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Farm Energy During An Era Of Scarcity*

By John Gostovich

Introduction

MANY PEOPLE think our continued economic prosperity is threatened and, perhaps, doomed as we enter an era of petroleum and natural gas scarcity. From 1950 to 1970, the amount of energy Americans consumed doubled. During this same period, U.S. population increased from 150 to 200 million people, an increment of 33 percent.



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In 1963, all food-related activities in the United States accounted for 12 per cent of the total U.S. energy use. This included all energy used directly and indirectly for farm agricultural production, food processing, transportation, wholesale and retail trade, and household use (cooking, refrigeration, freezing, and food shopping by car). Direct energy use is the energy actually used in the activity; indirect energy is that part of the energy used by other sectors whose output facilitates food-related activities, e.g., fertilizers and herbicides. Food-related energy as a percentage of total U.S. use did not change significantly from 1960 to 1970, indicating that the growth rate of food-related usage is about equal to the growth in total U.S. energy demand.

Today, farming accounts for less than one-fortieth of the nation's total energy demand. By comparison, automobiles in 1970 required nearly six times as much energy as did food production on the farm and accounted for over one-seventh of the total energy used. These figures should help explain why the federal government can promise farmers all the fuel they need.

American agricultural output must continue to grow if people are going to be fed; however, rising energy prices will make farmers and farm policymakers more conscious of agricultural energy requirements. Not only will energy waste have to be identified and curtailed, but energy conservation will be encouraged by high prices and the restricted market that caused them.

Agricultural production, just as any productive activity, combines land, labor, and capital to produce a product for which there is a demand. The amounts of each factor

employed in production are determined by the extent to which its use enhances the value of the product. When high prices are offered for the output, more inputs can be fruitfully employed. When demand falls, input levels are accordingly reduced; if prices offered fall low enough, profitable production becomes impossible, and activity ceases.

Primitive agriculture relied on human labor as its primary input. Rainfall, soil, and sunlight provided the vast majority of the energy required by the crops at no tangible cost. American agriculture is presently capital-, fuel-, and technology-intensive. As agricultural production has developed, additional inputs have displaced human labor, and nonphotosynthetic energy has come to dominate agriculture. Not only fuel for tractors, but fuel for production of tractors, fertilizer, chemical pest control, and electricity must be considered.

Minnesota has no natural deposits of oil, coal, or natural gas to satisfy the ever-growing appetite for fuels. If the United States continues to be plagued with shortages and rising energy costs, state and federal agencies may have to allocate energy. Because fuels had been relatively inexpensive and plentiful, agriculturalists have not gathered much information on farm fuel inputs. This lack of information limits the accuracy of this report. Nevertheless, this report should help place farm use of fuels in crop production in perspective with the state's total fuel requirements. Field corn is studied in detail because it is the state's most valuable crop, the technical aspects of its cultivation are fairly well-known, and its input needs are characteristic of the state's other primary crops.

Field corn in Minnesota

From 1960 to 1970, the acres of Minnesota field corn fell from 5,757,000 to 4,954,000, a decline of 15 per cent. During the same period, the average productivity of corn acreage in the state rose from 38 bushels per acre to 79 bushels per acre, an increase of over 100 per cent. Increasing productivity insured Minnesota corn output could expand 12 per cent while acreage was reduced. Because of favorable prices, corn acreage expanded to nearly 7 million acres last summer.

Use of hybrid seed corn and the availability of relatively inexpensive fertilizer have accounted for the majority of these yield increases. Inputs cannot, however, be isolated from one another in an analysis of production. Hybrid seed corn has been bred to respond well to chemical fertilizer; but the success of the crop also depends on rainfall, effective cultivation, pest control, and prompt harvesting. If the chemical fertilizer is withheld, the hybrid seed will often not do as well as the open-pollinated seed it has replaced. Similarly, today's high yields require greater planting densities which aggravate the problems of insect and weed control.

U.S. average corn yields are approaching 100 bushels per acre, and some farmers have been able to coax 300 bushels per acre out of the land. Tripling of productivity is a hopeful sign, but before such yields can be widely imitated, the economics of energy must be understood.

