Energy, Agriculture and Waste Management

Edited by
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Preface

Mankind has passed from a period of affluence for many to global environmental quality degradation, food and energy shortages, and natural resource depletion. As information is developed to describe this situation, we are continuously faced with contradictory statements regarding the major issues that will decide the future of man. This volume discusses three topics:

—Energy consumed in food production and philosophies that relate to various agricultures.

—Technology and energy costs of pollution control.

—Potential for producing energy from agricultural wastes.

American agriculture is charged with being inefficient and with wasting energy. Comprehensive studies of energy consumed in agriculture conducted in New York, Texas, Michigan, and California are summarized here. They indicate that even in diverse types of agriculture, less than 5% of the total energy is consumed in the farm production of food.

While the U.S. Congress has passed new and comprehensive pollution control legislation, others claim that we do not have the energy or the resources to prevent contamination of our environment with our wastes. Cywin, Tchobanoglous and other distinguished authors show that the energy consumed and costs of pollution control would appear to be acceptable. For example, energy required for water pollution control for each person is equivalent to a continuous burning 15-watt lightbulb.

Finally, the energy crisis and the demand for improved environmental quality sometimes result in contradictory solutions. In some cases, however, the two are complementary. Nearly half the chapters in this text deal with the potential of controlling organic wastes with processes that generate energy. Chapters on the bioconversion of animal manures to methane gas via the anaerobic fermentation process provide a comprehensive description of the history, the present and the future of this technology. The speed with which this topic is expanding was clearly emphasized in a response from a farmer to a statement at the conference that no anaerobic digesters were being used in U.S. agriculture. The farmer was quick to note that although all the "experts" had declined to give him detailed advice, he had been operating an anaerobic digester on a 350-head beef feedlot with tremendous success.

Complete answers to the questions surrounding energy, agriculture and waste management will not be found here. But these chapters by experts in the field provide one of the first attempts to answer them.

William J. Jewell
October 1975

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INTRODUCTION AND OPENING REMARKS TO THE SEVENTH ANNUAL CORNELL UNIVERSITY CONFERENCE ON ENERGY, AGRICULTURE AND WASTE MANAGEMENT

W. K. Kennedy*

Among lay people, the fear of a severe gasoline and fuel oil shortage is much less today than a year ago, but the current availability of adequate supplies of gasoline only leads the people of this country into a false sense of security. The supplies of oil and other fossil fuels are finite and while new reserves of petroleum and natural gas undoubtedly will be located, we know they will be exhausted in too short a time if we continue to use them as lavishly as we have in recent years. Perhaps the only benefit from the unfortunate conflict in the Middle East has been the development of an awareness in the United States and the other developed countries that inexpensive sources of energy are tremendous treasures which must be used carefully and efficiently until we learn how to utilize other sources of energy.

Modern agriculture has been developed through the use of cheap sources of energy for power on our farms and in our processing plants, and for the production of abundant supplies of nitrogen, other fertilizers, agricultural chemicals and other supplies. By substituting capital, mechanization and the liberal use of energy for labor, the farmers and related agricultural industries in the United States have been able to produce, process and market an abundance of food at prices far below those paid by consumers in most other countries. In retrospect, it is easy to criticize the rapid move in this country toward mechanization and the liberal use of fertilizer and other agricultural chemicals, but at the time these decisions were being made, they were correct in terms of economic conditions and the general attitudes of society. In 1975 we are aware that more attention should have been given to the cost and long-term availability of petroleum and natural gas as we developed our labor efficient, but energy intensive, agricultural systems.

Fortunately we do have alternatives to the continued use of several of our high energy practices. In the immediate future, we probably must depend on petroleum products to fuel our tractors, combines and other field machinery. Timeliness in completing tillage, spraying and harvesting operations is such that we will continue to use sizeable tractors where they are needed. In some cases, the size of our

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machinery can be reduced, such as spray equipment for apple orchards planted with size controlled trees instead of the large trees of the past. Nevertheless the saving of energy for our field machines probably will be modest at best and, in some cases, will continue to increase in order to reduce labor costs. In the case of fertilizer and pesticides, significant savings can be realized through timely applications and more careful control of rates of application. Greater use of animal manures and legumes in our farming practices can reduce the amounts of synthetic nitrogen fertilizer used on our farms. We can reduce pesticide and other chemical usage through more careful monitoring of pest populations and through greater use of other control procedures.

