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AGRICULTURE AND ENERGY: THE INTERLOCKING PUZZLE

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"There exists a single unified system from one end of the cosmos to the other; in the last analysis, everything is energy."

-- Barbara Ward and Rene' Dubos in Only One Earth

From the ancients who saw fire, water, air, and earth as the four elements to the modern scientist pondering all creation, the search has been on for a common denominator to the universe. Mystics see it as a Spirit. There are solipsists among us who deny the idea of reality and trust only their own senses. I have thought that notion to be the ultimate in egocentricity. Solipsist psychology reminds that a true scientist is first of all an extrovert, preoccupied with what goes on around him and not with himself.

Physical scientists of our era puzzle over the atomic table as the key to universality. Scholars such as Ward and Dubos, quoted above, see energy as the unifying system.

Confining our attention to agriculture, we can readily interpret its organic processes in terms of energy. I put my students through the catechism: "What is agriculture, basically?" The answer I wait for -- sometimes for a while -- is that agriculture is the site where energy received from the sun is absorbed by the chlorophyll of growing plants and converted into forms useful to mankind. I downplay the soil, calling it mainly anchor and sponge, and even regard the roots and stems of plants as little more than supporting scaffold and conduit.

The image is a bit fanciful and disregards the fact that plant products embody more than hydrocarbons as energy-bearers; they contain minerals too, and vitamins. But there is something mysterious, awesome, and other-worldly about the basic process upon which all human life depends.

Obviously, this charcterization puts animal life into a secondary category. More significant, though, is that

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attention is thereby directed to a performance ratio in agriculture that has been underappreciated, namely, the energy-conversion efficiency of the plant. In my classroom instruction I call this the first energy efficiency ratio of agriculture. How well -- how efficiently -- do plants capture and incorporate solar energy? We need to ask.

The answer is that they do badly. Of the energy contained in the sun's rays falling on the best Missouri corn field, only about two percent is incorporated in the corn plant, and only one percent in the grain. This is an appallingly low figure. One way to tantalize agronomists is to challenge them to double or triple that ratio! Think what a boon it would be to the world's food supply if the corn fields of mid-America would convert three percent of the sun's energy to grain, instead of one percent.

Incidentally, I read that part of the problem is that roots are better anchors than nutrient-conveyors. Foliar feeding of soybeans apparently will add materially to yields.

Energy for Power and Fertilization

The second energy ratio of agriculture relates to the role of energy in the cultural practices employed in modern farming. Energy is required to pull a plow or milk a cow; and huge quantities of energy are consumed in manufacture of nitrogen fertilizer by the Haber-Bosch process that uses natural gas as feedstock. It overstates only a little to say that the highly-praised technologies introduced to agriculture in our century are to large extent energy-based. Even the metals of machinery require enormous quantities of energy in their manufacture.

And so calculations are made of the ratio between the amount of industrial energy utilized in agriculture (the denominator) and the energy content of harvested products (numerator). That ratio varies a great deal according to the cultural practice followed and the commodity produced. In my judgment the ratio will become stock in trade for agricultural scientists, just as important as yield per acre or output per man. I will cite a few data below.

But let's philosophize a bit. Energy for cultural practices, and the second energy ratio as a performance measurement, are subordinate to the first conceptualization and the first energy ratio. We say we use industrial energy to replace human labor and animal draft power, or, in the case of fertilizer, to provide soil nutrients. Well, that is true. But in a different sense all we do is make the soil more hospitable for the plants, so that the chlorophyll can do its job better. We give the soil tilth and humus and water and mineral nutrients; we invite microorganisms below the

surface and discourage unwanted flora (weeds) above it. Mainly, all we are trying to accomplish is to expose as much leaf surface and chlorophyll of the plant as possible.

In the vernacular of our day, the final test, the bottom line, is how well that plant takes solar energy and turns out hydrocarbons. The first energy ratio in agriculture is what counts most.

In today's farming it is taken for granted that nearly all the energy used in cultural practices comes from industrial sources, that is to say, from fossil fuels. This is not necessarily the case. Photosynthesis in green leaves takes place irrespective of whether the plants have been cultivated by hand or by machine. As recently as my own youth much of the power came from organic sources, even some from my muscles. Sure, one reason I left the farm was to avoid milking cows by hand on a cold morning. But I have never believed that a mechanical milker was more skilled than my big fingers. A well aimed hoe will kill weeds better than a plow or herbicide.

Aside from sparing drudgery, what industrial energy does is add to the total resources made available to agriculture. The clearest illustration is replacement of horses and mules by motors of all kinds, even generators of electric power, so that the product of 60 million cropland acres can be used for human food instead of oats and hay for workstock.

In this regard the ethanol enthusiasm of a year or two ago presents a fascinating question. In terms of utilization of resources, feeding corn to a horse or turning it into ethanol for tractor fuel are of the same genre.[1] I have wondered what the comparative efficiency of the two processes might be. Economically, of course, a lot depends on what kind of energy source is used to distill the ethanol.

Sensitivity to Energy Ratios

Manifestly, the energy conversion ratios have gained attention as industrial energy has become scarcer and more costly. During the boom period for new technology energy came close to being a free good, and only a few kooky scientists and environmentalists reminded of the difference between a stock and a flow resource. But we were destined to learn better.

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[1] Admittedly, most tractors are diesel and cannot burn gasohol. But overall the two fuels can be regarded as substitutable.

OPEC was the great teacher. Most of us learned pretty fast when the price of oil jumped from $3.00 a barrel to $8.00, then $15.00, and on to its present $34.00.

The first energy ratio draws the attention of plant scientists. Although not usually labeled that way, the new thrust toward genetic engineering in plants can be regarded as a search for better solar-energy conversion.

More emphasis, and a more familiar kind of research, is devoted to the energy efficiency of cultural practices -- the second energy ratio. This involves both research into new or modified practices, and selectivity among the wide range of choices available. It carries a couple of side issues, however, both unwelcome. The first is the wish to avoid reducing agriculture's output materially. Obviously, the energy ratio can be improved if we cut back on various of the yield-increasing technologies. If nothing else is done, total farm output will be reduced. That is not a desirable outcome. The second side effect relates to use of power to spare human labor. Although my farm management friends are repelled by the idea, I conclude that U.S. agriculture will swing slowly back toward being more labor intensive. And I doubt every tractor operator will enjoy an airconditioned, radio-equipped cab. In view of the number of youth who are unemployed I am not sure a little more hand work would be bad. Some could go toward protecting soil and water. A likely outcome, though, is employment of more Hispanic workers in U.S. agriculture.

Widely Ranging Efficiencies

Almost a decade ago G.H. Heichel at the Connecticut Agricultural Experiment Station won a big readership for a small bulletin titled "Comparative Efficiency of Energy Use in Crop Production."[2] He presented shocking data contrasting, at the extremes, the efficiency in energy use in paddy rice production in the Philippines and irrigated rice in Louisiana. Since then other studies have developed more and better data for various cultural practices. I usually generalize that corn and wheat in the midwest yield two to five times the quantity of energy used in production. A few vegetables are inefficient, with ratios less than 1.0; but they are eaten for taste and to fill stomachs without overfeeding -- that is to say, overfattening. The discouraging inefficiency is animal agriculture, and the more so as we use confinement operations and grain feed. Even range production does not show up well. Apparently chemical fertilization of many pastures plus riding the range, as we used to sing, in a Ford V-8 instead of astride a horse, contribute a considerable energy input.

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[2]Bulletin 739, 1973.

Reduced tillage and other changes being made in cultural practices are energy saving. They are familiar and need not be reviewed here.

Using Farm Products for Industrial Energy

I have already referred to the gasohol enthusiasm, part of the broader issue of biomass. In principle this is little different from feeding hay to horses or mules. For a generation most of the energy content of the products of agriculture has gone directly or indirectly to human alimentation. Exceptions are the wearing of textiles, the burning of the tobacco leaf, and the use of a few milk and soybean products in industrial adhesives and other products. Until the last few years only a little land has been devoted to producing wood for burning. The only summary points I offer here[3] are that any substantial use of the crop products of agriculture for industrial energy would cut deeply into our food supply, removing at least half the animal products from American diets. Lots of us would become near-vegetarians without meaning to. Yet if and when an energy crisis comes it is conceivable that we would in fact prefer to divert appreciable quantities of our farm crops into motor fuel. We would also spur agricultural production to the utmost, creating worrisome problems of protecting the marginal soils that would be plowed.

This is one of the more dramatic, even explosive, aspects of the agriculture-and-energy equation.

Energy in Food Processing and Distribution

So far as the entire food system is concerned -- or, for that matter, the total food and textile system -- the big use of energy takes place past the farm. Data usually quoted are that the food system absorbs 16.5 percent of all energy but of this only a fifth, or 2.9 percent, is accounted for by energy for farming operations. Moreover, more energy is used in manufacture of nitrogen fertilizer than in power for field operations. This raises a nice question, incidentally, of what will happen to fertilizer prices if and when the price of natural gas is decontrolled.

I quote these data not in order to minimize the role of energy in farming or to suggest that field operations are not a fruitful place for conserving energy. An erg saved today is an erg retained for our future, wherever the saving takes place. What I am leading to is an idea seldom discussed, namely, that we may find it necessary to choose those kinds of products of agriculture that lend themselves to human con-

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[3] I and others have written quite a lot on the question the last year or so.

sumption without requiring energy-intensive processing and distribution. Some food products by their nature require lots of handling and preparation. An interesting nugget for speculation is that some of the animal food-vegetable food comparisons may be reweighted. For example, producing an egg may be energy-inefficient but it surely moves easily from the hen to the human stomach. At one time in my life, before I learned about salmonella, I ate raw eggs.

Postscript

The only concluding note I offer is that the whole topic of energy and agriculture is rapturous. It has so many facets! Agriculture is a producer of energy; better stated, it is a converter of energy. In the last generation agriculture has converted solar energy primarily into forms that are consumed directly or indirectly as human food. The power sources for farming have been industrial.

The most dramatic confrontation arises from trying to economize on industrial energy used in farming operations, even as pressure builds to divert the products of agriculture back into motor fuels -- analogous to the onetime division of the oat crop between oatmeal for humans and oats grain for horses.

Even so, the hidden factor, the sleeper, in the whole matter is how production on the farm may be modified in order to reduce the heavy energy component of getting products from the farm into consumption. I can foresee changes arising from this force that will affect the products produced, form of delivery, definitely the geographic location of production, and of course the means of transportation, processing, and storage that are employed.

Stick around! Things may get rugged but they will be interesting.