Input and energy requirements of Minnesota field corn

Corn, soybeans, oats, and hay provide about 80 per cent of the value of Minnesota's total crop output. Field corn has traditionally made up about half of this figure. Because of corn's preeminence, it was chosen for careful examination.

Machinery

The tractor and its attachments have replaced the horse-drawn implement, and as more land is farmed by fewer operators, the size and complexity of tractors have grown. In 1955, the average United States farm worker used 31 horsepower.

By 1965, this became 63 horsepower, an increase of over 100 per cent.

Gasoline

A farm machine, like an automobile, consumes far more energy in its lifetime than the energy utilized for its construction. One study estimates that 22 gallons of gasoline were used per corn-acre in tractors and harvesting equipment in 1970. This is a 45 percent increase over 1945. However, since larger tractors generally use diesel fuel, savings from increased efficiencies are expected. Diesel-powered farm equipment uses almost 30 per cent less fuel than does gasoline-fueled machinery of equal capability because diesel fuel has more energy per gallon than does gasoline and because diesel engines utilize higher compression ratios and higher combustion temperatures.

Conventional corn cultivation in Minnesota requires an estimated 10.4 gallons of gasoline per acre. This includes stalk chopping, moldboard plowing, disking, field cultivating, planting, cultivating, spraying, combining, and transporting. An alternative "no-till" program could cut fuel consumption by 50 per cent. Employing a minimum tillage program of stalk chopping, field cultivating, planting, cultivating, spraying, combining, and transporting, 5 gallons of gasoline could be saved per acre without affecting yields. Minimum tillage would also save machinery energy expense since the moldboard plow and disk could be eliminated.

In addition to reduced tillage, farmers could save considerable amounts of fuel by providing shaded or underground fuel storage tanks, better machinery maintenance, sharp cutting edges, proper lubrication, and by insuring that tractors are loaded to 75 per cent of capacity. In lighter soils, corn acreage can be disked, packed, planted, and fertilized in one operation instead of four. This saves time and fuel and greatly increases the amount of land that can be prepared in a day, an effective hedge against bad weather and other unforeseen circumstances.

Fertilizer

Like mining, farming is an extractive industry. Crops draw nutrients (energy) and minerals from

the soil which are then utilized as human and animal food. If this fertility is not replenished, land productivity declines.

Today's productive agriculture depends on the use of chemical fertilizers to return the nutrients which intensive cultivation has removed from the soil. In 1945, 7 pounds of nitrogen, 7 pounds of phosphorus, and 5 pounds of potassium were the average amounts of fertilizer applied to 1 acre of United States field corn. By 1970, these figures grew to 112, 31, and 60 pounds, respectively. In Minnesota, 1970 averages were 92.5, 66.4, and 60.2. This is a 16-fold increase in statewide nitrogen usage since 1940. Total Minnesota fertilizer expenditure in 1970 is estimated to be equivalent to 29.8 gallons of gasoline per acre, or 149 million gallons for the entire state.

The present growth rate in nitrogen application in all Minnesota crops is 19 per cent per year. This gives a doubling time of less than 5 years. Since cropland in the southern one-third of the state is approaching optimal fertilization given present prices and returns, continued expansion of fertilizer application will be concentrated in areas of the state endowed with lower soil fertility and shorter growing seasons. With prices on the rise, the actual growth of Minnesota fertilizer usage may be sharply curtailed in the next few years.

Historically, fertilizer prices have fallen as supplies have expanded. The federally imposed price freeze in 1973 certainly diverted much domestic fertilizer to export demand, where market prices are much higher, but the major impediment to continued inexpensive fertilizer is the fossil-fuel requirement of its production.