In recent years our scientists have developed techniques for growing plants from single cells. At first glance this appears to be an interesting, but useless bit of knowledge, but the perfection of tissue culture techniques opens up an entire new avenue for the improvement of plants. It is highly unlikely that our scientists would ever discover how to cross two dissimilar plants such as alfalfa and corn, but through the use of isolated cells of alfalfa and corn, and perhaps with the aid of selected viruses, our scientists may be able to transfer the appropriate genetic material from a cell of a legume to a cell of a corn or other non-legume plant. Then through tissue culture techniques, the corn plant cell with appropriate genetic material from the legume cell can be nurtured into a mature corn plant with the capability of supporting nitrogen fixing bacteria (rhizobium) on its roots. If this feat can be accomplished, and I am willing to predict it will be within the next decade, its value to mankind will be tremendous.

The opportunities to convert agricultural wastes into usable sources of energy are unlimited, but I do not wish to imply that the task will be easy. In many cases agricultural waste products have limited value at their place of origin. They may have high water content, they may be difficult to handle, they may be difficult to transport or spread on the land and the cost of utilizing them may be greater than present sources of energy or fertilizer materials. The counter to the high cost of utilization is the cost of disposing of these materials. You and your colleagues must continue to explore ways of turning waste products into productive uses. In many cases your efforts may be unsuccessful, but just a few successes will provide ample repayment for the time and dollars spent in these areas of research and development.

Section I

Energy and Food Production

1.

World Food, Energy, Man and Environment

David Pimentel*

As a result of overpopulation and environmental resource limitations the world is fast losing its capacity to supply adequate food. The world population today is 4 billion humans (1). Based upon current growth rates, and even allowing for reasonable reductions in birth rates in several countries, the National Academy of Sciences Committee estimated that the world population will reach at least 7 billion by the year 2000 (Figure 1). The committee concluded there is no feasible means to stop this explosive increase short of some unwanted catastrophe (1).

If we go back only about 2000 years, the records suggest that humans on earth numbered little more than 200 million (2)—about the density of the population of the United States today. World population was about 500 million as recently as 1650. It was shortly after 1700 that the human population explosion began (Figure 1).

Note how the rapid growth in world population coincides with the exponential use of fossil fuels (Figure 1). In addition to improving the quality of life, some fossil energy was used for disease control operations and to improve agricultural production to feed the growing population. Both the effective control of human diseases and increased food production have contributed significantly to the current rapid growth (1).

Of these two factors, the evidence suggests that reducing death rates with effective public health programs is the prime cause (3). The eradication of malaria-carrying mosquitoes by DDT and in-

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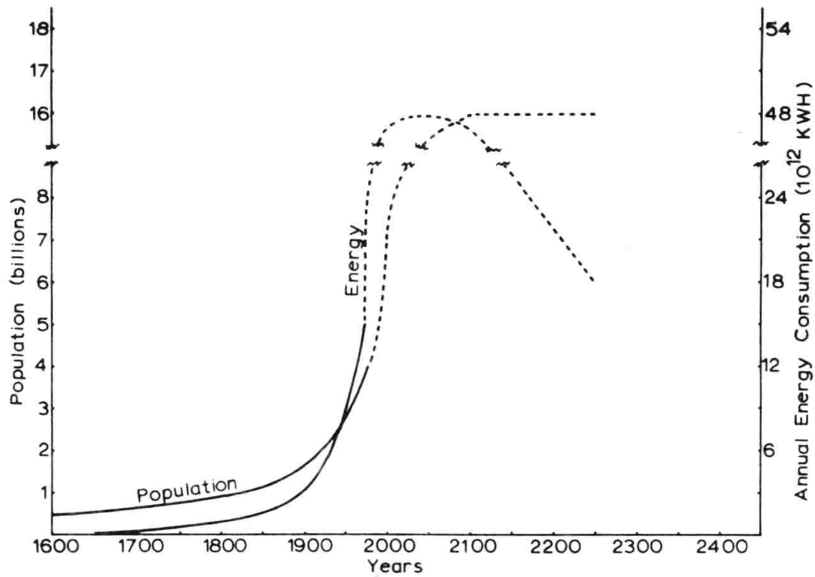

Figure 1. Estimated world population numbers (———) from 1600 to 1975 and projected numbers (— — — —) to the year 2250 (1, 3, 56). Estimated fuel consumption (———) from 1650 to 1975 and projected (— — — —) to the year 2250 (57).

secticides is a good example (note substantial quantities of energy required for production and application). In Ceylon (1946-47) after spraying with DDT, the death rate fell in one year from 20 to 14 per thousand (4). A similar dramatic reduction in death rates occurred after DDT was used in Mauritius where death rates fell from 27 to 15 per thousand in one year and population growth rates increased from 5 to 35 thousand (Figure 2).

