Energy and Conservation for the 1990s

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The 1980s were ushered in under a cloud of uncertainty in the world energy picture. During the decade of the 80s, phenomenal developments occurred in energy that are certain to influence the energy situation in the 1990s. Perhaps the most important of these developments was energy conservation, both mandated and voluntary. Other factors were the development of additional energy reserves, nuclear energy becoming more and more unpopular, and acid rain becoming a critical environmental concern.
How will these developments affect energy in the 1990s? Already some energy conservation efforts are being relaxed. With neither nuclear energy nor high-sulfur coal, more emphasis will have to be placed on gas, oil, and low-sulfur coal. The U.S. is still highly dependent upon imported oil, making the supply vulnerable to the whims of foreign governments. These factors coupled with the fact that energy demand is likely to increase substantially during the next few years make very real the possibility of an energy shortage and escalating energy prices in the 1990s.

Meanwhile, agriculture has entered a new era of Conservation farming that potentially could have a revolutionary effect in the 1990s. Soil erosion control and water quality protection has been mandated by Federal law, and energy conservation will likely come about as a part of low input sustainable agriculture resources and seeking ways to reduce production inputs and conserve energy to cut production costs. Fortunately, many of the same practices that conserve soil, water, fossil fuels, labor, and money are effective LISA practices. Reducing production inputs, such as fertilizers, pesticides, and tillage, reduces production costs and conserves energy.

The purpose of this paper is to outline the energy requirements of various crop production practices and indicate ways that farmers can conserve energy through tillage, N fertilizer practices, legumes, and animal manures.

Energy Used in Crop Production

Although large in total amount, the energy used in production agriculture is only about 3% of the total energy used in the U.S. This energy is divided among a number of direct and indirect uses in crop and livestock production. The various energy uses in crop production are grouped into several categories with total consumption for each shown in Table 1.

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Table 1. Estimated annual energy use for crop production. (Adapted from Stout et al., 1977.)

Use	Annual amount DFE┼ (billion gallons)
Fertilizer - production and application	4.55
Farm vehicles - pickup, auto, truck	1.95
Irrigation	1.85
Weed control - herbicide manufacture and application and cultivation	1.40
Harvesting and handling	1.25
Tillage - preplant	1.15
Crop drying	0.75
Planting	0.30
Other - frost protection, electricity, misc.	0.70
Total	13.90

┼Diesel fuel equivalent (155 MJ/gal)

The larger the energy requirement for a practice or input, the greater the potential for conserving energy and the greater the benefits of energy conservation on the overall economics of the system. Some uses, e.g., irrigation in arid and semi-arid climates, offer little opportunity for appreciable energy conservation without jeopardizing yields. At today's relatively low energy prices, a high risk of decreasing crop yields would not make sound economic sense. Nevertheless, energy used in many facets of crop production can often be decreased or managed more efficiently to produce equal yields with less energy or greater yields with the same amount of energy.

Tillage

Wittmus and Yazar (1981) compared inputs and practices for several corn production systems in Nebraska. Energy values were assigned by Frye (1984) to three of those systems--moldboard-plow, chisel-plow, and no-tillage--based on energy values shown in Table *2* for various inputs and operations. Total production energy values were estimated at 44.3, 42.7, and 40.0 gal DFE/acre for the respective tillage systems. Nitrogen

Table 2. Estimated average energy requirements of crop production inputs and operations. (Adapted from Frye, 1984.)

Management input or operalion	Unit	DFE† (gaUunil)
	100 lb machinery	24
Primary tillage		
Moldboard-plow (8 inches depth)	ac	1.82
Chisel-plow (8 inches depth)	ac	1.18
disk (once)	ac	0.64
Secondary tillage		
Disk	ac	0.64
Spike-tooth harrow	ac	0.32
Field cultivator	ac	0.64
Subsoiler (14 inches depth)	ac	2.14
Plant (36 inch rows)		
Moldboard-plow and reduced tillage	ac	0.43
No-tillage	ac	0.53
Weed Control		
Herbicides	lb a.i.	0.48
Spray herbicides	ac	0.11
Apply herbicides and disk second time	ac	0.75
Cultivate (each time)	ac	0.43
Fertilizer		
Nitrogen	lb N	0.17
Phosphorus	lb P_2O_5	0.02
Potassium	lb K_2O	0.01
Broadcast granular fertilizer	ac	0.21
Spray liquid fertilizer	ac	0.21
Apply anhydrous ammonia (no-tillage)	ac	1.18
Apply anhydrous ammonia (plowed soil)	ac	0.75
Irrigation	ac	30.91
Harvest		
Cornpicker-sheller	ac	1.39
Combine	ac	1.60
Miscellaneous		
Shred cornstalks	ac	0.75
Disk cornstalks	ac	0.43
Grain drill	ac	0.53
Seed (production)	lb	0.05

†Diesel fuel equivalent (155 MJ/gal)

fertilizer applied at the moderate rate of 150 lb N/acre (25.5 gal DFE/acre) for each system accounted for 58, 60, and 64% of the total energy used in moldboard-plow, chisel-plow, and no-tillage systems, respectively. This emphasizes the importance of N fertilizer in the crop-production energy budget and the potential to conserve energy through N management.

Fertilizers

Fertilizers represent energy used in manufacturing, transporting, handling, and applying the materials, and in the case of N, the raw material is a direct energy resource, natural gas. According to Nelson (1975), about 83% of the energy used in manufacturing fertilizers goes for N. Phosphorus and K manufacture use about 11 and 6%, respectively. Thus, to save substantial energy with fertilizers, it is necessary to concentrate efforts on N fertilizers. Energy conservation can be realized from practices that improve the efficiency of N fertilizers or practices that decrease the need for N fertilizer, such as the use of legume crops or animal manures.

Nitrogen Efficiency in Relation to Tillage

Nitrogen fertilizer efficiency has been shown to be greater in no-tillage than in moldboard-plow tillage when based on the amount of grain produced per unit of fertilizer N used (Frye, 1984). Generally, N efficiency (thus energy efficiency) is higher for moldboard-plow tillage than no-tillage at low N rates and lower yield levels, about equal for the two systems at moderate N rates, and higher for no-tillage at higher N rates where yields are more nearly optimized.

Although more fcrtilizer N is usually required to obtain peak yields of no-tillage corn, the N and the energy it represents are used more efficiently, because of the greater biological energy resulting from higher yields. The biological energy of corn is about 2.6 gal DFE/bu. This point is usually overlooked by those who cite higher N fertilizer requirement as a disadvantage to no-tillage corn production when comparing the two systems.

Timing of Nitrogen Application

Crops need only a small amount of N during the early stage of growth. Therefore, if much N is available during that time, it will not be used by the crop but will be subject to leaching and denitrification. Research in Kentucky and elsewhere has shown that delaying N application until the crop enters its rapid growth stage, when it has a high N demand, will usually increase N efficiency. For corn, that time is about 4 to 6 wk after planting.

In Kentucky, it is recommended that fertilizer N rates be decreased by 35 lb N/acre when at least two-thirds of the N is applied 4 to 6 wk after planting corn no-tillage on moderately well-drained soils or with moldboard-plow tillage on moderately well-drained or poorly drained soils. Nitrogen can be delayed on well-drained soils, but research results show little or no advantage over at-plant application. The energy represented by the 35-lb N/acre is about 5.95 gal DFE/acre (Table 2); however, if delayed application requires an extra trip over the field, the energy conserved will be 0.21 gal DFE/acre less, or about 5.74 gal DFE/acre.

Nitrogen Fertilizer Placement

Placement of N fertilizer affects its efficiency in two ways: volatilization loss of ammonia and N immobilization in decomposing crop residue. Subsurface injection of N fertilizers provides advantages over surface broadcast application with respect to both of these. Urea or urea-ammonium nitrate (UAN) solutions and solid urea are particularly susceptible to ammonia volatilization when surface-applied, especially in no-tillage (Murdock and Frye, 1985). Also, immobilization of N is greater in no-tillage than moldboard-plow tillage (Rice and Smith, 1984). Subsurface injection of N fertilizer prevents ammonia volatilization loss and places the N below crop residues on the surface that might result in N immobilization. Increased N efficiency has also been found when liquid N fertilizer was dribbled in a band instead of sprayed broadcast (Fox and Bandel, 1986).

If subsurface placement of fertilizers is done as a separate operation, substantially more fuel is required than for surface broadcast or spray application, especially for no-tillage. The energy requirement for subsurface injection has been estimated at 1.18 gal DFE/acre for no-tillage and 0.75 gal DFE/acre for moldboard-plow tillage (Frye, 1984). Because of the increased N efficiency, farmers can decrease the rate of urea or UAN fertilizers required to obtain optimal yields when applied subsurface injected or surface banded compared to surface broadcast. A reasonable estimate of the amount, based on research findings under a wide variety of conditions, might be about 15%. At 0.17 gal DFE/lb of N (Table 2) that could save energy equivalent to as much as 3 or 4 gal DFE/acre.

Adequate but not Excessive Nitrogen

Ideally N fertilizers should be applied to achieve optimal economic crop yields. This means obtaining and following a good N recommendation. In doing so, the amount of N should be adequate but not excessive. This is difficult to achieve since there is no suitable soil test on which to base N recommendations. Nevertheless, in many cases N fertilizer rates could be decreased on the basis of cropping history and commonsense judgement without decreasing crop yields. Studies in Nebraska and Iowa suggested that about half of all farmers may over-fertilize with N as a result of 20 to *25%* over estimations of their yield goals (Hallberg, 1986).

If one-half the farmers of the U.S. decreased N rates by 20%, about 1.06 million tons of N would be saved annually based on an estimated annual use of 10.6 million tons of N. At 0.17 gal DFE per lb of N, about 360 million gal DFE of energy could be saved in this way annually in the U.S. Again, this is small in relation to the total U.S. energy demand, but it would be profitable and environmentally prudent for individual farmers.