Currently, nitrogen fertilizer production is largely a process of combining atmospheric nitrogen with hydrogen derived from a carbonaceous material. In the United States, natural gas is the primary source of this hydrogen, which is combined with the nitrogen to produce anhydrous ammonia. Not only the cost and availability of natural gas, but also the cost of the large amounts of electricity used to drive the chemical reactions, enters into the problem. These great electrical demands explain why most U.S.

anhydrous ammonia production is centered in the region serviced by the Tennessee Valley Authority. The Republic of China, however, derives nitrogenous fertilizer from its abundant coal supply. If American electricity and natural gas continue to become more expensive, the Chinese technology may become a significant alternative for the United States given our large coal reserves.

The basic source of phosphate fertilizer is phosphate rock. This resource is most heavily mined in Florida, although deposits also exist in Tennessee, North Carolina, and the Western States. New Mexico is the major supplier of potassium salts for the fertilizer industry, with deposits in Utah and California supplying a small share of the product. Phosphorus and potassium fertilizers require about one-sixth of the energy required to produce ammonia since they are mined, concentrated, and blended rather than being synthesized from raw fuel feedstocks.

There are many ways to reduce the amounts of chemical nutrients and the energy these nutrients embody while still obtaining comparable yields. The simplest way to conserve fertilizer is to spread it more carefully. With an application rate of 160 pounds of nitrogen per acre, poor application can vary the concentration from 80 pounds at the edge of the swath to 240 pounds at the center. The 240-pound concentration yields only 4 more bushels of corn than the suggested rate, while the 80 pounds spread at the edge of the strip decreases the potential yield by 20 bushels per acre.

The return of animal wastes to the soil has been a traditional way of increasing both soil fertility and tilth. The yearly manure output from one dairy cow can provide over 100 pounds of nitrogen. With Minnesota average application of chemically produced nitrogen at about 112 pounds per acre per year for cornland, manure clearly is a significant potential source of nitrogen. Virtually all animal manure in Minnesota is presently returned to the soil. Nationally, however, much feedlot manure is not utilized. As fertilizer prices rise, feedlot operators may discover their huge output of animal wastes is a valuable by-product instead of a disposal headache.

The other low energy substitute for chemical fertilizer is green manure. Green manure is any crop grown to be plowed under for soil improvement. These crops add organic matter to the soil and, when legumes are used, add nitrogen. Unfortunately, when a field is supporting a green manure crop, it cannot simultaneously support anything else. For this reason, green manure requires some cash crop land to be taken out of production. The trade-off is between lower costs and lower average productivity. For the present, there is no economic incentive to adopt green manure practices.

Electricity

Electricity is an important input into crop production in the United States. Food-related activities accounted for 22 per cent of the electrical energy used in the United States in 1963. Of the total electrical usage for foods, primary agricultural production accounted for 2.2 per cent in 1963. This latter figure represents the total fossil fuel inputs into electrical generation rather than the energy in the delivered electricity itself.

Farm electrical consumption supports those "plant" activities which aid agricultural production. Among other things, electricity provides illumination and ventilation for barns and buildings, it moves and mixes feed in augers and mills, it powers sophisticated feeding and milking systems, and it drives the power tools, air compressors, and arc welders necessary for maintenance. Nationally, per capita electrical usage doubled between 1955 and 1970, while electricity used in farming an acre tripled during the same period. If this trend continues, electrical inputs into crop production will grow, and if new agricultural technologies require more electricity than those they replace, this growth will be accelerated.

Drying

Adoption of hybrid seeds and high fertilization rates have resulted in corn which matures in the early fall when drying conditions are poor. Consequently, much harvested corn must be dried before it can be safely stored. An estimated 30 per cent of all harvested corn in the

United States was dried in 1970. Most corn dryers use liquified petroleum gas (LP gas), and its usage amounted to 475,000 Btu per acre for all U.S. corn harvested. Minnesota farmers, since they work within a shorter growing season, dry more corn than the national average, but the exact percentage is not known.

Since the amount of energy used to dry the state's corn crop varies with total corn production and weather conditions, it is difficult to make firm estimates for years not covered by actual data.

Savings in energy for drying could be realized by planting early maturing hybrids, but the trade-off seems to be a reduced yield. More efficient dryers, including solar-powered units and dryers using unheated air, are being studied, and their use may become widespread in the next few years.

Other inputs for field corn

Additional energy is used in hybrid seed production, insecticides, herbicides, onfarm transportation, and irrigation. These inputs in the United States are estimated to be less than 10 per cent of the total energy delivered to the crop. Nationally, 3.8 per cent of all corn acres were irrigated in 1970. In Minnesota, this figure was 0.29 per cent in 1969.

Energy efficiency and economic realities

Of the additional inputs and energies applied to American corn over the years, a declining proportion is ending up in the energy embodied in the final farm output. An economist would call this the "declining marginal productivity of an input," and it can be illustrated by experimental data provided by the Agricultural Experiment Station at Waseca. When nitrogen application to corn was increased from 50 to 150 pounds per acre, yield grew from 122 bushels per acre to 136 bushels. When the fertilization rate was again increased, this time to 250 pounds per acre, yields increased very slightly to 138 bushels per acre.

Of course, the fact that an input is returning less yield at the margin does not insure that its usage will be curtailed. Inputs are chosen by considering both their economic

and productive returns. If corn is worth \$3 per bushel and nitrogen cost 15 cents per pound, a farmer whose land yields 100 bushels per acre when 100 pounds of nitrogen is applied will be left with a gross return of \$285 after paying for his fertilizer. If the farmer knows that, by doubling his nitrogen, he can increase his yields by 30 bushels per acre, he will want to apply this additional 100 pounds of nitrogen. His new gross return after fertilizer costs are paid will have risen to \$360 per acre. The 30 bushel-per-acre increase in yields is worth \$75, even after the fertilizer is paid for.

Now suppose that the price of natural gas is deregulated and market forces push the price of nitrogen to 50 cents per pound. Assuming that other prices have remained the same, the return above fertilizer cost at 100 pounds per acre is now \$250. When the nitrogen application rate is again doubled, the return is \$290. With higher nitrogen costs, the added value from the heavier nitrogen application is only \$40, down from \$75. This illustrates the power that input prices have over their usage. As input prices rise, their marginal value falls, and if the price becomes high enough, substitutes become attractive. However, given present prices and continued healthy demand for corn, there is no incentive for farmers to conserve energy by reducing output.

Reducing agricultural energy usage in Minnesota field corn production

U.S. corn production is estimated to yield about three times as much energy as it presently requires. Minnesota nitrogen usage for corn is about the same as the national corn average for 1970, while phosphorus and potassium applications are higher. More corn is dried in the state, but very little of the acreage is irrigated.

When inputs are totaled and the efficiency ratio is computed, Minnesota corn production in 1970 appears to be about 50 percent more efficient than the national average for the same year. In 1970, Minnesota consumed 1022×10^{12} Btu of energy. Of the energy used for corn production in Minnesota, the

amount used for implement fuel, irrigation, electricity, and LP gas in the corn crop amounted to 0.92 per cent of the state's total. Other agricultural energy inputs are "imported" in their finished form and do not draw from the state's energy budget. For this reason, they are omitted from the calculation.

In the preceding discussion of specific inputs, energy-conserving methods which do not affect output were mentioned. When these practices are followed, considerable efficiency is gained with no loss of financial return. Of course, a combination of all these methods has yet to be evaluated in a real agricultural setting, but the theoretical gains are promising. Using the full set of energy-saving methods presently available at no additional capital costs, it appears that Minnesota farmers can realize a 40 per cent gain in overall energy efficiency with no loss of output. As energy prices continue to increase, this conservation would result in increasing economy of operation and higher profits.

These examples should give a notion of the complex interactions between prices and profitable agricultural management. The farm is like a small manufacturing firm which faces both changing demand and variable prices for productive inputs. Not only must the farmer decide between various crops, he must decide on a particular management technique for each variety. Energy-conserving management will be implemented only if it offers a real financial advantage. Even if profits are maintained, energy savings which also reduce yields will reduce the flow of foodstuffs from the farmer to the consumer. This would tend to drive food prices to higher levels, increase inflation, and reduce the quantity of protein marketed for export.

