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ENERGY IN THE HOME

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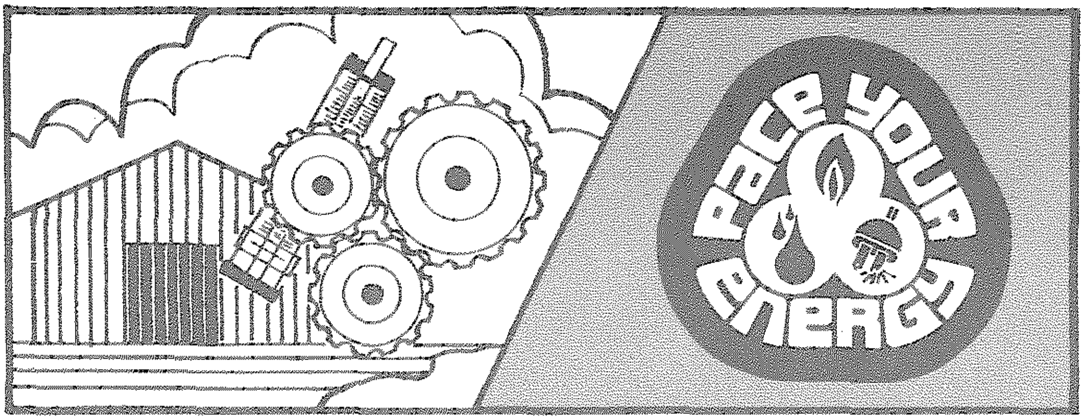

UNIVERSITY of KENTUCKY
COLLEGE of AGRICULTURE
DEPT. of AGRIC. ENGINEERING
COOPERATIVE EXTENSION SERVICE

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Introduction

Agriculture, even in its most primitive state, includes activities related to the collection and storage of solar energy in a form that can be used to sustain life. Energy must be expended in terms of human labor, animal labor, and fossil energy used for products and machinery utilized by agriculture. Because fossil energy is in short supply, many people are concerned, and rightfully so, about the effect that restricted energy availability will have upon agriculture production.

According to Hirst (7), 12% of the total energy used in 1963 in the United States was used as part of the total food chain. This includes off-farm food processing, transportation, and food preparation in addition to the on-farm usage. As indicated in Table 1, the on-farm use of energy only accounts for about 2.2% of the nation's total energy use. Today most estimates would suggest agriculture is using closer to 3% of the total energy. In any case, it is a relatively small percentage of the total. The energy used in home heating, transportation, or by industry far exceeds that used by agriculture.

Table 1.—Energy Use in Food Production and Consumption.

	% of U. S. Total	% of Food Related Energy Use
On-Farm (Agriculture)	2.2	18
Processing (Off-farm)	4.0	33
Transportation	0.4	3
Wholesale and Retail Trade	1.9	16
Home Storage and Preparation	3.6	30

But the importance of energy consumption by agriculture should not be underrated. Though small in terms of the total, agriculture still uses annually 4 billion gallons of gasoline, 2.5 billion gallons of diesel fuel, 1.3 billion gallons of L. P. gas, plus undetermined amounts of natural gas, kerosene, and other fuels. Agriculture uses 39.7 billion kilowatt-hours of electricity every year (3). In terms of L. P. gas, agriculture uses 17% of all that is sold. About 25% to 35% of this L. P. gas use goes into crop-drying, which is a very seasonal operation. Figure 1, which shows the type of fuel used by farms by major activity, shows that both coal and electricity are comparatively small and that agriculture is heavily dependent upon the petroleum fuels. Since this fuel is in the shortest supply, pressures will be exerted on agriculture to reduce energy usage and to improve the efficiency of agricultural operations.

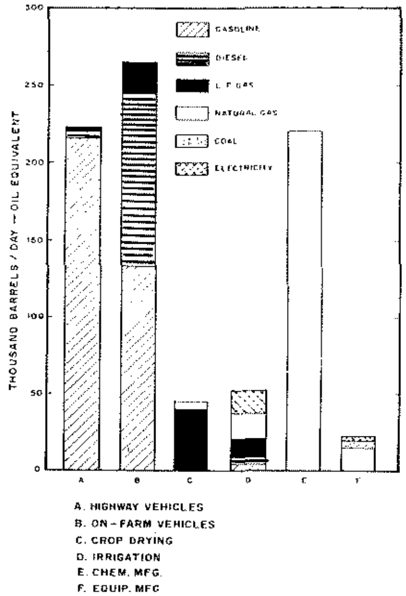

Figure 1.—Energy Use by Type of Fuel by U.S. Agriculture.

Ratio of Energy Input to Output

One measure of agricultural efficiency in terms of fossil energy use is the ratio of energy output in agricultural products to the fossil energy input in agricultural activities. For such an analysis one can consider the total food-chain or can restrict the analysis to the on-farm energy use. If this restriction is made, the energy associated with tillage, harvesting, storage facility manufacture, heating for farm buildings, machinery manufacture, fertilizer, seed production, pesticides, irrigation and drying should be included. Heichel (4,5) refers to these as cultural energy inputs. As suggested earlier, off-the-farm energy inputs in food processing, transportation and preparation are considerably greater; however, these inputs are largely beyond the control of the farmer and they should therefore be considered separately.

Crops and livestock have a wide range of "energy efficiencies." Cervinka (1) computed the ratios of energy output to energy input for a number of crops. Similarly, the National Academy of Sciences (9) in discussing agricultural production efficiency provides data for selected animal enterprises. The ratios from these two sources are shown in Table 2. This table shows that for most unprocessed farm crops more energy is produced than is used; however, when those crops are fed to animals to produce meat the ratio is much less than 1.0, indicating more energy is required than is produced. Although Table 2 would suggest barley or other grain crops should be grown on all land, this is misleading, because the barley is not suitable in unprocessed form for human consumption. However, the frozen broccoli is suitable. It must also be remembered that dietary requirements require the consumption of a variety of foods, and production decisions cannot be based solely on energy efficiency criteria.

Table 2.—Energy Efficiency of Selected Agricultural Enterprises.

Enterprise	Ratio Btu Output / Btu Input	Pounds Meat / Pounds Feed
Barley	6.6	
Corn	3.2	
Corn (including drying)	2.3	
Potatoes, raw	2.1	
Apples, raw	1.2	
Beans, green (frozen)	0.32	
Beans, green (canned)	0.29	
Broccoli (frozen)	0.13	
Broilers	0.12	0.36
Hogs	0.20	0.20
Cattle	0.06	0.07

The animal efficiency figures in Table 2 show that broilers are the most efficient in terms of changing pounds of feed into pounds of meat; however, the hog is the most energy efficient animal, providing more Btu of energy output for each Btu of energy input. Cattle are the least efficient, being two to three times less efficient than broilers and hogs. These figures are based upon conventional practice and show the inefficiency of feeding concentrates to cattle. If roughages are used this changes. Roller (12) reports a 20% improvement in energy efficiency when cattle are range forage fed to a weight of 850 pounds and then finished, instead of receiving conventional feedlot finishing. Not only do cattle become more efficient when fed forages, but more importantly, they are utilizing a material not suitable even in processed form for human consumption. This was graphically demonstrated by Steinhart et al., (13) as shown by Figure 2. Note that range-fed beef actually return more energy than they consume. This is done while utilizing land that in many cases is not suitable for other crops because of erosion or fertility problems.

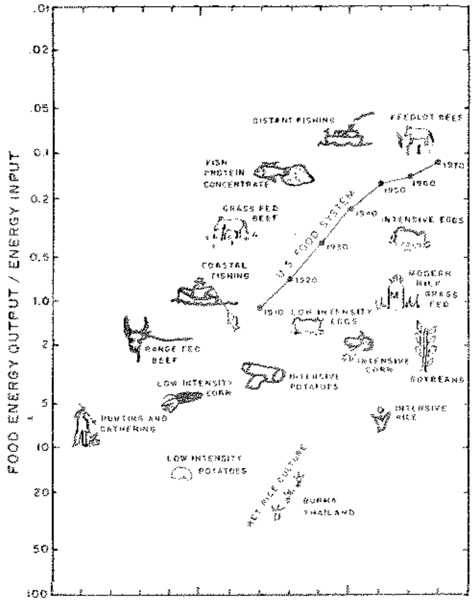

Figure 2.—Energy Subsidies for Various Food Crops. The energy history of the U.S. food system is shown for comparison (13).

In the last examples the total energy input in the food chain was used, not just the cultural inputs (on-farm). The cultural energy inputs are under the farmer's direct control and as such can be increased or decreased by him depending upon economic or societal requirements; however, it must be recognized that these energy inputs have a direct relationship to yield and production efficiency. Pimental (11) demonstrates the changes in yield and production efficiency that have occurred as the United States mechanized its agriculture when he reported that corn yield increased from 34 bu/acre in 1949 to 81 bu/acre in 1970. This increase in corn production is shown in Figure 3. During the same period the labor per acre decreased from 23 man-hours to 9 man-hours. A rather dramatic improvement in production efficiency while substantially increasing yield is shown. Similar increases in yield and production efficiency can be shown for most other crops.

The relationship between energy input and increased yield is also illustrated by Steinhart (13) (see Figure 4).

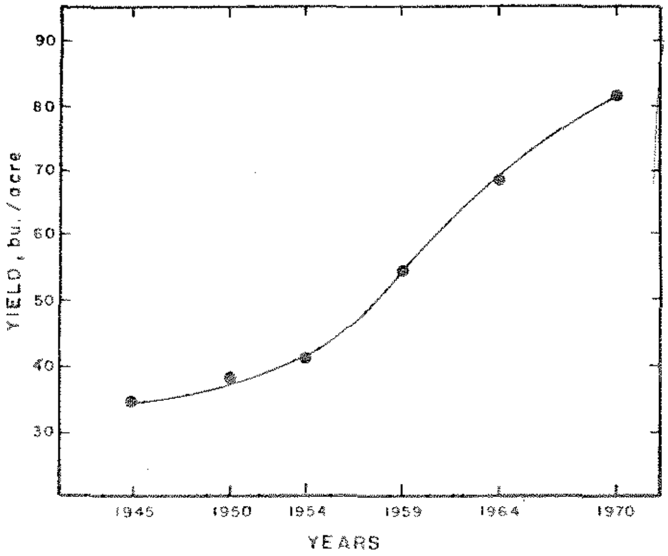

Figure 3.–Increase in Corn Yields from 1945 to 1970.

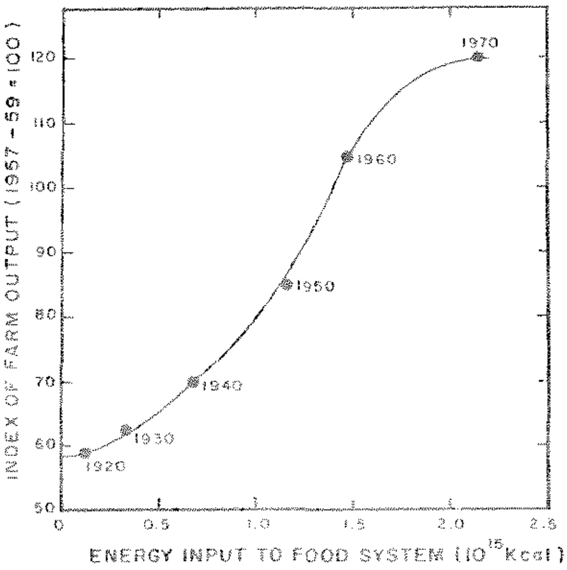

Figure 4.–Farm Output in Relationship to Energy Input Since 1920.

Certainly no one would argue that a reduction in fertilizer input (a significant component of the energy input into crop systems) would not in turn reduce yield. This does not mean that inefficient energy utilization does not exist in agricultural production. It does, and agriculture can economize on its utilization of energy. However, a general reduction or one which restricts a particular practice should be carefully evaluated in terms of its impact on both production and energy. This is particularly true in view of world-wide food supplies.

Effects of Cultural Practice on Energy Use

The influence of cultural practice can be dramatic in terms of energy input and yield. Heichel (*5*) reports that as little as 794,000 Btu/acre of energy input occurs under subsistence peasant type farming where all energy input is in the form of human energy. He reported yields (corn culture in Ghana) of 6,350,000 Btu of food being produced for this expenditure of energy. Farming with 1915 horse-pulled equipment along with stationary engines increased the yield to 31,700,000 Btu per acre. When all modern agricultural practices and equipment are used the yield is increased to 95,200,000 Btu per acre per year; however, at this point 19,800,000 Btu of energy is being expended per acre per year. In terms of energy use efficiency the corn farmer using primitive methods does the best job with about 8 Btu produced per Btu of energy input. The modern farmer only returns 4.8 Btu per Btu of energy input. Heichel (*6*) further reported that when irrigation is used the return drops dramatically to 2.2 Btu per Btu input. Though this suggests agriculture should return to the energy efficient procedures of primitive farming, the difficulty is that because yield is so much lower under such technology, adequate food cannot be produced.

Even the use of horse-drawn equipment would not produce enough food. Gavett (2) estimated that to produce the U. S. crops grown in 1974 with the animal power and technology of 1918, 61 million horses and mules would be required. It would take 20 years to produce this number from the 3 million now available. The animals would have to be fed every day and not just on working days. The feed needed would require hay and other forages from 180 million acres of cropland. This amounts to almost half of the current cropland in the United States. The amount of food for human consumption would be greatly reduced, food prices would rise and agricultural exports would be lost. It would be clearly unwise to feed our crops to horses and mules when people abroad are starving and when the crops could otherwise be traded in the world market for two-thirds of the fuel used in the total U. S. economy.

In view of world-wide food needs and the U. S. balance of trade, if high food output must be maintained, then modern agricultural techniques must be used. Under this constraint the options are fewer; however, the opportunity for conservation of energy still exists. This can be illustrated by considering several alternative production schemes. Using corn production as an example and considering all inputs, the energy use for five different cultural techniques is shown in Figure 5.

An analysis of alternative corn production schemes reveals that different practices have a definite impact on energy usage. For the five schemes evaluated, the most energy efficient system (no-tillage with drying restricted to 5 points moisture reduction) used 32% less energy than the least efficient (no-tillage, increased nitrogen fertilization and drying 10 points).

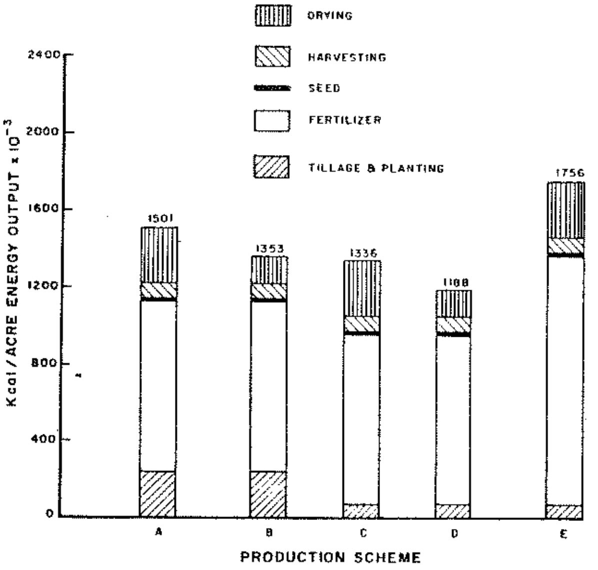

Figure 5.—Energy Usage by Various Agricultural Production Schemes.

A. Conventional-Tillage, Drying 10 points
B. Conventional-Tillage, Drying 5 points
C. No-Tillage, Drying 10 points
D. No-Tillage, Drying 5 pounds
E. No-Tillage, Heavier Fertilization, Drying 10 points

One of the most significant factors of this analysis is the relatively large energy input associated with fertilization, which accounts for approximately 60% of the total energy input for conventional culture. No-tillage is frequently regarded as improving energy efficiency when compared with conventional-tillage culture (10); however, if comparable high yields are desired with no-tillage, approximately 50 lb more nitrogen fertilization is normally recommended. This is shown in Figure 5 as Scheme E. Though the energy for field machinery operations with no-tillage was less than with conventional-tillage, the energy associated with the increased fertilization makes the no-tillage operation the most inefficient from an energy viewpoint.

The next largest energy input is that associated with drying. If heated air is used and the moisture content is to be reduced an average of 10 points (say 26% to 16%) by drying, then 1,170,000 Btu of energy is required. Reducing the drying requirements by 5 points (21% to 16%), reduced the energy required for drying to 587,000 Btu. In this case the impact on field losses of allowing the corn to remain in the field until it averaged 21% as opposed to 26% needs to be considered. This added field drying could be expected to increase field losses by about 4% (8). Assuming a yield of 100 bushels per acre, the energy in the lost corn would be equal to 1,600,000 Btu per acre. This is 2.7 times greater than the energy saved by delaying harvest.

If irrigation had been used (for example, 10 inches by means of sprinklers) an additional 1,490,000 to 5,800,000 Btu/acre of energy would have been required. This could result in a doubling of the total energy input. The potential for energy saving should also be apparent. For example, with conventional production, if agricultural waste could be used to replace one-half of the fertilizer, a savings of 1,750,000 Btu/acre of energy might be realized.

Similar analyses can be made of other agricultural operations and various alternative production schemes to evaluate the energy requirements for any desired crop or production system. Since the possible combinations are virtually endless, no attempt was made in this paper to evaluate other types of farm operations. It is apparent that in such analyses the effect on production (crop yield) must be evaluated so that the effect on both overall production and the energy required per unit of production can be determined. This was clearly demonstrated above in the example about increased field losses because of delaying the harvest to allow the moisture content to drop in the field.

Summary

This overview of the amounts and types of energy inputs into agriculture shows that although the energy used in production agriculture is a small portion of total U. S. energy consumption, conservation of that energy is desirable and will prove to have increasing economic benefits for an individual farmer as energy costs rise. To return to a less energy-intensive, technology-oriented agriculture would not be feasible while maintaining the present level of food production.

When analyses of the energy inputs into corn production are made it is important to consider the total operation. This includes changes in fertilization required by a change in machinery usage, effect on field losses, changes in yield and changes in product quality. A system which has a low fossil fuel requirement (gasoline, fuel oil, etc.) may not have the lowest overall energy requirement, particularly when yield is considered and the energy usage is computed per unit of food produced.

Despite large energy inputs, the energy yield in corn at harvest exceeds by several times the inputs. As energy is added in off-farm transport, processing and handling this may cease to be true, but for almost all crop operations the energy at point of harvest or on-farm storage exceeds the energy required to produce the crop. In this sense agriculture is a producer of energy rather than a user of energy. It is important to remember, however, that agriculture is not practiced to produce energy; rather, it exists to produce food, a basic commodity of man. Therefore, any reductions in the energy available to agriculture must be weighed against the acceptability of a potential decrease in food production.

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