Nitrogen from Legumes

A leguminous crop in rotation or as a winter cover or green-manure crop can be used to provide N for subsequent nonleguminous crops. The amount of N provided, especially the first year, depends greatly upon conditions. For example, the longer a soil has been in a legume meadow, the more N will be provided to a grain crop in the rotation. Also, the percent of the stand composed of legumes and the kinds of legumes will influence the amount of N supplied. In the case of winter cover crops, important factors include the kind of legume, the amount of growth made before killing or plowing under, whether the grain crop is grown under moldboard-plow tillage or no-tillage, and the number of years that the cover crop has been used consecutively.

Voss and Shrader (1984) estimated that the amounts of N provided to grain crops by legume meadows the first year of rotation were equivalent to 138, 100, and 20 lb/acre, where the percent of legumes in the stand were greater than SO%, 20 to 50%, and less than 20%, respectively. Based on a 5-ycar study in Kentucky, Ebelhar et al. (1981) estimated that a hairy vetch cover crop supplied N equivalent to 80 to 90 lb/acre of fertilizer N.

Even if one could estimate accurately the amount of N supplied by a legume crop to a nonlegume crop, it does not mean that a farmer should reduce the fertilizer N application by that amount. Hargrove (1986) found that a crimson clover cover crop provided all the N needed by grain sorghum, but results in Kentucky and elsewhere (Frye et al. 1988) indicate that a legume cover crop with corn tends to add on yields instead of replace N fertilizer, especially with no-tillage. That is, the corn yield response to a combination of N fertilizer and a legume cover crop tends to parallel at a higher level the crop's response to N fertilizer without a legume cover crop. Thus, it would be economically unwise for farmers to decrease N application for corn by more than a modest amount. In Kentucky, for example, it is recommended that the fertilizer N rate be decreased by 25 lb/acre for corn following a legume winter cover crop. This is equivalent to about 4.25 gal diesel fuel per acre.

Animal Manures

Animal manures arc a valuable source of N that can substitute for commercial N fertilizer. The N content of manures is highly variable and impossible to predict without a laboratory analysis; however, as a rule-of-thumb, 0.5% N, 0.25% P_2O_5, and 0.5% K_2O are generally accepted when an analysis is unavailable. About one-half of the nutrients are considered to be available to the crop the first year (Anderson, 1985). Using these values, a ton of manure would supply 5 lb N, 2.5 lb P_2O_5, and 5 Ib K_2O the first year of application. In terms of energy value of the nutrients, manure would be equivalent to about 0.95 gal DFE/ton. In most cases, this estimate would be very conservative because additional nutrients would be available in future years.

As in the case of legumes, manure can increase crop yields beyond that which can be obtained with N fertilizers suggesting unknown benefits in addition to N. Animal manure has the advantage over cover crops and green manure crops of being higher in N content (on a dry-weight basis), decomposing faster, and releasing more of its N the first year.

Energy Conservation with LISA Practices

The practices discussed above probably represent the best opportunities to conserve energy through LISA practices. Table *3* is a list of practices and an estimate of the amount of energy that could be saved by adopting each in crop production. The estimates are based on research information mostly from Kentucky. Research elsewhere might suggest different values. Energy values listed in Table 2 can be used to calculate estimates for any situation where N fertilizer, tillage, herbicides, or other energy-consuming production inputs arc reduced by a known amount.

Conclusions

Many conservation practices in crop production that fit the concept of low input sustainable agriculture (LISA) arc energy conservation practices. Chief among these arc conservation tillage, improved N fertilizer efficiency, and use of legumes and animal manures. No-tillage and chisel-plow tillage use less tractor fuel

Table 3. Estimated energy saving for various LISA cropping practices

Practice	Unit	DFE† (gal/unit)
No-tillage vs moldboard-plow tillage corn	ac	4.3
Chisel-plow vs moldboard-plow tillage corn	ac	1.5
No-tillage vs chisel-plow corn	ac	2.8
Delayed application of N fertilizer	ac	5.95
Subsurface placement of N for no-tillage	ac	3.0
Subsurface placement of N for		
moldboard-plow tillage	ac	3.6
Accurate estimate and supply of N needs	lb	0.17
Rotation with meadow:		
Four years or less	ac	4.25
Five years or more	ac	8.50
Legume winter cover crop	ac	4.25
Animal manure	ton	0.95

†Diesel fuel equivalent (155 MJ/gal). Based on energy values shown in Table 2.

than moldboard-plow tillage. Delayed application and subsurface placement of N fertilizer, especially urea or UAN, decrease N losses and increase N-use efficiency, particularly in conservation tillage systems. The result is lower rates of fertilizer N needed to obtain optimal yields. Considerable energy can be saved by realistic estimates of yield goals and N rates consistent with those yield goals. Legumes in rotations or as winter cover crops and animal manures can be used to substitute for a portion of the needs. Both legumes and manure seem to provide benefits in addition to the N supplied, adding to their energy efficiency.

Production agriculture uses only a small portion (about *3%)* of the total U.S. energy budget, and conservation efforts by farmers have little effect on the overall energy demand. Nevertheless, energy conservation on the farm can improve efficiency in the use of resources and increase profitability while contributing to an effective national energy conservation program.

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