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PRIME FARMLAND DISTURBANCE FROM COAL SURFACE MINING IN THE CORN BELT, 1980—2000

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by

David P. Bernard

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September 1979

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ABSTRACT

The five midwestern states that make up the Corn Belt farm production region--Illinois, Indiana, Iowa, Missouri, and Ohio--contain about 110 billion tons of coal reserves (19% of which are surface mineable) and 110 million acres of arable land (69% of which are prime farmlands). In 1975, this region was the site of 21% of the nation's total coal production and 50% of the nation's corn and soybean harvest. Because corn and soybeans are key elements in U.S. foreign trade and because nearly two-thirds of the regional coal production is from surface coal mines, it is important to understand the potential conflicts that may arise between the coal and agricultural industries in the Corn Belt. This report presents background data on the coal and agricultural industries in the Corn Belt states, along with the results of a quantitative analysis of the potential disruption of land and associated prime farmland due to future coal surface mining activity in the region. Estimates of potential land disruptions indicate that 452,000 acres of land, including 127,000 acres of prime farmland, could be disturbed in the period 1980-2000. Additionally, the data indicate that certain counties in the Corn Belt states may experience impacts significantly greater than the regional average would suggest.

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CONTENTS

FIGURES

TABLES

INTRODUCTION

The National Energy Plan (NEP), submitted to Congress by the President in April 1977, calls for increasing national coal production by about two-thirds to more than one billion tons per year by 1985 (U.S. Pres., 1977). Although recent events tend to confirm the conclusion that the future coal production levels called for in the NEP are unlikely to be realized in full by the end of this century (Gen. Acc. Off., 1977), it is still reasonable to assume that as supplies of natural gas and imported oil decline, the nation will require increased quantities of coal. This is especially true for electric power generation in light of the reassessment of nuclear power since the Three Mile Island accident. In passing the Powerplant and Industrial Fuel Use Act of 1978, Congress provided the necessary legislative incentives to "encourage and foster the greater use of coal and other alternative fuels, in lieu of natural gas and petroleum, as a primary energy source." These incentives, part of the so-called national energy package, are expected to necessitate accelerated coal extraction at some level higher than the present rate of production, although the precise level is still undetermined. To help offset environmental impacts which could accompany an increase in coal mining activities, Congress passed another part of the national energy package, the Surface Mining Control and Reclamation Act of 1977, which is intended to "assure that the coal supply essential to the Nation's energy requirements, and to its economic and social well-being is provided and [to] strike a balance between protection of the environment and agricultural productivity and the Nation's need for coal as an essential source of energy." The net result of these federal initiatives is expected to be increased national coal production with concomitant control and minimization of environmental consequences.

Although numerous authors (e.g., MITRE Corp., 1977; Kash et al., 1977; Murray, 1978) have raised important environmental questions concerning increased coal production, relatively little attention has been devoted to the effects of coal mining on agriculture. Much of what has been written on this topic (e.g., Caudill, 1973; Doyle, 1976; Ostendorf and Gibson, 1976; Toolan, 1978) may be categorized as emotionally biased and containing at best a modicum of factual information. The remaining reports either were written prior to the federal regulations which now influence surface mining activities, or deal with coal/agriculture conflicts outside the United States (Interagency Task Force, 1977; Janis et al., 1977; Goettel, 1977). The main objectives of the following report are to assemble background data on the coal and agricultural industries in the five midwestern states of the Corn Belt, and to present a quantitative analysis of the potential disruption of land area and associated prime farmland due to future coal surface mining in the Corn Belt.

SCOPE OF STUDY

The U.S. Department of Agriculture (USDA) recognizes 10 separate farm production regions in the conterminous United States (Fig. 1). The Corn Belt was chosen for analysis in this report because all of the states therein--

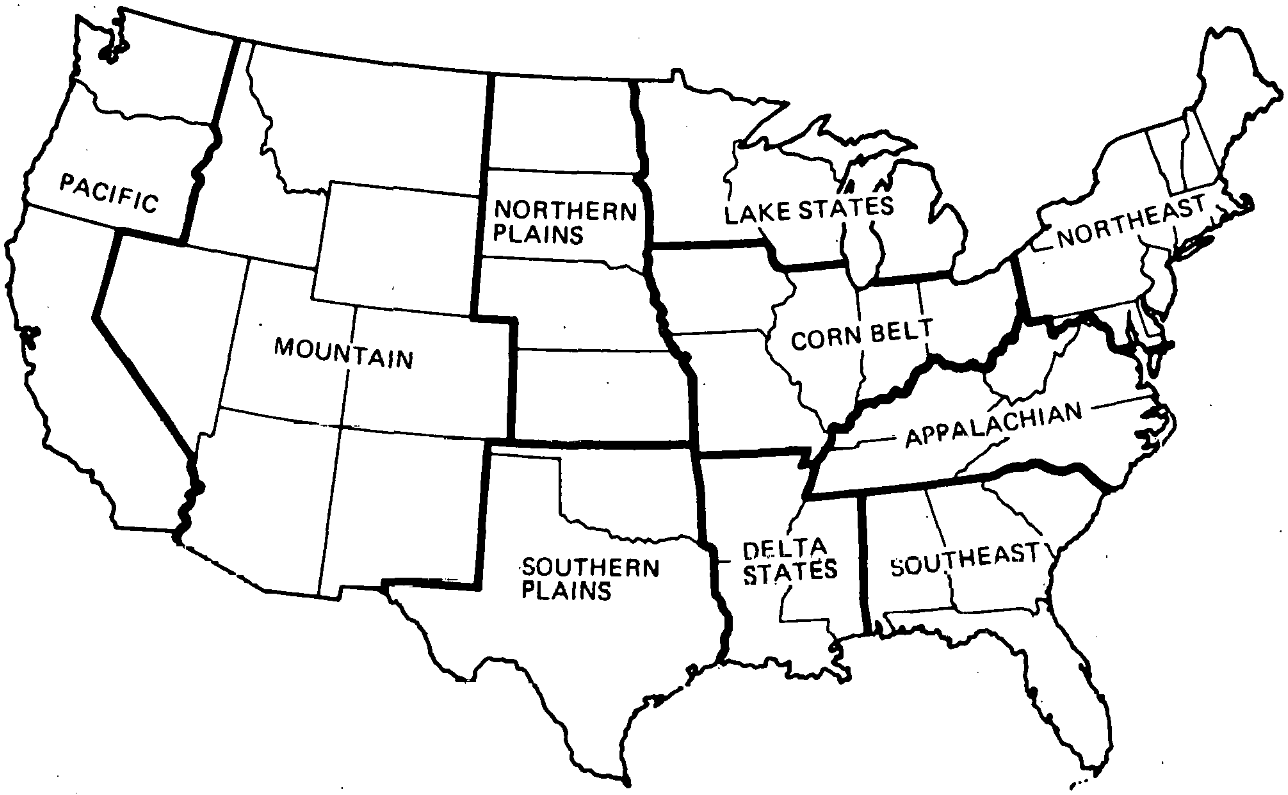

Figure 1. Farm Production Regions in the United States. From Dideriksen et al. (1977).

Illinois, Indiana, Iowa, Missouri, and Ohio--contain mineable coal, and furthermore, each is an important producer of agricultural products. Consequently, there exists concern as to whether increased coal surface mining in the Corn Belt would adversely affect agricultural land and local communities. On one hand, the two major crops in this region--corn and soybeans--are key elements in U.S. foreign trade, and anything which affects the total output of these crops could have important implications for the nation as a whole. On the other hand, over one-fifth of the nation's annual coal production is extracted from the Corn Belt, and nearly two-thirds of this production is from surface mines. A decrease in surface mining activities in this region--especially at a time when the President is calling for increased national coal production--could have important national repercussions. Thus, a clear understanding of the potential land conflicts which may arise between these two industries is a necessary first step toward minimizing problems for both groups.

The agricultural industry is considered in this report primarily from the context of crop production, especially row crops such as corn, soybeans, and other grains. However, since livestock sales accounted for over 45% of the 1976 Corn Belt agricultural cash receipts (U.S. Dep. Agric., 1977a), it is important to recognize that this, too, is an important component of this industry, especially in Iowa and Missouri. Furthermore, since historically those croplands affected by surface mining have often been reclaimed to livestock grazing rather than to crop production (Doyle, 1978; U.S. Soil Conserv. Serv., 1978), the balance in output from these two sectors can be locally affected by surface mining.

Several phases of the coal fuel cycle (extraction, reclamation, cleaning, combustion, and waste disposal) have the potential to affect the agricultural industry. Surface mining may affect farmland either directly through removal of the land immediately above the coal or indirectly through disturbance of land for storage and loading areas, haulage and access roads, and final-cut reservoirs (see section on Disturbed Lands). Underground mining may affect farmlands either directly through installation of surface support facilities, including haulage roads and waste disposal sites, or indirectly through subsidence. As surface mineable coal reserves are depleted or made unavailable through legislation, there will be increasing activity to extract coal using underground-mining methods.

Consideration of the coal industry in this report is limited to the land and soil impacts associated with surface mining of coal deposits. However, there is reason to believe that land and soil impacts caused by underground mining may be significant, and research to determine the magnitude of the effects and the acreages to be affected should be initiated.

TIME FRAME AND ACCURACY OF PROJECTIONS

The potential future disturbance of land and prime farmland in the Corn Belt from coal surface mining was calculated for the 20-year period between 1980 and 2000. This time frame was chosen to reflect the period in which declining oil and natural gas reserves will cause shifts in the U.S. energy system to alternative fuels such as coal. The proposed national initiatives are expected to result in a doubling of Corn Belt coal production, with surface mining operations projected to continue providing at least half the coal mined in the region.

It is important to recognize that considerable uncertainty still surrounds the coal industry and how recent legislation affects it. Throughout the remainder of this century, it is expected that, among other legislation, the Clean Air Act Amendments of 1977, the Surface Mining Control and Reclamation Act of 1977, and the Federal Coal Leasing Act of 1977 will affect coal mining activities. However, the full impact of these legislative actions has not yet been registered by the industry, with the result that forecasts of future coal mining activity must at present be viewed as trend indicators rather than absolute predictions. Consequently, estimates of land and prime farmland acreage which could be disturbed by future surface coal mining, such as those presented in this report for the Corn Belt, should be evaluated in light of the uncertainties associated with the coal industry.

PRIME FARMLAND DEFINITIONS

As Senator Charles Percy of Illinois has pointed out during Senate debates (Congressional Record, 20 May 1977, Vol. 123, No. 87, p. S8112), most farmers intrinsically know whether or not their land is prime farmland, regardless of what parameters are used to define the resource. Since there is no universally accepted definition of prime farmland (Counc. Environ. Qual., 1978), much confusion arises when attempts are made to quantify or even discuss the resource represented by this term.

A cursory review of the literature reveals that definitions of "prime farmland," "prime agricultural land," or similar terms can vary considerably according to the context in which they are used. For example, in California a definition of prime land is used to determine which lands will receive special protection and tax rates under the California Land Conservation Act (see Hansen and Schwartz, 1976), whereas in New Jersey a different definition is used to determine which agricultural lands will be preserved (Chumney, 1976). Further, since both of these definitions were designed primarily to protect agricultural productive capacity, they are not in agreement with Gibson's (1977) economic definition where he points out that "preserving prime agricultural land does not preserve agricultural productive capacity. There is a whole set of conditions essential to agriculture, and land is just one." In an editorial written in 1976, Raup points out that, in his opinion, any definition of prime land should include a foreign trade dimension, and should also incorporate consideration of the lands' ability to yield output at the lowest energy cost. He explains that before a useful definition of prime agricultural land can be developed at the local level, national guidelines regarding this resource need to be established.

Soil Conservation Service

As a first step toward establishing national guidelines, the U.S. Soil Conservation Service (SCS) has taken the lead at the federal level in dealing with issues concerning prime farmlands. On January 31, 1978, a working definition was published in the Federal Register (U.S. Soil Conserv. Serv., 1978). This definition makes specific reference to nine desirable soil characteristics including moisture, temperature, erodibility, frequency of flooding, and amount of large rock fragments. In general terms, the SCS considers prime farmland to be "land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops and [which] is also available for these uses ..." Prime farmland "has the soil quality, growing season and moisture supply to economically produce sustained high yields of crops when treated and managed ... according to acceptable farming methods." For the purpose of a national inventory, prime farmland can be in crop, pasture, range, forest, or other land uses, but not in urban, built-up, or water uses.

Several years ago a national project was undertaken by the state SCS offices to produce at least one detailed prime farmland soil map for each state. Most states produced only the one required county map, but others, such as Indiana, produced a state-wide map of prime farmland soils in addition to the detailed county map. Currently, a national prime farmland inventory of some 1200 high-priority counties is under way, but results are not expected before 1981 (Counc. Environ. Qual., 1978).

Office of Surface Mining

Late in the 5-year legislative process which culminated with enactment of the Surface Mining Control and Reclamation Act of 1977, a provision was inserted into the House version which was designed to extend additional protection to prime farmlands underlain by coal. In Section 701(20) of the final Act (PL 95-87), the term prime farmland is defined as having "the same meaning as that previously prescribed by the Secretary of Agriculture on the basis of such factors as moisture availability, temperature regime, ... susceptibility to flooding and erosion characteristics, and which historically have been used for intensive agricultural purposes, and as published in the Federal Register" (emphasis added). Because of the "published in the Federal Register" clause, the SCS technical definition described earlier is incorporated into the prime farmland definition which the Office of Surface Mining (the regulatory agency created to implement the new Act) must use in determining if a given mining operation will affect prime farmland. Unfortunately, both the historical-use clause and the intensive-agricultural-purposes clause have added to the previously mentioned confusion and, in effect, have created a new operational definition of prime farmlands. Much confusion would have been avoided if the Congress had identified the resource they wished to protect as prime cropland, referring to the fact that the prime farmland soils had been used for crop production. Nevertheless, for this report it is to be understood that the term prime farmland is referring to the SCS definition except where expressly stated otherwise.

THE CORN BELT - REGIONAL PERSPECTIVE

As a result of its fertile soils and continental climate, the Corn Belt is probably the single most productive agricultural region recognized by the U.S. Department of Agriculture and ranks among the world's outstanding grain-producing regions, yielding large quantities of food and feed grains, oilseed, livestock, hay, and other agricultural products. The five states which make up the Corn Belt contain some 165 million acres of land, 77 million acres of prime farmland, and 110 billion tons of mineable coal reserves (Table 1). Nationally, this represents 7% of the total land area, 22% of prime farmland, and 25% of mineable coal reserves. In 1976, there were about 35 million persons in the Corn Belt (Table 1), of whom 2.5% were employed in agriculture, and 0.2% worked in the mining industry. Each year the Corn Belt produces about 25% of the nation's agricultural output, and about 20% of the nation's coal.

AGRICULTURAL LAND CAPABILITY AND PRIME FARMLAND

Nearly three-quarters of the Corn Belt land is grouped in the top three land capability classes recognized by the Soil Conservation Service (Table 2). According to the SCS classification, soils can be ranked according to the amount of management required for crop production on each soil type (Dideriksen et al., 1977). Class I soils have few limitations restricting their use for any type of agriculture. Class II and III soils have limitations that reduce the choice of plants which can grow on them and require conservation practices to sustain their value for producing agricultural crops. Soils grouped into Class IV are considered borderline for agricultural use because they have very severe limitations that reduce the choice of plants which can be grown on them and because in addition, they may require very careful management practices. Soils in Classes V through VIII are either altogether unsuitable

Table 1. Land, Coal, and Human Resources in the Corn Belt

State/Region	Land (10^6 acres)			Coal Reserves[a] (10^9 tons)			Population[b] (10^6 persons)		
	Total Land[b]	Prime Farmland[c]	Cropland[d]	Surface	Deep	Total	Metro-politan	Nonmetro-politan	Total
Illinois	35.7	20.6	25.1	12.2	53.4	65.6	9.1	2.1	11.2
Indiana	23.1	14.0	14.1	1.7	8.9	10.6	3.5	1.8	5.3
Iowa	35.8	18.6	28.0	0	2.9	2.9	1.0	1.8	2.8
Missouri	44.2	12.2	20.8	3.4	6.1	9.5	3.0	1.7	4.7
Ohio	26.2	11.0	12.8	3.6	17.4	21.0	8.6	2.2	10.8
Corn Belt total	165.0	76.8	100.9	21.0	88.8	109.8	25.3	9.6	34.9
U.S. total	2263.6	349.0	466.6	136.9	299.8	436.7	156.8	58.1	214.9

[a]Data from Westerstrom and Harris (1975).
[b]Data from U.S. Bureau of the Census (1974).
[c]Data from Schmude (1978--personal communication, U.S. Soil Conservation Service, Washington, DC).
[d]Data from U.S. Department of Agriculture (1977a).

Table 2. Land Capability in the Corn Belt[a] (in 10^6 acres)

State/Region	Land Capability Class							
	I	II	III	IV	V	VI	VII	VIII
Illinois	5.7	16.5	5.2	2.2	0.3	1.8	0.9	0.2
Indiana	1.8	11.6	3.1	2.0	-	1.2	1.5	<0.1
Iowa	4.1	14.3	9.6	2.5	0.7	1.4	1.5	<0.1
Missouri	1.6	5.8	14.2	6.2	<0.1	3.9	8.7	0.1
Ohio	0.9	10.2	5.3	2.4	<0.1	2.4	1.9	<0.1
Corn Belt total[b]	13.2	62.2	36.2	15.2	1.0	10.6	13.4	
U.S. total	45.0	299.4	291.5	178.2	31.0	274.2	318.7	

[a]State data from U.S. Department of Agriculture (1971); regional (Corn Belt) and U.S. data from Dideriksen et al. (1977).
[b]Totals may not add due to independent rounding.

for agriculture, or their utility is restricted to pasture, range, woodland, or wildlife-habitat uses.

Prime farmland (according to the SCS definition) includes all Class I soils, more than 80% of Class II soils, and less than a third of Class III soils (Schmude, 1977). With proper management, there are about 110 million acres of arable land (Classes I through III) in the Corn Belt, and 39 million additional acres in Classes IV through VIII which, although not in urban or water uses, are unsuitable for producing crops. Recent studies have indicated that 76.8 million acres or nearly 50% of the land in the Corn Belt is prime farmland (Table 1); this is the largest amount of prime farmland of the ten agricultural regions in the nation (Fig. 2). All the Corn Belt states have

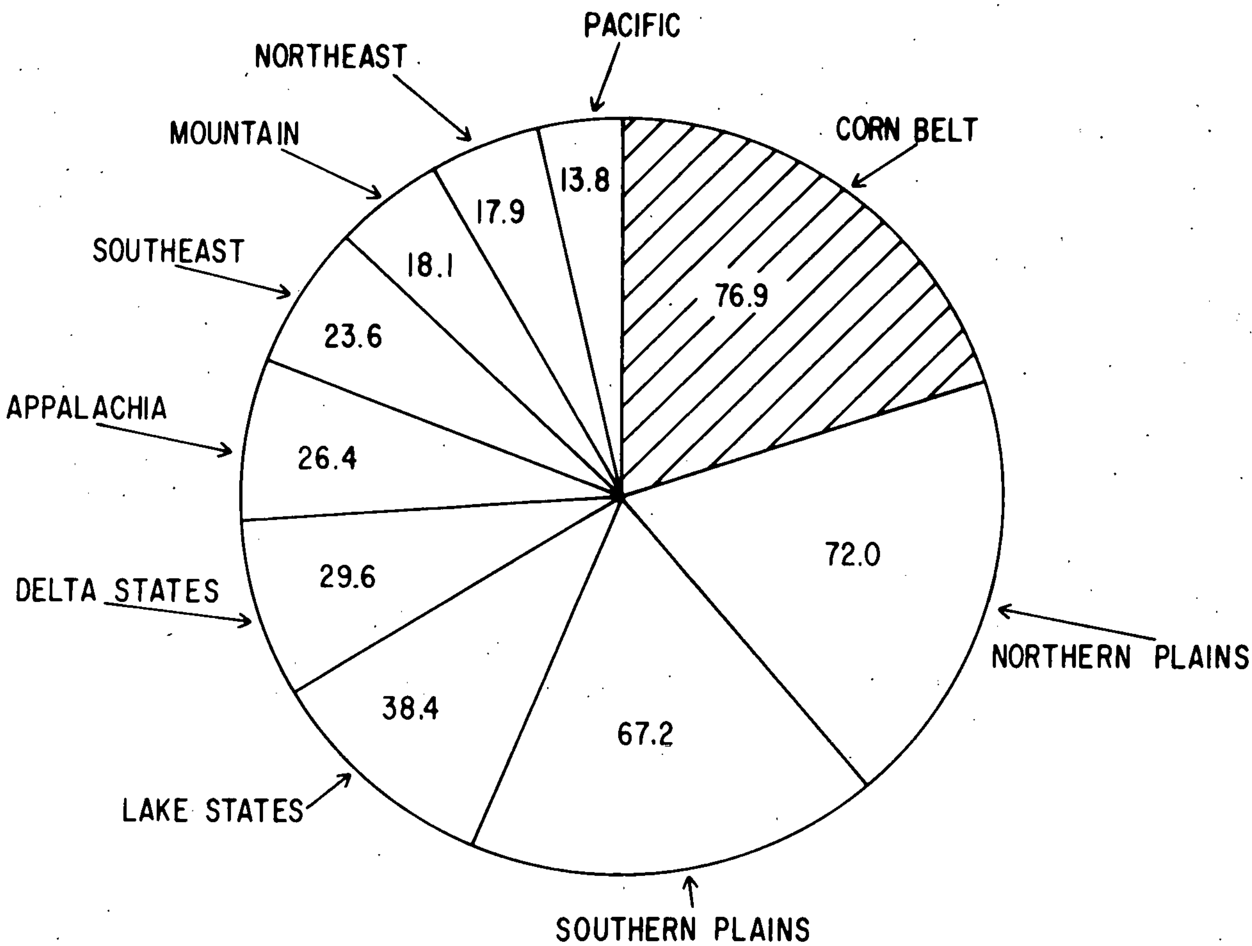

Figure 2. Distribution of Prime Farmlands in the United States (in 10^6 acres). Data from Schmude (1977).

prime farmland acreages exceeding 10 million acres. This vast amount of prime land is one of the key factors which has helped elevate the Corn Belt to a position among the world's most productive agricultural regions. In fact, over 70% of the land used for crop production in this part of the country is prime farmland (based upon data in Schmude, 1977).

AGRICULTURAL INDUSTRY

The agricultural industry has continued to develop in the Corn Belt since the nineteenth century when railroads made it possible for midwestern farmers to reach an ever wider market with their goods (Lewis, 1978). Today, these farmers produce enough to sell their agricultural products not only to their fellow countrymen, but to many other nations around the world as well. In fact, one major economic problem which plagues grain farmers in the United States is their chronic tendency to "overproduce" (Karlgaard, 1978). However, in a world in which the global population is rising rapidly, many people feel that U.S. farmers should be encouraged to continue producing food rather than participating in land set-aside programs. This is largely a moral and economic question which is now being debated by federal and state legislators throughout the nation. One thing is clear, though, and that is with conditions permitting, farmers in the Corn Belt have continued the trend toward ever-increasing crop harvests.

Farms, Land in Farms, and Farm Labor

During the past decade, the total number of farms in the Corn Belt has continually declined at an average rate of about 1.2% per annum (Fig. 3), down to 581,000 farms at the start of 1978 (U.S. Dep. Agric., 1977b). During the same period, the total acreage of land in farms also declined, but at a slower rate (0.2% per annum), down to 129.5 million acres in 1978 (Fig. 3). As a consequence, the average farm size has increased 19.2 acres over the average size of 203.7 acres in 1969.

Although the total land in farms has been declining in the Corn Belt in recent years, the actual acreage of cropland has increased as a result of shifting pasture and rangeland into cropland use. This land-use conversion not only indicates the flexibility of the Corn Belt agricultural industry, but also demonstrates that much of the land which had been used for pasture and range purposes is capable of supporting row crops. Of course, the degree

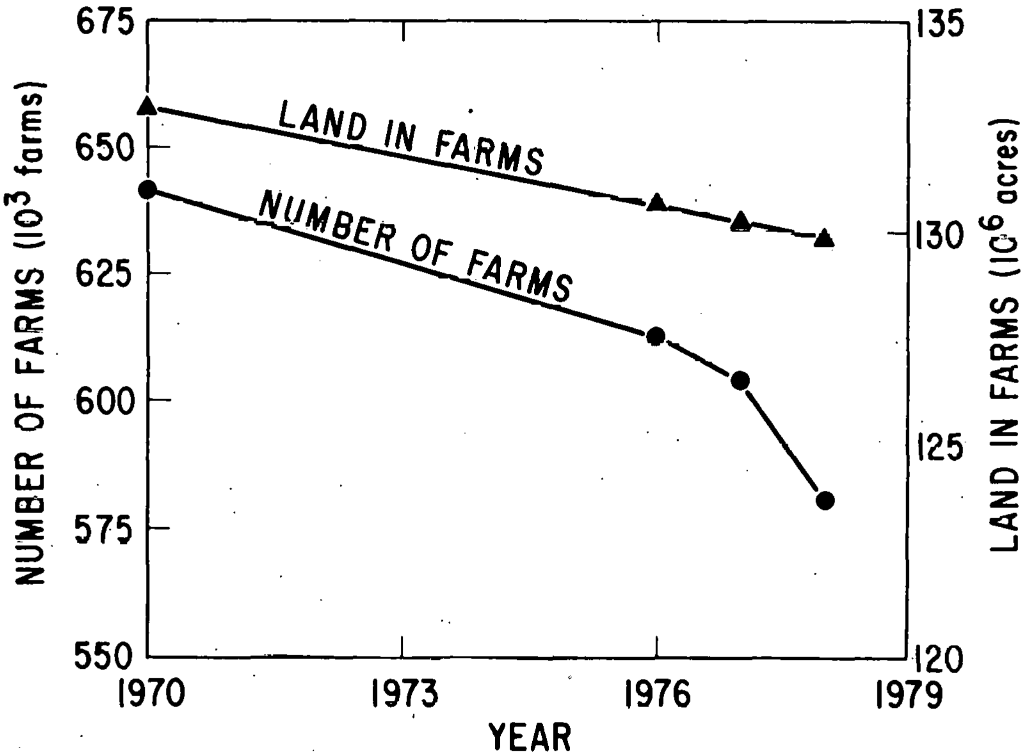

Figure 3. Land in Farms and Number of Farms in the Corn Belt, 1970-1978. Data from U.S. Department of Agriculture (1977b).

to which idle and pasture land can be converted into cropland is limited by the amount of land presently devoted to these two land uses. For example, in 1974 there was relatively little idle cropland in the Corn Belt (Table 3), but approximately 15% of the cropland in this region was being used for pasture. If all the cropland in use for pasture were returned to crop production, the total acreage available for raising cattle would be reduced to half that in use during 1974.

Table 3. Farmland in the Corn Belt, 1974[a] (in 10^6 acres)

	Cropland				Grassland, Pasture, and Range[f]
	Used for Crops[b]	Idle[c]	Used only for Pasture[d]	Total[e]	
Illinois	22.6	0.6	1.9	25.1	2.4
Indiana	12.3	0.4	1.4	14.1	1.6
Iowa	24.0	0.4	3.6	28.0	2.2
Missouri	13.1	0.9	6.7	20.8	6.4
Ohio	10.8	0.5	1.5	12.8	1.8
Corn Belt total	82.8	2.9	15.2	100.9	14.5
U.S. total	362.8	20.2	83.6	466.6	597.8

[a]Data from Frey (1977); totals may not add due to independent rounding.

[b]Cropland harvested, crop failure, and cultivated summer fallow.

[c]Cropland in cover, soil improvement crops not harvested or pastured, and other idle cropland.

[d]Land in crop rotation used only for pasture in 1974.

[e]Total average in crop rotation.

[f]Grasslands and other nonforested pasture and range in farms (excluding cropland used only for pasture) plus estimates of open or nonforested grazing land not in farms.

While farm size was increasing, there was also a migration of farmers from rural areas to the cities, resulting in a declining farm-worker population in the Corn Belt. In 1976, there were 874,000 farm workers in this area--about one-fifth of the nation's total farm workers; 19% of these workers were classified as hired-hands. In response to a declining farm population, the number of hired farm workers has been increasing since 1974 in all Corn Belt states except Missouri. Family farm workers in Indiana dropped 7% between 1974 and 1976, while at the same time there was a 2% increase in Missouri.

Clearly, the family farm is changing, and this may have long-term implications for the agricultural industry. Although it is not known exactly how mining operations affect the labor force in farm regions, it is undeniably true that the family farm, *sensu strictu*, can "out-starve" the integrated farm which relies on outside labor. Success of the agricultural industry relies equally on good agricultural land and on human resources, including the expertise of the family farmer. To protect the productive capacity of this industry, it is necessary not only to preserve the high-quality land but also to prevent dissipation of the human resources which have made the industry strong.

Crop Productivity and Production

Although the acreage of farmland, number of farms, and number of farm workers have been steadily declining, agricultural output has fluctuated, generally showing a slow increase in the Corn Belt during at least the last decade (Fig. 4a). Of course, there were years, such as 1974, in which adverse weather caused crop production to drop drastically, but from 1959 to 1975,

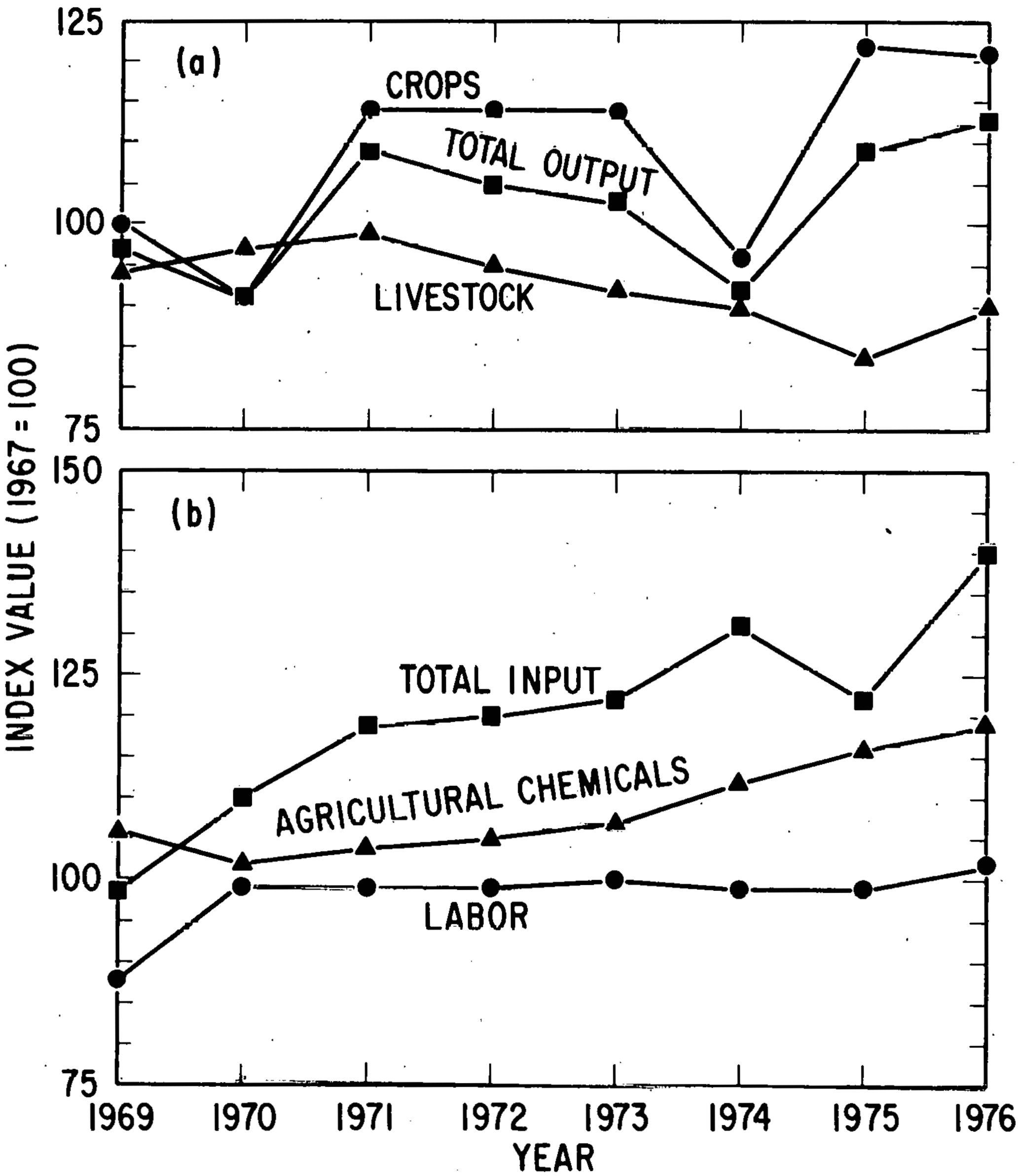

Figure 4. Farm Inputs and Production in the Corn Belt, 1969-1976. Data from U.S. Department of Agriculture (1977a).

the overall agricultural output of the region increased more than 56%. In 1976, the Corn Belt farm production region contributed 60% of U.S. corn and soybean harvests. In 1977, Illinois was the top producer of both corn and soybeans, and farmers in this region harvested some 3.5 billion bushels of corn, 2.2 billion bushels of soybeans, 255 million bushels of wheat, 146 million bushels of oats, and varying amounts of other field crops (Table 4). Average corn yields ranged from 76 bushels/acre in Missouri to 105 bushels/acre in both Illinois and Ohio. Harvests of soybeans, wheat and oats averaged about 36, 44, and 58 bushels/acre, respectively--all above the national averages for the same crops.

Table 4. Major Field-Crop Harvests and Yield in the Corn Belt, 1977[a] (harvest in 10^6 bushels; yield in bushels/acre)

State/Region	Corn		Soybeans		Wheat		Oats	
	Harvest	Yield	Harvest	Yield	Harvest	Yield	Harvest	Yield
Illinois	1152.9	105.0	1716.3	37.0	63.4	43.0	20.7	61.0
Indiana	633.4	102.2	12.1	33.5	55.8	45.0	8.0	53.0
Iowa	1091.2	88.0	245.8	34.0	3.1	37.0	81.1	59.0
Missouri	250.2	76.0	144.0	30.0	60.4	39.0	7.2	50.0
Ohio	380.1	105.0	116.6	34.5	72.4	47.0	28.5	59.0
Corn Belt total	3507.8	91.8	2234.8	36.1	255.1	43.6	145.5	58.5

[a]Compiled from state data summaries.

Several factors figure prominently in this high level of production (Fig. 4b). One key factor is, undoubtedly, the use of pesticides and fertilizer. For instance, in 1976 alone, farmers in the Corn Belt used more than 13.7 million tons of commercial fertilizer, which is nearly triple the total quantity used in the entire 5-year period between 1951 and 1955. Another contributing factor was increased dependence upon irrigation; between 1949 and 1974, the irrigated acreage in the Corn Belt rose from 16,000 to 295,000 acres. Finally, some crop varieties currently in use respond well to fertilization and other crop management techniques, producing superior yields with a given level of input. However, man still has relatively little control over the weather, and fluctuations in agricultural productivity despite the increased inputs reflect the variability of the climate. Generally, however, the midwestern climate has been favorable for crop growth during the past decade.

Future Agricultural Output

Given the uncertainty associated with predictions in any industry, it is difficult to derive an accurate prediction of future agricultural output from the Corn Belt. However, the U.S. Department of Agriculture has made agricultural projections for selected years through 2000 (Water Resour. Counc., 1975); these projections reflect domestic supply and demand relationships and foreign export conditions which existed in the United States during the period 1950 to 1972, and represent a continuation of historic economic conditions and policies.

Agricultural export projections were based upon the assumption of continued growth both in domestic consumption and in import demand by foreign countries. Further, a stable U.S. dollar was assumed, relative to other world currencies. The recent trend toward devaluation of the U.S. dollar may, however, contribute to an upsurge in export demand by making U.S. products more readily obtainable and relatively cheaper than those of other countries. This is desirable in light of the large grain surpluses which now exist in this country (U.S. Dep. Agric., 1979). Should the U.S. currency remain devalued for an extended period of time, new and higher export patterns could be established. Improved relations with the Peoples Republic of China may also lead to increasing demand for agricultural exports.

The projections of agricultural output show declining oat production in most of the Corn Belt states, but increasing production of other major field crops such as corn, soybeans, and wheat (Table 5). Overall, assuming a stable climate and an adequate supply of energy, agricultural production is expected to continue increasing in the Corn Belt during the remainder of this century, despite shifting land-use patterns which remove land from crop production. However, in a recent article, Swanson and Taylor (1977) suggested that increased energy costs in the Corn Belt could cause a shift in the corn to soybeans ratio, with soybeans being favored because they are a less energy-intensive crop. Reports on the implications of potential climatic changes are less conclusive (Hinckley, 1976; Moran et al., 1977), but indicate that increased stress from altered weather patterns could reduce crop yields or bring about a different mixture of crops planted in the Corn Belt.

COAL INDUSTRY

Coal Resources

All five states in the Corn Belt contain mineable coal deposits (Fig. 5). The Interior Coal Region underlies portions of the Corn Belt and is composed of two provinces: the Eastern Interior Province which is aligned in a northwest-southeast direction under central Illinois and southwestern Indiana, and the Western Interior Coal Province which is oriented north-south, and underlies southern Iowa, northwestern Missouri, and parts of surrounding states. Additionally, part of the Northern Appalachian Province is found in eastern Ohio. In all, there are about 110 billion tons of coal in the Corn Belt, of which 19% is surface mineable (Table 1).

The Eastern Interior Coal Region consists of coal fields in Illinois, southwestern Indiana, and western Kentucky. The coal is of Pennsylvanian age, is primarily bituminous in quality, and often has large amounts of sulfur present, although the sulfur content ranges from as low as 0.5% to 6.0% (U.S. Energy Res. Dev. Admin., 1977). Geologically, the coal is in a basin formation so that most of the reserves in central Illinois are too deep for surface mining. Consequently, surface mining activities in this coal region are confined to the perimeter of the basin where the coal is near the surface.

Table 5. Projected Field Crop Production in the Corn Belt, 1980-2000[a] (in 10^6 bushels)

State	Wheat	Corn[b]	Oats	Soybeans
Illinois				
1980	67.3	1324.1	27.4	275.3
1985	68.6	1459.5	25.4	309.2
2000	68.6	1884.1	15.5	343.9
Indiana				
1980	46.6	609.4	11.8	138.8
1985	47.1	673.0	11.2	159.7
2000	49.5	886.6	–[c]	193.5
Iowa				
1980	–[c]	1319.4	73.0	286.2
1985	–	1448.9	72.1	344.2
2000	–	1813.3	61.1	463.2
Missouri				
1980	53.2	258.8	–[c]	154.2
1985	54.5	275.6	–	184.7
2000	59.7	358.7	–	276.8
Ohio				
1980	41.7	302.0	38.0	97.1
1985	39.8	317.7	42.1	114.9
2000	33.9	404.3	53.1	170.0
Corn Belt				
1980	208.8	3813.7	150.2	951.6
1985	210.0	4174.7	150.8	1112.7
2000	211.7	5347.0	129.7	1447.4

[a]Data from Water Resources Council (1975).

[b]For grain.

[c]A dash indicates no production expected.

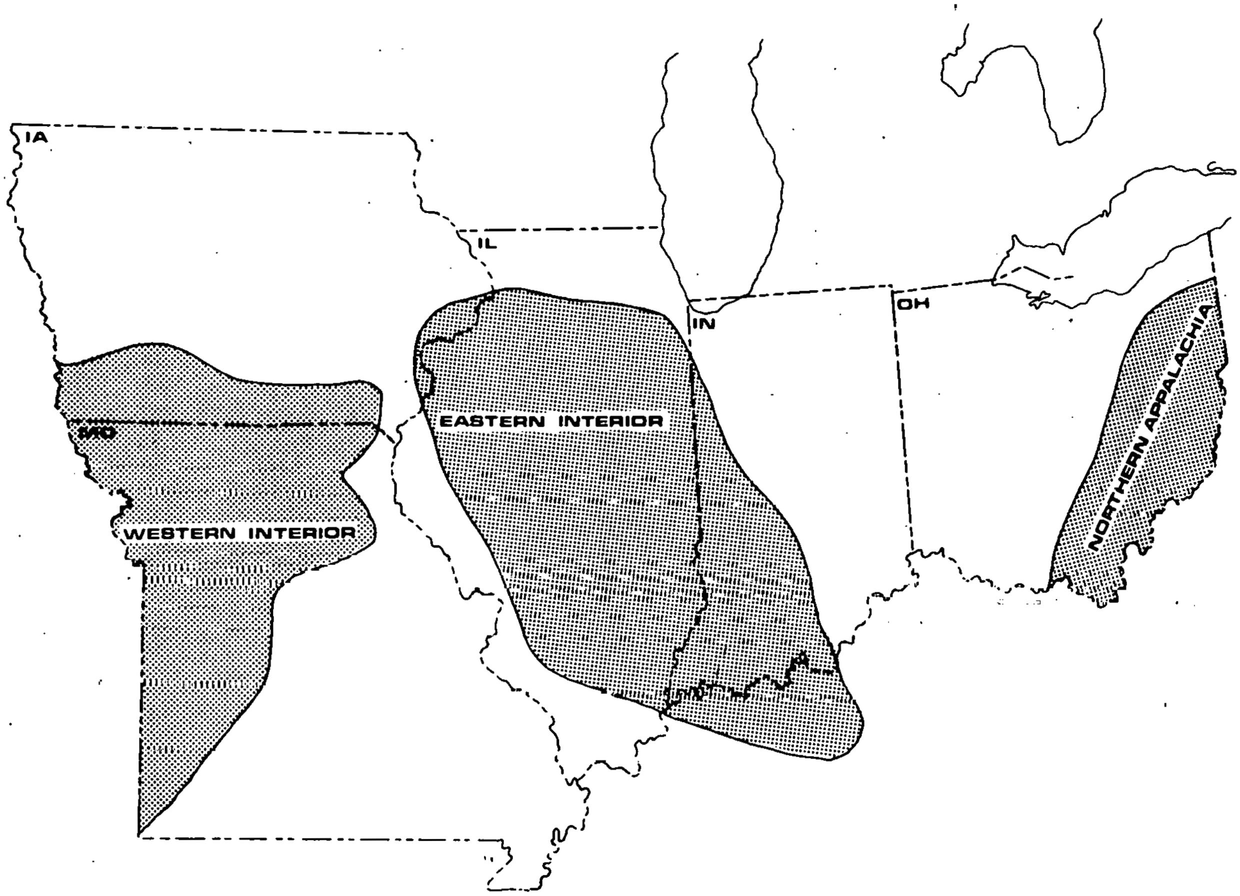

Figure 5. Location of Major Coal Deposits in the Corn Belt States.

The Western Interior Coal Region is found in southcentral Iowa, northwestern Missouri, and parts of Kansas, Arkansas, and Oklahoma. Most of the coal in this region is found in thin seams, and commercial mining is confined to strip-mining outcrops of the high-sulfur (> 2%) reserves.

Despite the high production of coal in this region, all Corn Belt states except Illinois import coal. The leading use of coal in each state is for electric power generation, although in Indiana and Ohio, large amounts are used in other industries. In 1972, over one-quarter of the total energy consumed in the Corn Belt states came from coal, with Ohio using the largest amount (37%) and Iowa the smallest (18%) (Drysdale and Calef, 1977). With these factors in mind, it seems plausible that the Corn Belt coal industry will continue to supply a substantial portion of the region's annual coal demand.

About 46% (∿ 9 billion tons) of the strippable coal in the Corn Belt lies beneath prime farmlands (Table 6). Although this is certainly a significant fraction of the available reserves in this region, it is important to note that nationally, just 17% of the strippable reserves lie beneath prime lands (Harper and Anderson, 1979). Thus, despite the claim that prohibiting surface mining on prime farmlands would severely reduce the national coal

Table 6. Strippable Coal Reserves in the Corn Belt[a]

State/Region	Strippable Reserves (10^9 tons) Total	Beneath Prime Farmland	Strippable Reserve Impact (%)
Illinois	12.2	6.5	53
Indiana	1.7	0.8	46
Iowa	NA	NA	NA
Missouri	3.4	1.2	36
Ohio	3.6	0.5	13
Corn Belt total	21.0	9.0	46
U.S. total	129.4	22.4	17

[a]Data from Harper and Anderson (1979).

NA = not available.

production (which no doubt it would, at least initially), it seems that from a noneconomic, national perspective it is possible to obtain large amounts of coal with a small impact to prime farmlands. However, at the present time this seems to be an untenable option for various economic and political reasons.

Coal Production

During the past 15 years, coal production in the Corn Belt has, on the average, been increasing at the rate of about 3% per annum (Fig. 6). This is a faster rate of growth than the national coal industry exhibited during the same period when the average growth rate was just slightly over 2% per year. In 1975, the total regional coal production was about 138 million tons, 65% of which came from surface mines; there were 433 surface mines and 58 deep mines in operation, employing about 30,000 miners (Table 7).

There are several factors which help explain the predominance of surface mines in the Corn Belt. First, surface mines are often more productive with fewer employees; the average daily output per worker is considerably higher in a surface mining operation than in deep mines (Table 7). In fact, on a national level, surface mines are more than twice as productive as their deep mining counterparts. During 1975, surface miners in the Corn Belt produced an average of 21.6 tons of coal per day per worker; each deep miner in the region produced 19.6 tons per day. However, in Ohio, deep mines had a better productivity record than surface mines in 1975, primarily because these mines were of the contour type.

A second major reason for the predominance of surface mining is that it is more efficient at removing coal from the seam. Surface mining methods on the average remove from 80 to 90% of the coal, in comparison to 45 to 50% in deep mining operations. Losses in surface mining are due mainly to spillage and losses in transit, whereas in deep mines (excluding the new continuous mining operations) much coal is left behind in the columns and pillars which

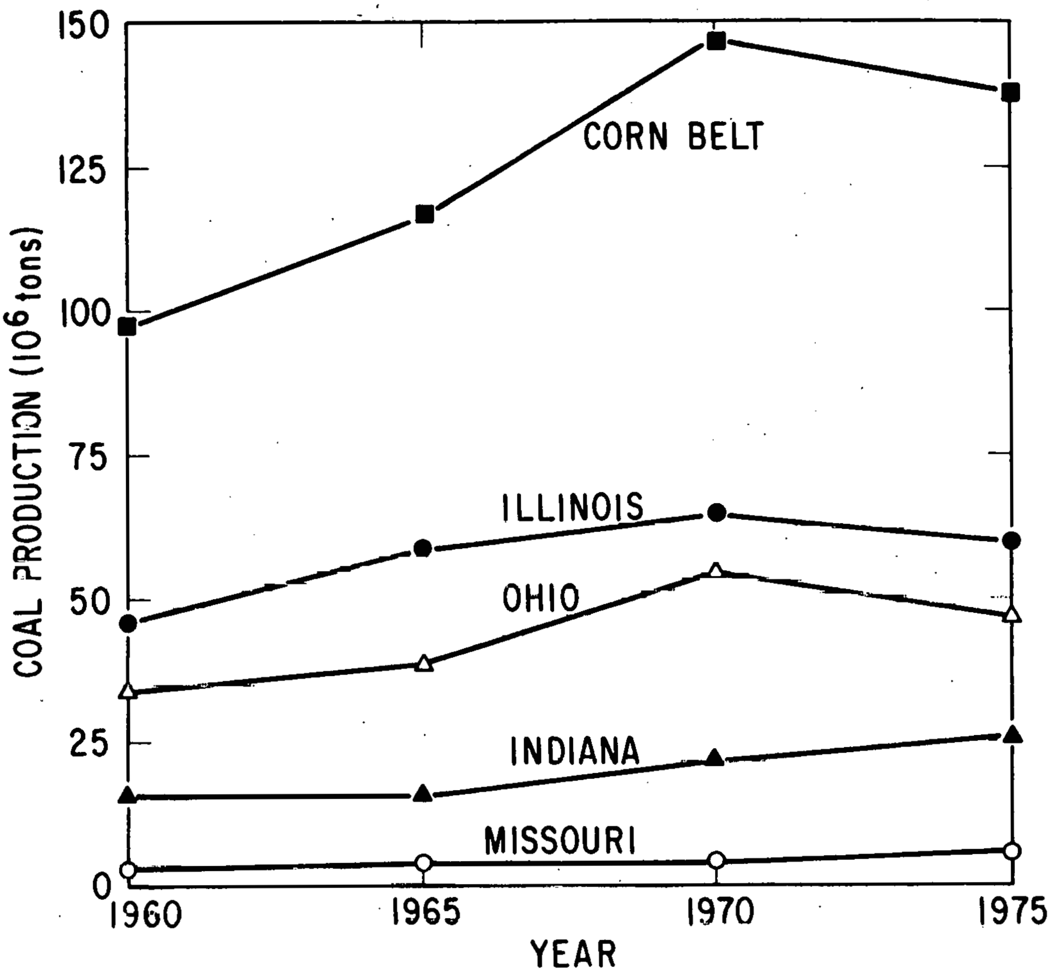

Figure 6. Coal Production in the Corn Belt States, 1960-1975. Data for 1960, 1965, and 1970 from U.S. Bureau of the Census (1974). Data for 1975 from Westerstrom and Harris (1975).

Table 7. Coal Mines, Productivity, and Employment in the Corn Belt, 1975[a]

State/Region	Number of Mines		Productivity (tons/man-day)		Number of Miners	
	Deep	Surface	Deep	Surface	Deep	Surface
Illinois	21	76	14.25	24.19	9,010	3,840
Indiana	2	60	16.10	29.69	80	2,960
Iowa	2	8	22.06	17.98	60	60
Missouri	0	13	0	21.14	0	890
Ohio	33	315	25.97	15.13	8,730	4,700
Corn Belt total	58	433	19.60	21.60	17,880	12,450
U.S. total	2,292	3,876	9.54	26.69	134,710	55,170

[a]Data from Westerstrom and Harris (1975).

support the mine roof. These and many other factors combine to favor surface mining operations in areas, such as parts of the Corn Belt, where coal seams are readily exposed to the surface by stripping methods.

Future Coal Production

Despite the new federal and state regulations placed on coal surface-mining operations, it is unlikely that this method of extraction will be abandoned in favor of the more dangerous and costly deep-mining methods. In all likelihood, surface mining will continue to be an important method of coal extraction in the Corn Belt.

According to the U.S. Bureau of Mines (Benson and Doyle, 1978; Rich, 1978), the Corn Belt coal industry is planning future expansions, a growth which is encouraged by the present federal administration. By 1980, it is expected that 12 new surface mines and 20 new deep mines will provide a combined additional capacity of over 65 million tons per year. Furthermore, legislation now in force partially removes some of the factors which could have interfered with the use of high-sulfur midwestern coals. The 1977 Clean Air Act Amendments prescribe measures for minimizing sulfur oxide (SO_x) emissions at all newly constructed and future coal-burning facilities. Presumably, many of the economic incentives for using low-sulfur western coals, which could have resulted in a decrease in the demand for high-sulfur midwestern coals, have now been eliminated.

LAND USE

Agricultural

Prior to 1800, the Corn Belt was largely unsettled and still supported forests and prairie grasslands. By 1835, however, much of this region had been settled, and the process of land clearing for agriculture was well under way. By 1974, more than 60% of the land in the Corn Belt was used as cropland (Frey, 1977); the remaining land was used (in descending order) for forest; grassland, pasture, and grazing; special uses; and other miscellaneous land uses (Fig. 7). In all, there were over 100 million acres of cropland in this region, of which more than 80% was being used for crop production and less than 3% was idle (see Table 3); 61.2 million acres of the land in crop production was prime farmland (Schmude, 1977), representing nearly 80% of the total acreage of prime farmland available. Thus, of the land currently used for growing crops in the Corn Belt, about 70% is prime farmland.

The patterns of crop types grown in the Corn Belt have changed significantly through time. During the period 1959 to 1975, there was an increase in the production of feed and food grains, oil crops, hay and forage, sugar crops, and tobacco in this agricultural region. At the same time, the production of nuts, fruits, and vegetables declined, as did the output of livestock and livestock products. In the 1977 crop year, there were about 36 million acres of cropland used for corn, 28 million acres for soybeans, 6 million acres for wheat, 2.4 million acres for oats, and various amounts of land used for other grains (Baker, 1978). In all, nearly two-thirds of the cropland was devoted to corn and soybeans. This changing land-use pattern has, in part, shown that there is a shifting emphasis away from integrated

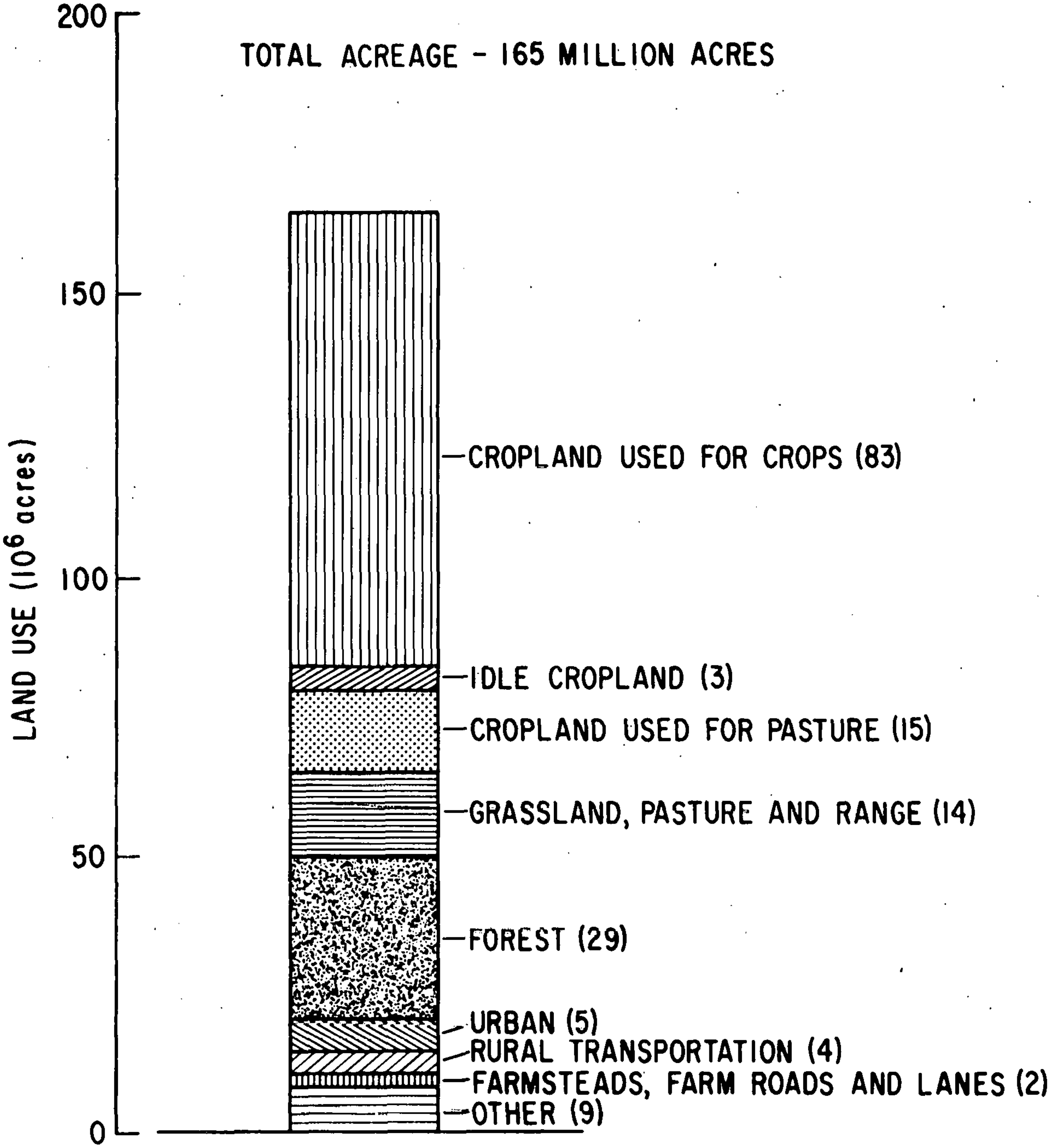

Figure 7. Land Use in the Corn Belt, 1974 (in 10^6 acres). Data from Frey (1977).

farming toward a more cash-oriented crop production system. Also, the variation in agricultural output demonstrates that farmers are willing to vary their crops according to the expected economic yields of one crop over another.

The economic factor will continue to be the predominant factor affecting land use in the future. If, through government support, the agricultural industry is encouraged to sustain a high level of output, then the total acreage of land in crops can be expected to rise somewhat. Current trends are toward continuous cropping and away from traditional crop rotation which periodically left a portion of the land idle. This has resulted in an increase in the total sustained acreage used for crop production (Table 8). There are about 11 million acres of high-potential cropland available in the Corn Belt which, although not currently in crop production (Dideriksen et al., 1977), could be put into use; however, nearly half these lands have problems, such as erosion and flooding, which would affect crop production (Dideriksen et al., 1977). Overall, there are only about 3 million acres of high-potential cropland available for which there are no major development problems. If national and international demands for agricultural products continue to increase, additional lands can be expected to be put into crop production.

Table 8. Projected Land Use in the Corn Belt, 1985-2000[a]

State/Region	Cropland: Harvested	Cropland: Not Harvested	Forest and Woodlands	Pasture, Range, and Other	Total Land in Farms
Illinois					
1985	22,800	1,587	2,077	2,349	28,814
2000	23,617	635	1,873	1,945	28,071
Indiana					
1985	12,007	1,432	1,887	1,618	16,944
2000	12,912	499	1,713	1,295	16,420
Iowa					
1985	24,402	3,220	1,559	3,863	33,043
2000	26,668	906	1,517	3,522	32,612
Missouri					
1985	13,307	7,319	5,533	5,244	31,402
2000	15,515	5,177	5,315	5,054	31,061
Ohio					
1985	9,495	2,802	1,916	2,086	16,299
2000	10,724	1,428	1,625	1,647	15,424
Corn Belt					
1985	82,012	16,360	12,972	15,158	126,503
2000	89,436	8,646	12,043	13,463	123,587

[a]Data from Water Resources Council (1975).

Nonagricultural

In 1974, 30% of the Corn Belt region was devoted to nonagricultural uses including forests and special-use areas such as urban developments, transportation systems, and others (Fig. 7). Together, these nonagricultural land uses accounted for nearly 50 million acres, with the single largest area in forests (59%). Best estimates of special-use land indicate that there were 5.5 million acres in use for urban areas, 3.8 million acres for rural transportation, and 3.4 million acres for miscellaneous uses such as rural parks, wildlife refuges, and farm roads and lanes (Frey, 1977).

As mentioned in the preceding section, future land use in the Corn Belt will be influenced by economics. In addition, current land-use patterns will influence future patterns. For example, commitment of agricultural land to urban, reservoir, road, and other special uses makes the land unavailable for agriculture, at least in the foreseeable future. In the past decade, considerable acreages of land have already been lost to these special uses, and, moreover, this trend is expected not only to continue but perhaps to show an increase. Barring legislation to control land-use patterns, it is therefore likely that at least several million additional acres of land will be lost in the Corn Belt between now and the turn of the century. Although this is but a small fraction of the total regional land area, the trend is disturbing, especially since much of the converted land has been of cropland quality.

Another factor affecting land use is mining for metals, nonmetals such as limestone, and fossil fuels. To fully understand the land-use conflicts, data on the acreages affected by non-coal mining are required, but are presently either unavailable or uncollated.

DISTURBED LANDS IN THE CORN BELT

Many, if not most, of man's activities can and often do affect the "quality" and availability of good agricultural land. This country is blessed with an abundance of prime farmland; nevertheless this land is a finite resource which cannot be readily replaced once destroyed and thus must be protected if the productive capacity of the agricultural industry is to be maintained. As traditional energy supplies become depleted, it will be increasingly difficult for the farm industry to maintain the present levels of productivity on a per acre basis. Consequently, to maintain or increase outputs it may be necessary to press additional land into production to offset the effects of reduced energy subsidies. This means that irreversible commitments of good farmland to nonagricultural uses could in the future have adverse impacts on the quantity of food produced in this country. This realization has led some members of society and government to begin discussing ways to reduce the "loss" of agricultural land. To effectively deal with the issue of land-use planning it is necessary for decision makers to have information concerning the following topics: (1) types of land disturbance, (2) acreage of land which has already been affected, (3) methods to reduce the impacts of various disturbances, and (4) projections of the acreage to be affected by various activities in the future.

TYPES AND MAGNITUDE OF LAND DISTURBANCE

At the functional level, disturbance of land or, more specifically, soil refers to the disruption of the functional soil ecosystem which exists at a site prior to mining. Conceptually, direct land disturbance refers herein to the land directly above the coal being removed, whereas indirect land disturbance refers to surface areas used for initial overburden and topsoil storage, coal piles, loading areas, haulage and access roads, and final-cut reservoirs. In some mining operations, indirect land disturbance may involve as much land as direct disturbance (Natl. Acad. Eng., 1974), especially when land requirements for preparation plants, boom towns, and other activities are considered. However, in the Midwest, the incremental increase of indirect over direct disturbance is usually a factor of about 1.2 (Counc. Environ. Qual. and Environ. Prot. Agency, 1977), which means that for every 5 acres directly disturbed, an additional acre is indirectly affected.

When topsoil is physically removed, transported to a new location, and "reconstructed," its physical, chemical, and biological characteristics are altered. Additionally, surface vegetation is destroyed, streams diverted, and other features of the premined site altered by the extraction process. Reestablishing nutrient cycling processes, soil-water relationships, and the groundwater table will be difficult, but necessary, if these aspects of the nation's soil resource are to be restored for future generations.

Fundamentally, each type of land disturbance has at least two dimensions--magnitude and duration. Wide fluctuations are known in both magnitude and duration of disturbance, and thus it would be possible to construct a matrix of activities ranging from those causing low magnitude-short duration disturbances, as in the case of subsistence farming on floodplains, to high magnitude-long duration disturbances which result from, for example, urbanization.

Unfortunately, relatively little information exists concerning the long- and short-term impacts of surface mining on agricultural lands used for row crops (see next section). In part, this is the result of two past land reclamation practices: (1) revegetating mine spoils without replacing the topsoil (largely using tree species, see Ashby et al., 1978), and (2) shifting land from row crops (prior to mining) to pasture, rangeland, or forest (after mining).

Between 1930 and 1971, more than 920,000 acres of land in the Corn Belt were disturbed by the mining industry which included surface extraction of sand and gravel, metals, building materials, and coal. By 1974, over 710,000 acres of land in the Corn Belt had been affected by coal mining (Carter et al., 1974), of which 44% were unreclaimed lands abandoned from previous mining operations (U.S. Soil Conserv. Serv., 1978).

According to the U.S. Soil Conservation Service (1978), none (or a negligible amount) of the 163,000 acres of cropland in the Midwest affected by surface mining are currently being used as cropland. With reclamation, only 21,500 acres are expected to be returned to cropland use (U.S. Soil Conserv. Serv., 1978), while at the same time the acreage of pasture and rangeland is expected to rise to 136,900 acres, up considerably from the original acreage (79,800 acres) for these land uses. This represents a net change of -86.8% for cropland and +172% for pasture and rangeland; forestland would also increase by about +134%.

An even greater amount of land in the Corn Belt has been affected by special land uses such as urban sprawl, road construction, and reservoir filling. During the 8-year period, 1967 to 1975, over 2.7 million acres of land were converted to urban and water uses; 172,500 acres of this land was prime farmland, with more than 80% of the losses being attributable to urban expansion (Lee, 1978). By 1975, 12.7 million acres of land in this region were devoted to special uses (Frey, 1977). Because many of these uses represent an irreversible land commitment, the continuing loss of land, much of which had been used for agriculture, is slowly eroding the resource upon which the agricultural industry is based.

To protect our agricultural lands, it is necessary that activities which result in the "irreversible" conversions of this resource to nonagricultural land uses be discouraged. However, as a nation, the comprehensive decision concerning what level of disturbance will be considered acceptable for activities on these lands has not yet been made, although Congress has addressed one dimension of the national land use issue--namely, the surface effects of coal mining. In a very real sense, the Surface Mining Control and Reclamation Act of 1977 represents not only the first attempt to satisfactorily reach a national compromise between two competing land uses, but it also indicates that the country is prepared to accept land disturbances of a large magnitude, provided the duration of the impacts are relatively short.

RECLAMATION OF DISTURBED LANDS

Historically, the coal industry has demonstrated a lack of corporate responsibility in its practice of abandoning ruined land areas. Although this abandonment is no longer legally possible, the industry continues to suffer from the bad image it acquired in the past. To ensure that mined lands will not be abandoned, at least 31 states have enacted some sort of legislation regulating the surface disturbance of lands by mining operations (Imhoff et al., 1976). However, as public needs have changed, so too have the reclamation laws. In Illinois, for example, the reclamation laws were changed four times over a period of 16 years (Ashby et al., 1978), and each time a slightly different emphasis was placed on reclamation goals, with the latest set of laws containing a mechanism (Rule 1104) to protect the state's valuable farmlands from the effects of surface coal mining. Because the laws enacted throughout the country were often significantly different with respect both to increased mining costs resulting from the states' legislation and to the degree of environmental protection, Congress felt it necessary to promote a standard approach to controlling the surface effects of mining.

Legal Aspects

After at least 5 years of debate, Congress enacted the federal Surface Mining Control and Reclamation Act (SMCRA) of 1977 (PL 95-87), thereby giving a unified national direction to activities related to the environmental effects of surface mining for coal. The act was signed into law on August 3, 1977, and is designed to prevent the environmentally damaging coal surface-mining practices of the past. The law requires that lands disturbed by present, and some past, mining activities be reclaimed using the best available methods. Whereas the act seeks to minimize adverse environmental consequences, it was designed to allow adequate coal production to meet present and future national coal needs. Fundamentally, the act underscores the philosophy that reclamation operations should as a minimum "restore the land affected to a condition capable of supporting the uses it was capable of supporting prior to any mining ..." (Sec. 515(b)(2)).

The Final Rules for Permanent Regulatory Program of the Office of Surface Mining (OSM) implement the provisions of the SMCRA. Standards are prescribed pertaining to topsoil handling, protection of the hydrologic balance in the area, backfilling and grading requirements, and revegetation success. Once the states have adopted these regulations, or an approved alternative, it is expected that the competitive advantages which the industry enjoyed under the old nonunified regulations will be eliminated, and all mining operations in compliance with the regulations will be conducting business in a way which leaves the land suitable for other uses following reclamation.

To ensure compliance with these and other regulations, the regulatory authority (be it OSM or an approved state program) will collect a bond from each surface mining operation which will be refunded upon successful completion of the various requirements. In the SMCRA, Congress provided for special protection for the national prime farmland resource by stating that "no part of the [remaining] bond or deposit shall be released ... until soil productivity for prime farmlands has returned to equivalent levels of yield as nonmined land of the same type in the surrounding area under equivalent management practices ..." (Sec. 519(c)(2)). The OSM has interpreted this to mean that prior to bond release for operation on prime farmlands, the operator must demonstrate, through a revegetation program, that the productive capacity of the land has indeed been restored. To this end, Section 823.15 of the Final Program Rules deals with revegetation success on prime farmlands. An implicit assumption is that an operator will not be issued a mining permit in the first place unless sufficient evidence is offered in the permit application to indicate that the operator has the technological capability to restore prime farmlands to their original productivity within a reasonable period of time (approximately 10 years). However, neither the SMCRA nor the regulations prevent restored prime farmlands from being converted to nonagricultural uses.

According to Paone et al. (1974), about 60% of the land disturbed by the mining industry in the Corn Belt from 1930 to 1971 was reclaimed, and as noted above, these reclaimed acres were predominantly used for forests and grazing. In 1971, more acres were reclaimed than were disturbed by mining (Paone et al., 1974), and it appears that the trend is toward reclaiming a significant fraction of the lands disturbed by mining. To promote reclamation of abandoned mined lands, the U.S. Department of Agriculture has established the Rural Abandoned Mine Reclamation Program which, on a cost-sharing basis, will financially subsidize such reclamation efforts.

Field Research

Scientific studies to date have not demonstrated widespread applicability and success of methods for returning large tracts of prime farmlands to their premining levels of productivity on a sustained basis, with inputs and management comparable to that used prior to mining (Doyle, 1978). However, this should not be taken to mean that the OSM final regulations are inadequate, for they are as yet untested. In fact, the new rules and regulations outlined by OSM (U.S. Dep. Inter., 1979) are based upon state-of-the-art reclamation technology and as such will require an advance in the quality of reclamation programs used by many mining companies. Although initially there may be problems in fulfilling the requirements set forth by OSM, there is every indication that once the industry recognizes the necessity to restore disturbed lands to high reclamation standards, the technological and methodological studies which will make such reclamation possible will be carried out and the necessary steps will be taken to ensure that disturbed lands are reclaimed to the standards required to obtain bond release.

Prior to recent (1970 or more current) state and federal legislation requiring topsoil segregation and replacement after mining, field research on surface-mine reclamation had focused on developing methods for revegetating areas with no topsoil. Studies at the University of Illinois in the late 1940s showed that corn yields as high as 60.5 bushels/acre could be achieved with a high level of management (Grandt, 1978b). In the 1950s and early 1960s, Peabody Coal researchers found that by using various fertilizer treatments and crop rotations over a 10-year period, an average field-crop harvest of 87.5 bushels/acre could be achieved (Grandt, 1978b). These two studies confirmed that row crops could successfuly be grown and harvested on surface-mined lands with no replaced topsoil.

Recent studies on test plots in the Corn Belt have shown that with topsoil replacement, corn harvests of up to 124 bushels/acre and soybean harvests of about 19 bushels/acre can be obtained (Grandt, 1978b). This high level of corn yield represents over 80% of the expected yield from the same soil on unmined lands. These results were obtained by planting the land directly after topsoil replacement; according to Grandt (1978a) even better results would have been obtained if the area had been seeded to a legume-grass mixture for the first year--allowing the restored lands to settle properly and the chemical, physical, and biological aspects to become stabilized--and then planted in field crops. Grandt (1978a) recommends that deep-rooted legumes be grown for at least five years on lands where the topsoil has been replaced; he suggests that a crop rotation consisting of corn, soybeans, cereal grain, and hay will return the land to a high level of agricultural productivity, but he gives no indication of the best order for these crops to be planted in after topsoil replacement.

Since both corn and soybeans have successfully been grown on reclaimed surface-mined lands, there is no question that the land can be returned to agricultural row-crop production. Two major questions remain: (1) how high will the long-term, sustained yields be, and (2) what effect will "hidden" problems such as subsidence, poor drainage, and redevelopment of root-barrier zones have on future crop production at the reclaimed site? If these and other problems can be overcome and the mined lands indeed returned to agricultural use, then the mining companies will surely have been successful in protecting the national cropland resource.

Currently, the two most difficult problems facing the OSM and the coal mining industry are (1) how to reconstruct soil so that the physical and chemical characteristics are returned to a condition which is adequate for plant rooting, with special reference to soil/water relationships, and (2) how to determine yields (including management level, weather-induced variability, etc.). With respect to the first problem, it has been suggested (McCormack, 1976; Jansen, 1979) that when soils are reconstructed it may be possible to actually improve the land quality at that site by repositioning sodic or other undesirable layers at some depth below the normal rooting zone. In addition, root-penetration barriers could be removed, and the reclaimed site tiled--actions which would improve the agricultural value of the site. These seem to be practical suggestions, and ones to which OSM could agree.

Another physical problem with which the industry must deal is how to move topsoil without subjecting it to excessive compaction. Much of the existing earth-moving equipment in use was developed either with no reference to compaction, or in such a way as to maximize compaction such as is necessary for road or earth-dam construction. With time, new equipment will be developed to overcome these problems. Perhaps the conveyor-belt systems which are used in the mining industry in Germany can and will be adapted for use in this country, as is being done by the Southwestern Illinois Coal Company at their CAPTAIN Mine in Percy, Illinois (Holloway, 1979).

With respect to the problem of determining yields, few suggestions have yet been advanced. Clearly, yields must in some way be corrected for weather-induced variability, but precisely how has yet to be determined. I would suggest that if the average county yield for a given crop is, e.g., five units below the 10-year average, then the operator should be allowed to adjust his yield data upward by five units, and vice versa when the county yields are higher than the 10-year average.

Another important factor affecting yields is the level of management. In addition to the skill and knowledge of the farmer, management involves use of support materials such as fertilizer, pesticides, and irrigation water. When evaluating the question of management level there are two important factors to consider: (1) impact of management errors on yield, and (2) relationship between yield and managment level. In the first case, the fundamental concern is that at an intermediate management level, application of more fertilizer than is called for will, in all likelihood, have a greater stimulatory effect on plant growth than will addition of the same amount of excess fertilizer over what is called for at a high management level. Consequently, the choice of high-level management as used in the regulations helps avoid the problem of higher than expected yields resulting from errors in fertilizer addition.

The second topic of concern is whether there is a linear relationship between yields at a high level of management and those at a lower level. As the amount of fertilizer used increases, the importance of soil characteristics may become masked. Hence it is possible that a poorly reclaimed soil could go unnoticed at a high level of management during reclamation, but once the land is returned to a farmer who uses a lower level of management, the yields would be lower than expected. Both of these concerns are real and must be dealt with both by OSM and by the industry if the prime farmland standards are to be meaningful.

Because it has not been demonstrated that large tracts of mined prime agricultural lands can be restored to their original levels of crop production, some people still argue against permitting mining of prime agricultural lands. Congress considered this alternative prior to passage of the SMCRA, but resolved not to impose a moratorium for surface mining operations on prime farmlands. However, Congress did provide a process in which lands may be protected by having them designated unsuitable for mining. With this in mind, it is now time to accept the reality of surface mining on prime farmlands. The size of the reclamation challenge is best realized by studying estimates of the acres which could be affected during the remainder of this century.

PROJECTIONS OF LAND AND PRIME FARMLAND DISTURBANCE

Projections of the acreages of land and prime farmland which could be directly affected by coal surface-mining in the Corn Belt during the period 1980 to 2000 have been made for each coal-producing county in the five states. These predictions were based on information regarding the projected level of coal surface mining, thickness of the seam to be mined, density of the coal, and amount of overlying prime agricultural farmland. The estimates of disturbed land include both direct and indirect disturbances. The acreages of land and prime farmland to be affected were calculated using an algorithm described in the Appendix. The assumptions, supporting data, and detailed projections are also given in the Appendix.

The magnitude of direct impacts is obviously very large, whereas the magnitude of indirect impacts varies according to the nature of the particular activity, with most indirect disturbances having a moderate impact. The duration of direct disturbances could be short-term, depending on the land-use patterns which become established following reclamation by the coal companies. However, if reclaimed cropland is no longer used for crop production, such as has often been the case when reclaimed lands are used for grazing, the effects on agricultural output for the affected area could be significant. The duration of indirect impacts depends upon the degree to which indirectly impacted areas are reclaimed and could be either short-term as, for example, with coal storage piles, or long-term as in the case of abandoned railroad sidings.

According to the projections, in the 20-year period from 1980 to 2000, a total of about 452,000 acres of land, of which 127,000 acres are prime farmland, will be disturbed by surface mining in the five states of the Corn Belt (Table 9). During this period, surface mining operations in Illinois and

Table 9. Projected Coal Production from Surface Mining and Accompanying Land and Prime Farmland Disturbance in the Corn Belt, 1980–2000

	Projected Coal Production (10^6 tons/year)			Projected Land Disturbed[a] (10^3 acres)	
State/Region	1980	1990	2000	Total Land	Prime Farmland
Illinois	25	31	38	88	40
Indiana	23	30	37	95	42
Iowa	< 1	< 1	< 1	2	1
Missouri	6	9	15	76	22
Ohio	29	34	41	191	22
Corn Belt	83	104	132	452	127

[a]Data from SEAS (MITRE Corporation, 1977).

Indiana are expected to disturb similar amounts of land and prime farmland, even though the annual production of coal in Illinois is 2.5 times that in Indiana. The reasons for the seeming incongruity are (1) surface coal mining is responsible for less than half the coal produced in Illinois, whereas over 90% of Indiana coal production is from surface mines, and (2) the thickness of Indiana coal seams is generally less than that of mined Illinois seams.

Although the total amount of land and prime farmland disturbed in each state during 1980-2000 may represent a seemingly small percentage of the total land or prime farmland area, the effect of mining may be significant on a county basis. In some cases, entire communities may be disrupted. The data indicate that in Perry County, Illinois, for example, about 9% of the prime farmland may be affected by surface mining by the year 2000 (Table 10). This is in addition to the acreage which has already been disturbed, and, if trends continue, will only be the beginning of a pattern of disturbance in this county which can be expected to continue into the next century. It should be noted, however, that even without the federal regulations, Illinois required some level of land reclamation (Imhoff et al., 1976).

Table 10. Cropland Withheld from Agricultural Production in the Corn Belt, 1978[a,b] (in acres)

State/Region	Feed Grains	Wheat	Total
Illinois	544,568	61,508	606,076
Indiana	351,140	32,898	384,038
Iowa	1,198,709	3,986	1,202,695
Missouri	338,811	104,570	443,381
Ohio	120,330	35,544	155,874
Corn Belt total	2,553,558	238,506	2,792,064

[a]Includes only land in USDA set-aside and voluntary diversion programs.

[b]Data from Agricultural Stabilization and Conservation Service, Washington, DC (21 March 1979--personal communication).

Other counties throughout the Corn Belt can also be expected to be affected. In Warrick County, Indiana, over 9000 acres of prime farmland may be directly disrupted during the 20-year period, affecting 10% of the county's prime farmland area. The figures are even higher for some counties in Ohio. For example, 14% or more of the prime farmland in Belmont County, Ohio, may be directly disturbed by mining. These figures are in addition to the surface disturbances from the mining activities which have already taken place in many of these counties, and are for direct disturbances only. Including indirect disturbances, up to 17% of the prime farmland in Belmont County, Ohio, could be disturbed by the end of the century. Thus, in some cases, the local impacts may be larger than the regional averages would suggest.

DISCUSSION AND CONCLUSIONS

To further add to the analysis of this issue, preliminary estimates have been made of the coal production losses which could accompany a ban on surface mining in selected Illinois, Ohio, and Indiana counties where prime farmland disturbances are expected to be greatest. For example, if surface mining were prohibited in Perry County, Illinois, for 20 years, the total amount of prime farmland which would be protected would be at least 6000 acres, and the total coal production losses would be about 68 million tons. In Indiana's Warrick County, a ban on surface mining prime lands could save more than 7000 acres from disturbance, but the state's annual total coal production would drop by more than 70 million tons, or about 10%. Thus, it appears that a ban on surface mining in areas with prime farmland could have a measurable impact on regional coal production, but the acreage of prime land which would be protected is of considerable local importance.

Moreover, even if it were assumed that the entire 20-year total land area disturbed in the Corn Belt would be permanently removed from corn production and that the average yield would have been 100 bushels per acre on all the disturbed lands, the total annual loss of corn production would represent 1% of the current annual corn production in this region. From the context of local impacts, this suggests that, currently, the key issue concerning prime agricultural lands and surface mining is the social utility of the lands for coal extraction versus the long-term productivity of the reclaimed land.

Based on data in Lee (1978), estimates have been made of the total prime farmland disturbance which could result if current patterns of urbanization, road building, and water projects are allowed to continue through the remainder of the century. The results indicate that, as expected, the total amount of land converted to special uses is an order of magnitude greater than the amount of land disturbed by surface mining.

The value of good agricultural lands lies in sustained high levels of agricultural output from these lands, and our concern for protecting this land base is, in part, a function of the recognition that this resource is of fundamental importance to the well-being not only of U.S. citizens, but also to citizens of lesser-developed countries. Some people have used this argument to support the position that surface mining should not be allowed to take place on agricultural lands. However, it is interesting to note that in 1978, approximately 2.8 million acres of land in the Corn Belt states were "set-aside" under USDA voluntary crop-land diversion programs (Table 10). Since no crop harvests are allowed on these lands, and because cattle are permitted to graze these areas only in the spring, it is clear that "set-aside" programs have a significant impact on agricultural production. However, these lands can be rapidly shifted back into row-crop agriculture, and thus the impact on production is deliberate and of a temporary, reversible nature. Further, cropland diversion programs may promote good land management by providing the economic means for farmers to plant uneconomical crop covers which help not only in soil-building processes but also in controlling erosion.

Land-use conflicts which may arise between the agricultural and coal industries are potentially a constraint to the future expansion of surface mining activities in the Corn Belt, especially with reference to mining prime agricultural lands. As has been pointed out, direct land disturbance from surface coal extraction, per se, is by no means the sole source of disturbed acreage. In fact, indirect land disturbances may contribute significantly to the total amount of disturbed land. Moreover, the land indirectly affected may be more difficult to reclaim than the land which was only affected by topsoil and overburden removal and replacement. For this reason alone, it is unlikely that the total acreage affected by mining activities will ever be completely restored to its original use.

SUMMARY

1. The Corn Belt contains about 110 billion tons of coal reserves, 19% of which are surface mineable.

2. There are about 110 million acres of arable land in the Corn Belt, 69% of which are prime farmland.

3. Thirty-five million people live in the Corn Belt; over 30,000 work in the coal industry, and there are at least 875,000 farmers.

4. In 1975, 21% of the total coal produced in the nation was mined in the Corn Belt states, and over 50% of the nation's corn and soybean harvest was grown there.

5. By 1971, at least 920,000 acres of land had been disturbed by previous mining in the Corn Belt; the majority of the acreage could be attributed to coal mining operations.

6. As of 1975, there were about 13 million acres of Corn Belt land devoted to special non-farm uses, much of it in irreversible land uses such as urban developments, reservoirs, and roadways.

7. Current federal and state laws pertaining to surface mining require reclamation, including topsoil replacement, of disturbed lands; although reclamation research has not yet demonstrated restoration of original crop productivity on large tracts of reclaimed prime farmlands disrupted by surface mining, the federal regulations are too new for definitive data to be available; since the regulations are based upon state-of-the-art reclamation technology there is reason to believe the lands could be restored to their original levels of productivity 10-15 years after mining.

8. Estimates of the potential land disruptions in the Corn Belt which could accompany future coal surface mining at the levels called for in the National Energy Plan show that 452,000 acres of land could be disturbed in the period 1980-2000, which is equivalent to 0.3% of the total regional land area.

9. If prime farmlands are incorporated into future coal surface-mining operations, we estimate that, at the levels of coal extraction called for in the National Energy Plan, 127,000 acres of prime farmland in the Corn Belt could be disturbed in the 20-year period 1980-2000, which is equivalent to 0.2% of the total regional prime farmland area.

10. Certain counties in the Corn Belt may experience greater impacts from disturbance of land and prime farmland than the regional averages would suggest: examples include Perry County in Illinois; Pike and Warrick counties in Indiana; Henry County in Missouri; and Belmont, Harrison, and Jefferson counties in Ohio.

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APPENDIX. METHOD FOR CALCULATING LAND AND PRIME FARMLAND DISTURBANCE

Surface mining operations on prime farmlands initially result in the severe disruption of the land surface, regardless of the methods used for topsoil and overburden removal and replacement. Nevertheless, through careful material handling and with special attention to topsoil replacement, the agricultural capability of the land can be restored within a reasonable time, generally less than 10 years. To assess the quantity of land which may be affected by future surface mining activities, an algorithm was used in conjunction with coal production forecasts ranging through the year 2000. This appendix gives details of that algorithm including the assumptions used in its operation, the supporting data, and the results.

To achieve the highest accuracy possible, modeling was done at the county level; however, the results are considered to be of primary value when viewed at the regional level. Both county- and state-level data are presented for completeness.

ALGORITHM AND ASSUMPTIONS

Surface mining operations have both direct and indirect impacts. Direct impacts, as used here, refer to the disturbance of land immediately above the coal being removed, whereas indirect impacts refer to all other land affected by the mining operation. To calculate the acreage of prime farmland (only) affected by a given level of coal extraction, the following equation was used:

$$P = \left[\left(\frac{e \cdot s}{d \cdot t}\right) \frac{1}{r}\right] \frac{p}{c} \qquad (1)$$

where: P = prime farmland directly disturbed annually, in acres;
e = projected total yearly coal extraction, in tons;
s = fraction of total coal extraction to be surface mined;
d = coal density, in tons/acre-foot;
t = seam thickness, in feet;
r = efficiency of coal removed (recovery rate), as fraction of total coal mined;
p = county prime farmland area, in acres; and
c = total county area, in acres.

In this estimation method, the major assumption is that both the coal and prime farmland are homogeneously distributed throughout the county. Although this is not necessarily the case in all counties, the best available data on prime farmland are given at the county level. Hence, calculations combining coal data with the most accurate prime farmland data inherently have this assumption. For this reason, the results are most meaningful at the regional level. It is possible to select certain counties and conduct a detailed analysis of the coincidence of prime farmlands and surface mineable coal (Harper, 1979), but maps showing the location of prime farmlands are not yet available for the entire county. In fact, for many states, the U.S. Soil Conservation Service has but one or a few such maps, which are not necessarily of areas that contain surface-mineable coal.

Another assumption was that prime farmlands will not be differentiated and avoided by surface mining operations in the Corn Belt. In these five states, 46% of the strippable coal reserve lies beneath prime farmlands (Harper and Anderson, 1979). Even with enforcement of the strict provisions contained in the prime farmland portion of the regulation implementing the Surface Mining Control and Reclamation Act of 1977 (SMCRA), it is unlikely that surface mining operations in the Midwest will avoid prime farmlands. Rather, it is expected that the performance standards will be met at higher cost, and that this economic burden will be passed on to the consumer of the coal.

There were several assumptions pertaining to the coal resource itself. First, for consistency, it was presumed that the bituminous coal found in the Corn Belt has a bulk density value of 1800 tons/acre-foot. This is the value most commonly used, but Treworgy et al. (1978) reported a value of around 1790 tons/acre-foot for Illinois coal, and Peele and Church (1948) reported a value of 1764 tons/acre-foot. Thus, the assumed value may be high, and the estimate of acreage disturbed may be low as a result.

Another assumption pertaining to the coal was that there is but one seam per mining operation, and that the thickness of this seam is equal to the thickness of the average strippable county seam. Although there are often multiple seams in the vertical profile of coal areas in the Corn Belt and these seams may contain partings, the average county thickness is assumed to account for this by giving a value for the strippable thickness, rather than the absolute thickness of the total coal reserve.

Finally, it was assumed that future surface mining operations will be 98% efficient in removing coal from the seam. On the average current surface mining operations remove 80 to 90% of the coal, but the SMCRA requires that operators remove the maximum amount possible--hence the 98% efficiency. This value may be somewhat optimistic (high) which would result in the projections of the acreage of prime farmland affected being low.

PROJECTIONS OF FUTURE COAL MINING

The Strategic Energy Analysis System (SEAS) developed by the MITRE Corporation (1977) contains a subroutine which projects coal production. Data from this model have been used by the U.S. Department of Energy (DOE) for several projects, and MITRE has used this model successfully in several assignments for DOE. The important feature of this model is that it reflects the initiatives of the first National Energy Plan. In short, the assumptions which underlie the SEAS coal data are: (1) high conservation, (2) reduced oil imports, (3) increased coal use, and (4) full compliance by 1985 of all emission sources with regulations promulgated by the U.S. Environmental Protection Agency and the individual states. Although much has changed in the energy scene since 1977, the SEAS data are still the best available at the county level, because subsequent models have focused on coal production regions which vary from model to model and which are not calibrated to the county level.

A comparison of coal production forecasts generated by the SEAS model with forecasts from other models shows that for 1980, the SEAS data are less than 2% below the value which DOE recently forecast for that year (Table A.1). In addition, the SEAS forecasts for 1990 and 2000 are near the median of the range given by other forecasts for the corresponding years (Table A.1). When viewed at the national level, it appears that the SEAS model adequately projects future coal production; consequently, it is assumed that this model is equally valid for the Corn Belt states. Further, since the data from the SEAS model are given at the county level, this model is ideally suited for calculations such as were required in this study.

Table A.1. Projected Annual Coal Production in the Corn Belt and in the United States, 1980-2000

	Coal Production (10^6 tons)			
	Corn Belt[a]		United States	
Year	Surface	Total	SEAS[a]	Others
1980	83	139	771	780[b]
1990	104	181	1257	1145-1348[c]
2000	132	240	1720	1324-1920[d]

[a]Data from MITRE Corporation (1977).

[b]Data from U.S. Department of Energy (as cited in Coal Outlook, 5 February 1979).

[c]Data from Energy Information Administration (1978).

[d]Data from Basile (1977).

Data Inputs

County-level data on seam thickness, total land area, and acreage of prime farmlands were obtained as follows. Average county seam thicknesses for Illinois, Indiana, and Ohio were calculated by multiplying the fraction of the county's total coal reserves that are contained in each coal seam by the average thickness for that seam (Baker, 1978). Total land area for each county was taken from the County and City Data Book (U.S. Dep. Commerce, 1972). The unpublished county prime farmland data were obtained from M. Anderson, Energy and Environmental Systems Division, Argonne National Laboratory. The county data on seam thickness, total land area, and acreage of prime farmland used in calculating the estimates are presented in Table A.2.

County estimates on the acreage of land and prime farmland disturbed in Illinois, Indiana, and Ohio were made using Equation 1, as described earlier. For Missouri and Iowa, state estimates were made using the assumptions and methods outlined below.

Table A.2. Seam Thickness, Total Land Acreage, and Prime Farmland Acreage for Counties Containing Surface-Mineable Coal in Illinois, Indiana, and Ohio

County	Seam Thickness (inches)	Total Land (acres)	Prime Farmland (acres)
Illinois			
Adams	24	551,770	284,500
Bond	82	241,900	122,000
Brown	24	195,800	90,100
Bureau	56	554,200	410,900
Calhoun	24	158,100	46,500
Cass	31	237,400	122,500
Christian	77	453,800	343,000
Clark	82	323,200	172,200
Clay	55	297,000	137,000
Clinton	81	277,800	120,600
Coles	61	323,800	236,200
Crawford	62	283,500	117,500
Cumberland	78	222,100	127,900
Douglas	83	268,800	255,300
Edgar	60	401,900	323,000
Edwards	72	144,000	75,200
Fayette	81	449,900	234,100
Franklin	67	277,800	99,800
Fulton	42	561,300	330,100
Gallatin	60	209,900	122,400
Greene	32	347,500	208,300
Grundy	34	276,500	209,700
Hamilton	67	278,400	119,900
Hancock	24	510,100	339,800
Henry	51	528,600	333,400
Jackson	30	387,200	105,300
Jefferson	119	366,700	135,300
Jersey	35	240,600	123,300
Kankakee	35	433,900	295,400
Knox	47	465,900	285,300
LaSalle	48	736,000	549,800
Lawrence	55	239,400	136,400
Livingston	32	667,500	522,400
Logan	63	398,100	333,500
McDonough	24	372,500	284,900
McLean	48	750,700	617,000
Macon	65	369,900	279,000
Macoupin	64	558,100	375,300
Madison	69	469,100	254,100
Marion	78	370,600	139,200
Marshall	33	250,200	188,100
Mason	63	346,200	153,700
Menard	63	199,700	141,300
Mercer	47	355,800	211,500
Monroe	84	244,500	99,200
Montgomery	66	451,200	313,700
Morgan	42	359,000	241,100
Moultrie	84	208,600	179,700
Peoria	63	398,700	216,400
Perry	81	281,000	83,300
Putnam	45	102,400	62,600
Randolph	78	380,200	141,200
Richland	76	233,000	37,600
Rock Island	54	271,400	132,300
St. Clair	80	430,700	196,300
Saline	61	245,100	105,500
Sangamon	67	562,600	410,800
Schuyler	30	277,800	148,500
Scott	25	160,600	92,500
Shelby	78	481,300	327,100
Stark	78	186,200	133,500
Tazewell	56	417,300	271,600

Table A.2. Continued

County	Seam Thickness (inches)	Total Land (acres)	Prime Farmland (acres)
Illinois (cont.)			
Vermillion	66	575,400	411,600
Wabash	55	142,100	90,600
Warren	27	346,200	264,300
Washington	80	361,000	147,500
Wayne	80	457,600	197,200
White	71	321,300	170,300
Will	35	542,100	289,100
Williamson	74	274,600	77,700
Woodford	30	337,900	245,100
Indiana			
Clay	43	233,000	78,700
Daviess	40	275,200	153,700
DuBois	41	277,100	77,100
Fountain	40	254,100	177,300
Greene	54	351,400	141,800
Knox	73	330,200	216,100
Martin	40	220,800	46,500
Monroe	40	247,000	46,500
Owen	32	249,600	74,200
Parke	32	284,800	157,500
Perry	40	245,800	51,800
Pike	65	214,400	91,400
Putnam	40	313,600	144,100
Spencer	41	253,400	127,500
Sullivan	54	292,500	144,000
Vermillion	37	168,300	101,100
Vigo	55	265,600	143,900
Warrick	69	250,200	92,800
Ohio			
Athens	28	322,600	31,600
Belmont	33	341,800	23,000
Butler	34	301,400	142,200
Carroll	38	249,600	49,500
Columbiana	42	341,800	67,200
Coshocton	44	359,700	44,100
Gallia	41	301,400	43,900
Guernsey	39	337,900	42,200
Hardin	34	298,900	202,300
Harrison	25	256,600	24,200
Hocking	34	269,400	20,900
Holmes	37	271,400	78,700
Jackson	32	268,200	22,400
Jefferson	32	263,000	12,800
Lawrence	29	291,800	22,500
Mahoning	32	265,600	61,000
Meigs	48	279,000	31,700
Monroe	43	291,800	21,600
Morgan	22	268,800	8,500
Muskingum	27	416,600	55,200
Noble	22	254,700	18,100
Perry	47	262,400	39,400
Scioto	34	389,100	51,600
Stark	36	368,600	107,100
Tuscarawas	37	364,200	72,300
Vinton	39	263,000	70,300
Washington	22	410,200	351,600
Wayne	24	359,000	206,200

State estimates of the 20-year land and prime farmland acreage which could be affected by surface mining in Missouri were based on (1) the SEAS data for total state coal production, 1980 through 2000, (2) an assumed seam thickness of 2.0 feet (Interagency Task Force, 1977), and (3) a coal bulk density of 1800 tons/acre-foot. These data were used to produce estimates of the total land disruption for the state. Estimates of prime farmland disturbance were calculated using Equation 1 and assuming that 28.5% of the land over the coal reserves is prime farmland--that is, the distribution of prime farmland in the coal producing areas is the same as for the state as a whole.

Calculations for Iowa were based upon a 1975 level of coal surface extraction of 259,000 tons (Westerstrom and Harris, 1975) and the assumption that the state total would increase at the same rate as the regional total output of surface mined coal; thus, by the year 2000 the total output would be 2.69 times higher than the 1975 level. It is unlikely that Iowa coal will be mined in significant quantities in the near future. As Levins et al. (1976) stated, "The development of Iowa coal depends most on the discovery of large veins of low sulfur coal which could be mined at approximately one-half of current costs and burned without processing." Nevertheless, the total land disturbance was calculated using an average coal seam thickness of 3.0 feet (Interagency Task Force, 1977). Estimates of the total prime land disturbance were based upon Equation 1 and the assumption that, on the average, 52% of Iowa's land is prime farmland.

The SEAS data on projected coal mining activity by state and county are presented in Table A.3. Data for Iowa are not presented because the SEAS model fails to recognize this state as a producer of coal from surface mines.

Results

Results of the computer calculations on the county acreage of land and prime farmland expected to be disturbed in Illinois, Indiana, and Ohio by coal surface mining are presented in Table A.4 for selected years between 1980 and 2000. These data are for direct disturbances only and, for the text of this report, have been converted to total acreages (direct plus indirect disturbances). To convert from acres directly affected to total acreage, the following equation was used:

$$T = K \cdot D \qquad (2)$$

where: T = total county land affected by surface mining, in acres;
K = conversion constant; and
D = county land directly affected by surface mining, in acres.

For the Corn Belt, a K factor of 1.27 was used (Counc. Environ. Qual. and Environ. Prot. Agency, 1977), and both T and D were defined in such a way that either the land or prime farmland values can be used in Equation 2.

Table A.3. Historical and Projected Coal Mining Activity for Illinois, Indiana, Missouri, and Ohio by County for 1975-2000 Showing Total Coal Mined and Percentage of Total Mined by Surface-Mining or Deep-Mining Methods

County	1975			1980			1985			1990			1995			2000		
	Total (10^3t)	Surface (%)	Deep (%)	Total (10^3t)	Surface (%)	Deep (%)	Total (10^3t)	Surface (%)	Deep (%)	Total (10^3t)	Surface (%)	Deep (%)	Total (10^3t)	Surface (%)	Deep (%)	Total (10^3t)	Surface (%)	Deep (%)
Illinois																		
Adams	0	0	0	0	0	0	14	100	0	33	100	0	55	100	0	78	100	0
Bond	0	0	0	159	0	100	318	0	100	570	0	100	849	0	100	1176	0	100
Brown	0	0	0	0	0	0	17	100	0	40	100	0	65	100	0	94	100	0
Bureau	0	0	0	89	0	100	224	20	80	426	25	75	649	27	73	907	27	73
Calhoun	0	0	0	0	0	0	1	100	0	3	100	0	5	100	0	7	100	0
Cass	0	0	0	100	0	100	24	91	9	54	93	7	88	93	7	125	93	7
Christian	4305	0	100	4590	0	100	4873	0	100	5320	0	100	5811	0	100	6381	0	100
Clark	0	0	0	15	0	100	29	0	100	52	0	100	77	0	100	107	0	100
Clinton	0	0	0	115	0	100	229	0	100	411	0	100	612	0	100	848	0	100
Coles	0	0	0	7	0	100	14	0	100	25	0	100	37	0	100	51	0	100
Crawford	0	0	0	38	0	100	76	0	100	136	0	100	203	0	100	281	0	100
Cumberland	0	0	0	0	0	0	<1	100	0	2	100	0	3	100	0	4	100	0
Douglas	2540	0	100	2576	0	100	2611	0	100	2665	0	100	2723	0	100	2788	0	100
Edgar	0	0	0	150	0	100	300	0	100	539	0	100	803	0	100	1111	0	100
Edwards	0	0	0	5	0	100	10	0	100	17	0	100	25	0	100	34	0	100
Fayette	0	0	0	101	0	100	201	0	100	361	0	100	538	0	100	745	0	100
Franklin	5594	0	100	5860	0	100	6124	0	100	6539	0	100	6995	0	100	7522	0	100
Fulton	2638	100	0	2526	99	1	2916	99	1	3437	98	2	4002	97	3	4637	97	3
Gallatin	1794	50	50	1902	45	55	2100	43	57	2403	40	60	2734	38	62	3117	35	65
Greene	0	0	0	5	0	100	97	91	9	222	93	7	358	93	7	512	94	6
Grundy	0	0	0	22	0	100	127	65	35	272	71	29	431	73	27	612	73	27
Hamilton	0	0	0	209	0	100	419	0	100	751	0	100	1119	0	100	1549	0	100
Hancock	0	0	0	0	0	0	6	100	0	14	100	0	22	100	0	32	100	0
Henry	0	0	0	2	0	100	84	94	6	193	96	4	312	96	4	447	96	4
Jackson	55	100	0	72	73	27	154	75	25	268	74	26	394	74	26	536	73	27
Jefferson	4508	0	100	4663	0	100	4816	0	100	5056	0	100	5318	0	100	5620	0	100
Jersey	0	0	0	4	0	100	32	78	22	71	82	18	114	83	17	163	84	16
Kankakee	0	0	0	7	0	100	18	18	82	34	22	78	51	24	76	71	24	76
Knox	1334	100	0	1274	>99	<1	1402	99	1	1572	99	1	1755	98	2	1961	98	2
LaSalle	0	0	0	94	0	100	221	15	85	414	19	81	628	20	80	876	21	79
Lawrence	0	0	0	77	0	100	153	0	100	275	0	100	410	0	100	567	0	100
Livingston	0	0	0	50	0	100	109	7	93	199	9	91	299	10	90	415	10	90
Logan	0	0	0	70	0	100	140	0	100	250	0	100	373	0	100	517	0	100
McDonough	0	0	0	0	0	0	10	100	0	23	100	0	37	100	0	53	100	0
McLean	0	0	0	36	0	100	72	0	100	130	0	100	193	0	100	267	0	100
Macon	0	0	0	38	0	100	76	0	100	137	0	100	204	0	100	282	0	100
Macoupin	2584	0	100	2880	0	100	3211	1	99	3727	2	98	4295	3	97	4955	4	96
Madison	0	0	0	118	0	100	342	31	69	671	37	63	1033	39	61	1450	40	60
Marion	0	0	0	36	0	100	73	0	100	130	0	100	194	0	100	269	0	100
Marshall	0	0	0	31	0	100	86	28	72	167	34	66	256	36	64	359	37	63

Table A.3. Continued

County	1975 Total (10^3t)	1975 Surface (%)	1975 Deep (%)	1980 Total (10^3t)	1980 Surface (%)	1980 Deep (%)	1985 Total (10^3t)	1985 Surface (%)	1985 Deep (%)	1990 Total (10^3t)	1990 Surface (%)	1990 Deep (%)	1995 Total (10^3t)	1995 Surface (%)	1995 Deep (%)	2000 Total (10^3t)	2000 Surface (%)	2000 Deep (%)
<u>Illinois</u> (cont.)																		
Menard	0	0	0	125	0	100	250	0	100	449	0	100	670	0	100	927	0	100
Mercer	0	0	0	1	0	100	10	79	21	23	83	17	37	84	16	52	85	15
Monroe	0	0	0	0	0	0	1	100	0	3	100	0	5	100	0	8	100	0
Montgomery	1709	0	100	2047	0	100	2385	0	100	2920	0	100	3511	0	100	4200	0	100
Morgan	0	0	0	12	0	100	77	68	32	167	73	27	265	75	25	377	76	24
Moultrie	0	0	0	11	0	100	21	0	100	38	0	100	57	0	100	78	0	100
Peoria	1196	100	0	1162	98	2	1476	97	3	1899	95	5	2360	95	5	2879	93	7
Perry	11675	100	0	11198	99	1	11476	98	2	11858	97	3	12261	96	4	12703	94	6
Putnam	0	0	0	51	0	100	101	0	100	181	0	100	270	0	100	374	0	100
Randolph	8209	53	47	8009	52	48	8100	52	48	8217	53	47	8337	53	47	8461	53	47
Rock Island	0	0	0	1	0	100	8	71	28	17	77	23	27	78	22	38	79	21
St. Clair	3442	50	50	3438	48	52	3759	50	50	4205	52	48	4690	54	46	5237	56	44
Saline	2025	11	89	2238	9	91	2551	12	88	3024	14	86	3545	15	85	4145	17	83
Sangamon	0	0	0	305	0	100	609	0	100	1093	0	100	1629	0	100	2255	0	100
Schuyler	0	0	0	0	0	0	42	100	0	98	100	0	160	100	0	229	100	0
Scott	0	0	0	0	0	0	35	100	0	81	100	0	131	100	0	187	>99	<1
Shelby	0	0	0	61	0	100	125	2	98	225	3	97	337	3	97	466	3	97
Stark	270	100	0	257	100	0	303	100	0	365	100	0	431	100	0	506	100	0
Tazewell	0	0	0	6	0	100	32	63	37	69	69	31	109	71	29	155	71	29
Vermillion	15	100	0	149	10	90	357	25	75	670	28	72	1015	29	71	1414	30	70
Wabash	775	0	100	797	0	100	824	1	99	865	1	99	909	2	98	960	3	97
Warren	0	0	0	0	0	0	4	100	0	9	100	0	15	100	0	22	100	0
Washington	0	0	0	133	0	100	268	1	99	482	1	99	719	1	99	996	1	99
Wayne	0	0	0	8	0	100	15	0	100	27	0	100	41	0	100	57	0	100
White	0	0	0	85	0	100	170	0	100	306	0	100	455	0	100	630	0	100
Will	0	0	0	0	0	0	3	100	0	8	100	0	12	100	0	18	100	0
Williamson	3364	53	47	3415	49	51	3665	49	51	4031	48	52	4430	48	52	4886	47	53
Woodford	0	0	0	19	0	100	38	0	100	68	0	100	101	0	100	140	0	100
Total	58032	45	55	61346	41	59	68433	40	60	79005	39	61	90598	38	62	103928	37	63
<u>Indiana</u>																		
Clay	1102	100	0	1040	99	1	1375	99	1	1952	98	2	2442	98	2	3237	98	2
Daviess	97	100	0	96	95	5	271	98	2	588	95	5	862	96	4	1324	97	3
Dubois	1	100	0	1	82	18	9	98	2	24	94	6	37	95	5	59	96	4
Fountain	40	100	0	38	99	1	128	>99	<1	281	99	1	420	99	1	655	>99	<1
Gibson	0	0	0	61	0	100	59	0	100	352	0	100	422	0	100	506	0	100
Greene	863	100	0	820	99	1	1160	99	1	1769	96	4	2279	96	4	3113	97	3
Knox	808	100	0	824	92	8	1127	94	6	1943	80	20	2467	81	19	3291	83	17
Martin	0	0	0	0	0	0	49	100	0	131	100	0	207	100	0	336	100	0

Table A.3. Continued

County	1975 Total (10^3t)	1975 Surface (%)	1975 Deep (%)	1980 Total (10^3t)	1980 Surface (%)	1980 Deep (%)	1985 Total (10^3t)	1985 Surface (%)	1985 Deep (%)	1990 Total (10^3t)	1990 Surface (%)	1990 Deep (%)	1995 Total (10^3t)	1995 Surface (%)	1995 Deep (%)	2000 Total (10^3t)	2000 Surface (%)	2000 Deep (%)
Indiana (cont.)																		
Owen	11	100	0	10	100	0	61	100	0	147	100	0	226	100	0	359	100	0
Parke	4	100	0	6	59	41	33	92	8	91	84	16	136	87	13	210	90	10
Perry	0	0	0	<1	0	100	<1	0	100	3	0	100	3	0	100	4	0	100
Pike	5560	98	2	5226	98	2	5536	98	2	6014	97	3	6324	97	3	6670	97	3
Posey	0	0	0	33	0	100	32	0	100	189	0	100	226	0	100	271	0	100
Spencer	547	100	0	513	100	0	544	100	0	586	100	0	616	100	0	650	100	0
Sullivan	3348	100	0	3225	97	3	3887	98	2	5362	90	10	6379	90	10	7950	91	9
Vanderburgh	0	0	0	21	0	100	20	0	100	119	0	100	142	0	100	171	0	100
Vermillion	2974	100	0	2809	99	1	2860	99	1	1252	90	10	556	72	28	334	44	56
Vigo	34	100	0	87	37	63	415	87	13	1230	74	26	1803	79	21	2746	83	17
Warrick	9724	99	1	9141	99	1	9634	99	1	10409	98	2	10878	98	2	9045	97	3
Total	25113	99	1	23951	97	3	27200	98	2	32441	92	8	36424	92	8	40927	91	9
Missouri																		
Adair	0	0	0	1	100	0	13	100	0	38	100	0	63	100	0	93	100	0
Audrain	0	0	0	3	100	0	31	100	0	91	100	0	148	100	0	219	100	0
Barton	563	100	0	565	100	0	578	100	0	605	100	0	628	100	0	655	100	0
Bates	1138	100	0	1144	100	0	1191	100	0	1291	100	0	1381	100	0	1489	100	0
Boone	0	0	0	9	100	0	83	100	0	245	100	0	398	100	0	591	100	0
Callaway	0	0	0	5	100	0	51	100	0	152	100	0	248	100	0	368	100	0
Carroll	0	0	0	8	100	0	76	100	0	225	100	0	366	100	0	543	100	0
Cedar	0	0	0	<1	100	0	8	100	0	24	100	0	38	100	0	57	100	0
Chariton	0	0	0	6	100	0	63	100	0	187	100	0	303	100	0	450	100	0
Dade	0	0	0	<1	100	0	8	100	0	23	100	0	38	100	0	56	100	0
Henry	1880	100	0	1899	100	0	2063	100	0	2414	100	0	2739	100	0	3140	100	0
Howard	3	100	0	6	100	0	35	100	0	98	100	0	157	100	0	231	100	0
Jasper	0	0	0	2	100	0	24	100	0	71	100	0	115	100	0	170	100	0
Johnson	0	0	0	16	100	0	152	100	0	451	100	0	734	100	0	1089	100	0
Lafayette	0	0	0	2	100	0	23	100	0	68	100	0	111	100	0	165	100	0
Livingston	0	0	0	3	100	0	26	100	0	78	100	0	126	100	0	188	100	0
Macon	948	100	0	959	100	0	1050	100	0	1246	100	0	1428	100	0	1652	100	0
Monroe	0	0	0	1	100	0	13	100	0	39	100	0	64	100	0	94	100	0
Montgomery	0	0	0	<1	100	0	3	100	0	8	100	0	12	100	0	18	100	0
Pettis	0	0	0	1	100	0	14	100	0	42	100	0	67	100	0	99	100	0
Putnam	353	100	0	356	100	0	386	100	0	449	100	0	508	100	0	580	100	0
Ralls	0	0	0	<1	100	0	6	100	0	18	100	0	29	100	0	42	100	0
Randolph	511	100	0	520	100	0	601	100	0	777	100	0	941	100	0	1145	100	0
Ray	0	0	0	<1	100	0	7	100	0	19	100	0	31	100	0	47	100	0
St. Clair	0	0	0	2	100	0	17	100	0	52	100	0	84	100	0	124	100	0

Table A.3. Continued

County	1975 Total (10^3t)	1975 Surface (%)	1975 Deep (%)	1980 Total (10^3t)	1980 Surface (%)	1980 Deep (%)	1985 Total (10^3t)	1985 Surface (%)	1985 Deep (%)	1990 Total (10^3t)	1990 Surface (%)	1990 Deep (%)	1995 Total (10^3t)	1995 Surface (%)	1995 Deep (%)	2000 Total (10^3t)	2000 Surface (%)	2000 Deep (%)
Missouri (cont.)																		
Saline	0	0	0	3	100	0	31	100	0	91	100	0	148	100	0	220	100	0
Schuyler	0	0	0	3	100	0	30	100	0	88	100	0	143	100	0	213	100	0
Sullivan	0	0	0	<1	100	0	3	100	0	8	100	0	14	100	0	20	100	0
Vernon	242	100	0	253	100	0	353	100	0	569	100	0	772	100	0	1027	100	0
Total	5638	100	0	5772	100	0	6937	100	0	9464	100	0	11831	100	0	14787	100	0
Ohio																		
Athens	128	100	0	337	35	65	906	20	80	1087	31	69	1612	33	67	2227	33	67
Belmont	15283	59	41	15334	55	45	16928	50	50	17164	51	49	18308	48	52	19581	46	54
Carroll	235	100	0	344	64	36	680	39	61	819	48	52	1156	46	54	1551	45	55
Columbiana	814	90	10	883	78	22	1203	61	39	1334	64	36	1651	60	40	2019	56	44
Coshocton	2909	76	24	2782	75	25	2911	74	26	3129	76	24	3393	77	23	3687	78	22
Gallia	331	100	0	364	85	15	552	67	33	718	74	26	986	72	28	1299	71	29
Guernsey	1144	97	3	1262	82	18	1728	61	39	1785	61	39	2122	53	47	2512	47	53
Harrison	6647	55	45	6647	52	48	7284	48	52	7484	49	51	8038	48	52	8658	47	53
Hocking	480	100	0	483	93	7	568	80	20	580	80	20	641	73	27	695	66	34
Holmes	671	100	0	631	99	1	654	98	2	684	98	2	721	97	3	760	96	4
Jackson	678	90	10	663	86	14	801	81	19	1016	85	15	1295	85	15	1619	85	15
Jefferson	4137	81	19	4140	76	24	4786	68	32	5119	70	30	5809	67	33	6594	65	35
Lawrence	149	100	0	219	64	36	450	41	59	581	53	47	847	53	47	1157	53	47
Mahoning	412	100	0	431	89	11	548	72	28	579	73	27	678	66	34	793	61	39
Meigs	967	0	100	1032	0	100	1216	3	97	1318	10	90	1526	16	84	1769	21	79
Monroe	1115	0	100	1190	0	100	1362	<1	>99	1370	<1	>99	1482	<1	>99	1613	<1	>99
Morgan	655	100	0	683	89	11	878	73	27	956	74	26	1145	69	31	1363	64	36
Muskingum	3173	96	4	3089	92	8	3435	85	15	3620	85	15	3987	82	18	4396	79	21
Noble	489	100	0	547	83	17	884	66	34	1230	75	25	1757	74	26	2372	74	26
Perry	2495	3	97	2593	3	97	2933	6	94	3224	14	86	3700	21	79	4254	27	73
Scioto	0	0	0	<1	0	100	3	16	84	5	41	59	7	47	53	11	50	50
Stark	461	100	0	492	87	13	692	70	30	849	75	25	1116	72	28	1427	71	29
Tuscarawas	1589	92	8	1630	84	16	2054	71	29	2338	74	26	2856	71	29	3454	69	31
Vinton	1677	80	20	1638	77	23	1792	72	28	1896	73	27	2078	72	28	2283	71	29
Washington	76	100	0	102	69	31	188	44	56	226	52	48	314	50	50	417	49	51
Wayne	56	100	0	53	99	1	55	97	3	56	97	3	58	95	5	59	94	6
Total	46771	66	34	47567	61	39	55488	54	46	59161	57	43	67283	55	45	76568	54	46

Totals may not add due to independent rounding.

Table A.4. Projected Annual Land and Prime Farmland (PF) Disturbance by Surface Mining in Illinois, Indiana, and Ohio by County, 1980-2000 (in acres)

	1980		1985		1990		1995		2000	
County	Land	PF	Land	PF	Land	PF	Land	PF	Land	PF
Illinois										
Adams	0	0	4	2	9	5	15	8	22	11
Brown	0	0	5	2	11	5	19	9	27	12
Bureau	0	0	6	4	13	10	21	16	30	22
Calhoun	0	0	< 1	< 1	1	< 1	1	< 1	2	1
Cass	0	0	5	2	11	6	18	9	25	13
Cumberland	0	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Fulton	403	237	463	272	542	319	628	369	723	426
Gallatin	97	57	102	60	109	64	117	68	125	73
Greene	0	0	19	11	44	26	72	43	103	62
Grundy	0	0	17	13	39	30	63	48	91	69
Hancock	0	0	2	1	4	3	6	4	9	6
Henry	0	0	11	7	25	16	40	25	57	36
Jackson	12	3	26	7	44	12	65	18	88	24
Jersey	0	0	5	2	11	6	18	9	26	14
Kankakee	0	0	1	< 1	1	1	2	2	3	2
Knox	184	113	202	123	225	138	250	153	278	170
LaSalle	0	0	5	4	11	8	18	13	26	19
Livingston	0	0	2	1	4	3	6	5	9	7
McDonough	0	0	3	2	6	5	11	8	15	12
Macoupin	0	0	4	3	9	6	15	10	22	15
Madison	0	0	10	6	24	13	40	21	57	31
Marshall	0	0	5	4	12	9	19	14	28	21
Mercer	0	0	1	1	3	2	4	3	6	4
Monroe	0	0	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1
Morgan	0	0	8	6	20	13	32	21	46	31
Peoria	122	66	153	83	194	105	239	130	289	157
Perry	936	278	951	282	970	288	989	293	1008	299
Randolph	364	135	371	138	379	141	388	144	397	147
Rock Island	0	0	1	< 1	2	1	3	1	4	2
St. Clair	139	63	160	73	187	85	216	98	249	113
Saline	23	10	33	14	47	20	61	26	78	34
Schuyler	0	0	9	5	22	12	36	19	52	28
Scott	0	0	9	5	22	13	35	20	51	29
Shelby	0	0	< 1	< 1	1	< 1	1	1	1	1
Stark	22	16	26	19	32	23	37	27	44	32
Tazewell	0	0	2	2	6	4	9	6	13	9
Vermilion	1	1	9	7	20	14	31	22	44	31
Wabash	0	0	1	< 1	1	1	2	2	3	2
Warren	0	0	1	1	2	2	4	3	5	4
Washington	0	0	< 1	< 1	< 1	< 1	1	< 1	1	< 1
Will	0	0	1	< 1	1	1	2	1	3	2
Williamson	154	44	165	47	178	50	193	55	209	59
Total	2458	1023	2796	1210	3243	1457	3728	1726	4270	2028

Table A.4. Continued

County	1980 Land	1980 PF	1985 Land	1985 PF	1990 Land	1990 PF	1995 Land	1995 PF	2000 Land	2000 PF
Indiana										
Clay	165	56	218	74	305	103	382	129	507	171
Daviess	15	9	45	25	95	53	141	79	218	122
DuBois	< 1	< 1	2	< 1	4	1	6	2	10	3
Fountain	6	4	22	15	47	33	71	50	111	77
Greene	102	41	145	59	215	87	278	112	382	154
Knox	70	46	99	65	145	95	186	122	254	166
Martin	0	0	8	2	22	5	35	7	57	12
Owen	2	1	13	4	31	9	48	14	76	23
Parke	1	< 1	7	4	16	9	25	14	40	22
Pike	535	228	568	242	612	261	643	274	678	289
Spencer	85	43	91	46	98	49	103	52	108	54
Sullivan	392	193	475	234	607	299	721	355	902	444
Vermillion	507	304	516	310	204	122	72	44	26	16
Vigo	4	2	45	24	113	61	176	96	284	154
Warrick	895	332	944	350	1009	374	1053	391	868	322
Total	2781	1260	3198	1454	3523	1562	3940	1739	4521	2030
Ohio										
Athens	29	3	44	4	84	8	129	13	183	18
Belmont	1763	119	1780	120	1817	122	1848	124	1872	126
Carroll	39	8	48	9	70	14	96	19	126	25
Columbiana	111	22	118	23	137	27	159	31	183	36
Coshocton	321	39	334	41	367	45	403	49	444	54
Gallia	52	8	62	9	88	13	119	17	154	22
Guernsey	183	23	186	23	193	24	199	25	205	26
Harrison	950	90	970	92	1020	96	1070	101	1123	106
Hocking	91	10	92	10	94	10	95	10	93	10
Holmes	116	34	119	34	124	36	130	38	136	39
Jackson	120	10	136	11	181	15	231	19	289	24
Jefferson	674	33	699	34	767	37	840	41	921	45
Lawrence	33	3	44	3	73	6	107	8	146	11
Mahoning	82	19	84	19	90	21	96	22	102	23
Meigs	0	0	5	1	19	2	34	4	53	6
Monroe	0	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Morgan	189	6	197	6	219	7	243	8	270	9
Muskingum	705	94	722	96	766	102	811	108	859	114
Noble	141	10	180	13	284	20	403	29	542	38
Perry	10	1	25	4	65	10	112	17	167	25
Scioto	0	0	< 1	< 1	< 1	< 1	1	< 1	1	< 1
Stark	82	24	93	27	122	35	155	45	192	56
Tuscarawas	248	49	267	53	316	63	372	74	435	86
Vinton	221	59	228	61	246	66	264	71	285	76
Washington	22	19	26	22	37	31	49	42	63	54
Wayne	15	9	15	9	15	9	16	9	16	9
Total	6199	689	6473	725	7193	819	7982	923	8859	1040

Totals may not add due to independent rounding.

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TABLE OF ENGLISH/METRIC CONVERSION FACTORS

To convert from	To	Multiply by
acre	square meter (m^2)	4046.873
acre-foot	cubic meter (m^3)	1233.489
bushel	cubic meter (m^3)	0.035
foot	meter (m)	0.3048
inch	meter (m)	0.0254
ton, short	kilogram (kg)	907.1847

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