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Energy and U.S. Agriculture

Irrigation Pumping, 1974-80

Gordon Sloggett

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Abstract

Land irrigated with onfarm pumped water increased 7.5 million acres to 42 million acres from 1974 to 1980. Sharply higher energy prices pushed energy pumping costs from $570 million to $1.9 billion. Pump irrigators are applying energy-saving technologies such as low-pressure center pivots, which alone saved about $42 million in 1980. Favorable economic conditions could lead to 3 to 4 million additional pump-irrigated acres in the water-short Great Plains by the year 2020 and significant increases in the more humid Eastern United States.

Keywords: Irrigation, energy.

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Summary

U.S. farmers increased onfarm pump irrigation by 21 percent from 1974 to 1980, adding 7.5 million pump-irrigated acres. Farmers irrigated 42.6 million acres in 1980 with onfarm pumps, and pump energy accounted for 23 percent of total energy used onfarm for crop production. Most irrigation pumps used electricity, followed in descending order by natural gas, diesel, liquefied petroleum gas (LPG), and gasoline. Diesel fuel use about doubled, but the use of gasoline and LPG for pumping irrigation water declined.

This report is the third in a series, and updates 1978 irrigation estimates. The study focuses on 1980 pump-irrigated farmland and prospects for irrigation as well as fuel costs.

The cost of energy for onfarm pump irrigation rose from $570 million to more than $1.9 billion between 1974 and 1980, due to more acreage irrigated and much higher energy prices. Natural gas prices rose by 400 percent, diesel by 335 percent, LPG by 210 percent, and gasoline by 254 percent. Electricity increased the least, with a doubling in price.

Pump irrigation showed rapid growth in spite of higher energy prices. The cost of energy for pumping irrigation water is a small portion of the total crop production costs in many pump-irrigation areas. Also there were rather favorable crop prices during 1974-80, encouraging pump irrigation. Sales from irrigated farms increased 5 percent between 1974 and 1978 to 29 percent of overall sales.

Pump irrigators can reduce their energy costs by irrigating more efficiently. Tail-water recovery for surface-water irrigation systems is becoming very popular and can reduce energy use by 10 to 30 percent. Also, low-pressure center pivot sprinkler systems saved U.S. farmers an estimated $42 million in energy costs during 1980.

Favorable economic conditions could lead to a 3- to 4-million-acre increase in irrigation in the Great Plains by the year 2020. The eastern half of the United States, where irrigation grew by 3.2 million acres from 1974 to 1980, shows potential for irrigation gains. Soil and water resources there could support an additional 26 million acres of irrigated land.

Energy and U.S. Agriculture: Irrigation Pumping, 1974-80

Gordon Sloggett*

Introduction

Land irrigated in the United States with the aid of energy-using pumps on farms and ranches increased from 35 million acres to 42.6 million acres from 1974 to 1980. According to the Census of Agriculture, all irrigated farms accounted for 24 percent of farm sales in 1974 and 29 percent in 1978. This increase reflects greater production from increased acreage.

This study examines the amount of U.S. farmland irrigated with onfarm pumps since 1974, the fuels used to power the pumps, and implications for future irrigation. This report is the third in a series begun in 1974 concerning energy used to pump and distribute irrigation water (*15*).[1] These estimates span the entire country, including farm production regions and individual States (fig. 1).

Energy used for pumping irrigation water was 23 percent of all onfarm energy used for agricultural production in 1978 (*17*). Growth in pump irrigation, increasing energy prices, and changing energy price relationships have heightened the importance of the types, amounts, and geographical patterns of energy consumed in pumping irrigation water.

To estimate energy use, it was necessary to determine: (1) acreage irrigated from ground water and from pumped surface water, (2) feet of lift required for ground water and pumped surface water, (3) types of distribution systems used to apply water to fields, (4) types of power units used for pumping, and (5) acre-feet of water applied.[2] Estimates were also obtained of pumping unit efficiency and pressure needed to operate distribution systems. These factors were determined and applied uniformly for all States.

Background

Data used in making estimates for 1974 and 1977 were sent to State irrigation specialists for updating to 1980.[3] The procedure for estimating energy use is described in appendix I. However, studies of energy used in irrigation became available for California, Idaho, Oregon, and Washington after the 1974 estimates were made. In those States, changes were made to the 1974 estimates using the Knutson and King data (*10, 11*). Electricity consumption for Kansas irrigation pumping also employed other data (*1*).

The results presented in this report are based on estimates of statewide averages from various sources. They are not the result of scientific sampling; therefore, no procedure is available to determine the statistical accuracy of the results. These data, however, are considered reasonable estimates of the extent of pump irrigation. They indicate shifts that occurred through use of different types of energy for pumping.

Irrigation Terminology

The following information defines commonly used phrases in irrigation.

Acreage irrigated from ground water. Water in aquifers is commonly referred to as ground water and must be pumped from wells for irrigation. Several States conduct surveys or have other procedures to estimate acreage irrigated from ground water. These estimates were used where available. Otherwise, total acreage irrigated in 1974 came from the 1974 Irrigation Survey in the *Irrigation Journal* (*8*). The proportion of acreage irrigated from ground water, as published by the U.S. Geological Survey (USGS), was then multiplied by total acreage irrigated to get an estimate of acreage irrigated from ground water in 1974 (*14*). Estimates for 1977 and 1980 were estimated from that base.

Acreage irrigated from pumped surface water. Surface water is in lakes, streams, or rivers. Some of this water is pumped onto fields for irrigation, but no data source was found for acres irrigated in this manner. Therefore, each State irrigation specialist estimated how many acres were irrigated with water pumped from surface sources.

Feet of lift. Feet of lift is the height water must be raised from its source to the field for application. State irrigation specialists estimated a weighted statewide average feet of lift figure for irrigation wells in their State. They also provided a weighted average feet of lift estimate for onfarm pumped surface water. The weight was approximate acreage irrigated according to pumping depths. Changes in feet of lift (app. table 1) in some of the States from 1974 through 1980 were the result of either actual changes as perceived by the irrigation specialists or improved information on which they based their estimates.[4]

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[1]Italicized numbers in parentheses cite sources listed in the References section.

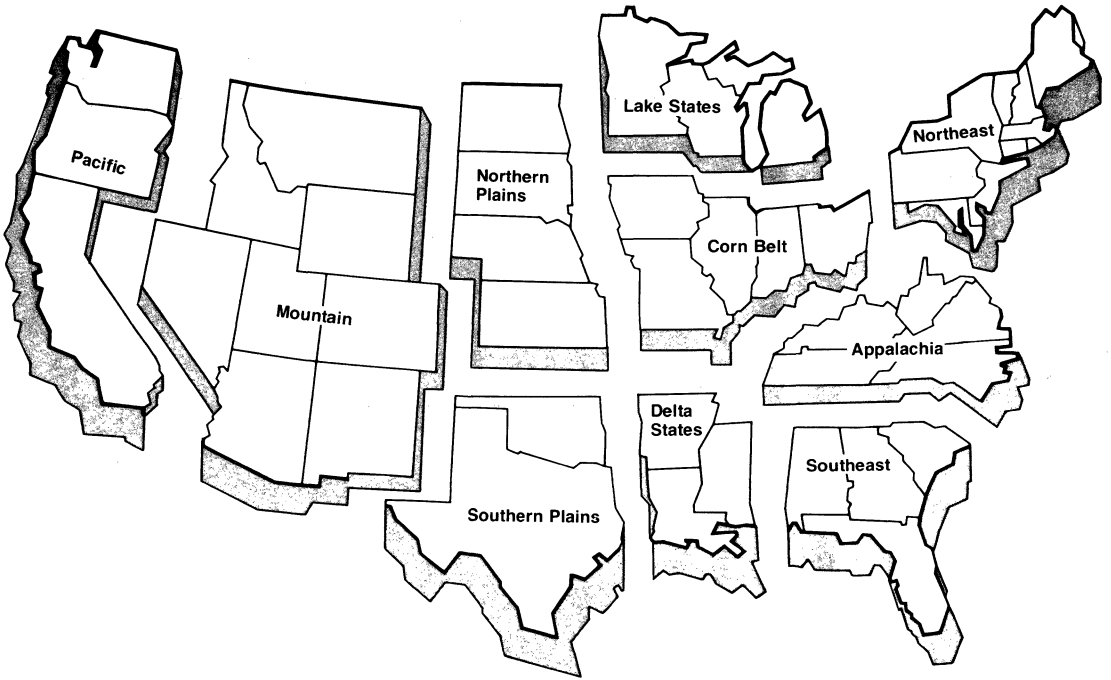
[2]An acre-foot is 1 foot of water applied over 1 acre.

[3]A list of irrigation specialists contacted for State estimates appears in appendix III.

[4]The estimates are subject to error, and changes in pumping lifts caused by declining water levels may or may not be reflected in the data provided by the irrigation specialists.

Figure 1

Farm Production Regions



Distribution systems and power units. Major water distribution systems included various sprinkler and flooding methods used to put water on fields. Power units were run by electricity, diesel, gasoline, natural gas, and liquefied petroleum gas (LPG). Information on numbers of distribution systems and types of power units in the 1974 Irrigation Survey in the *Irrigation Journal* were used where available for the 1974 energy estimates.[5] When this information was not available for 1974 and for all the 1977 and 1980 surveys, irrigation specialists provided estimates of distribution system and power unit use.

Acre-feet applied. USGS data provided estimates of the quantity of water applied per acre; each State irrigation specialist reviewed the estimates (*14*). Several specialists offered alternative estimates and, in some instances, USGS data were modified.

Pumping unit efficiency. A new irrigation pump has an efficiency of about 75 percent (efficiency is a measure of energy input to water output). Efficiency declines when wear occurs. Irrigation engineers in those States having significant amounts of ground water estimated average operational pump efficiency. Since their estimates varied, coefficients for three pump efficiency ratings were used to provide three estimates of energy consumption (table 1).

Table 1—Fuel energy requirements for pumping 1 acre-foot of water at 1 pound per square inch (psi)

Energy	Horsepower hours[1]	Percentage of efficiency		
		65	60	55
		Unit fuel per acre-foot per psi		
Electricity	1.149 per kWh	4.2385	4.5917	5.0090
Diesel	12.35 per gallon	.4000	.4330	.4659
Gasoline	9.875 per gallon	.5004	.5417	.5830
Natural gas	79 per MCF[2]	.0625	.0677	.0729
LPG	7.9 per gallon	.6254	.6771	.7287

[1] Units of fuel in this column refer to the assumed number of horsepower hours produced per unit of fuel.

[2] MCF equals 1,000 cubic feet.

Source: Material provided by Delbert Schwab, agricultural engineer, Oklahoma State University, Stillwater.

[5] It was necessary to assume that each type of power unit pumped an equal amount of water in order to estimate area irrigated by type of energy. However, in States where natural gas is used extensively, those wells typically irrigated more acreage than non-natural-gas-powered wells. *Irrigation Journal* estimates of power units are percentages of each type. Therefore, adjustments were made to increase acreage irrigated with natural-gas-powered-wells in Arizona, Kansas, New Mexico, Oklahoma, and Texas. The remaining acreage in those States was then divided proportionately with *Irrigation Journal* figures.

An error was made in estimating energy requirements in 1974 and 1977 for pumping with electricity (see table 1). The new estimate is slightly lower, and 1974-77 electricity use has been adjusted downward to reflect the correction. Power units operating the pumps were assumed to be in average condition. All energy estimates in this report assume a 60-percent water pump efficiency and power units in average operating conditions. Estimates of energy consumption for 55-percent pump efficiency may be determined by increasing the 60-percent estimates by 7.62 percent. Estimates for 65-percent efficiency may be made by decreasing the 60-percent estimates by 7.63 percent. All energy estimates in this report may be adjusted similarly.

Distribution system pressure requirements. State irrigation specialists established pounds per square inch (psi) requirements for various irrigation distribution systems. A middle range was selected because estimates varied:

Type of system	*psi*
Big gun	165
Center pivot	100
Other sprinkler	70
Surface distribution	5

The estimates included the pressure required to overcome friction loss in lines from the pump through the distribution system and to apply water to the land. The pressure required to operate the system was included with that needed to get the water to ground level.

Since 1977, a great deal of interest has focused on low-pressure center pivot irrigation systems. For the 1980 data, irrigation specialists estimated the percentage of the center pivots in their States that were considered low-pressure systems and at which pressure they were operating. The average pressure required to operate the low-pressure systems was about 35 psi. The estimated percent of low-pressure center pivot systems for each State is shown in appendix table 9. Energy consumption estimates for 1980 include adjustments in the energy estimation model for low-pressure center pivot systems (see appendix I).

Survey Results

National, State, and regional irrigation survey results are highlighted. Energy estimates are based on the number of acres irrigated with pumped water as well as quantity of water pumped. A summary of several irrigated acreage estimates in the United States is shown in appendix table 10. The data in this report were received from many of the same irrigation specialists who provided data to the *Irriga-*

tion Journal. The *Irrigation Journal* estimates are among the higher estimates of irrigated acreage. Thus, estimates of irrigated acreage and subsequent energy estimates in this report may be higher than estimates based on other sources of data.

Area Irrigated

The area irrigated with pumped water increased by 21 percent from 1974 to 1980 (table 2). Ground water was the source of water for much of the increase, but land irrigated with both ground water and surface water increased most rapidly. Regional changes revealed that pump irrigation in the Corn Belt and Lake States grew much faster than other regions of the country (table 3). However, the Northern Plains contributed over half of the newly pump-irrigated land. The Southern Plains had a slight decline in pump-irrigated land from 1974 to 1980 in the Texas High Plains where the Ogallala aquifer is becoming depleted.

Distribution Systems

Big gun sprinklers brought the largest percentage increase among types of distribution systems (table 4). Center pivots provided the largest increase in acreage irrigated. Nebraska alone experienced a 1.6-million-acre increase in center pivot irrigation from 1974 to 1980, according to the University of Nebraska's Remote Sensing Center. Sprinkler irrigation accounted for 84 percent of the overall increase in irrigation for the period.

Acres irrigated with gravity distribution systems had the smallest percentage increase from 1974 to 1980. These systems, generally the least expensive method of irrigating, were the first to be developed. They required relatively flat, nonsandy land and an adequate water supply. Most of the areas in the Nation that can benefit from irrigation and have these two attributes developed systems before 1974. During the sixties and seventies, the widespread adoption of automatic sprinkler systems, such as center pivots, big gun, and side roll, took place on rolling or sandy land with adequate water supplies for irrigation.

Types of Energy Used

Acreage where electricity, diesel, and natural gas were used to pump irrigation water increased during 1974-80, while gasoline and LPG use declined (table 5). The trend is unmistakable. The irrigated areas using diesel grew most rapidly, followed by electricity and natural gas.

Natural gas usually is the least expensive fuel for pumping irrigation water, but it is not available in many areas. Electricity is usually the next best alternative. Many electric

Table 2—Acreage irrigated with onfarm pumped water, by source of water

Item	1974	1977	1980	Change, 1974-80	Percentage change, 1974-80
	Million acres				*Percent*
Ground water	25.6	30.0	31.6	6.0	23
Surface water	7.3	8.0	7.9	.6	8
Acreage with both sources	2.2	2.3	3.1	.9	41
Total	35.1	40.3	42.6	7.5	21

Table 3—Regional changes in acreage irrigated with onfarm pumped water, 1974-80

Farm production region	1974	1980	Change, 1974-80	Percentage change, 1974-80
	1,000 acres			*Percent*
Northeast	292	320	28	10
Lake States	411	1,154	743	181
Corn Belt	370	930	560	151
Northern Plains	7,250	11,030	3,780	52
Appalachia	192	290	98	51
Southeast	2,041	3,477	1,436	70
Delta States	2,688	3,037	349	13
Southern Plains	9,517	9,018	-499	-5
Mountain	6,020	6,284	264	4
Pacific	6,286	6,965	679	11
Alaska	7	2	-5	-71
Hawaii	76	86	10	13
Total	35,150	42,593	7,438	21

Table 4—Acreage irrigated with onfarm pumped water, by type of distribution system

Distribution system	1974	1977	1980	Change, 1974-80	Percentage change, 1974-80
	Million acres				*Percent*
Big gun	0.6	1.3	1.9	1.3	217
Center pivot	3.7	6.2	8.1	4.4	119
Other sprinkler	7.6	8.1	8.2	.6	8
Gravity	23.2	24.7	24.4	1.2	5
Total	35.1	40.3	42.6	7.5	21

utilities are operating at capacity, however, and are not anxious to add to peak loads with more irrigation customers. There was no shortage of diesel fuel or engines, and being the next preferred source of energy, diesel fuel had the most rapid growth from 1974 to 1980.

Quantity of Energy Used

The overall increase in energy used for onfarm pump irrigation reflected not only the 7.5-million-acre increase in acreage irrigated but a greater use of sprinklers (table 6). Sprinklers irrigated 84 percent of the increased acreage, although they used much more energy than gravity-flow irrigation systems. Diesel use increased much more than other energy sources.

Costs of Energy Used

The 256-percent increase in spending for energy for onfarm pumping of irrigation water from 1974 to 1980 centered on much higher prices as well as increased energy use (table 7). The prices of all forms of energy increased sharply after the first oil embargo. Natural gas prices increased the most, but diesel was not far behind (table 8). Over $1 billion of the $1.4-billion increase in pumping cost can be attributed to higher prices.

Table 5—Acreage irrigated with onfarm pumped water, by type of energy

Energy	1974	1977	1980	Change, 1974-80	Percentage change, 1974-80
	Million acres				*Percent*
Electricity	15.7	18.3	20.2	4.5	29
Diesel	3.9	6.8	7.7	3.8	97
Gasoline	1.5	1.3	1.0	-.5	-33
Natural gas	10.6	11.5	11.2	.6	6
LPG	3.3	2.4	2.5	-.8	-24
Total	35.1	40.3	42.6	7.5	21

Observations and Implications

The irrigated acreage and energy cost increases between 1974 and 1980 led to these issues for the eighties: the feasibility of further expansion of pump irrigation in the face of declining water levels in certain areas, the impact of even higher energy prices, and irrigator reaction to both issues.

Growth of Pump Irrigation

Declining water levels and increased energy costs will likely inhibit the growth of irrigation. Ground water is declining steadily under 16 million irrigated acres of U.S. farmland (*16*). One of the major areas of ground-water decline was the Texas High Plains where about 6 million acres were irrigated, after a decline of about 500,000 acres from 1974 to 1980 (table 3). Analysts estimate that over half of the High Plains water supply will be depleted by the year 2020 (*18*). The pump-irrigated area in the Texas High Plains will continue to decline, and some of the other ground-water decline areas will probably begin decreasing before the turn of the century.

While pump irrigation will eventually decrease in the ground-water decline areas, favorable economic conditions have caused pump irrigation to increase where adequate water supplies and proper soil and climatic conditions exist. An intergovernmental agency task force identified 26 million potentially irrigable acres in the eastern part of the United States (*9*). Although that potential may not be realized, pump irrigation increased by 3.2 million acres in the eastern farm production regions from 1974 to 1980 (table 3). Considerable expansion of pump irrigation is possible in the eastern half of the United States, given continued favorable economic conditions.

Table 6—Quantity of energy used for onfarm pumped irrigation water

Fuel	Unit	1974	1977	1980	Change, 1974-80	Percentage change, 1974-80
		Units of fuel				*Percent*
Electricity	Bil. kWh	14	17	19	5	36
Diesel	Mil. gal.	175	350	420	245	140
Gasoline	do.	65	78	61	-4	-6
Natural gas	Mil. MCF	132	149	149	17	13
LPG	Mil. gal.	238	217	252	14	5

Preliminary results from the Economic Development Administration's study of the declining Great Plains Ogallala aquifer indicate an increase of 3.5 million irrigated acres by the year 2020 under favorable economic, technological, and agronomic conditions (*13*). Irrigation from the Ogallala aquifer will eventually decline because more water is being withdrawn than is naturally being returned; nonetheless, potential for expansion exists.

Changing Energy Prices

Average prices of energy increased from a low of 139 percent for electricity to a surge of 400 percent for natural gas from 1973 to 1980 (table 8). Natural gas showed the largest percentage increase in price, but it remains the lowest cost fuel for pumping irrigation water (table 9). However, price relationships between types of energy changed dramatically between 1973 and 1980 affecting the relative cost of pumping. In 1973, little cost difference separated electricity and diesel energy for pumping, and natural gas was from three-fourths to two-thirds cheaper than diesel or electricity. By 1980, the cost of electricity for pumping was 42 percent less than the cost of diesel, and natural gas was only one-third cheaper than electricity. Natural gas still is cheaper than electricity, but the gap is narrowing rapidly. Natural gas is not available in many pump irrigation areas, and in those areas, electricity has a clear price advantage over diesel.

Table 7—Total cost of energy for onfarm pumped irrigation water

Energy	1974	1977	1980	Change, 1974-80	Percentage change, 1974-80
	Million dollars				*Percent*
Electricity	268	513	869	601	224
Diesel	62	156	422	360	581
Gasoline	31	37	70	39	126
Natural gas	99	187	375	276	279
LPG	68	73	153	85	122
Total	530	966	1,887	1,357	256

Although rising energy prices have had a major impact on the cost of pumping irrigation water, irrigation continues to expand because commodity prices have also increased (table 9). The seasonal average U.S. price per bushel for corn was $2.38 in 1973 and $3.27 in 1980. Assuming a 130-bushel yield, gross receipts would have increased by $115.70 per acre ($3.27 - $2.38 × 130) between 1973 and 1980. The only example in table 9 where increased energy costs would not be covered by increased revenue is the diesel-powered center pivot in the Oklahoma Panhandle. The increased energy cost for the more common natural gas-powered systems in the Oklahoma Panhandle was only $46 compared with increased revenues of $115.70. All of the increased pump energy costs were offset by increased revenues in the Nebraska examples.

Production costs other than irrigation fuel have also increased. However, gross receipts for irrigated corn with a 130-bushel yield at $3.27 would be $425.10. The production costs shown in table 9 do not include a charge for land and management but only in one example, Oklahoma Panhandle diesel-powered center pivot, does revenue not allow for returns to land and management. Thus, there has been an incentive to expand pump irrigation. The examples in table 9 are typical of the Great Plains where about half of the increase in onfarm pump irrigation occurred from 1973 to 1980.

Cost Reduction Alternatives

Pump irrigators have little control over crop or energy prices, and they cannot be sure that crop prices will con-

Table 8—Selected energy prices in the United States[1]

Item	Unit	1973	1974	1977	1980	Percentage change, 1973-80
		Dollars per unit				*Percent*
Electricity	kWh	0.023	0.027	0.035	0.055	139
Diesel	Gal.	.23	.37	.45	1.00	335
Gasoline	do.	.33	.47	.57	1.17	254
Natural gas[2]	MCF	.50	1.00	1.50	2.50	400
LPG	Gal.	.20	.30	.39	.62	210

[1] *Agricultural Statistics*, U.S. Dept. Agr., 1972-80
[2] Estimated.

tinue to cover projected increases in energy costs. They do, however, have some alternatives to help overcome the increasing cost of energy. They can: irrigate more efficiently and use less water and energy, grow crops that use less water, use a less expensive energy source, or stop irrigating.

Efficiency

Many pump irrigators could reduce energy use by irrigating more efficiently through scheduling, using tail-water pits, or employing more efficient application systems. Irrigators may also reduce energy use by improving the mechanical efficiency of their pumping equipment.

Scheduling is a procedure that considers current evapotranspiration rates, rainfall, and soil moisture to determine the proper irrigation water requirements of the crop. Traditionally, irrigation applications were predetermined with little attention paid to current climatic conditions. Potentially, scheduling could reduce irrigation water use by 20 to 30 percent, but unpredictable weather and labor and mechanical problems would likely cut water savings to around 10 percent (*7*). A 10-percent reduction in water use would lead to an equivalent energy savings.

Tail-water pits also increase irrigation efficiency. A pit is dug at the low point of a gravity-irrigated field. Water that otherwise runs off the field is caught in the pit and recirculated through the irrigation system. The amount of water pumped from the ground can be reduced from 10 to 30 percent with a tail-water pit depending on soil type, slope of the field, and other physical factors. Energy savings are not the equivalent of the water savings because it must be pumped from the pit. However, the energy savings can be significant because feet of lift from the pit is usually substantially less than from the original source.

No estimates are available concerning the extent of scheduling and tail-water pit adoption by pump irrigators. Several State and private organizations offer scheduling services and, because of rising energy prices, those services are becoming popular. Tail-water pits are mandatory in some States, and rising energy prices have also made them a popular conservation measure.

Low-pressure center pivot irrigation systems require less energy than standard center pivot systems and are often mentioned as an energy-saving alternative. Standard systems can be converted to low pressure, and, of course, new center pivots can be ordered with the low-pressure option. However, low-pressure center pivot systems require soils with a high water intake rate and low rates of slope to prevent runoff. Thus, not all center pivot applications can be low pressure.

An estimated 20 percent of the center pivot systems in place were low pressure in 1980 (app. table 9). Manufacturers of center pivots reported that 40 to 80 percent of their sales in 1980 were low-pressure systems (*3*). The average low-pressure system required about 35 psi to operate, compared with 100 psi for high-pressure systems.

The energy savings from the low-pressure center pivot systems were estimated by using the energy estimation model in appendix I and variously assuming: no low pressure, the inplace situation, and all low pressure. Inplace systems saved $42 million in 1980. If all center pivots had been low pressure, the savings would have been $203 million. Of course, not all center pivots can be converted to low pressure, but the potential exists for additional savings.

Basically, a powerplant and a pump distribute irrigation water. The powerplant can be an electric motor or an internal combustion engine. An electric motor maintains a rather constant efficiency throughout its useful life with little maintenance. An internal combustion engine requires peri-

Table 9—Production costs per acre for irrigated corn in Nebraska and Oklahoma

Item	South-central Nebraska[1]		Oklahoma Panhandle[2]	
	Gravity flow	Center pivot	Gravity flow	Center pivot
	Dollars			
Production costs[3]	236	264	280	270
Irrigation fuel costs:[4]				
Electricity—				
1973	8	20	28	44
1980	18	48	60	105
Diesel—				
1973	7	19	23	41
1980	31	83	102	180
Natural gas—				
1973	2	6	8	14
1980	12	32	40	70

[1] "Estimated Crop and Livestock Production Budgets," Agricultural Economics Extension Staff, University of Nebraska, Lincoln, IEC 79-872, 1980.
[2] Oklahoma State Univesity, Department of Agricultural Economics, Budget Record No. 72100767, 72100860, 1980.
[3] Exclusive of irrigation fuel and land charges.
[4] Prices used from table 8. Feet of lift is 100 feet for Nebraska and 250 feet for Oklahoma.

odic maintenance to prevent significant reductions in efficiency. An improperly maintained internal combustion engine can easily operate at 50 percent of attainable efficiency. A water pump also requires periodic maintenance to maintain peak efficiency.

A properly designed water pump can operate at 75- to 80-percent efficiency. However, various studies indicate that irrigation pumps in the United States operate at an average of 55- to 60-percent efficiency (*4, 6, 12*). While a 20-percent improvement appears possible, another study indicates that a 10-percent improvement would be a more realistic possibility (*5*). The energy use estimates in this report assume a 60-percent pump efficiency. A 10-percent improvement in pump efficiency was estimated to result in a 15.3-percent reduction in energy use (p. 4), amounting to a savings of $288 million in 1980.

While it appears that pump irrigators have several opportunities to reduce energy costs, all of the alternatives carry additional costs. Scheduling requires more management, labor, and some equipment. Tail-water pits require construction and maintenance as well as a power unit, pump, and pipes. Retrofitting center pivots requires low-pressure conversion and a possible change in power unit and pump. Improving pumping plant efficiency requires additional maintenance. The pump irrigators' decisions to take advantage of energy-saving alternatives depend on the profitability of making a change. Rapidly rising energy prices accelerate the process.

Reduced Water Use

A farmer who is irrigating efficiently, though losing ground to higher energy prices, may switch to a crop that requires less water. A typical crop change in the Great Plains would substitute sorghum for corn. The pump irrigator's decision to change to another crop would depend on the relative profitability of the alternate crop and the equipment complement needed for that crop.

Cheaper Energy Sources

Changing to another energy source involves several factors other than price, including accessibility to the source, future availability of that source, and the capital cost of changing. Electricity and natural gas provide some accessibility problems for pump irrigators. The type of electricity and powerlines needed for large pump motors are not always available at the well site. Erecting a powerline increases capital costs and may eliminate any economic advantages of shifting to electric power. Only those pump irrigators who have access to pipelines can choose natural gas as an alternate energy source, but many pump-irrigation areas of the country do not have natural gas pipelines. Regions that have access to pipelines generally use natural gas, because it is the least expensive energy source for pump irrigators.

The decision to change energy sources also depends on future availability of that source, even if the pump irrigator is located close to all possible energy sources. Many electric utilities are operating at or near capacity. Pump irrigators add to peak load periods, which inhibits some electric utilities from adding irrigators to the nearly full generating capacity. Many utilities place an annual limit on the number of new irrigators added to the distribution system. Thus, electricity may not be available to all pump irrigators.

Natural gas for irrigation is a special case because its use is regulated by the Federal Government. Some have proposed reducing the priority for irrigation into an interruptible service classification which would allow gas companies to stop service to irrigators during peak summer periods. Yields could decline significantly because of interrupted service during the peak irrigation season.

Another factor influencing the decision to change energy sources is the capital investment, or disinvestment. A pumping plant, replaced because of high energy costs, would have little salvageable value, reflecting little demand for such a unit.

A detailed analysis of pump irrigation, including irrigation system selection, responses to rising energy costs, and power plant and irrigation system conversion potentials is available in (*2*). The report gives a description of the various energy alternatives available to pump irrigators including changes in energy price and price relationships, distribution systems, pumping depths, and other factors. The reader should consult this source for an analysis of energy cost saving conversion possibilities.

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Appendix I—Procedure

The method used to estimate energy used for irrigation determined how much water was pumped, and how much effort, or work, was required to pump and distribute that amount of water. The next step determined how much energy was needed to perform that amount of work for ground water and surface water.

The quantity of water pumped in each State was determined as follows:

$$AF_i = (AI_i)(AFA_i) \quad (1)$$

where

AF_i = acre-feet of water used from ground water (pumped surface water) sources in ith State,

AI_i = acres irrigated from ground water (pumped surface water) in ith State, and

AFA_i = average annual acre-feet applied per acre in ith State.

$i = 1, \ldots 50,$

The work required to pump the water to ground level was measured in psi. The psi is determined by dividing the feet of lift by 2.31. The total work (acre-feet psi) required to get the ground water to the surface in each State was determined by:

$$TPW_i = (AF_i)(PW_i) \quad (2)$$

where

TPW_i = total work required to get water to ground level in the ith State,

AF_i = equation (1), and

PW_i = psi required to get water to ground level for the average feet of lift in the State.

$i = 1, \ldots 50,$

Work required to distribute ground water (pumped surface water) in each State is estimated as follows:

$$TPD_i = AF_i \sum_{j=1}^{4} (DP_{ij})(PD_j), \quad (3)$$

where

$i = 1, \ldots 50$ States

$j = 1, \ldots$ four types of irrigation systems,[1]

where

TPD_i = total work required to distribute ground water (pumped surface water) in the ith State,

AF_i = equation (1),

DP_{ij} = percentage of acres irrigated in ith State by jth system, and

PD_j = pressure required to operate jth system.

The sum of equation (2) plus equation (3) is the total work (acre-feet psi) to irrigate with ground water (pumped surface water) in a State. The amount of energy consumed to pump and distribute the irrigation water by each energy source is estimated as follows:

$$ER_{ij} = \{TPW_i + TPD_i\}\{(ET_{ij})(ETR_j)\}, \quad (4)$$

$i = 1, \ldots 50$ States

$j = 1, \ldots$ five types of power units,

where

ER_{ij} = energy required in ith State by the jth power unit,

TPW_i and TPD_i = equations (2) and (3),

ET_{ij} = proportion of acres irrigated in ith State with jth power units,

ETR_j = amount of fuel required to pump 1 acre-foot of water at one psi with jth power unit.

Equation (4) assumes that the various distribution systems use equal proportions of the types of power units in the State, that is, sprinkler systems power units are distributed proportionally the same as gravity-flow power units.

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[1]In States with low-pressure center pivot systems,

$$PD_2 = \{(PH)(100)\} + \{(PL)(35)\},$$

where

PH = the percent of high-pressure center pivots, and

PL = the percent of low-pressure center pivots.

Appendix II—Tables

Appendix table 1—Feet of lift required for pumping and acre-feet of irrigation water applied, by source and by region and State[1]

Region and State	Ground water			Surface water			Acre-feet applied
	1974	1977	1980	1974	1977	1980	
	Feet of lift						*Acre-feet*
Northeast:							
Connecticut	80	80	80	20	20	20	0.42
Delaware	50	50	50	20	15	15	.58
Maine	0	0	15	15	15	15	.20
Maryland	50	20	25	50	20	25	.85
Massachusetts	80	80	80	10	10	10	.42
New Hampshire	0	0	0	20	20	20	.42
New Jersey	175	175	175	20	20	20	.60
New York	80	80	80	25	25	25	.60
Pennsylvania	150	150	150	35	30	30	.42
Rhode Island	0	0	0	20	20	20	.42
Vermont	0	0	0	20	20	20	.42
Lake States:							
Michigan	100	100	100	20	20	20	.67
Minnesota	70	70	80	10	10	10	.75
Wisconsin	75	75	75	20	15	15	1.00
Corn Belt:							
Illinois	55	55	55	0	15	15	.50
Indiana	150	150	125	25	25	15	.83
Iowa	35	35	40	25	15	15	.58
Missouri	75	75	75	25	25	25	.50
Ohio	100	100	100	25	25	25	.50
Northern Plains:							
Kansas	180	180	190	15	15	15	1.70
Nebraska	100	100	100	20	20	20	1.75
North Dakota	75	75	75	35	35	35	1.00
South Dakota	70	80	120	150	150	130	1.25
Appalachia:							
Kentucky	75	75	75	25	25	25	.33
North Carolina	150	150	150	35	35	15	.50
Tennessee	100	100	100	25	25	25	.58
Virginia	12	12	12	30	30	30	.83
West Virginia	0	0	0	25	25	25	.45

See footnote at end of table

Continued—

Appendix table 1—Feet of lift required for pumping and acre-feet of irrigation water applied, by source and by region and State[1] —Continued

Region and State	Ground water			Surface water			Acre-feet applied
	1974	1977	1980	1974	1977	1980	
	Feet of lift						*Acre-feet*
Southeast:							
Alabama	150	150	150	40	40	100	1.50
Florida	85	95	95	5	6	7	1.00
Georgia	250	250	250	15	15	15	1.30
South Carolina	100	100	100	20	20	20	1.00
Delta States:							
Arkansas	45	60	90	15	15	15	1.83
Louisiana	100	100	100	10	10	10	1.83
Mississippi	110	50	50	15	15	15	2.00
Southern Plains:							
Oklahoma	200	200	200	20	16	16	1.83
Texas	200	200	210	40	40	40	1.50
Mountain:							
Arizona	350	375	400	0	0	0	5.40
Colorado	115	120	125	10	10	10	1.10
Idaho	266	266	266	0	11	11	3.20
Montana	100	100	100	60	60	50	2.70
Nevada	100	100	100	20	20	20	5.00
New Mexico	250	250	260	5	5	5	2.75
Utah	225	225	225	15	15	15	3.00
Wyoming	150	150	150	25	25	25	1.83
Pacific:							
California	110	110	135	10	10	10	3.17
Oregon	266	266	266	11	11	11	3.00
Washington	287	287	270	26	26	26	4.20
Alaska	100	100	100	10	10	10	.25
Hawaii	700	700	700	10	10	10	6.00

[1] Estimated statewide average weighted by number of wells at each depth.

Appendix table 2—Acreage irrigated with onfarm pumped water, by source and region and State

Region and State	Ground water			Surface water			Both			Total		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 acres											
Northeast:	137	153	166	155	151	154	0	0	0	292	304	320
Connecticut	1	2	1	8	10	7	0	0	0	9	12	8
Delaware	20	26	35	6	4	7	0	0	0	26	30	42
Maine	0	0	0	7	7	7	0	0	0	7	7	7
Maryland	8	17	22	16	16	18	0	0	0	24	33	40
Massachusetts	1	1	1	31	31	31	0	0	0	32	32	32
New Hampshire	0	1	0	6	7	7	0	0	0	6	7	7
New Jersey	75	75	75	30	30	30	0	0	0	105	105	105
New York	30	30	30	29	24	25	0	0	0	59	54	55
Pennsylvania	2	2	2	17	17	17	0	0	0	19	19	19
Rhode Island	0	0	0	3	3	3	0	0	0	3	3	3
Vermont	0	0	0	2	2	2	0	0	0	2	2	2
Lake States:	253	605	906	158	146	248	0	0	0	411	751	1,154
Michigan	56	56	234	53	53	137	0	0	0	109	109	371
Minnesota	82	352	430	50	45	61	0	0	0	132	397	491
Wisconsin	115	197	242	55	48	50	0	0	0	170	245	292
Corn Belt:	274	490	751	96	135	172	0	7	7	370	632	930
Illinois	50	40	129	0	13	13	0	0	0	50	53	142
Indiana	19	36	55	14	20	28	0	2	2	33	58	85
Iowa	50	150	227	7	15	15	0	0	0	57	165	242
Missouri	143	248	324	55	57	86	0	5	5	198	310	415
Ohio	12	16	16	20	30	30	0	0	0	32	46	46
Northern Plains:	6,380	8,977	10,130	684	676	710	186	185	190	7,250	9,838	11,030
Kansas	2,230	3,073	3,489	65	75	85	10	10	15	2,305	3,158	3,589
Nebraska	4,074	5,670	6,316	505	440	440	176	175	175	4,755	6,285	6,931
North Dakota	33	85	127	23	11	11	0	0	0	56	96	138
South Dakota	43	149	198	91	150	174	0	0	0	134	299	372
Appalachia:	17	23	25	175	107	265	0	3	10	102	223	200
Kentucky	1	1	1	26	26	26	0	0	0	27	27	27
North Carolina	5	7	3	104	110	150	0	3	10	109	120	163
Tennessee	6	7	10	11	12	15	0	0	0	17	19	25
Virginia	3	3	11	31	47	63	0	0	0	36	55	74
West Virginia	0	0	0	3	2	1	0	0	0	3	2	1

Continued—

Appendix table 2—Acreage irrigated with onfarm pumped water, by source and region and State—Continued

Region and State	Ground water			Surface water			Both			Total		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
						1,000 acres						
Southeast:	1,058	1,343	2,178	980	1,359	1,285	3	8	14	2,041	2,710	3,477
Alabama	8	25	35	17	30	95	0	5	10	25	60	140
Florida	960	1,076	1,450	823	960	817	0	0	0	1,783	2,036	2,267
Georgia	80	230	663	114	347	323	0	0	0	194	577	986
South Carolina	10	12	30	26	22	50	3	3	4	39	37	84
Delta States:	1,466	1,486	1,837	722	676	525	500	500	675	2,688	2,662	3,037
Arkansas	900	900	1,075	296	300	75	500	500	675	1,696	1,700	1,825
Louisiana	340	284	395	332	276	350	0	0	0	672	560	745
Mississippi	226	302	367	94	100	100	0	0	0	320	402	467
Southern Plains:	7,770	8,320	7,091	1,491	1,569	1,215	256	256	712	9,517	10,145	9,018
Oklahoma	680	730	746	40	118	120	0	0	0	720	848	866
Texas	7,090	7,590	6,345	1,451	1,451	1,095	256	256	712	8,797	9,297	8,152
Mountain:	3,587	3,636	3,711	1,149	1,206	1,238	1,284	1,325	1,340	6,020	6,167	6,284
Arizona	552	550	550	0	0	0	391	390	390	943	940	940
Colorado	900	940	940	45	50	60	700	710	720	1,645	1,700	1,720
Idaho	1,106	1,149	1,140	528	549	557	0	0	0	1,634	1,698	1,697
Montana	40	57	58	284	316	389	0	0	0	324	373	447
Nevada	170	170	170	34	34	34	0	0	0	204	204	204
New Mexico	634	585	653	43	43	43	143	175	180	820	803	876
Utah	60	60	70	164	164	80	0	0	0	224	224	150
Wyoming	125	125	130	50	50	75	50	50	50	225	225	255
Pacific:	4,561	4,912	4,687	1,725	1,845	2,078	0	0	200	6,286	6,757	6,965
California	4,073	4,388	4,065	380	410	410	0	0	200	4,453	4,798	4,675
Oregon	246	264	292	644	686	738	0	0	0	890	950	1,030
Washington	242	260	330	701	749	930	0	0	0	943	1,009	1,260
Alaska	3	1	1	4	1	1	0	0	0	7	2	2
Hawaii	70	80	80	6	6	6	0	0	0	76	86	86
Total	25,576	30,026	31,563	7,345	7,967	7,887	2,224	2,284	3,148	35,150	40,277	42,598

Appendix table 3—Acreage irrigated with onfarm pumped water, by type of distribution system and region and State[1]

Region and State	Big gun			Center pivot			Other sprinkler			Surface		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 acres											
Northeast:	19.24	25.85	33.34	17.99	42.56	47.52	249.56	229.76	232.93	5.63	5.76	6.21
Connecticut	0	0	.49	.08	0	0	8.83	11.88	7.01	.01	.12	50
Delaware	7.00	11.48	15.96	8.56	13.56	21.07	10.38	4.96	4.97	0	0	0
Maine	0	0	0	.07	0	0	32.03	6.93	6.93	.34	.07	.07
Maryland	1.19	3.96	6.14	3.58	23.43	20.88	19.07	5.61	12.98	0	0	0
Massachusetts	0	0	0	.32	0	0	5.88	31.68	31.68	0	.32	.32
New Hampshire	0	0	0	.06	0	0	1.96	6.93	6.93	0	0	.07
New Jersey	0	0	0	5.28	5.25	5.25	95.12	94.50	94.50	5.28	5.25	5.25
New York	8.22	7.56	7.90	0	0	0	50.49	46.44	47.10	0	0	0
Pennsylvania	2.82	2.85	2.85	0	0	0	16.01	16.15	16.15	0	0	0
Rhode Island	0	0	0	.03	.30	.30	8.83	2.70	2.70	.01	0	0
Vermont	0	0	0	.02	.02	.02	2.94	1.98	1.98	0	0	0
Lake States:	49.16	178.80	322.00	209.41	440.06	617.67	127.15	120.32	200.13	26.73	11.82	14.20
Michigan	10.92	10.90	115.01	62.24	62.13	155.82	36.04	35.97	100.17	0	0	0
Minnesota	24.63	101.42	128.91	68.97	245.08	297.13	11.17	40.60	52.76	26.73	9.90	12.20
Wisconsin	13.61	66.48	78.08	78.20	132.85	164.72	79.95	43.75	47.20	0	1.92	2.00
Corn Belt:	47.02	84.00	139.84	70.18	233.52	419.54	64.91	77.32	90.56	187.99	237.16	278.06
Illinois	10.00	11.98	27.11	25.00	27.60	101.60	14.00	13.02	10.02	1.00	.40	1.27
Indiana	2.66	16.02	13.34	11.97	22.96	37.69	11.30	11.84	26.61	7.31	7.18	7.36
Iowa	8.62	25.95	46.37	7.47	91.50	159.95	12.65	12.60	13.30	28.75	34.95	22.38
Missouri	20.99	26.01	48.98	20.99	85.12	113.96	4.84	4.24	5.01	150.93	194.63	247.05
Ohio	4.74	4.04	4.04	4.74	6.34	6.34	22.12	35.62	35.62	0	0	0
Northern Plains:	60.31	115.42	159.80	1,536.07	3,178.23	3,688.31	580.12	721.23	797.55	5,073.73	5,823.12	6,384.34
Kansas	45.45	12.75	52.04	449.96	806.83	987.92	45.45	64.66	75.18	1,764.62	2,273.76	2,473.86
Nebraska	0	62.85	69.31	1,025.06	2,136.90	2,356.54	467.50	565.65	623.79	3,263.04	3,519.60	3,881.36
North Dakota	3.30	12.89	11.15	26.40	74.65	117.53	1.87	2.69	4.80	23.92	5.77	4.52
South Dakota	11.55	26.93	27.30	34.65	159.85	226.32	65.29	88.23	93.78	22.13	23.99	24.60
Appalachia:	8.61	27.60	131.41	8.06	8.09	19.79	161.76	181.37	132.11	13.80	5.93	6.68
Kentucky	0	0	0	0	0	0	26.47	25.95	25.95	.27	1.04	1.05
North Carolina	0	5.50	99.51	6.54	6.10	14.79	91.52	106.30	47.01	10.89	2.10	1.69
Tennessee	1.64	2.06	6.00	1.52	1.99	5.00	11.17	12.16	11.05	2.56	2.79	2.95
Virginia	6.97	19.04	25.90	0	0	0	29.66	35.96	48.10	.05	0	0
West Virginia	0	1.00	0	0	0	0	2.94	1.00	0	.03	0	.99

See footnote at end of table.

Continued—

Appendix table 3—Acreage irrigated with onfarm pumped water, by type of distribution system and region and State[1]—Continued

Region and State	Big gun			Center pivot			Other sprinkler			Surface		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 acres											
Southeast:	321.50	685.06	920.66	63.73	167.89	614.42	488.85	554.02	532.98	1,165.51	1,303.03	1,408.94
Alabama	5.63	38.10	83.50	5.96	16.20	43.60	13.00	5.70	7.90	.24	0	0
Florida	307.20	376.60	493.00	19.20	21.52	29.00	292.27	336.84	341.08	1,164.82	1,301.04	1,403.92
Georgia	0	256.58	308.04	38.57	129.12	510.00	154.29	191.30	167.96	0	0	0
South Carolina	8.67	13.78	31.12	0	1.05	31.82	29.29	20.18	16.04	1.45	1.99	5.02
Delta States:	19.66	25.84	67.40	24.88	28.70	167.76	60.10	43.62	108.20	2,583.61	2,563.84	2,692.89
Arkansas	14.00	23.00	52.50	16.96	20.00	52.50	47.92	34.00	70.00	1,617.13	1,623.00	1,649.25
Louisiana	3.40	2.84	14.90	3.40	5.68	85.90	6.73	5.60	18.85	659.11	545.88	625.35
Mississippi	2.26	0	0	4.52	3.02	29.36	5.46	4.02	19.35	307.36	394.96	418.29
Southern Plains:	103.38	107.56	103.90	521.48	774.89	779.59	1,766.17	1,836.76	1,669.46	7,121.34	7,425.78	6,466.04
Oklahoma	20.40	14.60	22.38	81.60	124.10	208.88	270.88	349.24	364.98	347.20	360.06	269.76
Texas	87.98	92.97	81.52	439.88	650.79	570.71	1,495.59	1,497.52	1,304.48	6,774.15	7,065.72	6,196.28
Mountain:	.80	5.44	11.43	918.30	1,027.34	1,208.26	1,659.66	1,722.70	1,724.94	3,441.81	3,411.52	3,344.37
Arizona	0	0	0	28.29	28.20	28.20	37.72	28.20	28.20	876.99	883.60	883.60
Colorado	0	0	0	353.34	546.50	600.60	64.45	50.00	51.00	1,227.01	1,103.50	1,068.40
Idaho	0	0	0	179.74	186.78	186.67	1,209.16	1,256.52	1,255.78	245.10	254.70	254.55
Montana	.80	5.44	10.68	23.39	36.06	60.19	54.48	79.01	112.60	240.16	252.49	263.53
Nevada	0	0	0	10.22	10.54	10.54	10.22	10.54	10.54	184.57	182.92	182.92
New Mexico	0	0	0	233.25	129.20	224.91	15.98	30.83	59.87	571.07	642.97	591.22
Utah	0	0	0	19.56	19.56	11.20	179.60	179.60	120.10	24.84	24.84	18.70
Wyoming	0	0	0.75	70.50	70.50	85.95	88.00	88.00	86.85	66.69	66.50	81.45
Pacific:	0	38.59	54.18	295.93	316.39	544.98	2,434.48	2,581.33	2,660.37	3,555.59	3,820.69	3,705.47
California	0	0	0	0	0	0	935.13	1,007.58	981.75	3,517.87	3,790.42	3,693.25
Oregon	0	28.50	38.28	97.90	104.50	155.88	792.10	817.00	832.92	0	0	2.92
Washington	0	10.09	15.90	198.03	211.89	389.10	707.25	756.75	845.70	37.72	30.27	9.30
Alaska	0	0	0	.80	0	0	3.19	1.98	1.98	0	0	0
Hawaii	0	0	0	0	.80	.80	14.00	28.00	28.00	56.00	57.14	57.14
Total	642.32	1,294.16	1,939.58	3,667.83	6,218.47	8,103.81	7,609.91	8,098.41	8,174.64	23,232.61	24,665.79	24,360.13

[1] Includes only areas irrigated with pumped water.

Appendix table 4—Acreage irrigated with onfarm pumped water, by type of energy and region and State[1]

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
								1,000 acres							
Northeast:	30.44	29.93	25.48	67.58	100.13	106.46	176.24	160.07	133.81	0	0	41.25	18.17	13.87	13.00
Connecticut	.92	1.20	.40	2.38	3.12	2.0	5.50	7.44	2.4	0	0	0	.12	.24	3.2
Delaware	2.59	3.56	2.52	7.78	18.22	31.22	11.76	6.98	8.26	0	0	0	3.89	1.24	0
Maine	.69	0	0	2.08	2.10	2.10	4.16	4.90	4.90	0	0	0	0	0	0
Maryland	2.38	1.82	3.06	9.54	16.83	23.98	7.15	11.55	9	0	0	0	4.77	2.80	3.96
Massachusetts	4.25	4.16	4.16	0	0	0	24.51	23.69	23.69	0	0	0	3.92	4.15	4.15
New Hampshire	.59	.70	.70	1.78	2.03	2.03	3.56	4.27	4.27	0	0	0	0	0	0
New Jersey	10.57	10.50	6.75	15.85	31.50	16.50	73.98	57.75	39.0	0	0	41.25	5.28	5.25	1.50
New York	5.87	5.40	5.30	23.48	21.60	23.90	29.35	27.00	25.80	0	0	0	0	0	0
Pennsylvania	2.07	2.09	2.09	3.20	3.23	3.23	13.37	13.49	13.49	0	0	0	.19	.19	.19
Rhode Island	.30	.30	.30	.89	.90	.90	1.78	1.80	1.80	0	0	0	0	0	0
Vermont	.20	.20	.20	.59	.60	.60	1.19	1.20	1.20	0	0	0	0	0	0
Lake States:	295.76	452.83	594.46	81.34	236.91	423.68	23.17	49.38	106.43	0	0	0	10.52	11.88	29.43
Michigan	87.36	87.20	155.82	16.38	16.35	118.72	5.46	5.45	89.04	0	0	0	0	0	7.42
Minnesota	72.32	237.30	287.86	39.45	119.55	179.84	9.20	32.21	6.13	0	0	0	10.52	7.94	17.17
Wisconsin	136.08	128.33	150.78	25.51	101.01	125.12	8.50	11.72	11.26	0	0	0	0	3.94	4.84
Corn Belt:	71.43	155.23	285.96	74.66	255.08	429.39	122.88	94.40	60.96	1.81	24.90	6.28	99.31	102.39	145.41
Illinois	6.00	7.04	63.27	9.00	9.15	63.27	24.50	25.82	6.44	0	0	2.99	10.50	10.99	4.03
Indiana	3.32	16.78	39.74	4.65	15.78	26.31	13.30	13.60	14.43	.38	.38	0	11.59	11.46	4.52
Iowa	11.50	63.00	109.20	20.13	62.55	103.05	23.00	34.05	18.40	0	.90	0	2.88	4.50	11.35
Missouri	39.55	52.31	57.65	36.14	160.70	229.86	40.44	2.53	3.29	1.43	23.62	3.29	71.19	70.84	120.91
Ohio	11.06	16.10	16.10	4.74	6.90	6.90	12.64	18.40	18.40	0	0	0	3.16	4.60	4.60
Northern Plains:	1,572.54	2,612.42	3,274.00	1,543.16	2,914.17	2,792.47	152.09	72.04	79.05	2,429.50	3,231.31	3,621.01	1,552.95	1,008.06	1,263.47
Kansas	169.90	503.03	787.88	138.53	534.53	460.43	22.40	0	0	1,792.00	1,911.46	2,067.36	183.00	208.98	273.33
Nebraska	1,308.34	1,885.50	2,148.61	1,360.00	2,262.60	2,217.92	118.34	62.85	69.31	637.50	1,319.85	1,524.82	1,331.42	754.20	970.34
North Dakota	42.18	80.42	122.05	8.88	13.88	12.54	3.33	1.70	2.54	0	0	.99	1.11	0	0
South Dakota	52.12	143.47	215.46	36.08	103.16	101.70	8.02	7.49	7.20	0	0	0	37.42	44.88	47.64
Appalachia:	104.60	18.38	29.80	21.72	87.24	139.40	62.01	114.28	112.44	.30	1.50	2.05	3.59	1.60	6.31
Kentucky	0	0	0	4.01	4.10	4.10	22.73	22.90	22.90	0	0	0	0	0	0
North Carolina	98.05	11.40	19.79	5.45	58.50	101.21	5.45	50.10	39.0	0	0	0	0	0	3.0
Tennessee	3.38	4.20	3.95	5.07	5.82	8.05	6.76	7.06	8.90	.30	1.50	2.05	1.39	.42	2.05
Virginia	2.93	2.52	5.92	6.60	18.48	26.01	24.94	32.82	40.81	0	0	0	2.20	1.18	1.26
West Virginia	.24	.26	.14	.59	.34	.03	2.14	1.40	.83	0	0	0	0	0	0

See footnote at end of table.

Continued—

Appendix table 4—Acreage irrigated with onfarm pumped water, by type of energy and region and State[1]—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
							1,000 acres								
Southeast:	584.83	581.94	962.07	1,044.72	1,613.51	1,967.11	188.86	240.16	209.85	0.16	2.10	1.90	222.01	272.29	336.07
Alabama	3.72	6.00	14.65	9.93	38.10	113.65	9.93	10.20	4.75	.16	2.10	1.90	1.03	3.60	5.05
Florida	541.87	534.00	614.74	953.62	1,233.00	1,289.76	96.00	75.32	101.50	0	0	0	192.00	193.68	261.00
Georgia	7.71	34.62	305.66	73.29	317.35	512.72	82.93	150.02	98.60	0	0	0	28.93	75.01	69.02
South Carolina	32.52	7.32	27.02	7.88	25.06	50.98	0	4.62	5.00	0	0	0	0	0	1.00
Delta States:	504.02	780.66	1,571.66	645.22	1,102.70	1,197.32	590.49	309.78	92.77	204.53	182.00	116.75	744.00	286.86	58.50
Arkansas	339.20	565.00	1,316.25	184.40	616.00	406.25	424.00	191.00	25.00	70.00	70.00	56.25	678.40	258.00	21.25
Louisiana	100.90	84.00	104.30	269.06	232.44	502.20	134.53	114.76	63.10	134.53	112.00	60.50	33.63	16.80	14.90
Mississippi	63.92	131.66	151.11	191.76	254.26	288.87	31.96	4.02	4.67	0	0	0	31.96	12.06	22.35
Southern Plains:	2,006.68	2,346.75	2,054.13	151.25	166.18	165.78	108.38	114.65	102.45	6,742.20	6,949.07	6,204.01	508.88	568.35	492.62
Oklahoma	102.00	141.80	140.02	48.76	58.70	73.30	20.40	21.68	20.92	435.20	472.88	498.10	113.42	152.94	133.66
Texas	1,904.68	2,204.95	1,914.11	102.49	107.48	92.48	87.98	92.97	81.53	6,307.00	6,476.19	5,705.91	395.45	415.41	358.96
Mountain:	4,297.28	4,499.86	4,535.95	307.18	350.43	324.69	85.97	77.14	147.22	1,151.64	1,103.75	1,083.77	183.64	135.82	196.37
Arizona	612.95	648.60	648.60	0	0	0	0	0	0	330.05	291.40	291.40	0	0	0
Colorado	1,100.00	1,138.00	1,135.60	100.00	100.10	49.80	20.00	20.00	100.80	330.00	332.00	332.00	100.00	100.00	100.80
Idaho	1,568.64	1,630.08	1,623.55	49.02	50.94	50.91	16.34	16.98	22.54	0	0	0	0	0	0
Montana	270.51	315.09	382.51	36.93	39.01	46.44	13.74	14.61	13.00	.40	0	0	3.25	4.30	5.05
Nevada	159.44	163.20	163.20	40.88	40.80	40.80	2.04	0	0	0	0	0	2.04	0	0
New Mexico	203.93	223.25	232.44	46.65	76.00	108.29	31.10	22.80	8.33	484.19	473.35	451.97	54.42	7.60	74.97
Utah	190.40	190.40	130.60	15.68	15.68	8.20	0	0	0	0	0	0	17.92	17.92	11.20
Wyoming	191.41	191.25	219.45	18.02	18.00	20.25	2.75	2.75	2.55	7.00	7.00	8.41	6.01	6.00	4.35
Pacific:	6,197.39	6,716.80	6,744.75	3.61	9.00	134.17	0	0	0	85.00	31.20	85.30	0	0	0
California	4,364.39	4,757.80	4,461.65	3.61	9.00	127.95	0	0	0	85.00	31.20	85.30	0	0	0
Oregon	890.00	950.00	1,026.70	0	0	2.92	0	0	0	0	0	0	0	0	0
Washington	943.00	1,009.00	1,256.40	0	0	3.30	0	0	0	0	0	0	0	0	0
Alaska	2.80	1.60	1.60	.20	0	0	1.00	.40	.40	0	0	0	0	0	0
Hawaii	71.63	85.14	85.14	0	0	0	.72	0	0	0	0	0	0	0	0
Total	15,737.32	18,281.54	20,162.00	3,937.94	6,835.35	7,676.00	1,511.81	1,231.90	1,040.00	10,615.13	11,525.83	11,160.00	3,343.07	2,401.12	2,538.00

[1] Includes only acres irrigated with pumped water.

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State[1]

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 kWh			1,000 gallons						1,000 MCF			1,000 gallons		
Ground water:															
Northeast:	5,894	5,418	4,142	848	2,042	2,151	4,362	3,005	2,041	0	0	242	546	370	172
Connecticut	26	40	10	0	9	5	18	29	7	0	0	0	4	1	12
Delaware	683	1,179	752	193	565	874	363	266	296	0	0	0	151	58	0
Maine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maryland	279	444	1,054	105	356	707	99	306	249	0	0	0	82	87	155
Massachusetts	26	26	26	0	0	0	18	17	18	0	0	0	4	3	0
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Jersey	4,138	2,980	1,490	285	843	281	3,417	1,933	1,055	0	0	242	305	219	0
New York	679	684	747	256	258	275	401	403	368	0	0	0	0	0	0
Pennsylvania	63	63	63	9	9	9	48	48	48	0	0	0	1	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake States:	79,421	203 517	264,580	2,131	9,336	16,076	750	2,404	3,893	0	0	0	462	899	1,726
Michigan	19,154	19,239	45,642	339	340	3,279	141	141	3,077	0	0	0	0	0	321
Minnesota	21,526	104,658	124,419	1,107	4,934	7,358	323	1,646	249	0	0	0	462	514	933
Wisconsin	38,742	79,619	94,519	685	4,061	5,439	286	615	567	0	0	0	0	385	473
Corn Belt:	10,865	35,097	83,033	1,185	4,208	8,598	2,792	2,474	1,344	6	9	7	2,391	2,777	3,088
Illinois	2,126	1,767	22,116	301	199	2,086	1,024	653	107	0	0	0	549	347	0
Indiana	1,011	7,542	14,491	133	711	683	477	574	475	3	3	0	507	609	158
Iowa	1,882	16,506	36,306	312	1,439	3,424	446	973	476	0	0	0	70	182	595
Missouri	4,567	7,585	8,423	388	1,788	2,336	673	44	58	3	5	7	1,212	1,566	2,265
Ohio	1,270	1,696	1,697	51	68	69	171	228	229	0	0	0	54	71	72
Northern Plains:	950,041	1,513,810	1,755,290	92,922	183,784	170,756	5,573	5,121	5,636	25,551	36,745	38,756	112,776	98,113	123,358
Kansas	115,012	172,854	199,463	7,747	39,578	31,583	1,938	0	0	19,383	23,982	24,282	16,961	23,208	28,809
Nebraska	808,581	1,236,371	1,383,099	84,140	139,913	134,634	3,289	4,862	5,264	6,166	12,762	14,474	94,569	72,929	92,108
North Dakota	15,229	45,438	66,819	302	714	637	142	127	177	0	0	0	59	0	0
South Dakota	11,218	59,147	105,918	732	3,578	3,902	204	131	195	0	0	0	1,187	1,974	2,441
Appalachia:	1,824	2,620	4,980	83	318	370	208	331	401	1	2	5	24	37	54
Kentucky	0	0	0	2	2	3	16	14	14	0	0	0	0	0	0
North Carolina	1,346	1,764	3,883	7	98	75	9	21	0	0	0	0	0	0	0
Tennessee	384	556	734	54	65	138	91	92	87	1	2	5	14	20	54
Virginia	93	299	363	20	151	154	92	202	300	0	0	0	10	16	0
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See footnote at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State[1]—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 kWh			*1,000 gallons*						*1,000 MCF*			*1,000 gallons*		
Ground water:															
Southeast:	125,652	184,751	473,530	12,666	38,689	71,005	6,029	13,258	15,103	1	0	0	10,723	19,911	27,541
Alabama	296	1,818	4,363	74	791	1,328	93	280	0	1	0	0	9	206	205
Florida	116,806	162,665	219,313	11,015	23,010	31,022	3,937	4,477	6,037	0	0	0	9,843	14,392	19,404
Georgia	1,576	16,626	238,224	1,412	14,373	37,683	1,999	8,500	9,066	0	0	0	872	5,312	7,932
South Carolina	6,974	3,640	11,630	164	514	973	0	0	0	0	0	0	0	0	0
Delta States:	108,128	188,326	649,576	14,066	23,172	34,459	14,482	7,866	3,028	680	669	651	22,289	9,969	2,635
Arkansas	67,162	143,485	581,101	3,167	13,531	14,613	9,905	4,836	914	248	302	343	19,808	9,068	1,143
Louisiana	21,977	18,666	29,270	5,527	4,929	13,012	3,457	2,936	1,973	432	367	308	1,080	550	617
Mississippi	18,989	26,174	39,205	5,372	4,712	6,834	1,120	93	140	0	0	0	1,400	350	876
Southern Plains:	1,201,454	1,440,310	1,373,206	8,783	8,622	9,506	8,759	8,888	8,678	66,344	70,385	67,525	43,792	51,559	47,405
Oklahoma	94,456	136,756	154,358	3,563	3,034	4,281	2,229	1,898	2,142	5,943	7,473	8,703	11,143	16,608	14,728
Texas	1,106,999	1,303,554	1,218,848	5,220	5,587	5,224	6,530	6,990	6,536	60,401	62,911	58,822	32,649	34,951	32,677
Mountain:	4,548,815	5,401,290	5,613,379	25,403	24,940	31,590	11,173	7,628	4,942	34,421	34,731	36,205	21,874	6,195	24,082
Arizona	1,817,529	2,762,817	2,933,542	0	0	0	0	0	0	14,432	18,304	19,435	0	0	0
Colorado	347,367	359,350	21,076	1,178	1,296	43,062	300	300	303	4,700	4,747	2,072	1,842	1,842	1,864
Idaho	1,385,869	1,442,413	1,442,413	3,920	4,075	4,075	1,626	1,690	1,690	0	0	0	0	0	0
Montana	31,804	65,815	67,491	591	1,061	1,089	687	919	943	7	0	0	66	255	262
Nevada	325,120	174,845	174,852	7,862	4,122	4,122	492	0	0	0	0	0	615	0	0
New Mexico	348,226	303,434	342,947	9,383	11,922	18,279	7,825	4,474	1,759	15,161	11,559	11,873	17,117	1,864	19,789
Utah	117,009	117,009	113,070	908	908	744	0	0	0	0	0	0	1,624	1,624	1,551
Wyoming	175,896	175,607	175,406	1,561	1,558	1,969	244	243	246	122	121	92	610	609	616
Pacific:	4,417,754	4,765,477	4,838,827	0	0	17,645	0	0	0	1,000	1,136	1,638	0	0	0
California	3,592,593	3,879,345	3,762,964	0	0	15,712	0	0	0	1,000	1,136	1,638	0	0	0
Oregon	278,965	299,300	331,055	0	0	731	0	0	0	0	0	0	0	0	0
Washington	546,196	586,832	744,808	0	0	1,202	0	0	0	0	0	0	0	0	0
Alaska	287	103	103	2	0	0	12	3	3	0	0	0	0	0	0
Hawaii	607,114	723,736	723,761	0	0	0	723	0	0	0	0	0	0	0	0
Total ground water	12,507,243	14,455,730	15,784,412	158,089	295,120	362,154	54,864	50,982	45,063	128,004	144,680	145,027	214,877	189,833	230,059

See footnote at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State[1] —Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 kWh			1,000 gallons						1,000 MCF			1,000 gallons		
Surface water:															
Northeast:	3,408	2,867	2,818	718	947	1,125	2,259	1,964	1,865	0	0	0	333	253	342
Connecticut	120	151	55	34	37	26	85	110	39	0	0	0	0	4	65
Delaware	182	148	137	52	74	164	97	39	49	0	0	0	40	9	0
Maine	101	0	0	29	13	14	72	40	40	0	0	0	0	0	0
Maryland	481	389	523	182	374	452	170	321	288	0	0	0	142	103	142
Massachusetts	581	570	570	0	0	0	395	382	383	0	0	0	79	84	84
New Hampshire	90	106	106	26	28	29	64	76	76	0	0	0	0	0	0
New Jersey	907	638	639	128	180	181	749	414	414	0	0	0	67	47	47
New York	519	436	360	195	164	186	306	257	254	0	0	0	0	0	0
Pennsylvania	352	350	351	51	51	51	268	267	267	0	0	0	5	4	5
Rhode Island	45	47	47	13	13	13	32	33	34	0	0	0	0	0	0
Vermont	30	31	31	9	8	9	21	21	22	0	0	0	0	0	0
Lake States:	36,528	26,490	35,450	828	2,451	3,973	310	493	1,710	0	0	0	115	42	340
Michigan	13,765	13,773	20,703	243	243	1,487	101	101	1,396	0	0	0	0	0	145
Minnesota	5,381	8,431	10,547	277	424	604	81	154	67	0	0	0	115	42	194
Wisconsin	17,382	4,286	4,200	307	1,783	1,881	128	237	248	0	0	0	0	0	0
Corn Belt:	3,170	6,688	8,529	247	1,678	2,199	621	1,044	1,005	0	115	16	553	641	1,196
Illinois	0	285	387	0	50	36	0	227	171	0	0	16	0	121	221
Indiana	464	2,905	2,594	61	219	298	219	411	201	0	0	0	246	428	96
Iowa	268	710	2,887	44	157	35	63	113	341	0	3	0	10	0	0
Missouri	868	616	486	78	1,163	1,742	128	0	0	0	112	0	230	0	788
Ohio	1,571	2,169	2,170	63	87	88	212	292	293	0	0	0	66	91	91
Northern Plains:	39,973	115,611	133,896	2,092	12,063	11,042	1,637	810	708	0	588	591	9,898	7,971	8,966
Kansas	1,453	1,746	2,279	274	1,440	1,557	0	0	0	0	0	0	428	1,310	1,709
Nebraska	9,543	57,010	56,490	0	6,451	5,499	1,126	224	215	0	588	591	6,567	3,362	3,762
North Dakota	1,621	3,437	4,013	32	71	42	15	0	0	0	0	0	6	0	0
South Dakota	27,356	53,418	71,114	1,786	4,100	3,945	497	586	494	0	0	0	2,896	3,297	3,495
Appalachia:	18,344	2,566	5,574	336	1,819	4,014	1,173	3,172	3,784	0	3	4	98	59	261
Kentucky	0	0	0	45	43	44	317	309	310	0	0	0	0	0	0
North Carolina	17,247	1,144	2,847	90	1,078	2,953	113	1,214	1,455	0	0	0	0	0	139
Tennessee	470	540	490	66	75	96	111	118	204	0	3	4	35	0	39
Virginia	575	812	2,233	122	612	921	578	1,485	1,811	0	0	0	64	59	82
West Virginia	52	69	5	12	8	0	54	43	3	0	0	0	0	0	0

See footnote at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State[1] —Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 kWh			*1,000 gallons*						*1,000 MCF*			*1,000 gallons*		
Surface water:															
Southeast:	25,685	42,597	92,295	6,205	25,593	22,029	1,384	9,514	3,072	0	11	12	568	5,654	2,390
Alabama	406	751	2,005	102	677	3,251	128	215	236	0	11	12	20	31	118
Florida	17,902	23,516	19,477	5,064	7,862	6,512	0	0	0	0	0	0	0	0	0
Georgia	991	17,597	65,702	888	16,212	10,393	1,257	8,996	2,500	0	0	0	548	5,622	2,188
South Carolina	6,388	733	5,111	151	841	1,874	0	302	335	0	0	0	0	0	84
Delta States:	13,079	18,754	13,134	2,146	3,407	5,554	1,837	1,527	806	96	66	64	2,305	1,276	319
Arkansas	6,602	11,973	377	467	1,896	533	974	960	89	0	0	6	1,947	1,130	56
Louisiana	4,892	3,357	9,272	1,230	865	4,309	770	554	703	96	66	59	241	99	195
Mississippi	1,585	3,423	3,485	448	645	712	94	12	14	0	0	0	117	47	69
Southern Plains:	121,171	145,315	107,940	1,122	2,535	2,746	477	1,010	810	3,574	3,536	2,658	6,420	8,952	7,993
Oklahoma	0	11,258	8,469	360	1,769	2,178	0	531	454	0	121	125	2,251	4,759	4,882
Texas	121,171	134,057	99,472	762	766	569	477	479	356	3,574	3,414	2,534	4,169	4,193	3,111
Mountain:	592,044	645,509	661,343	3,785	4,208	4,961	909	1,077	2,003	4	3	19	2,356	2,461	1,246
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	1,833	1,896	4,000	0	0	0	0	0	10	0	0	0	0	0	12
Idaho	294,091	305,712	305,712	830	863	1,579	362	401	1,317	0	0	0	0	0	0
Montana	123,959	159,693	241,883	1,513	1,751	2,622	516	657	656	0	0	0	215	273	410
Nevada	8,134	14,736	14,738	197	347	347	12	0	0	0	0	0	15	0	0
New Mexico	4,504	3,945	11,322	0	0	0	0	0	0	4	3	9	0	0	0
Utah	153,205	153,205	68,076	1,189	1,189	365	0	0	0	0	0	0	2,126	2,126	799
Wyoming	6,320	6,320	15,612	56	56	49	18	18	20	0	0	10	55	55	25
Pacific:	1,372,975	1,467.438	1,679.218	69	898	0	0	0	0	0	0	0	0	0	0
California	232,424	250,411	250,411	69	898	0	0	0	0	0	0	0	0	0	0
Oregon	466,180	496,528	534,165	0	0	0	0	0	0	0	0	0	0	0	0
Washington	674,372	720,498	894,642	0	0	0	0	0	0	0	0		0	0	0
Alaska	63	69	69	0	0	0	3	2	2	0	0	0	0	0	0
Hawaii	192	1,791	1,792	0	0	0	0	0	0	0	0	0	0	0	0
Total surface water	2,226,633	2,475,695	2,742.058	17,548	55,599	57,643	10,611	20,613	15,765	3,673	4,323	3,364	22,645	27,309	23,053
Total ground water and surface water	14,733,876	16,931,425	18,526,460	175,637	350,719	419,797	65,475	77,652	60,825	131,677	149,003	148,391	237,522	217,142	252,614

[1]Total may not add due to rounding.

Appendix table 6—Quantity of energy used per acre for onfarm pumped irrigation water, by region and State

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	kWh			*Gallons*						*MCF*			*Gallons*		
Ground water:															
Northeast:	427.71	356.70	359.26	35.05	34.10	35.29	53.32	41.99	41.04	0	0	5.86	63.45	58.57	68.12
Connecticut	199.79	201.24	201.24	0	18.98	18.98	23.57	23.74	23.74	0	0	0	29.46	29.68	29.68
Delaware	341.43	377.90	358.03	32.20	35.64	33.76	40.28	44.58	42.24	0	0	0	50.35	55.73	0
Maine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maryland	349.14	359.94	532.18	32.88	41.11	50.18	41.14	51.43	62.78	0	0	0	51.42	64.29	78.48
Massachusetts	198.56	201.24	201.24	0	0	0	23.42	23.74	23.74	0	0	0	29.28	29.68	29.68
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Jersey	551.72	397.40	397.41	52.03	37.48	37.48	65.09	46.88	46.88	0	0	5.86	81.36	58.60	58.60
New York	226.51	228.13	226.31	21.36	21.51	21.34	26.72	26.91	26.70	0	0	0	0	0	0
Pennsylvania	285.77	287.82	287.83	26.95	27.14	27.14	33.71	33.96	33.96	0	0	0	42.14	42.44	42.44
Rhode Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake States:	436.62	541.02	534.76	42.41	52.16	50.06	52.49	61.90	57.48	0	0	0	70.38	81.91	76.98
Michigan	427.53	429.45	464.40	40.32	40.50	43.79	50.44	50.67	54.79	0	0	0	0	0	68.48
Minnesota	477.29	495.54	490.42	45.01	46.73	46.25	56.31	58.46	57.86	0	0	0	70.38	73.08	72.32
Wisconsin	421.11	662.55	661.99	39.71	62.48	62.43	49.68	78.17	78.10	0	0	0	0	97.71	97.62
Corn Belt:	214.30	262.51	320.55	20.90	20.69	24.20	30.14	37.88	41.69	3.51	3.15	2.02	33.14	30.39	24.64
Illinois	354.34	294.55	355.40	33.42	27.78	33.51	41.80	34.75	41.93	0	0	0	52.25	43.44	0
Indiana	532.02	640.24	470.80	50.17	60.38	44.40	62.77	75.53	55.54	7.85	9.44	0	78.46	94.41	69.42
Iowa	189.12	275.10	355.42	17.83	25.94	33.52	22.31	32.46	41.93	0	0	0	27.89	40.57	52.41
Missouri	159.67	149.91	137.18	15.06	14.14	12.94	18.84	17.69	16.18	2.35	2.21	2.02	23.55	22.11	0
Ohio	302.47	303.04	303.05	28.52	28.58	28.58	35.68	35.75	35.75	0	0	0	44.60	44.69	44.69
Northern Plains:	663.83	631.50	717.82	62.41	69.09	66.74	80.24	83.09	81.17	10.52	11.71	11.09	98.32	108.50	105.09
Kansas	733.49	393.50	334.85	69.17	80.23	75.11	86.54	0	0	10.82	12.55	11.75	108.17	125.47	117.46
Nebraska	656.05	705.09	687.35	61.87	66.49	64.82	77.40	83.18	81.09	9.67	10.40	10.14	96.75	103.98	101.36
North Dakota	607.08	636.39	591.16	57.26	60.01	55.75	71.64	75.08	69.74	0	0	0	89.55	0	0
South Dakota	668.93	748.99	835.85	63.08	70.63	78.82	78.92	88.36	98.61	0	0	0	98.64	110.45	123.26
Appalachia:	298.80	318.74	364.26	26.83	34.49	35.71	30.07	44.41	44.74	4.72	4.88	5.41	40.61	56.11	54.10
Kentucky	0	0	0	14.61	14.47	14.48	18.28	18.11	18.12	0	0	0	0	0	0
North Carolina	299.14	299.14	359.85	28.21	28.21	33.93	35.29	35.29	0	0	0	0	0	0	0
Tennessee	320.29	331.16	366.85	30.20	31.23	34.59	37.79	39.07	43.28	4.72	4.88	5.41	47.23	48.83	54.10
Virginia	230.50	466.85	412.55	21.74	44.03	38.90	27.19	55.08	48.67	0	0	0	33.99	68.84	0
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued—

Appendix table 6—Quantity of energy used per acre for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	kWh			*Gallons*						*MCF*			*Gallons*		
Ground water:															
Southeast:	358.18	533.19	708.40	34.03	60.67	67.94	45.13	94.50	90.01	3.63	0	0	52.50	87.88	88.68
Alabama	246.40	466.27	440.70	23.24	43.97	41.56	29.07	55.01	0	3.63	0	0	36.34	68.20	64.99
Florida	347.64	503.92	504.17	32.78	47.52	47.54	41.01	59.45	59.48	0	0	0	51.26	74.31	74.35
Georgia	476.83	1,331.84	1,159.07	46.45	113.62	109.30	58.11	142.14	136.74	0	0	0	72.63	0	170.92
South Carolina	670.54	606.77	645.41	63.24	57.22	60.86	0	0	0	0	0	0	0	0	0
Delta States:	287.42	297.86	436.28	34.17	28.98	41.29	32.87	39.37	57.37	4.93	5.28	7.08	37.17	43.81	60.23
Arkansas	239.87	292.83	442.74	22.62	27.61	41.75	28.30	34.55	52.23	3.54	4.32	6.53	35.37	43.18	65.29
Louisiana	430.91	438.19	529.29	40.64	41.32	49.91	50.84	51.70	62.44	6.35	6.42	7.81	63.55	64.62	78.05
Mississippi	428.84	262.63	323.71	39.62	24.77	30.53	49.56	30.99	38.19	0	0	0	61.95	38.73	47.74
Southern Plains:	764.67	778.45	817.59	76.87	80.09	88.11	93.32	95.51	101.50	11.30	11.52	12.13	116.64	123.93	120.64
Oklahoma	926.04	1,228.99	1,217.15	87.33	103.92	114.78	109.25	103.01	143.59	13.66	16.25	0	136.56	162.51	179.48
Texas	753.47	755.20	784.96	71.06	71.22	74.02	88.89	89.10	92.60	11.11	11.14	11.58	111.11	111.37	115.75
Mountain:	1,438.13	1,620.74	2,817.41	159.26	114.03	60.46	165.28	112.69	90.56	29.27	31.12	31.03	253.30	86.63	153.75
Arizona	2,965.21	4,259.66	4,522.88	0	0	0	0	0	0	43.73	62.82	66.70	0	0	0
Colorado	390.35	368.69	423.21	36.81	43.01	39.91	46.05	53.81	49.93	5.76	6.73	6.24	57.56	67.26	62.41
Idaho	1,253.04	1,253.04	1,253.34	118.17	118.17	118.17	147.07	147.07	147.07	0	0	0	0	0	0
Montana	1,119.88	1,519.27	1,531.10	105.61	143.27	144.38	132.12	179.24	225.78	16.51	0	0	165.14	224.04	225.07
Nevada	2,451.88	1,285.63	1,285.67	231.24	121.24	121.24	289.27	0	0	0	0	0	361.57	0	0
New Mexico	2,132.77	1,663.57	1,790.00	201.13	156.88	168.80	251.62	196.26	211.17	31.45	24.53	0	314.51	245.32	263.96
Utah	2,294.30	2,294.30	1,878.23	216.36	216.36	177.12	0	0	0	0	0	0	0	338.33	276.97
Wyoming	1,182.49	1,180.56	1,160.09	111.51	111.33	109.40	139.51	139.28	136.86	17.44	17.41	17.11	174.38	174.00	171.07
Pacific:	1,104.18	1,104.18	1,036.60	0	0	0	0	0	0	13.69	15.00	0	0	0	0
California	882.04	882.04	928.90	0	0	0	0	0	0	13.69	15.00	0	0	0	0
Oregon	1,134.00	1,134.00	1,145.52	0	0	0	0	0	0	0	0	0	0	0	0
Washington	2,257.00	2,257.00	2,284.69	0	0	0	0	0	0	0	0	0	0	0	0
Alaska	136.60	128.91	128.91	12.88	0	0	16.12	15.21	0	0	0	0	0	0	0
Hawaii	8,760.69	0	9,138.39	0	0	0	1,033.60	0	0	0	0	0	0	0	0

Continued—

Appendix table 6—Quantity of energy used per acre for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	kWh			*Gallons*						*MCF*			*Gallons*		
Surface water:															
Northeast:	204.54	194.54	202.01	20.63	23.54	24.74	23.92	22.20	22.19	0	0	0	34.81	33.63	32.63
Connecticut	151.83	151.09	156.40	14.32	14.25	14.75	17.91	17.83	18.45	0	0	0	0	22.28	23.06
Delaware	306.63	335.55	327.04	28.92	31.64	30.84	36.18	39.59	38.58	0	0	0	45.22	49.48	0
Maine	146.09	0	0	13.78	6.53	6.53	17.24	8.16	8.16	0	0	0	0	0	0
Maryland	303.90	486.68	484.65	28.66	45.90	45.70	35.85	57.42	57.18	0	0	0	44.82	71.77	71.47
Massachusetts	141.02	141.45	141.46	0	0	0	16.64	16.69	16.69	0	0	0	20.80	20.86	20.86
New Hamsphire	151.83	150.99	151.10	14.32	14.24	14.25	17.91	17.81	17.83	0	0	0	0	0	0
New Jersey	295.46	212.82	212.83	27.86	20.07	20.07	34.86	25.11	25.11	0	0	0	43.57	31.38	31.38
New York	180.55	181.85	179.74	17.03	17.51	16.95	21.30	21.45	21.20	0	0	0	0	0	0
Pennsylvania	189.16	187.53	187.55	17.92	17.69	17.69	22.42	22.13	22.13	0	0	0	28.02	27.66	27.66
Rhode Island	151.83	158.14	158.14	14.32	14.91	14.91	17.91	18.66	18.66	0	0	0	0	0	0
Vermont	151.83	152.92	152.93	14.32	14.42	14.42	17.91	18.04	18.04	0	0	0	0	0	0
Lake States:	320.80	345.57	355.57	26.61	42.35	38.73	34.96	46.86	44.18	0	0	0	29.15	47.63	48.47
Michigan	323.40	324.86	359.80	30.50	30.64	33.93	38.15	38.33	42.45	0	0	0	0	0	53.06
Minnesota	197.66	323.02	308.76	18.64	30.46	29.12	23.32	38.11	36.43	0	0	0	29.15	47.63	45.53
Wisconsin	394.33	525.28	524.99	37.19	49.54	49.51	46.52	61.97	61.94	0	0	0	0	0	0
Corn Belt:	152.86	314.73	291.18	13.73	32.46	26.58	20.57	35.93	34.86	0	5.24	5.48	20.33	58.33	42.44
Illinois	0	274.80	371.65	0	25.92	35.05	0	32.42	43.85	0	0	5.48	0	40.52	54.80
Indiana	325.49	581.17	289.45	30.69	54.81	27.30	38.40	68.57	34.15	0	0	0	48.00	85.70	42.68
Iowa	178.42	236.75	409.53	16.83	22.32	38.62	21.05	27.93	48.31	0	3.49	0	26.31	0	0
Missouri	379.21	360.66	282.57	7.47	34.01	26.65	9.43	0	0	0	5.32	0	11.68	0	41.67
Ohio	229.00	206.62	206.63	21.60	19.48	19.48	27.02	24.38	24.38	0	0	0	33.77	30.47	30.47
Northern Plains:	282.72	537.05	552.01	38.55	47.47	47.20	19.82	77.93	73.65	0	6.37	7.38	24.38	76.79	61.03
Kansas	110.89	179.08	132.16	10.46	34.93	38.97	0	0	0	0	0	0	16.35	54.62	60.94
Nebraska	125.83	431.89	414.15	0	40.73	39.05	14.84	50.95	48.86	0	6.37	7.38	18.55	63.69	61.07
North Dakota	394.82	381.10	444.89	8.94	35.94	41.95	11.19	0	0	0	0	0	13.98	0	0
South Dakota	773.96	828.20	801.38	72.99	78.10	75.57	91.31	97.79	94.54	0	0	0	114.13	122.13	120.21
Appalachia:	186.22	252.57	345.56	18.04	23.32	31.11	21.29	29.70	36.56	0	3.16	3.70	32.90	63.73	49.18
Kentucky	0	0	0	11.59	11.20	11.20	14.49	14.01	14.01	0	0	0	0	0	0
North Carolina	184.35	208.00	316.28	17.38	19.61	29.83	21.75	24.54	37.31	0	0	0	0	0	46.64
Tenessee	215.62	214.51	251.14	20.33	20.23	23.68	25.44	25.31	29.63	0	3.16	3.70	31.80	0	37.03
Virginia	227.40	432.16	443.04	21.44	40.75	41.78	26.83	50.99	52.27	0	0	0	33.53	63.73	65.33
West Virginia	215.09	265.51	232.96	20.28	25.04	33.11	25.38	31.32	33.89	0	0	0	0	0	0

Continued—

Appendix table 6—Quantity of energy used per acre for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	kWh			*Gallons*						*MCF*			*Gallons*		
Surface water:															
Southeast:	109.75	180.93	314.33	9.23	25.20	23.90	25.05	95.20	73.05	0	5.27	6.22	31.96	123.70	93.68
Alabama	160.62	357.56	422.01	15.15	33.72	39.80	18.95	42.18	49.79	0	5.27	6.22	23.69	52.73	62.23
Florida	86.95	111.34	108.36	8.20	10.50	10.22	0	0	0	0	0	0	0	0	0
Georgia	219.51	845.21	656.16	20.70	79.71	61.88	25.90	99.72	77.41	0	0	0	32.37	124.64	96.76
South Carolina	302.45	555.58	567.90	28.52	52.39	53.55	0	65.55	0	0	0	0	0	0	83.74
Delta States:	102.32	126.38	158.72	9.18	11.24	15.31	12.25	13.89	20.14	1.45	1.20	2.59	15.96	21.53	21.65
Arkansas	111.52	159.65	100.41	10.52	15.06	9.47	13.16	18.83	11.85	0	0	1.48	16.44	23.54	14.81
Louisiana	98.05	81.08	189.23	9.25	7.65	17.84	11.57	9.57	22.32	1.45	1.20	2.79	14.46	11.96	27.90
Mississippi	84.68	106.99	116.17	7.99	10.09	10.95	9.99	12.62	13.70	0	0	0	12.49	15.78	17.13
Southern Plains:	278.24	292.66	288.19	30.32	43.33	47.43	32.83	46.81	47.77	4.10	4.21	4.17	48.11	58.78	62.32
Oklahoma	0	636.07	641.55	45.22	59.98	60.50	0	75.84	75.69	0	9.38	9.46	70.72	93.80	94.60
Texas	278.24	279.97	275.28	26.24	26.40	25.96	32.83	33.03	32.48	4.10	4.13	4.06	41.03	41.29	40.59
Montain:	375.79	351.21	782.62	46.71	69.37	72.26	55.13	81.87	95.97	1.63	1.42	3.67	48.03	136.26	108.93
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	62.16	67.93	69.45	0	0	0	7.33	8.01	8.19	0	0	0	0	10.02	10.24
Idaho	556.99	556.99	638.02	52.44	52.44	94.49	73.14	73.14	118.21	0	0	0	0	0	0
Montana	512.01	587.63	714.72	48.28	55.42	67.40	60.40	69.33	84.32	0	0	0	75.50	86.66	105.39
Nevada	303.04	541.80	541.82	28.58	51.09	51.09	35.75	0	0	0	0	0	44.69	0	0
New Mexico	110.79	96.60	277.17	0	0	0	0	0	0	1.63	1.42	4.09	0	0	0
Utah	1,099.03	1,099.03	967.01	103.64	103.64	91.19	0	0	0	0	0	0	162.07	162.07	142.60
Wyoming	148.13	148.13	148.13	13.97	13.97	13.97	17.48	17.48	17.48	0	0	3.37	21.84	21.84	21.84
Pacific:	752.02	752.02	816.30	19.24	99.86	0	0	0	0	0	0	0	0	0	0
California	611.64	611.64	616.79	19.24	99.86	0	0	0	0	0	0	0	0	0	0
Oregon	723.87	723.87	730.73	0	0	0	0	0	0	0	0	0	0	0	0
Washington	962.01	962.01	972.43	0	0	0	0	0	0	0	0	0	0	0	0
Alaska	90.68	86.44	86.44	0	0	0	10.70	10.20	0	0	0	0	0	0	0
Hawaii	649.64	301.67	301.67	0	0	0	0	0	0	0	0	0	0	0	0

Appendix table 7—Total cost of energy for onfarm pumped irrigation water, by region and State[1]

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 dollars														
Ground water:															
Northeast:	148	217	252	463	1,023	2,310	2,150	1,583	2,425	0	0	604	204	148	134
Connecticut	1	1	1	0	5	5	9	17	9	0	0	0	1	0	9
Delaware	18	47	46	73	276	953	178	125	358	0	0	0	48	23	0
Maine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maryland	7	18	63	40	174	770	48	168	301	0	0	0	28	34	121
Massachusetts	1	1	2	0	0	0	9	9	21	0	0	0	1	1	3
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
New Jersey	104	119	91	246	430	284	1,674	1,025	1,245	0	0	604	125	87	0
New York	17	27	46	100	131	289	208	214	435	0	0	0	0	0	0
Pennsylvania	2	2	4	3	4	9	23	26	56	0	0	0	0	0	0
Rhode Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake States:	1,766	7,123	17,119	771	4,211	16,408	364	1,221	4,592	0	0	0	143	359	1,053
Michigan	441	673	2,738	122	163	3,246	72	71	3,600	0	0	0	0	0	196
Minnesota	473	3,662	8,709	410	2,220	7,505	155	823	306	0	0	0	143	205	569
Wisconsin	852	2,787	5,671	240	1,827	5,656	137	326	686	0	0	0	0	153	288
Corn Belt:	239	1,145	4,315	438	1,868	8,080	1,335	1,288	1,596	4	12	13	722	1,058	1,733
Illinois	47	52	1,327	117	90	2,169	492	340	133	0	0	0	165	104	0
Indiana	22	301	869	51	355	676	239	287	560	2	5	0	157	243	95
Iowa	42	495	1,634	112	604	3,253	210	526	571	0	0	0	20	54	351
Missouri	100	227	383	140	786	1,915	310	21	64	3	6	13	364	626	1,238
Ohio	28	67	102	18	31	67	86	114	268	0	0	0	16	28	49
Northern Plains:	18,986	65,733	87,282	31,857	81,839	168,992	2,687	2,614	6,697	19,163	34,501	96,890	30,306	29,631	67,969
Kansas	2,300	6,096	10,789	2,866	17,018	30,951	911	0	0	14,538	19,185	60,705	4,410	6,962	15,845
Nebraska	16,171	55,636	69,155	28,608	62,961	133,288	1,612	2,480	6,264	4,626	15,315	36,185	25,534	21,878	50,660
North Dakota	289	1,681	2,539	112	321	656	68	70	213	0	0	0	18	0	0
South Dakota	224	2,366	4,766	271	1,538	4,097	95	65	221	0	0	0	344	789	1,464
Appalachia:	40	107	240	33	153	380	101	167	462	1	1	14	8	156	36
Kentucky	0	0	0	1	1	3	7	7	17	0	0	0	0	0	0
North Carolina	30	79	194	3	46	77	4	10	0	0	0	0	0	0	0
Tennessee	9	13	30	22	32	141	44	48	100	1	1	14	5	149	36
Virginia	2	13	16	7	72	159	45	101	345	0	0	0	4	6	0
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See footnote at end of table.

Continued—

Appendix table 7—Total cost of energy for onfarm pumped irrigation water, by region and State[1]—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
							1,000 dollars								
Ground water:															
Southeast:	2,764	9,072	25,797	4,710	16,583	75,770	2,792	6,325	17,067	1	0	0	3,744	4,379	20,339
Alabama	6	63	262	29	356	1,301	42	140	0	1	0	0	3	61	127
Florida	2,570	8,133	13,159	4,076	9,204	33,504	1,851	2,105	6,641	0	0	0	3,445	4,317	15,135
Georgia	35	748	11,911	537	6,755	39,944	900	4,080	10,426	0	0	0	296	0	5,077
South Carolina	154	127	465	69	267	1,021	0	0	0	0	0	0	0	0	0
Delta States:	2,379	7,623	30,450	5,076	10,610	33,469	6,684	4,329	3,500	510	801	2,090	7,125	4,072	1,633
Arkansas	1,478	5,739	26,731	1,045	6,224	13,590	4,556	2,757	1,060	186	544	857	6,339	3,627	685
Louisiana	484	522	1,171	1,990	2,218	12,362	1,590	1,527	2,269	324	256	1,233	324	275	413
Mississippi	418	1,361	2,548	2,041	2,167	7,517	538	45	171	0	0	0	462	140	534
Southern Plains:	26,432	43,209	61,794	3,022	3,880	9,593	3,811	4,889	9,958	49,758	90,753	168,810	12,588	20,623	29,620
Oklahoma	2,078	4,102	6,946	1,247	1,365	4,369	1,003	1,044	2,507	4,457	8,968	21,758	3,120	6,643	10,015
Texas	24,354	39,106	54,848	1,775	2,514	5,224	2,808	3,845	7,451	45,301	81,785	147,052	9,468	13,980	19,605
Mountain:	84,142	118,031	234,880	9,382	10,411	31,623	5,289	3,772	5,758	25,816	53,869	90,556	6,817	2,265	16,351
Arizona	36,351	58,019	132,009	0	0	0	0	0	0	10,824	27,456	48,587	0	0	0
Colorado	7,642	12,461	21,820	424	538	1,324	138	154	351	3,525	5,459	12,010	534	718	1,010
Idaho	22,174	23,078	43,272	1,303	1,833	3,993	780	845	1,994	0	0	0	589	0	0
Montana	509	1,053	2,670	207	424	1,110	330	414	1,150	5	0	0	20	76	157
Nevada	4,877	5,245	8,743	3,145	1,854	4,369	246	0	0	0	0	0	197	0	0
New Mexico	6,965	9,103	17,147	3,378	4,649	18,096	3,678	2,237	1,970	11,371	20,807	29,682	4,793	559	13,654
Utah	1,755	2,925	3,957	363	408	722	0	0	0	0	0	0	520	649	1,086
Wyoming	3,870	6,146	5,262	562	701	2,009	117	122	293	92	146	277	165	262	443
Pacific:	79,847	173,211	246,137	127	0	17,116	0	0	0	750	1,704	7,158	0	0	0
California	71,851	162,566	225,778	0	0	15,241	0	0	0	750	1,704	7,158	0	0	0
Oregon	3,626	4,190	9,932	127	0	709	0	0	0	0	0	0	0	0	0
Washington	4,369	6,455	10,427	0	0	1,166	0	0	0	0	0	0	0	0	0
Alaska	10	3	8	1	0	0	7	2	0	0	0	0	0	0	0
Hawaii	19,427	36,187	54,282	0	0	0	433	0	0	0	0	0	0	0	0
Total ground water	236,180	461,664	762,556	55,880	130,581	363,743	25,652	26,187	52,056	96,002	181,643	366,135	62,691	62,665	138,868

See footnote at end of table.

Continued—

Appendix table 7—Total cost of energy for onfarm pumped irrigation water, by region and State[1]—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
	1,000 dollars														
Surface water:															
Northeast:	86	121	172	280	474	1,194	1,127	1,044	2,221	0	0	0	119	117	259
Connecticut	3	5	3	13	18	27	43	58	47	0	0	0	0	2	50
Delaware	4	5	8	20	36	179	47	18	59	0	0	0	13	4	0
Maine	3	0	0	11	6	14	37	20	48	0	0	0	0	0	0
Maryland	12	15	32	69	183	493	83	176	349	0	0	0	48	49	110
Massachusetts	15	32	35	0	0	0	202	202	459	0	0	0	28	37	66
New Hampshire	3	5	6	10	15	30	33	41	91	0	0	0	0	0	0
New Jersey	23	25	39	54	92	182	367	219	489	0	0	0	27	21	30
New York	13	17	22	76	83	196	159	136	300	0	0	0	0	0	0
Pennsylvania	9	14	21	19	26	50	129	141	312	0	0	0	2	2	3
Rhode Island	1	2	3	5	6	14	16	17	40	0	0	0	0	0	0
Vermont	1	1	2	3	4	9	11	10	26	0	0	0	0	0	0
Lake States:	840	927	2,232	298	1,110	4,045	152	254	2,015	0	0	0	36	18	207
Michigan	317	482	1,242	88	116	1,473	52	50	1,633	0	0	0	0	0	89
Minnesota	124	295	738	102	191	616	39	77	82	0	0	0	36	18	119
Wisconsin	400	149	252	108	802	1,957	62	126	300	0	0	0	0	0	0
Corn Belt:	73	251	463	90	750	2,106	304	531	1,202	0	5	41	168	258	645
Illinois	0	8	23	0	22	38	0	118	214	0	0	41	0	46	139
Indiana	10	116	157	23	109	295	109	205	237	0	0	0	76	175	57
Iowa	6	21	130	16	66	33	29	61	409	0	5	0	3	0	0
Missouri	20	18	24	28	511	1,655	59	0	0	0	0	0	69	0	385
Ohio	36	86	130	23	40	85	106	146	342	0	0	0	19	36	62
Northern Plains:	800	4,887	6,300	774	5,317	10,918	792	401	858	0	706	1,491	2,910	2,948	5,108
Kansas	29	61	124	101	619	1,526	0	0	0	0	0	0	246	419	940
Nebraska	191	2,565	2,824	0	2,903	5,444	552	114	256	0	706	1,476	1,773	1,176	2,069
North Dakota	32	127	152	12	32	43	7	0	0	0	0	15	52	0	0
South Dakota	547	2,136	3,200	661	1,763	3,905	233	287	602	0	0	0	839	1,352	2,097
Appalachia:	422	105	263	127	862	4,130	571	1,562	4,378	0	0	10	34	25	171
Kentucky	0	0	0	17	20	42	152	154	369	0	0	0	0	0	0
North Carolina	396	51	142	33	507	3,041	55	583	1,688	0	0	0	0	0	92
Tennessee	10	13	20	27	37	98	53	61	235	0	0	10	12	0	26
Virginia	13	36	100	45	294	949	283	742	2,083	0	0	0	22	25	53
West Virginia	1	3	0	4	3	0	27	19	4	0	0	0	0	0	0

See footnote at end of table.

Continued—

Appendix table 7—Total cost of energy for onfarm pumped irrigation water, by region and State[1]—Continued

Region and State	Electricity			Diesel			Gasoline			Natural gas			Liquefied petroleum gas		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974	1977	1980
								1,000 dollars							
Surface water:															
Southeast:	591	1,764	4,778	2,315	11,493	23,204	623	5,219	3,159	0	16	30	193	2,373	1,529
Alabama	10	26	120	39	305	3,186	57	107	284	0	16	30	7	12	73
Florida	412	1,175	1,169	1,874	3,145	7,033	0	0	0	0	0	0	0	0	0
Georgia	23	527	3,285	337	7,606	11,016	566	4,948	2,875	0	0	0	186	2,361	1,400
South Carolina	147	34	204	63	437	1,968	0	163	0	0	0	0	0	0	55
Delta States:	301	751	615	767	1,559	5,373	847	841	928	72	49	248	734	576	206
Arkansas	152	478	17	154	872	495	448	547	103	0	0	14	623	508	33
Louisiana	113	93	371	443	389	4,094	354	288	809	72	49	234	72	49	131
Mississippi	37	177	227	170	297	783	45	6	17	0	0	0	39	18	42
Southern Plains:	2,787	4,359	4,857	385	1,141	2,790	205	555	937	2,680	4,585	6,646	1,839	3,939	5,186
Oklahoma	0	337	381	126	796	2,222	0	292	531	0	146	312	630	2,094	3,319
Texas	2,787	4,021	4,476	259	344	569	205	263	405	2,680	4,439	6,334	1,209	1,845	1,867
Mountain:	9,386	12,865	29,975	1,410	1,881	4,993	468	595	2,390	3	5	52	123	967	830
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	42	116	240	0	0	0	1	2	11	0	0	7	0	1	7
Idaho	4,705	4,891	15,906	307	388	1,547	205	263	1,554	0	0	0	39	0	0
Montana	1,983	2,554	9,675	529	700	2,674	248	295	800	0	0	0	65	0	246
Nevada	121	442	737	79	156	368	6	0	0	0	0	0	4	0	0
New Mexico	90	138	566	0	0	0	0	0	0	0	5	22	0	0	0
Utah	2,298	3,830	2,383	475	535	354	0	0	0	0	0	0	0	871	559
Wyoming	145	895	468	20	102	50	8	35	24	0	0	30	15	95	18
Pacific:	16,102	25,394	56,684	26	449	0	0	0	0	0	0	0	0	0	0
California	4,648	10,517	9,372	26	449	0	0	0	0	0	0	0	0	0	0
Oregon	6,059	6,952	25,060	0	0	0	0	0	0	0	0	0	0	0	0
Washington	5,394	7,925	22,252	0	0	0	0	0	0	0	0	0	0	0	0
Alaska	2	3	5	0	0	0	2	1	0	0	0	0	0	0	0
Hawaii	6	89	134	0	0	0	0	0	0	0	0	0	0	0	0
Total surface water	31,396	51,538	106,487	6,482	25,036	58,752	5,110	11,008	18,087	2,755	5,503	8,518	5,972	11,332	14,140
Total ground water and surface water	267,576	513,202	869,043	62,362	155,617	422,495	30,762	37,195	70,143	98,757	187,146	374,653	67,692	73,951	153,008

[1] Total may not add due to rounding.

Appendix table 8—Prices used for energy cost calculations, by region and State

Region and State	Electricity per kWh			Diesel per gallon			Gasoline per gallon			Natural gas per MCF			Liquefied petroleum gas per gallon		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974[1]	1977	1980	1974	1977	1980
								Dollars							
Northeast:															
Connecticut	0.025	0.040	0.061	0.39	0.51	1.04	0.51	0.53	1.20	0	0	0	0.36	0.45	0.78
Delaware	0.25	.040	.061	.38	.49	1.09	.49	.47	1.20	0	0	0	.32	.45	.78
Maine	0.25	.040	0	.39	.50	0	.51	.50	0	0	0	0	.36	0	0
Maryland	.025	.040	.060	.38	.49	1.09	.49	.55	1.21	0	0	0	.34	.48	.78
Massachusetts	.025	.040	.061	.39	.51	1.04	.51	.53	1.20	0	0	0	.36	.45	.78
New Hampshire	.025	.050	0	.39	.52	0	.51	.55	0	0	0	0	.36	0	0
New Jersey	.025	.040	.061	.42	.51	1.01	.49	.53	1.18	0	0	2.50	.41	.45	.63
New York	.025	.040	.061	.39	.51	1.05	.52	.53	1.18	0	0	0	.36	.45	0
Pennsylvania	.025	.040	.061	.37	.51	.97	.48	.53	1.17	0	0	0	.40	.45	.68
Rhode Island	.025	.040	0	.39	.51	0	.51	.53	0	0	0	0	.36	0	0
Vermont	.025	.040	0	.39	.52	0	.51	.50	0	0	0	0	.36	0	0
Lake States:															
Michigan	.023	.035	.060	.36	.48	.99	.51	.50	1.17	0	0	0	.31	0	.61
Minnesota	.023	.035	.070	.37	.45	1.02	.48	.50	1.23	0	0	0	.31	.43	.61
Wisconsin	.023	.035	.060	.35	.45	1.04	.48	.53	1.21	0	0	0	.32	.43	.61
Corn Belt:															
Illinois	.023	.030	.060	.39	.45	1.04	.48	.52	1.25	0	0	0	.30	.38	.63
Indiana	.023	.040	.060	.38	.50	.99	.50	.50	1.18	0	1.50	2.50	.31	.41	.60
Iowa	.023	.030	.045	.36	.42	.95	.47	.54	1.20	0	1.90	2.50	.29	.38	.59
Missouri	.023	.030	.045	.36	.44	.96	.46	.46	1.20	0	1.20	2.50	.30	.42	.60
Ohio	.023	.040	.060	.36	.46	.97	.50	.50	1.17	0	0	0	.30	.40	.68
Northern Plains:															
Kansas	.020	.035	.055	.37	.43	.98	.47	.50	1.16	0	.80	2.50	.26	.32	.55
Nebraska	.020	.045	.050	.34	.45	.99	.49	.51	1.19	0	1.20	2.50	.27	.35	.55
North Dakota	.020	.037	.038	.37	.45	1.03	.48	.55	1.20	0	0	2.50	.30	0	.59
South Dakota	.020	.040	.045	.37	.43	1.05	.47	.49	1.13	0	0	2.50	.29	.41	.60
Appalachia:															
Kentucky	.023	.029	.045	.38	.46	.96	.48	.50	1.19	0	0	0	.33	.45	.66
North Carolina	.023	.045	.050	.37	.47	1.03	.49	.48	1.16	0	0	0	.31	0	.66
Tennessee	.023	.025	.040	.40	.50	1.02	.48	.52	1.15	0	0	2.50	.34	.38	.67
Virginia	.023	.045	.045	.37	.48	1.03	.49	.50	1.15	0	0	0	.35	.42	.64
West Virginia	.023	.055	0	.37	.45	0	.49	.45	0	0	0	0	.35	0	0

See footnote at end of table.

Continued—

Appendix table 8—Prices used for energy cost calculations, by region and State—Continued

Region and State	Electricity per kWh			Diesel per gallon			Gasoline per gallon			Natural gas per MCF			Liquefied petroleum gas per gallon		
	1974	1977	1980	1974	1977	1980	1974	1977	1980	1974[1]	1977	1980	1974	1977	1980
	Dollars														
Southeast:															
Alabama	0.023	0.035	0.060	0.39	0.45	0.98	0.45	0.50	1.20	0	1.50	0	0.34	0.39	0.62
Florida	.023	.050	.060	.37	.40	1.08	.47	.47	1.10	0	.90	2.50	.35	.37	.78
Georgia	.023	.030	.050	.38	.50	1.06	.45	.55	1.15	0	0	0	.34	.42	.64
South Carolina	.023	.035	.040	.42	.52	1.05	.47	.54	0	0	0	0	.35	.50	0
Delta States:															
Arkansas	.023	.040	.046	.33	.46	.93	.46	.57	1.16	0	1.80	2.50	.32	.45	.60
Louisiana	.023	.028	.040	.36	.45	.95	.46	.52	1.15	0	.75	4.00	.30	.50	.67
Mississippi	.023	.052	.065	.38	.46	1.10	.48	.48	1.22	0	0	0	.33	.40	.61
Southern Plains:															
Oklahoma	.023	.030	.045	.35	.45	1.02	.45	.55	1.17	0	1.20	2.50	.28	.44	.68
Texas	.023	.030	.045	.34	.45	1.00	.43	.55	1.14	0	1.30	2.50	.29	.44	.60
Mountain:															
Arizona	.020	.021	.045	.37	0	1.05	.48	0	1.17	0	1.50	2.50	.30	0	.73
Colorado	.023	.035	.060	.36	.45	1.01	.46	.52	1.16	0	1.15	2.50	.29	.39	.59
Idaho	.016	.016	.030	.37	.45	.98	.48	.50	1.18	0	0	2.00	.29	0	.63
Montana	.016	.016	.040	.35	.40	1.02	.48	.45	1.22	0	0	0	.30	.35	.60
Nevada	.015	.030	.050	.40	.45	1.06	.50	0	0	0	0	0	.32	0	0
New Mexico	.020	.035	.050	.36	0	.99	.47	0	1.12	0	1.80	2.50	.28	.41	.69
Utah	.015	.025	.035	.40	.45	.97	.50	0	1.16	0	0	0	.32	.41	.70
Wyoming	.023	.035	.030	.36	.45	1.02	.48	.50	1.19	0	0	3.00	.27	.43	.72
Pacific:															
California	.020	.042	.060	.37	.50	.97	.48	0	0	0	0	4.37	.30	0	0
Oregon	.013	.014	.030	.35	0	.97	.46	0	0	0	0	0	.30	0	0
Washington	.008	.011	.014	.35	0	.97	.49	0	0	0	0	0	.30	0	0
Alaska	.032	.040	.075	.30	0	1.15	.60	.70	0	0	0	0	0	0	0
Hawaii	.030	.050	.075	0	.60	0	.60	0	0	0	0	0	0	0	0

[1] Natural gas is assumed to be 75 cents per MCF.

Appendix table 9—Estimated low-pressure center pivot irrigated area, United States, 1980[1]

State	Center pivot irrigated area		State	Center pivot irrigated area	
	All	Low pressure		All	Low pressure
	1,000 acres			*1,000 acres*	
Alabama	44	7	Missouri	114	6
Arkansas	52	41	Nebraska	2,356	236
Arizona	28	5	New Mexico	225	74
Colorado	600	240	North Dakota	117	12
Delaware	21	5	North Carolina	15	4
Georgia	510	357	Oregon	156	8
Idaho	187	10	South Carolina	32	6
Illinois	101	5	South Dakota	226	11
Indiana	38	4	Tennessee	5	1
Iowa	160	6	Texas	570	86
Kansas	988	293	Washington	389	4
Louisiana	86	17	Wisconsin	164	2
Michigan	155	23	Wyoming	86	13
Minnesota	297	45			
Mississippi	29	15	Total	7,751	1,536

[1] Estimated by irrigation specialists in their respectives States.

Appendix table 10—Selected estimates of irrigated land in the United States*

State	U.S. Geological Survey, 1980[1]	*National Resource Inventory,* 1977[2]	*Irrigation Journal,* 1978[3]	*Census of Agriculture,* 1978[4]	*Irrigation Age,* 1979[5]
			1,000 acres		
Alabama	75	37	65	59	77
Arizona	1,319	1,284	1,035	1,211	1,604
Arkansas	1,841	2,468	1,699	1,686	1,108
California	9,734	9,102	9,099	8,604	9,442
Colorado	2,680	4,008	3,030	3,458	3,548
Connecticut	17	8	9	7	7
Delaware	11	37	42	34	37
Florida	2,041	2,683	3,056	1,991	2,133
Georgia	997	676	785	464	512
Idaho	4,047	3,961	3,934	3,508	3,683
Illinois	150	66	110	130	91
Indiana	65	140	71	75	62
Iowa	150	82	180	101	120
Kansas	3,406	3,381	3,417	2,686	3,302
Kentucky	14	9	28	15	22
Louisiana	743	1,211	663	682	642
Maine	11	22	6	7	8
Maryland	33	39	33	29	32
Massachusetts	45	18	3	17	23
Michigan	323	236	334	226	197

See footnotes at end of table.

Continued—

Appendix table 10—Selected estimates of irrigated land in the United States*—Continued

State	U.S. Geological Survey, 1980[1]	*National Resource Inventory,* 1977[2]	*Irrigation Journal,* 1978[3]	*Census of Agriculture,* 1978[4]	*Irrigation Age,* 1979[5]
			1,000 acres		
Minnesota	462	398	434	272	310
Mississippi	482	354	502	310	318
Missouri	240	783	267	344	189
Montana	2,591	2,868	3,114	2,086	2,182
Nebraska	7,099	6,960	7,257	5,698	6,620
Nevada	855	1,218	1,305	899	1,001
New Hampshire	2	0	6	2	2
New Jersey	75	155	174	78	136
New Mexico	1,430	1,536	1,240	904	1,136
New York	58	81	54	56	55
North Carolina	149	278	161	93	89
North Dakota	175	107	150	141	99
Ohio	48	55	43	26	32
Oklahoma	903	844	896	602	628
Oregon	2,000	2,535	1,967	1,920	1,995
Pennsylvania	63	10	19	15	21
Rhode Island	4	0	3	3	3
South Carolina	73	44	50	33	38
South Dakota	387	485	409	341	195
Tennessee	21	36	19	14	10
Texas	7,700	8,565	8,950	7,018	6,802
Utah	1,187	1,300	2,034	1,185	1,142
Vermont	2	7	2	2	1
Virginia	41	88	61	44	42
Washington	1,619	2,000	1,643	1,681	1,870
West Virginia	2	10	2	1	2
Wisconsin	236	340	253	235	242
Wyoming	1,819	1,884	1,790	1,685	1,621
U.S. total	57,425	62,409	60,404	50,678	53,431

*These estimates of acres irrigated include all irrigated land. The indicated acres irrigated in the text of this report are only those acres irrigated with onfarm pumped water. Significant areas are irrigated without the use of onfarm pumps in some States.

Part of the reason for the different estimates of acres irrigated is the different survey years. Most of the surveys are not annual so the same years cannot be compared. The definition of irrigated land also causes some differences. For example, the Census of Agriculture only includes land irrigated in the census year, and the National Resource Inventory land irrigated in 2 of the last 4 years. Other differences may be attributed to sample error.

[1] *Estimated Use of Water in the United States, 1980,* U.S. Geological Survey, preliminary data.
[2] *National Resource Inventory, 1977,* U.S. Dept. Agr., Soil Conservation Service, 1980.
[3] *Irrigation Journal,* Brantwood Publications, Inc., Elm Grove, Wisc., Nov.-Dec. 1979.
[4] *Census of Agriculture, 1978,* U.S. Dept. Commerce, Bureau of the Census.
[5] *Irrigation Age,* Webb publication, 1999 Shepard Road, St. Paul, Minn., Jan. 1982.

Appendix III—State Irrigation Specialists

Alabama: Larry Curtis, Agricultural Engineering, Auburn University, Auburn 36830

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Colorado: Donald L. Miles, Cooperative Extension, Colorado State University, Rocky Ford 81067

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Indiana: Rolland Wheaton, Extension Agricultural Engineering, Purdue University, West Lafayette 47901

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Kentucky: Joseph R. Davis, State Conservation Engineer, USDA, SCS, Lexington 40507

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South Carolina: C. V. Privette, Agricultural Engineering, Clemson University, Clemson 29631

South Dakota: John L. Wiersma, Water Resources Institute, South Dakota State University, Brookings 57006

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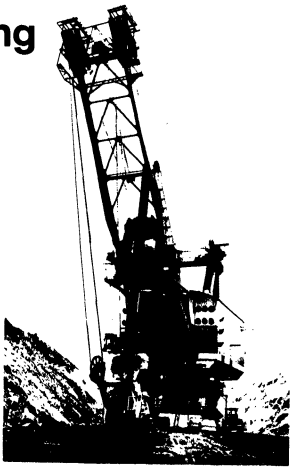
Northern Great Plains Coal Mining



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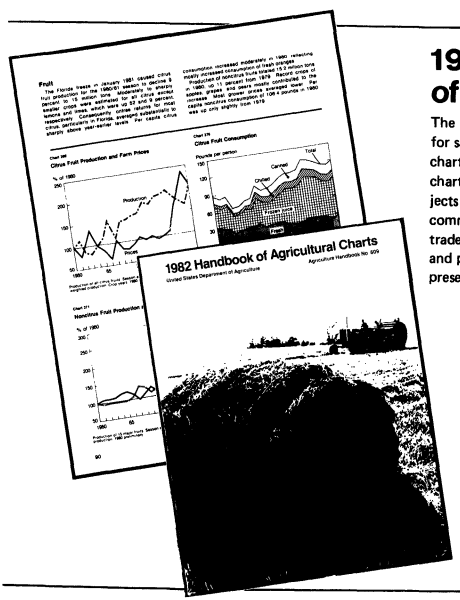

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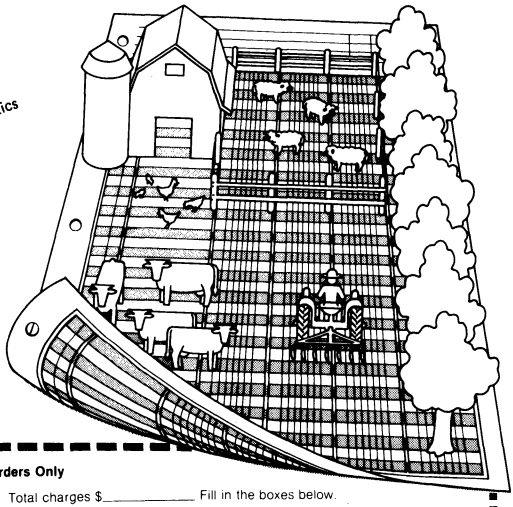

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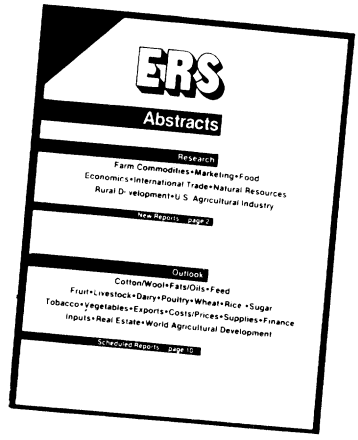

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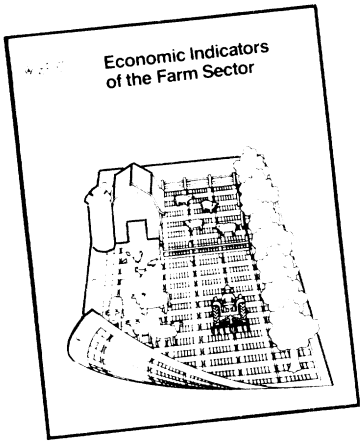

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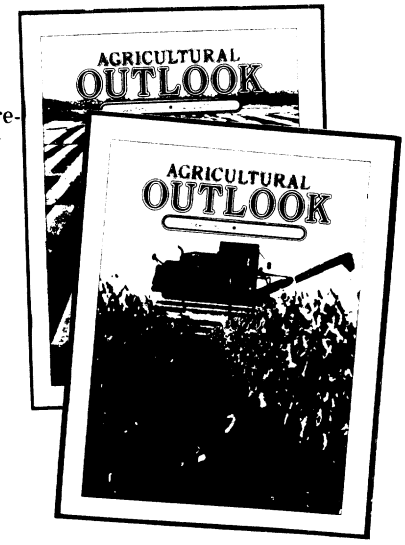

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