Meanwhile in both Ceylon and Mauritius fertility rates did *not* decrease and an explosive increase in population numbers resulted. Recent history documents similar results in other nations where medical technology and medical supplies have significantly reduced death rates (5). It is relatively easy to reduce death rates through public health measures, but birth rates are difficult to change. Birth rates are interwoven with social and religious systems of the people.

With increasing human numbers in the world, many regions could no longer support a hunting-gathering economy. The shift had to be made to a more permanent type agriculture (6). "Slash and burn" or "cut and burn" agriculture was the first technology employed, *i.e.*, cutting trees and brush and burning them on site. This killed weeds and added nutrients to the soil. Crop production was good for a couple of years before soil nutrients were depleted. After

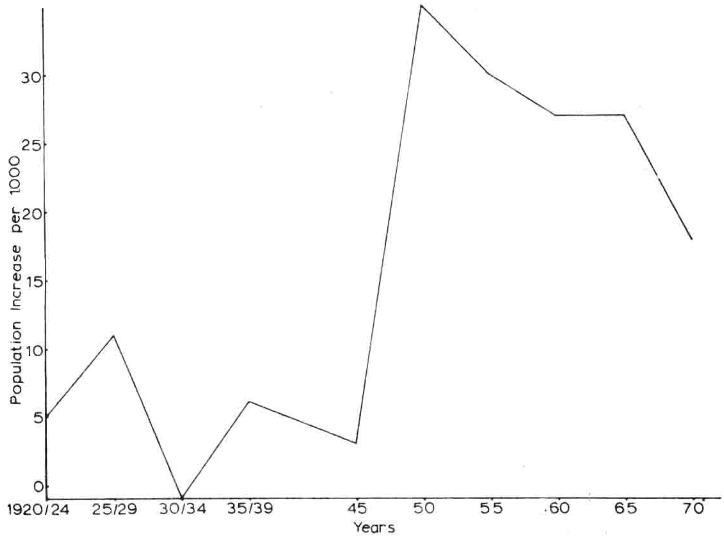

Figure 2. Population growth rate on Mauritius from 1920 to 1970. Note from 1920 to 1945 the growth rate was about 5 per thousand whereas after malaria control in 1945 the growth rate exploded to about 35 per thousand and has since very slowly declined (4, 58). After 25 years the rate of increase is still nearly 4 times the 1920-45 level.

use, it then takes about 20 years for the forest to regrow and for soil nutrients to be renewed.

Cut and burn crop technology required few tools (ax and hoe) and lots of manpower. For example, in a part of Mexico "slash and burn" corn culture was investigated and Lewis (7) reported that a total of 1,144 hours of labor was required to raise a hectare of corn (Table 1). Other than manpower, the only inputs were the ax, hoe, and seeds. Similar data were obtained for corn production in Guatemala (Table 2).

Table 1. Energy inputs in corn production in Mexico using only manpower.

Input	Quantity/ha	kcal/ha
Labor[a]	1,144 hr	622,622
Ax + Hoe[b]	16,500 kcal	16,500
Seeds[c]	10.4 kg	36,508
Total		675,730
Corn yield[a]	1,944 kg	6,842,880
kcal return/kcal input		10.13

[a] Lewis (7). See Table 4.
[b] Ax and hoe assumed to weigh 23 kg. See Table 3.
[c] 10.4 kg × 3,520 kcal/kg = 36,608 kcal.

Table 2. Energy inputs in corn production in Guatemala using only manpower.

Inputs	Quantity/ha	kcal/ha
Labor[a]	1,415 hr	770,114
Ax + Hoe[b]	16,500 kcal	16,500
Seeds[c]	10.4 kg	36,608
Total		823,222
Corn yield[d]	1,066 kg	3,752,320
kcal return/kcal input		4.56

[a] Corn production in San Pedro Necta, Guatemala infertile Llano soil (8). See Table 4 for labor energy input.
[b] Ax and hoe assumed to weigh about 23 kg. See Table 3.
[c] 10.4 kg × 3,520 kcal/kg = 36,608 kcal.
[d] From reference (8).

The yield of 1,944 kg/ha in Mexico provided about 6,842,880 kcal. Allowing for 3,000 kcal of corn per person per day, this yield was suitable for more than 6 persons. