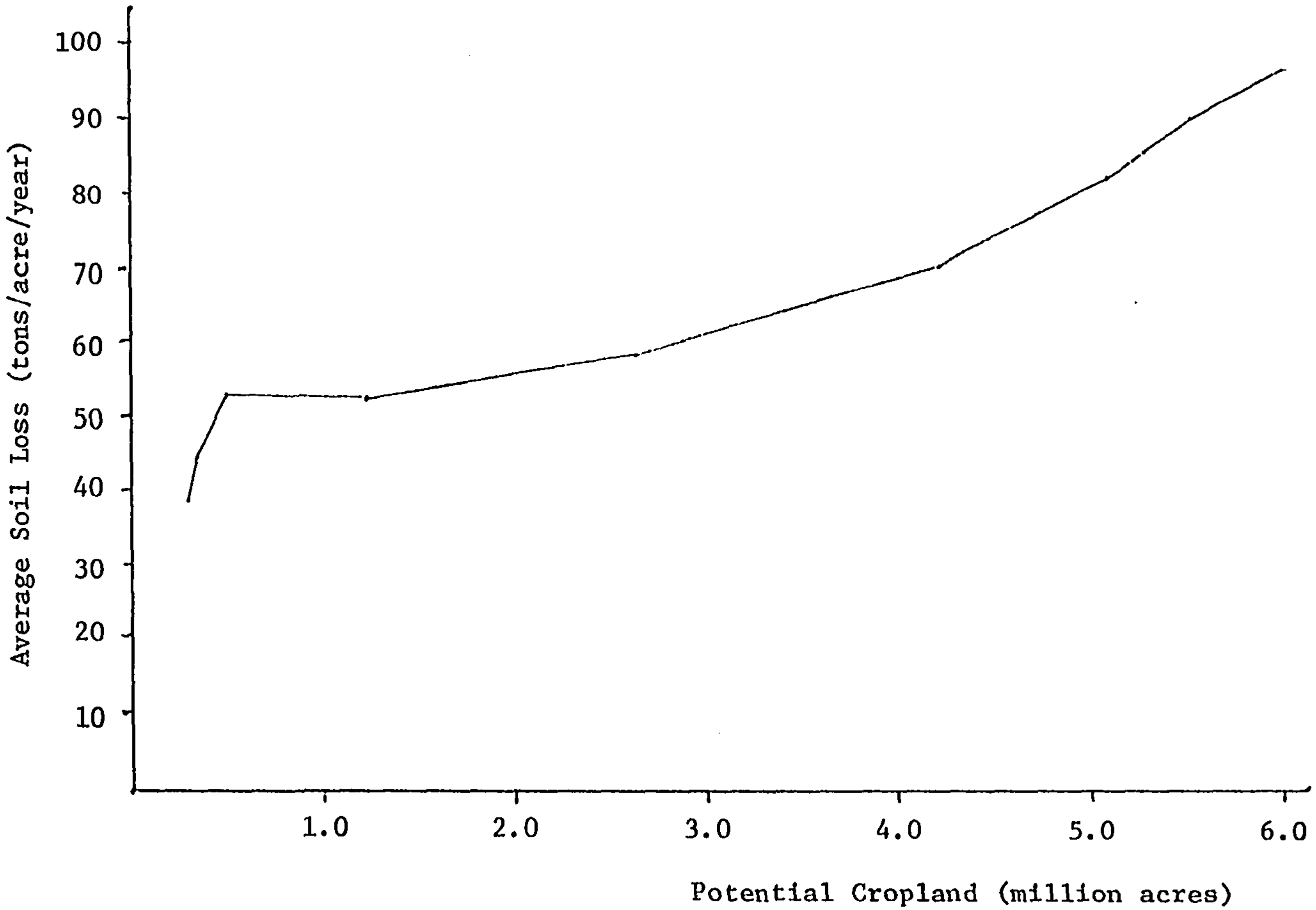

Figure 5.3. Average soil loss and potential cropland under 20 sets of crop prices-4% discount rate

The relative share of potential cropland in pasture exhibits a distinctive pattern. Table 5.24 presents potential cropland for all 20 price runs by land use. In addition, the percent of pasture is also given. Figure 5.4 depicts the percentage of potential cropland in pasture as potential cropland increases assuming a 4% discount rate. Up to 1.3 million acres of potential cropland, the share from pasture is less than from forest, however, the portion from pasture steadily increases. From 1.3 million acres to 5.0 million acres the relative shares of pasture and forest remain constant at about 80% and 20% respectively. Beyond 5.0 million acres the relative share of pasture gradually decreases to about 25%, at 6.015 million acres.

Table 5.25 presents a breakup of potential cropland by slope phase (0-2%, 2-5%, 5-9%, 9-14%, 14-18%, 18-30% and 30+%). For each slope phase and discount rate a box is drawn around the first entry in which all available noncropland in that slope phase is potential cropland.

Two particular points are reflected in Table 5.25. First, the pattern of zero's at the top of the table indicate at which price each slope phase initially becomes potential cropland. For example the first slope phase (0-2%) enters with the first prices step, with corn price at $2.08 per bushel. However noncropland with slopes greater than 30% do not become potential cropland until the sixth price step, where corn is $3.05 per bushel. Second, the pattern of boxes, near the bottom of the table, indicates at what price all noncropland in that slope phase is potential cropland. For example all noncropland

Table 5.24. Potential cropland in pasture and forest under 20 sets of crop prices

	Pasture			Forest			Proportion of Pasture		
Discount Rate	4%	6%	8%	4%	6%	8%	4%	6%	8%
	(1000 acres)			(1000 acres)			(Percent)		
Price step									
1	75.0	75.0	14.0	162.0	73.0	57.0	31.6	50.7	19.7
2	97.0	75.0	75.0	198.0	148.0	96.0	32.9	33.6	43.9
3	254.0	179.0	149.0	281.0	213.0	170.0	47.5	45.7	46.7
4	940.0	706.0	634.0	390.0	280.0	227.0	70.7	71.6	73.6
5	2,052.0	1,802.0	1,557.0	570.0	487.0	382.0	78.3	78.7	80.3
6	2,631.0	2,421.0	2,202.0	794.0	640.0	565.0	76.8	79.1	79.6
7	3,538.0	3,288.0	2,821.0	853.0	802.0	713.0	80.6	80.4	79.8
8	4,121.0	3,914.0	3,809.0	1,009.0	980.0	855.0	80.3	80.0	81.7
9	4,174.0	4,151.0	4,144.0	1,092.0	1.023.0	981.0	79.3	80.2	80.7
10	4,231.0	4,188.0	4,174.0	1,128.0	1,092.0	1,023.0	79.0	79.3	80.6
11	4,395.0	4,380.0	4,380.0	1,194.0	1,128.0	1,084.0	78.6	79.5	80.2
12	4,474.0	4,430.0	4,409.0	1,201.0	1,201.0	1,179.0	78.8	78.7	78.9
13	4,519.0	4,519.0	4,504.0	1,354.0	1,281.0	1,209.0	76.9	77.9	78.9
14	4,533.0	4,526.0	4,526.0	1,354.0	1,346.0	1.309.0	77.0	77.1	77.6
15	4,533.0	4,533.0	4,533.0	1,482.0	1,376.0	1,346.0	75.4	76.8	77.1
16	4,533.0	4,533.0	4,533.0	1,482.0	1,482.0	1,391.0	75.4	75.4	75.4
17	4,533.0	4,533.0	4,533.0	1,482.0	1,482.0	1,482.0	75.4	75.4	75.4
18	4,533.0	4,533.0	4,533.0	1,482.0	1,482.0	1,482.0	75.4	75.4	75.4
19	4,533.0	4,533.0	4,533.0	1,482.0	1,482.0	1,482.0	75.4	75.4	75.4
20	4,533.0	4,533.0	4,533.0	1,482.0	1,482.0	1,482.0	75.4	75.4	75.4

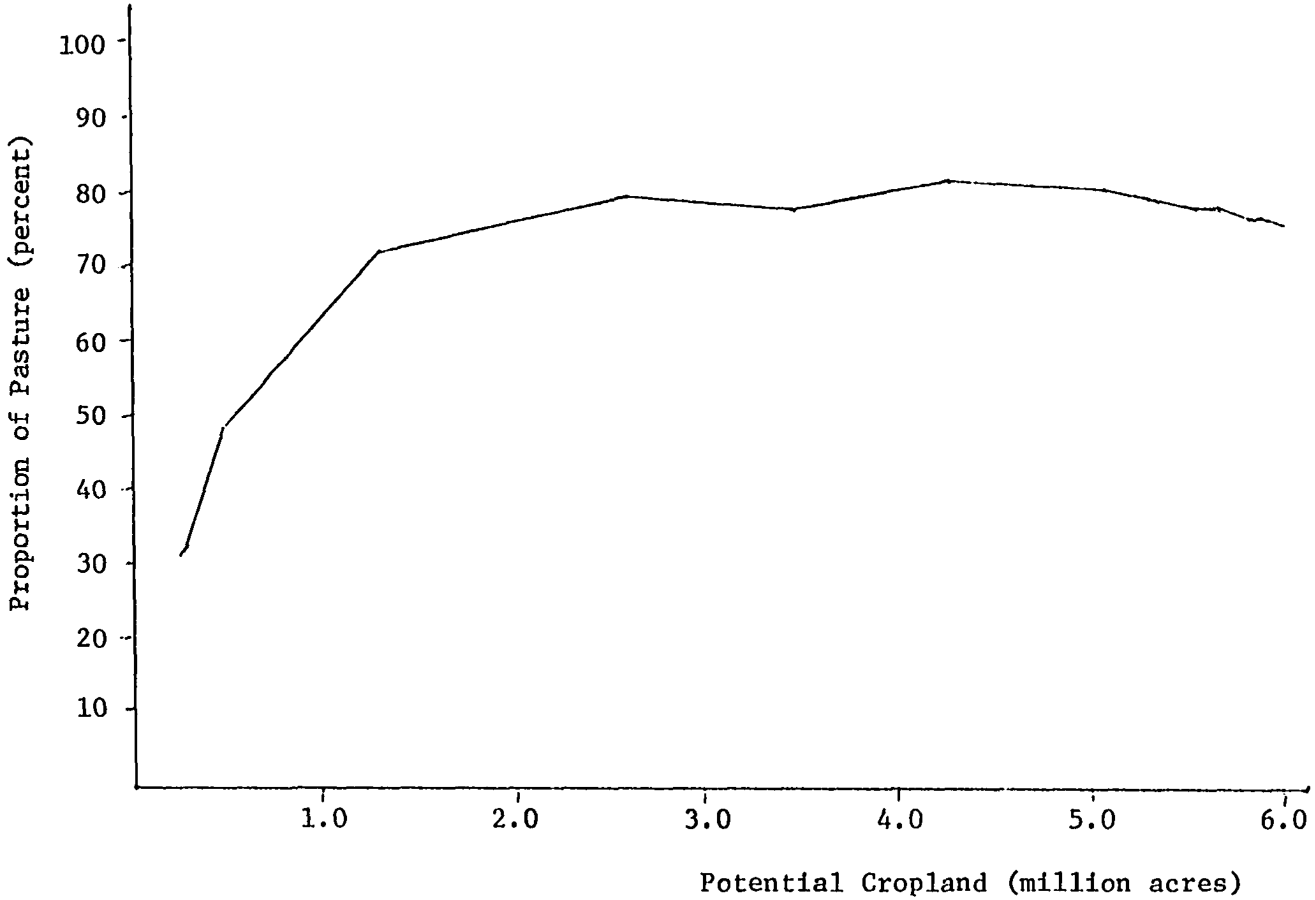

Figure 5.4. Proportion of potential cropland in pasture under 20 sets of crop prices - 4% discount rate

Table 5.25. Potential cropland by slope phase under 20 sets of crop prices

	Slope Phase								
	0-2%			2-5%			5-9%		
Discount Rate	4%	6%	8%	4%	6%	8%	4%	6%	8%
Price Step	(1000 acres)								
1	128.0	76.0	7.0	35.0	35.0	35.0	37.0	37.0	29.0
2	150.0	114.0	76.0	49.0	35.0	35.0	37.0	37.0	37.0
3	217.0	157.0	143.0	66.0	36.0	36.0	88.0	81.0	51.0
4	311.0	251.0	193.0	397.0	193.0	156.0	205.0	198.0	176.0
5	531.0	418.0	338.0	582.0	500.0	299.0	436.0	373.0	358.0
6	747.0	635.0	509.0	699.0	692.0	627.0	589.0	474.0	452.0
7	812.0	790.0	723.0	878.0	841.0	714.0	689.0	682.0	661.0
8	819.0	812.0	805.0	933.0	925.0	871.0	830.0	734.0	682.0
9	826.0	826.0	812.0	970.0	925.0	925.0	846.0	830.0	823.0
10	855.0	826.0	819.0	970.0	970.0	932.0	846.0	846.0	846.0
11	863.0	855.0	826.0	977.0	970.0	962.0	846.0	846.0	846.0
12	863.0	863.0	863.0	977.0	977.0	970.0	860.0	846.0	846.0
13	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
14	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
15	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
16	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
17	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
18	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
19	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0
20	863.0	863.0	863.0	977.0	977.0	977.0	860.0	860.0	860.0

Table 5.25 (continued)

Slope Phase											
9-14%			14-18%			18-30%			30+%		
4%	6%	8%	4%	6%	8%	4%	6%	8%	4%	6%	8%
(1000 acres)											
37.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37.0	37.0	23.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68.0	68.0	68.0	58.0	50.0	21.0	38.0	0.0	0.0	0.0	0.0	0.0
167.0	167.0	167.0	204.0	139.0	131.0	38.0	38.0	38.0	8.0	0.0	0.0
635.0	598.0	575.0	354.0	331.0	308.0	76.0	61.0	53.0	8.0	8.0	8.0
741.0	692.0	649.0	400.0	393.0	370.0	203.0	159.0	144.0	46.0	16.0	16.0
1,068.0	978.0	734.0	672.0	527.0	490.0	211.0	211.0	174.0	61.0	61.0	38.0
1,241.0	1,137.0	1.129.0	804.0	797.0	725.0	419.0	405.0	368.0	84.0	84.0	84.0
1,248.0	1,248.0	1,241.0	820.0	812.0	805.0	457.0	449.0	442.0	99.0	84.0	84.0
1,255.0	1,248.0	1,248.0	841.0	820.0	812.0	479.0	457.0	449.0	113.0	113.0	91.0
1,263.0	1,263.0	1,263.0	879.0	864.0	864.0	648.0	597.0	590.0	113.0	113.0	113.0
1,278.0	1,270.0	1,270.0	886.0	886.0	864.0	677.0	655.0	655.0	134.0	134.0	120.0
1,278.0	1,278.0	1,270.0	975.0	931.0	931.0	742.0	713.0	678.0	178.0	178.0	134.0
1,278.0	1,278.0	1,278.0	975.0	967.0	959.0	749.0	742.0	713.0	185.0	185.0	185.0
1,285.0	1,278.0	1,278.0	983.0	975.0	967.0	786.0	771.0	749.0	261.0	185.0	185.0
1,285.0	1,285.0	1,285.0	983.0	983.0	975.0	786.0	786.0	771.0	261.0	261.0	193.0
1,285.0	1,285.0	1,285.0	983.0	983.0	983.0	786.0	786.0	786.0	261.0	261.0	261.0
1,285.0	1,285.0	1,285.0	938.0	983.0	983.0	786.0	786.0	786.0	261.0	261.0	261.0
1,285.0	1,285.0	1,285.0	983.0	983.0	983.0	786.0	786.0	786.0	261.0	261.0	261.0
1,285.0	1,285.0	1,285.0	983.0	983.0	983.0	786.0	786.0	786.0	261.0	261.0	261.0

with slopes between 0-2% is potential cropland by the twelfth step, with corn less than $6.00 per bushel. All noncropland with slopes greater than 30% do not become potential cropland until the seventeenth price set, with corn at $9.56 per bushel.

These patterns are more pronounced in Figure 5.5, constructed from data in Table 5.26. Table 5.26 is the proportion of potential cropland, by slope phase, for all 20 price steps and a 4% discount rate. Figure 5.5 indicates that from 200,000 to 500,000 acres of potential cropland the majority has slopes less than 9%. As potential cropland increases the relative share of steeper sloped land increases. At 1.3 million acres of potential cropland 68% has slopes less than 9%. This proportion falls to 45% at 6 million acres. This analysis indicates that as potential cropland increases a relatively greater share will have steeper slopes, and consequently more erosive. While potential cropland less than 500,000 acres have no slopes greater than 30%, at 6 million acres of potential cropland 261,000 acres, or almost 5% have slopes greater than 30%, most of which comes in after the price of corn reaches 5 dollars per bushel.

Table 5.27 presents an alternative view of potential cropland by slope phases. Each column represents the cumulative percent of potential cropland in each slope phase, with a 4% discount rate. That is, of 863,000 total noncropland acres with slopes between 0-2%, 17.4% is potential cropland in price step 2, 25.1% in price step 3, 36.0% in price step 4, and so on. Table 5.27 indicates at which set of crop prices all

Table 5.26. Proportion of potential cropland by slope phase under 20 sets of crop prices - 4% discount rate

Slope Phase	0-2%	2-5%	5-9%	9-14%	14-18%	18-30%	30+%
				(percent)			
Price Step							
1	54.0	14.8	15.6	15.6	0	0	0
2	50.8	16.6	12.5	12.5	7.5	0	0
3	40.6	12.3	16.4	12.7	10.8	7.1	0
4	23.4	29.8	15.4	12.6	15.3	2.9	0.6
5	20.3	22.2	16.6	24.2	13.5	2.9	0.3
6	21.8	20.4	17.2	21.6	11.7	5.9	1.3
7	18.5	20.0	15.7	24.3	15.3	4.8	1.4
8	16.0	18.2	16.2	24.2	15.7	8.2	1.6
9	15.7	18.4	16.1	23.7	15.6	8.7	1.9
10	16.0	18.1	15.8	23.4	15.7	8.9	2.1
11	15.4	17.5	15.1	22.6	15.7	11.6	2.0
12	15.2	17.2	15.2	22.5	15.6	11.9	2.4
13	14.7	16.6	14.6	21.8	16.6	12.6	3.0
14	14.7	16.6	14.6	21.7	16.6	12.7	3.1
15	14.3	16.2	14.3	21.4	16.3	13.1	4.3
16	14.3	16.2	14.3	21.4	16.3	13.1	4.3
17	14.3	16.2	14.3	21.4	16.3	13.1	4.3
18	14.3	16.2	14.3	21.4	16.3	13.1	4.3
19	14.3	16.2	14.3	21.4	16.3	13.1	4.3
20	14.3	16.2	14.3	21.4	16.3	13.1	4.3

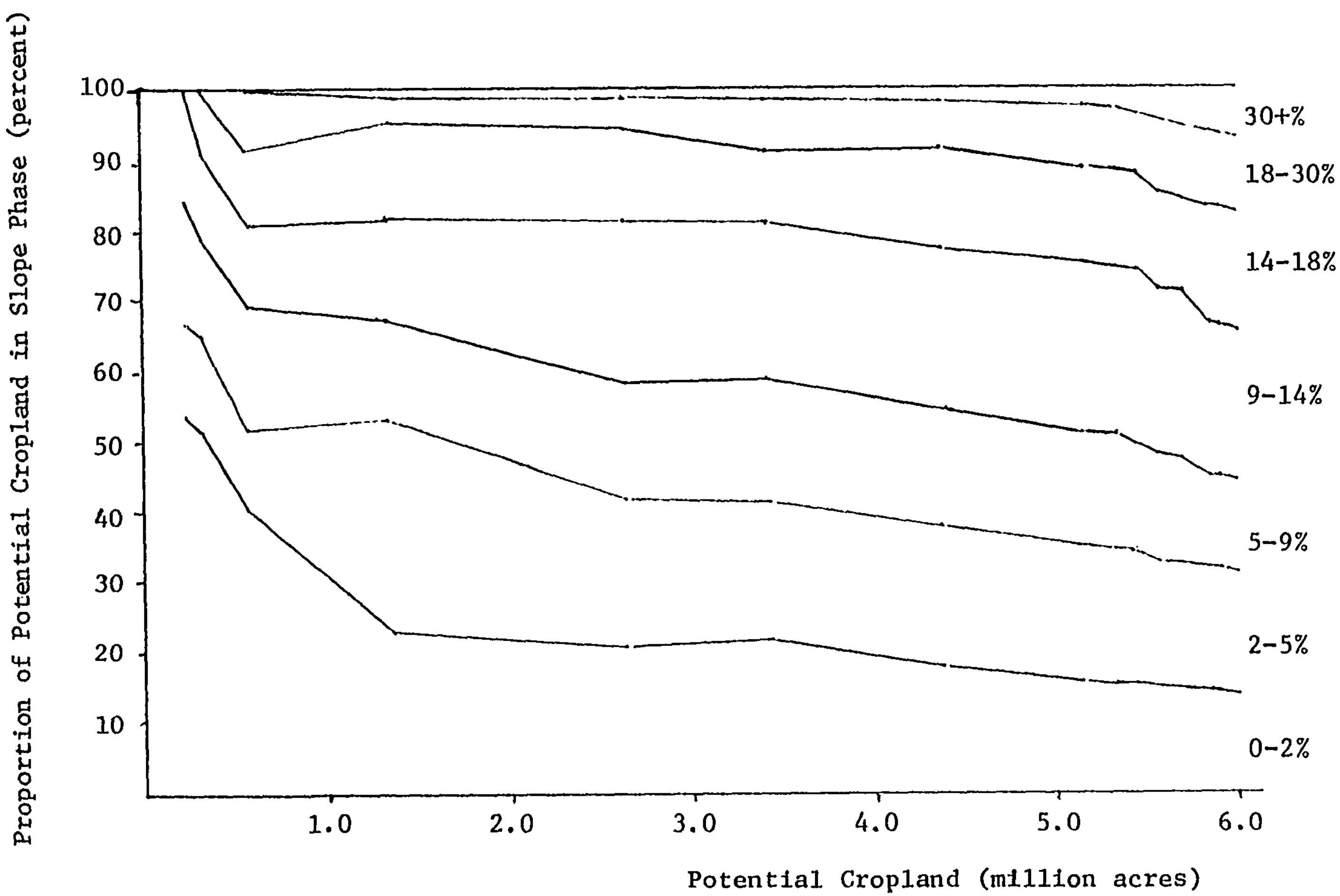

Figure 5.5. Proportion of potential cropland in slope phases under 20 sets of crop prices - 4% discount rate

Table 5.27. Cumulative percent of potential cropland by slope phases for 20 sets of crop prices - 4% discount rate

Slope Phase	0-2%	2-5%	5-9%	9-14%	14-18%	18-30%	30+%
Price Step				(percent)			
1	14.8	3.6	4.3	2.9	0	0	0
2	17.4	5.0	4.3	2.8	2.2	0	0
3	25.1	6.8	10.2	5.3	5.0	4.8	0
4	36.0	40.6	23.8	13.0	20.8	4.8	3.1
5	61.5	59.6	50.7	49.4	36.0	9.7	3.1
6	86.6	71.5	68.5	57.7	40.7	25.8	17.6
7	94.1	89.9	80.1	83.1	68.4	26.8	23.4
8	94.9	95.5	96.5	96.6	81.8	53.3	32.2
9	95.7	99.3	98.4	97.1	83.4	58.1	37.9
10	99.1	99.3	98.4	97.7	85.6	60.9	43.3
11	100.0	100.0	98.4	98.3	89.4	82.4	43.3
12	100.0	100.0	100.0	99.5	90.1	86.1	51.3
13	100.0	100.0	100.0	99.5	99.2	94.4	68.2
14	100.0	100.0	100.0	99.5	99.2	95.3	70.9
15	100.0	100.0	100.0	100.0	100.0	100.0	100.0
16	100.0	100.0	100.0	100.0	100.0	100.0	100.0
17	100.0	100.0	100.0	100.0	100.0	100.0	100.0
18	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20	100.0	100.0	100.0	100.0	100.0	100.0	100.0

noncropland in that slope phase is potential cropland i.e., at price step 12, 100% of all noncropland in slopes between 5-9% was potential cropland, at a 4% discount rate.

An interesting point is the increase in crop prices needed to make all noncropland with slopes less than 2% potential cropland. It was necessary for corn to increase to over $5.00 per bushel for this to occur, with a 4% discount rate. Evidently some of this land had poor productivity, drainage problems, or dense forests.

Figure 5.6 graphs the cumulative percent of potential cropland for slope phase 0-2% and 30+% for illustrative purposes. All other slope phases lie in between. Clearly, the flatter land is potential cropland before the steeper land. But again, not all 0-2% sloped noncropland is potential cropland until there are about 5 1/2 million acres. What is also indicated by Figure 5.6 together with Figure 5.5 is that increases in potential cropland greater than 5 1/2 million acres come almost exclusively from noncropland with slopes greater than 9 %.

The relationship between potential cropland and crop prices discussed in this section indicates two key points. First, potential cropland is relatively responsive to crop prices, up to 5.0 million acres. After 5.0 million acres, crop prices have very little effect on potential cropland. It is necessary for corn to increase to almost $8.00 per bushel before all pasture and forestland in Iowa becomes potential cropland.

Second, average soil loss increases as potential cropland increases. Analysis of the slope composition of potential cropland indicates the reason for this. As potential cropland increases a relatively greater

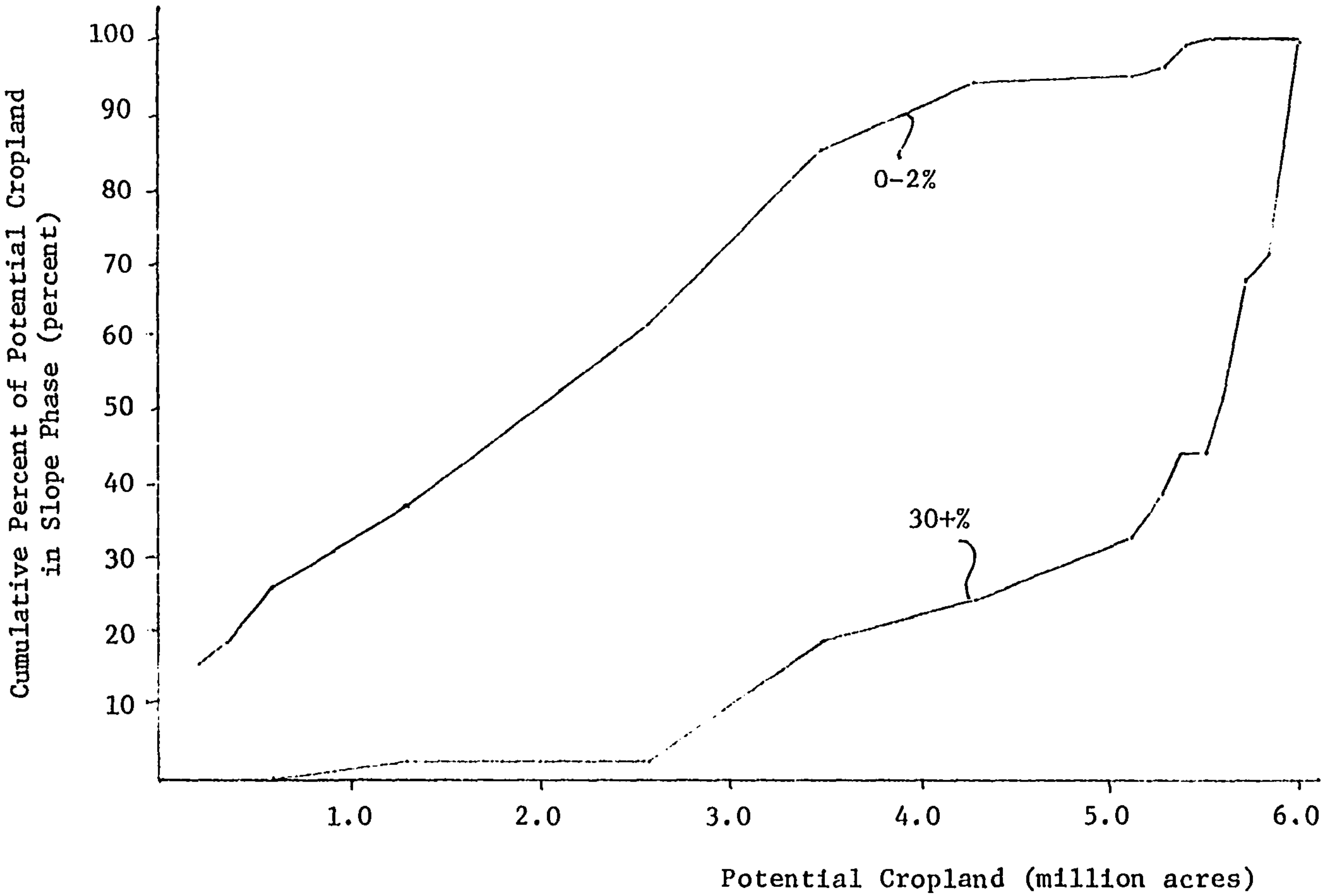

Figure 5.6. Cumulative percent of potential cropland in 0-2% and 30+% slope phases under 20 sets of crop prices - 4% discount rate

share is in steeper slopes. Since steeper sloped cropland is more susceptible to soil erosion, average soil loss increases.

A 5 ton/acre/year soil loss constraint was imposed on the model and rerun with all twenty sets of crop prices. Potential cropland, gross soil loss and average soil loss estimated with the soil loss constraint are presented in Table 5.28. Two points are immediately apparent from Table 5.28. First, not all noncropland is potential cropland at even the twentieth price step, i.e., $12.72 per bushel of corn. Over 120,000 acres of noncropland fail to meet the 5 ton/acre/year soil loss constraint. Second average soil loss reaches a maximum of less than 2 tons/acre/year compared to 98 tons/acre/year with the unconstrained estimates of the model (see Table 5.23).

Figure 5.7 graphs corn price against potential cropland estimated under the soil loss constraint, analogous to Figure 5.1. For the purposes of comparison the curve in Figure 5.1 is redrawn in Figure 5.7. Clearly, the constrained curve traces out the same pattern as the unconstrained curve. However, the constrained curve lies slightly above the unconstrained curve. Thus for a given price there is less potential cropland with the soil loss constraint than without, as predicted in Chapter IV. However, the average difference between constrained and unconstrained estimates of potential cropland, with identical crop prices and discount rates is 94,800 acres, ranging from 28,000 to 188,000 acres.

Figure 5.8 presents the relationship between gross soil loss and potential cropland, analogous to Figure 5.2.[1] Up to 3.3 million acres,

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[1]The gross soil loss axis in Figure 5.8 is in different units that Figure 5.2. Caution should be used when comparing the graphs.

Table 5.28. Estimated potential cropland, gross soil loss and average soil loss with soil with soil loss constraint, under 20 sets of crop prices

	Potential Cropland			Gross Soil Loss			Average Soil Loss		
Discount Rate	4%	6%	8%	4%	6%	8%	4%	6%	8%
	(1,000 acres)			(1,000 tons/year)			(tons/acre/year)		
Price Step									
1	209.0	120.0	43.0	100.9	34.6	28.4	0.48	0.29	0.66
2	267.0	195.0	143.0	173.2	100.9	78.5	0.65	0.52	0.55
3	477.0	349.0	276.0	456.1	245.8	148.2	0,98	0.70	0.54
4	1,211.0	935.0	796.0	1,195.8	973.7	919.5	0.98	1.04	1.16
5	2,564.0	2,171.0	1,880.0	2,738.0	2,488.6	2,337.0	1.07	1.15	1.24
6	3,308.0	2,980.0	2,634.0	3,619.9	3,298.1	3,043.1	1.09	1.11	1.16
7	4,311.0	3,980.0	3,425.0	5,460.9	4,660.5	3,846.4	1.27	1.17	1.12
8	5,027.0	4,805.0	4,516.0	7,100.0	6,818.7	6,156.4	1.41	1.42	1.36
9	5,176.0	5,085.0	5,036.0	7,379.5	7,270.3	7,185.9	1.43	1.43	1.43
10	5,269.0	5,183.0	5,108.0	7,579.6	7,406.2	7,305.3	1.44	1.43	1.43
11	5,499.0	5,418.0	5,374.0	8,230.4	8,018.0	7,990.2	1.50	1.48	1.49
12	5,584.0	5,541.0	5,498.0	8,510.1	8,408.8	8,316.3	1.52	1.52	1.51
13	5,782.0	5,709.0	5,630.0	9,072.4	8,875.5	8,637.0	1.57	1.55	1.53
14	5,789.0	5,774.0	5,737.0	9,104.5	9,048.4	8,956.2	1.57	1.57	1.56
15	5,880.0	5,819.0	5,781.0	9,458.2	9,220.9	9,081.0	1.61	1.58	1.57
16	5,887.0	5,887.0	5,827.0	9,549.0	9,549.0	9,260.5	1.62	1.62	1.62
17	5,887.0	5,887.0	5,887.0	9,549.0	9,549.0	9,549.0	1.62	1.62	1.62
18	5,887.0	5,887.0	5,887.0	9.549.0	9,549.0	9,549.0	1.62	1.62	1.62
19	5,887.0	5,887.0	5,887.0	9,549.0	9,549.0	9,549.0	1.62	1.62	1.62
20	5,887.0	5,887.0	5,887.0	9,549.0	9,549.0	9,549.0	1.62	1.62	1.62

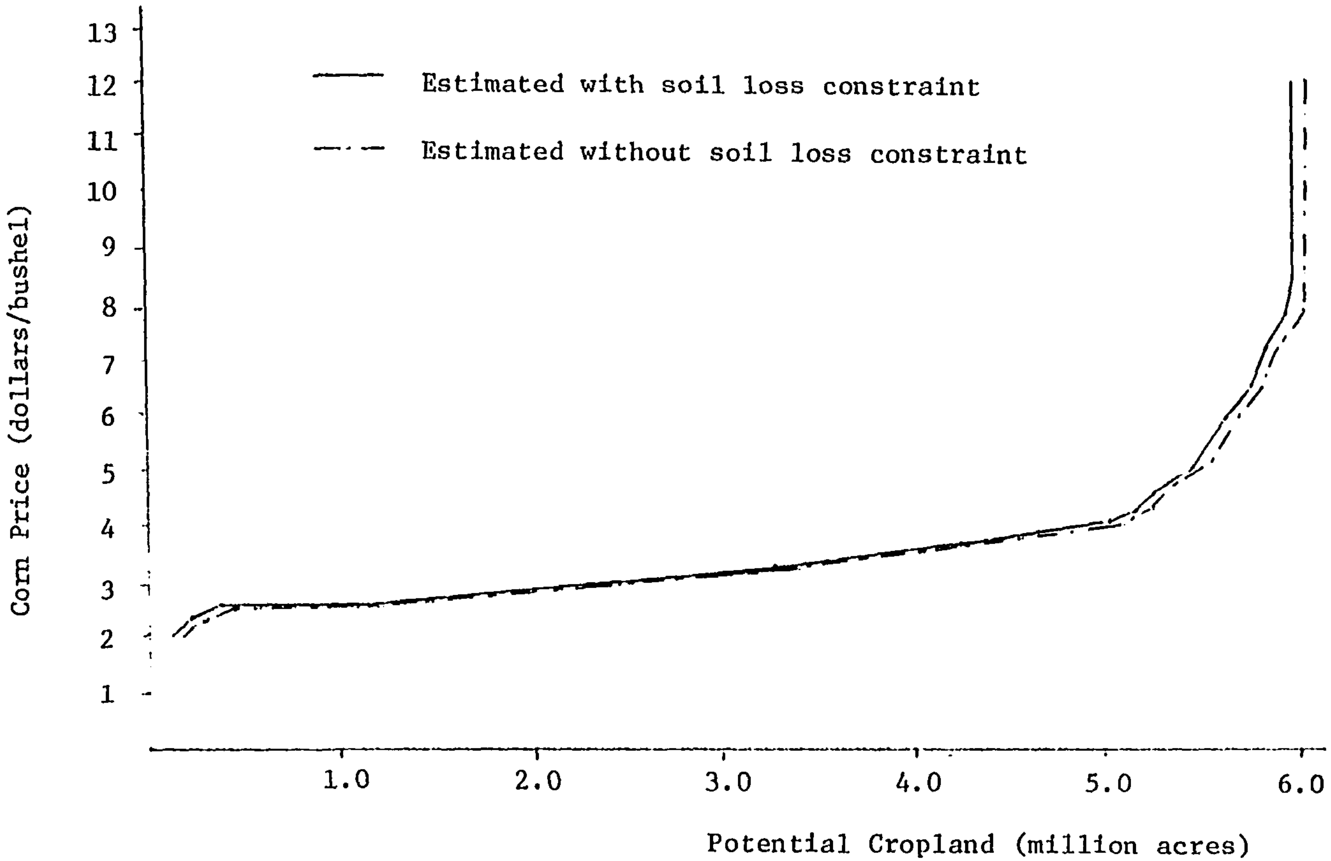

Figure 5.7. Estimates of potential cropland by corn price - 4% discount rate

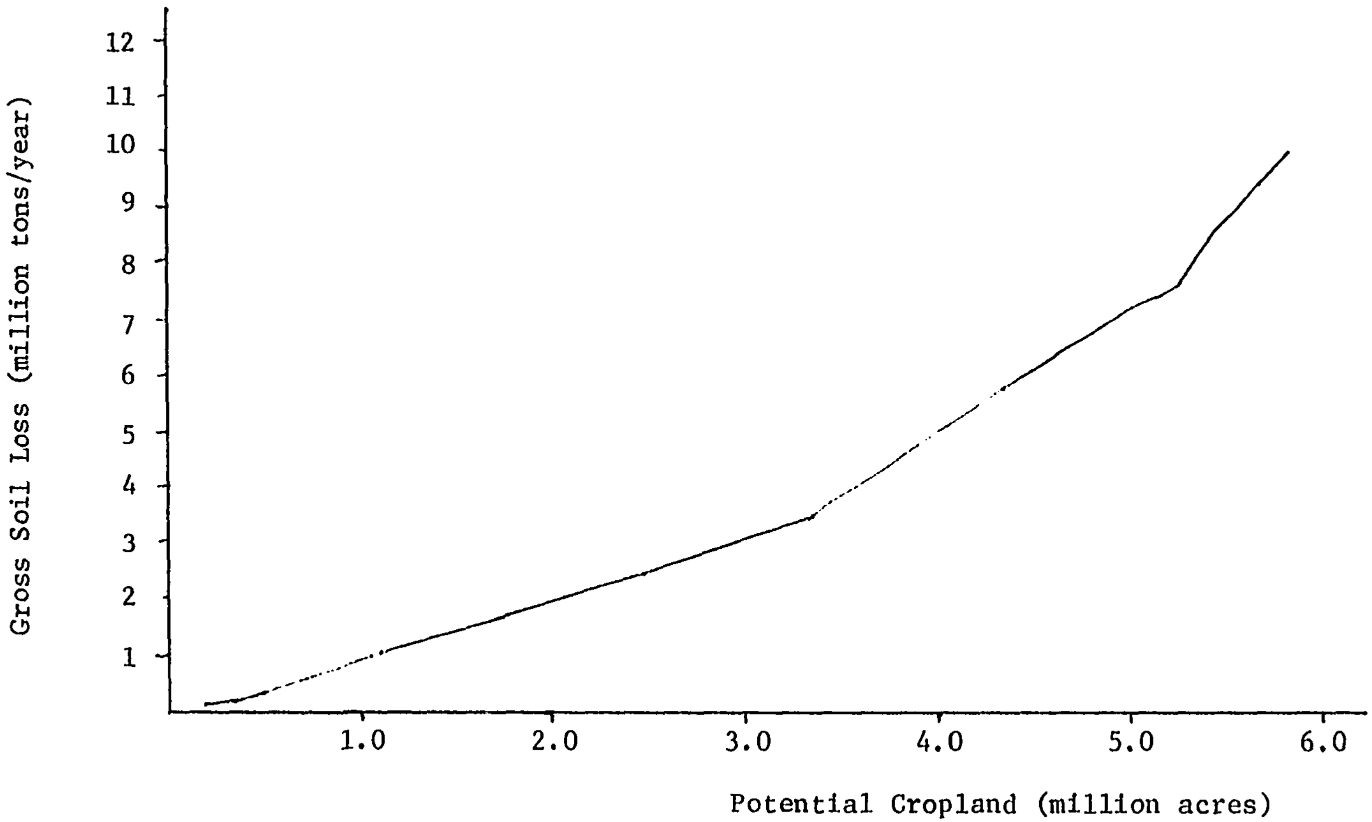

Figure 5.8. Gross soil loss and potential cropland under 20 sets of crop prices and soil loss constraint - 4% discount rate

the relationship between gross soil loss and potential cropland appears to be linear. Beyond 3.3 million acres the curve is slightly concave from above. Figure 5.9 graphs average soil loss against potential cropland estimated under the soil loss constraint. The analysis of Figure 5.8 is reinforced by Figure 5.9. Between 500,000 acres and 3.3 million acres average soil loss is nearly constant, indicating the slope of the curve in Figure 5.8 is constant. Beyond 3.3 million acres the average soil loss steadily increases. This implies that the marginal rate of soil loss is greater than the average, thus the gross soil loss/potential cropland curve is increasing at an increasing rate.

The implications of the 5 ton/acre/year soil loss constraint are two fold. First, almost all noncropland included in this study can meet the soil loss constraint, given high enough prices. Second, the soil loss constraint does not appear to have a severe constrictive effect on potential cropland, as shown by the proximity of the constrained and unconstrained curves in Figure 5.7. This indicates that agricultural production can increase on the extensive margins if needed to meet increased demand, without deteriorating environmental quality. If 13 tons/acre/year is the average soil loss of all 24 million acres of Iowa cropland, then an additional 6 million acres with an average soil loss of 2 tons/acre/year would reduce the overall average to slightly less than 11 tons/acre/year. This is in constrast to adding 6 million acres of cropland that did not need the soil loss constraint, which would increase average soil loss in Iowa to 30 tons/acre/year. While total

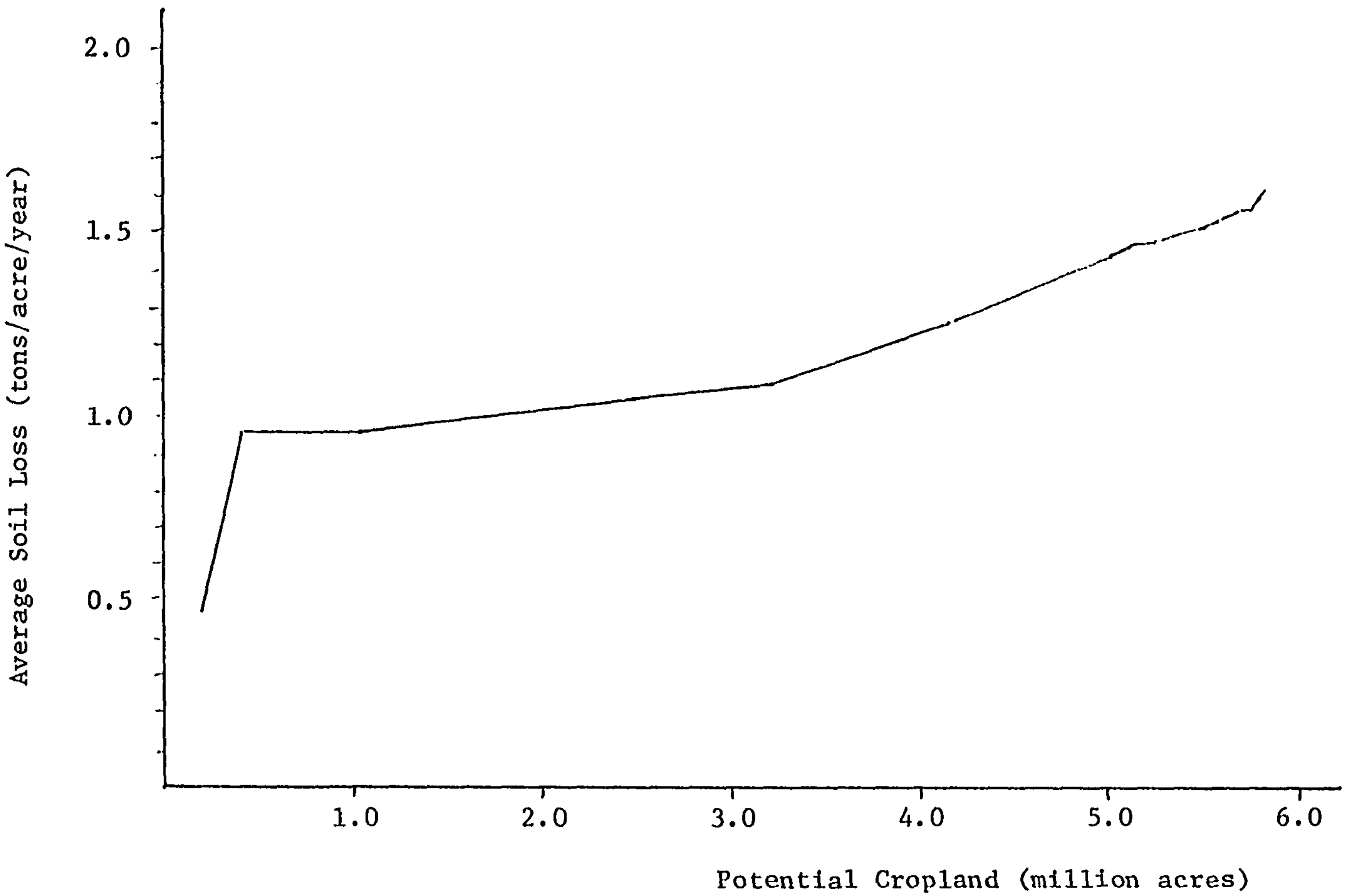

Figure 5.9. Average soil loss and potential cropland under 20 sets of crop prices and soil loss constraint - 4% discount rate

soil loss will increase in both cases, and consequently increase the sediment load in streams, the example is meant to show that the potential cropland can be less erosive than current cropland, and thus prevent drastic deterioration of environmental quality that might result if the soil loss constraint was not met on potential cropland.

CHAPTER VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

This chapter is divided into three sections. First, a summary of the study is presented in which the primary results are restated. Second, the results are interpreted and principal conslusions are down. Third, recommendations are made for future research possibilities.

Summary

This study investigated two aspects of the supply of potential cropland in Iowa. First, potential cropland was estimated under alternative scenarios reflecting possibile 1985 economic conditions. Second, the responsiveness of potential cropland to increased crop prices was examined. This section summaries the results from these two analyses.

Eight price/cost/yield scenarios were combined with three discount rates and two sets of land use data for 48, unconstrained 1985 projections of potential cropland. An additional 48 estimates resulted when the model was constrained by a 5 ton/acre/year soil loss limit.

The most pessimistic scenario for farmers, projected to 1985, D, assumed average crop yields from 1968 to 1977, baseline crop prices, and crop production costs one-third higher than 1974 levels. Estimation of potential cropland under scenario D were less than 50,000 acres, by far the lowest of all eight scenarios. The most optimistic scenario, G, assumed high export demand crop prices, 1974 production costs and High Level Management crop yields. Scenario G, with a 4% discount rate estimated 3.86 million acres of potential cropland. All six estimates of potential cropland, without the soil loss constraint were greater than 2.46 million acres, for scenario G. Variation was due to different discount rates and land use data. The remaining six scenarios produced estimates of potential cropland between these two extremes, from slightly less than 100,000 acres to about 1.0 million acres.

The 5 ton/acre/year soil loss constraint, averaged over all eight scenarios, three discount rates and two sets of land use data, reduced potential cropland 44%, gross soil loss 97.5% and net income 46%. High export demand crop prices estimated, on average, 5 times as much potential cropland as baseline crop prices. With 1974 production costs,estimates of potential cropland were 10 times as great as with 1985 production costs. High Level Management yields lead to estimates of potential cropland 18 times as great as average yields from 1968 to 1977. Decreasing the discount rate from 8% to 6%, and from 6% to 4% increased potential cropland 2 and 1 1/2 times, respectively.

Average soil loss from potential cropland estimated under the 5 ton/acre/year soil loss constraint was slightly less than 2 tons/acre/year, regardless of scenario, discount rate or land use data. Without the soil loss constraint average soil loss was from 0.0 to 72.4 tons/acre/year. The variation was due primarily to the quantity of potential cropland estimated.

Averaged over scenarios and discount rates, 1977 land use data resulted in estimates of potential cropland 128,000 acres less than 1967 land use data. At the 0.05 and 0.01 significance levels the difference between 1967 and 1977 data estimates was statistically different from zero.

Land use data from 1977, average yields from 1968 to 1977, 1974 production costs and 1977 crop prices were used as a base to test the responsiveness of potential cropland to crop prices. The analysis indicated a doubling of 1977 crop prices from 2 to 4 dollars per bushel for corn would lead to 5 million acres of potential cropland, under a 4% discount rate. If crop prices were doubled again, from 4 to 8 dollars per bushel for corn only 1 million acres more would be potential cropland. At $8.69 for corn all 6.015 million acres of noncropland used in the model was potential cropland.

Average soil loss increased as potential cropland increased, reaching 98.1 tons/acre/year when all 6.015 million acres were potential cropland. Approximately 80% of potential cropland was from pastureland and 20% from forestland. This remained constant from 1 1/2 to 6 million acres. Up to 1 1/2 million acres the share of pastureland was less than forestland but steadily increasing. The proportion of potential cropland in slopes less than 9% steadily decreased as potential cropland increased, from 85% at 200,000 acres to less than 50% at 6 million acres.

The 5 ton/acre/year soil loss constraint reduced potential cropland, on average, 94,800 acres over all twenty price steps. At the twentieth price step only 5.887 million acres were potential cropland, with the soil loss constraint, compared to 6.015 million acres without. Average soil loss for the 5.887 million acres was 1.62 tons/acre/year.

Con lusions

Six conclusions are drawn from the results of this study.

1. Scenarios projected to 1985 indicate that expansion on the extensive margins of production in Iowa is possible to meet future increases in agricultural demand, if intensive expansion does not occur. Up to 3.86 million acres of potential cropland exist under the most optimistic conditions.

2. Comparison of potential cropland estimates from 1967 and 1977 land use data indicate an average difference of about 130,000 acres. This implies that 130,000 acres of noncropland were converted to cropland from 1967 to 1977. This is only a small fraction of the 2 1/2 million acre increase in harvested cropland for this period. The comparison of 1967 and 1977 data estimates also shows great consistency. While 1977 data estimates were 130,000 acres less than 1967, they were consistently less, regardless of scenario, discount rate or soil loss constraint. Considering the difference in the characteristics of the land use data this is remarkable. For example, 1967 data were comprised of 1700 land types, the smallest being about 200 acres. However, 1977 data comprised of only 300 land types, the smallest being 7,000 acres.

3. The changes in potential cropland due to changes in crop prices, production costs, yields, discount rate and the soil loss constraint were of the predicted direction. However, it is difficult to compare to the relative of changes in different variables on potential cropland due to the different magnitudes of changes in the variables.

4. Analysis of the responsiveness of potential cropland to increases in crop prices indicate a large quantity of noncropland could be converted to cropland, with relatively small increases in crop prices. Around 5 million acres of potential cropland exist if crop prices double. However, beyond 5 million acres potential cropland becomes relatively less responsive to crop prices. If crop prices double again only an additional 1 million acres would become potential cropland.

5. Analysis of both 1985 projections and crop price responsiveness indicate potential cropland is extremely susceptible to soil erosion. As potential cropland increases average soil loss also increases, reaching a maximum of 98 tons/acre/year on all 6.015 million acres of potential cropland, compared to the average for current Iowa cropland of 13.0 tons/acre/year. This indicates that the conversion of noncropland to cropland, if effective soil erosion control measures are not used, could be extremely detrimental to environmental quality.

6. However, application of a 5 ton/acre/year soil loss constraint indicates that noncropland can be converted to cropland with far less deterioration of environmental quality. Average soil loss on potential cropland regardless of scenario, discount rate or land use data was generally less than 2 tons/acre/year. The crop price responsiveness analysis indicated 5.887 million acres could meet the 5 ton/acre/year soil loss constraint, with an overall average soil loss of 1.62 tons/acre/year. Thus, it appears possible to increase agricultural production on the extensive margins without seriously reducing environmental quality.

Recommendations for Further Study

Seven recommendations for additional research based upon the methodology developed in this study are discussed in this section.

1. The 5 ton/acre/year soil loss constraint was used in this study in place of explicit knowledge of the external diseconomies from soil erosion. It was assumed that soil loss less than 5 tons/acre/year resulted in no external diseconomies. There is little data to either support or deny this contention. The results of this study indicate further need to investigate the 5 ton/acre/year soil loss constraint. The methodology developed in this study could be used to determine tradeoffs between gross soil loss and potential cropland from altering the constraint to various levels.

2. A valuable improvement in this methodology would be the explicit estimation of external diseconomies associated with soil erosion to replace the 5 ton/acre/year soil loss constraint. Estimation of other external diseconomies would also refine this model. Most important would be the opportunity costs associated with the destruction of natural environments. Recent studies, such as Krutilla and Fisher [18] have attempted to estimate recreational benefits and other costs of destroying natural environments. While much research is still needed in this area, enough background is available to make this a fruitful step.

3. A third recommendation for refining the methodology developed in this study is to expand the model from a partial equilibrium analysis to a more general equilibrium model. The first step in this direction would be to include expansion of agricultural production on the intensive

margins. Since the possibility exists for technological breakthroughs in the future. If significant increases in crop yields occur in the future, results of this study would be substantially altered.

4. A fourth recommendation for refining the estimates produced by this model is to incorporate an explicit location variable. Many of the investment costs, and the effects of soil erosion are site specific. Crop prices, although slight, vary from one part of the state to the next. Rainfall, and consequently soil loss is not constant over all regions of Iowa. For an accurate estimation of private and social costs and benefits it is necessary to take into consideration a spatial dimension.

5. The methodology in this study was developed in a manner that it could be transferred to other areas. Most obvious is the applition of the model to the 48 contiguous states. While the effort involved in estimating the supply of potential cropland for the United States would be many times that required for this study, all data used are currently available or could be obtained on a national level. It should be noted that the extension of the model to the entire U.S. would essentially require incorporation of a spatial dimension as discussed above. The best way to accomplish this is to divide the U.S. into distinct geographic regions, either states, counties or resource regions. The important criteria would be to insure that all land types are relatively homogeneous, with exogenous variables such as rainfall, price, etc., the same for each geographic region.

6. The sixth recommendation is to extend the methodology to other resources. Many natural resources are available in large lumps with essentially homogeneous quality like cropland. Water, petroleum and minerals are but a few of the natural resources which could be viewed within the framework used in this study. The uncertainty surrounding supplies of water in arid regions, and petroleum and minerals world-wide could be examined by this framework.

7. In application of this model to Iowa, it was assumed land classified by the Soil Conservation Service as "other"[1] land in both the 1967 CNI and 1977 NEI would not be converted to cropland under foreseeable economic conditions. However, in light of the analysis of the crop price responsiveness of potential cropland this assumption deserves more investigation. The price of corn reached over 8 dollars per bushel before all pastureland and forestland became potential cropland. Under these conditions there might be sufficient pressure to force the conversion of "other" land to cropland. The conversion of some "other" land would probably require government intervention. While this study was concerned only with noncropland that could be converted to cropland through private decision making, a logical extension of this study would be to investigate noncropland under public control. This would be especially important if the model were applied to other parts of the U.S. with large amounts of publicly owned land.

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[1]See Chapter II, page 11, for a discussion of "other" land.

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APPENDIX. INVESTMENT COST DATA

Table A.1. Land Improvement Contractors investment cost data, Iowa

Observation	Drainage Tile 5"	Drainage Tile 6"	Surface Drainage	Clearing Cost: Pasture	Clearing Cost: Forest Grazed	Clearing Cost: Forest Not Grazed	Channeled Land
	(Dollars/Foot)			(Dollars)			
1	.80	.90	200	75.00	200.00	500.00	1000.00
2	.75	.86	180	100.00	400.00	850.00	750.00
3	.85	.95	250	100.00	325.00	650.00	800.00
4	1.05	1.12	150	75.00	--	--	500.00
5	.90	.95	200	100.00	200.00	550.00	800.00
6	1.10	1.11	200	83.75	306.80	716.41	--
7	.95	.95	175	80.00	200.00	625.00	750.00
8	1.00	1.10	225	75.00	200.00	750.00	800.00
9	.95	1.10	250	75.22	468.12	882.50	--
10	.85	.90	300	75.00	250.00	750.00	1000.00
11	1.05	1.16	180	--	150.00	575.00	1000.00
12	1.15	1.20	150	--	200.00	725.00	1200.00
13	1.10	1.10	150	125.00	300.00	600.00	750.00
14	.80	.95	200	69.60	235.20	595.62	--
15	1.05	1.05	225	100.00	250.00	700.00	800.00
16	.85	.95	175	--	250.00	600.00	750.00
17	1.00	1.00	250	125.00	--	750.00	1000.00
18	.90	1.10	225	75.00	200.00	650.00	650.00
19	1.10	1.15	175	90.00	300.00	625.00	1000.00
20	.80	.95	200	75.00	400.00	700.00	--
Mean	.95	1.03	203	88.15	268.62	673.40	846.88
Std. Dev.	.119	.098	39.31	17.00	67.34	96.25	167.21

Table A.2. Soil Conservation Service investment cost data, Iowa

Observation	Drainage tile 5"	Drainage tile 6"	Surface Drainage	Terrace Costs (slope) 2-5	5-9	9-14	14-18	Channeled land
	(Dollars/foot)			Dollars				
1	.95	1.00	175	192	266	323	349	-
2	1.00	1.00	200	-	-	-	-	100
3	-	-	-	170	200	220	265	-
4	1.10	1.15	250	-	-	-	-	-
5	.85	.95	225	222	286	388	439	500
6	.75	.80	200	-	-	-	-	-
7	.65	.70	175	142	176	208	274	-
8	-	-	-	200	220	356	415	-
9	1.00	1.10	200	-	-	-	-	-
10	.95	.95	180	-	-	-	-	-
11	-	-	-	225	295	375	400	-
12	1.00	1.05	175	-	-	-	-	-
13	.85	.90	200	167	191	233	304	-
14	.85	.90	150	250	310	400	430	1500
15	1.00	1.00	150	-	-	-	-	-
16	.95	1.00	175	217	236	252	289	-
17	.95	1.05	200	-	-	-	-	-
18	-	-	-	157	181	192	245	-
19	1.00	1.00	-	235	305	416	459	-
20	1.10	1.10	200	175	250	285	355	-
Mean	.93	.98	190.33	196.2	242.7	304.4	351.7	1000
Std. Dev.	.116	.110	26.22	32.69	47.37	78.42	72.33	408.25