Patterns of energy use in Minnesota crop production

Four factors largely determine the types and amounts of fuels used in producing the agricultural output of any region. They are: (1) the amount of land under cultivation; (2) the amount of land devoted to each of the various crops; (3) the level of mechanization and technology employed by an area's farm-

ers; and (4) input and output prices.

Minnesota has about 50 million acres. Roughly three-fifths of this land is in farms, while the majority of the remaining area is forested. Of the farm land, the amount under cultivation has varied between 15 and 20 million acres during the last 25 years. Agricultural energy expenditures are usually figured on a per-acre basis. As the amount of land under plow increases, so does the total energy requirement.

The six major crops grown in Minnesota are field corn, soybeans, wheat, barley, oats, and hay. Each crop requires varying amounts of energy for its successful cultivation, and each yields varying amounts of energy (calories) and utilizable protein. Both the total land devoted to crops and the amount of land assigned to each depend on a complex relationship between input costs, input availability, effective demand for each crop, and past patterns of agricultural practices. These economic constraints work within a larger milieu whose elements include natural soil endowment, length of the growing season, topographic contours, and rainfall. Despite the large degree of technological management which has been brought to Minnesota agriculture, no human activities can effectively hedge against wind, hail, flood, and drought. This sobering fact should temper those who feel that plentiful inputs and large demand for outputs guarantee a bountiful harvest.

Between 1940 and 1974, the amount of Minnesota farmland planted in the six crops has increased from about 16 million to over 20 million acres. The amount of land committed to wheat and soybeans has increased the most, followed by a steady increase in the acreage of field corn, the state's biggest cash crop. Aside from idle land recently brought into production, much of the new plantings of corn, wheat, and soybeans have displaced land once devoted to oats and hay.

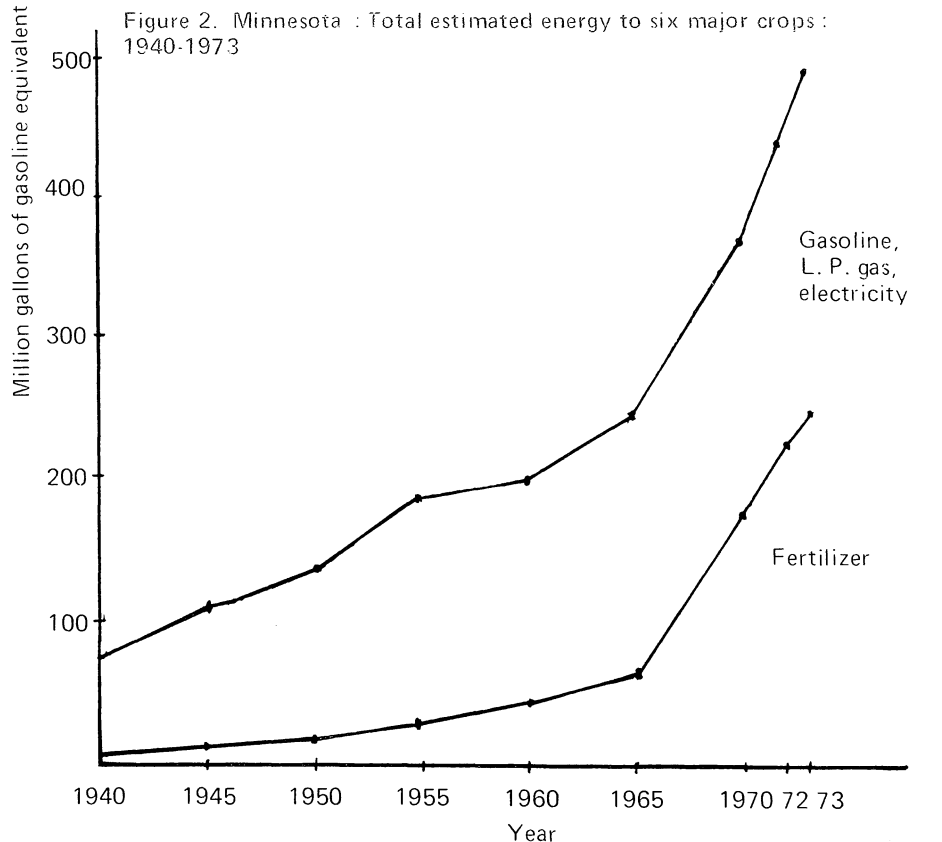
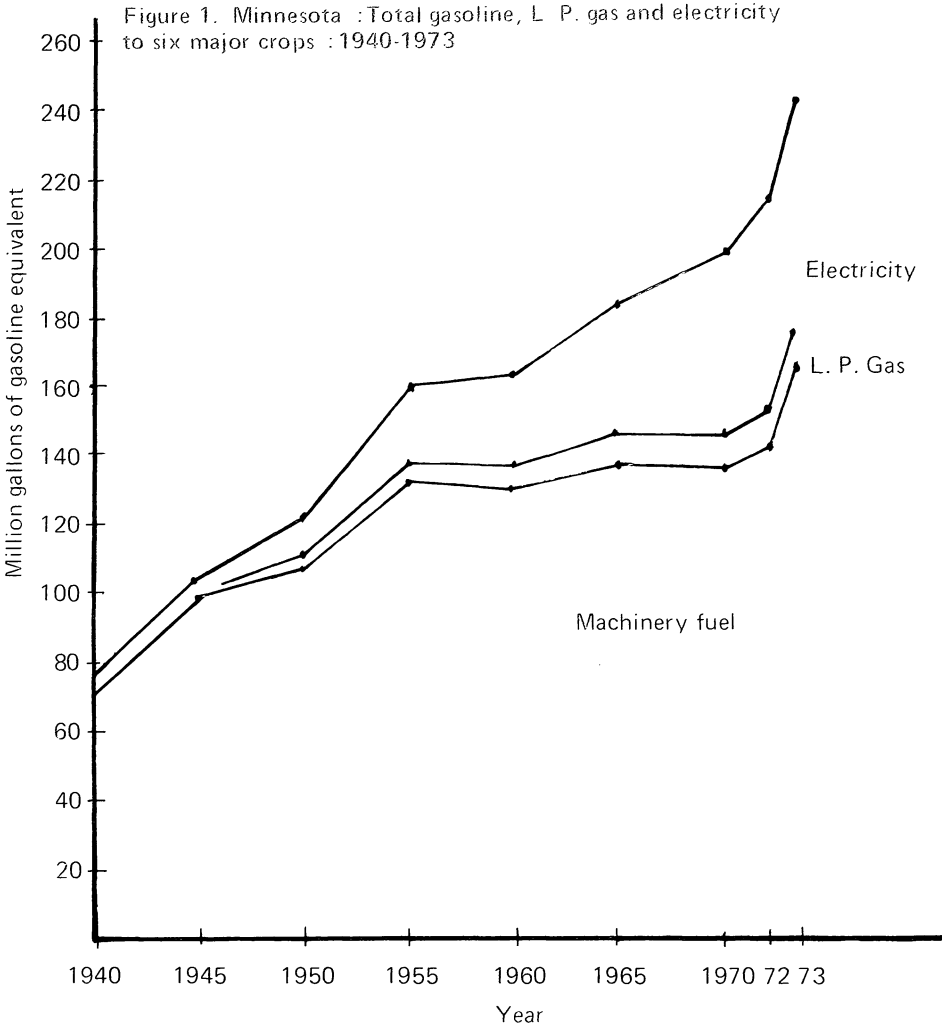
Since the workhorse has nearly vanished from rural Minnesota, tractors are providing the power for ground preparation, planting, cultivation, and harvesting. From the 72 million gallons of gasoline used in Minnesota in 1940, the gasoline budget for these six crops has almost doubled to 136 million gallons for 1970. While these figures

seem huge, the entire state used over 1.9 billion gallons of gasoline in 1970. Thus, crop production uses only about 7 per cent of the total amount (figure 1).

That portion of rural electricity going to farms is difficult to estimate. Not only are data lacking for electrical usage by Minnesota farmers, but it is very difficult to assign that portion of the state's electrical generation which aids in crop production. An estimated 2.2 per cent of all electricity in the United States is used in farming. Since Minnesota has a large agricultural commitment, 3 per cent has been used to calculate the state's portion of electrical energy destined for agriculture. No attempt has been made to separate this total farm electrical budget into its crop and livestock components (figure 1).

Liquified petroleum gas (LP gas) represents a surprisingly large percentage of the nation's farm fuel usage, varying between 13 and 15 per cent of the total farm fuel use between 1969 and 1974. These figures not only represent LP gas used for crop drying, but also include gas used for tractors, brooders, farrowing houses, and other portable and permanent heating facilities. In 1970, LP gas for crop drying (mostly corn) used 3.2 per cent of the LP gas used in the state, or 0.1 per cent of the state's total energy use (figure 1).

When these figures for motor fuels, electricity, and LP gas are aggregated, an estimate of the total energy budget for Minnesota crop production can be made. When these totals are compared with the total energy used in the state, that percentage of energy devoted to crops can be estimated. The 7.9 per cent figure for 1940 reflects the highly agricultural nature of the Minnesota economy 35 years ago. Despite the lower level of farm mechanization at the time, agriculture then used almost 8 per cent of all energy used in the state. Since 1970, the proportion of the state's energy going to crop production has remained at about 3 per cent. When the value of the state's agricultural output is considered, the economic and social returns of the fuel used by Minnesota farmers seem large when compared to the quantity of energy they consume.



Gasoline, diesel fuel, electricity, and LP gas used by Minnesota farmers are the four necessary agricultural inputs which come out of the state's energy supply. Chemical fertilizer materials, essential for continuing farm productivity, also represent large quantities of energy, even though they are produced elsewhere and do not figure into the state's primary energy use. Between 1955 and 1970, Minnesota farmers increased their use of nitrogen (N) 10 times and their use of potassium (K_2O_5) and phosphorus (P_2O) about five-fold. When the state's fertilizer usage is converted to energy expenditures, the amount of energy required to fertilize the state's crops is about equal to that of gasoline, electricity, and LP gas required to farm the crops (figure 2).

Traditionally, land and labor productivities have been the "yardstick" used to measure the efficiency of American agricultural enterprises. However, when energy utilization is under consideration, a ratio can be made between the caloric energy in the crop output and the fossil fuel-

based energy of the inputs employed in production. This ratio measures the average energy productivity of the inputs. For the six Minnesota crops, this ratio has been falling over the years, indicating that less of the input energy is ending up in the crop output despite rising per acre productivities.

If Minnesota's agricultural output is to continue to expand, increasingly large amounts of energy can be expected to aid in the process. The established trend to subsidize agricultural production with mechanical and technological innovations will only increase farmers' dependence on nonrenewable fossil fuels. Especially crucial is the reliance on natural gas for agricultural nitrogen. Natural gas production in the United States has probably peaked, and as various interests vie for the product, high prices and supply "crunches" can be foreseen. If the farmer cannot pass his increasing input costs along to the consumer, he loses incentive to expand his operation. If the consumer must continue to expend a larger proportion of income on

food and fuels, discontent, especially in an inflationary era, is certain to continue.

There is a need for more information about the interplay between agricultural output and energy usage. Agronomists must continue to explore the relationships between output and energy inputs. The possible gains through fertilization, irrigation, and multiple cropping need to be examined in light of potential energy availability. Agricultural economists must study the marginal costs and benefits of various cultural practices to insure growing productivity and economic prosperity. Statisticians working for the U.S. Census, the U.S.D.A., and the State Crop and Livestock Reporting Service must gather data showing the actual end uses of energy in agriculture.

All the data in the world, however, will be of little value unless strong commitments are made at the national and state levels to formulate comprehensive programs of energy conservation. Future generations will greet feast or famine depending on what is done now.

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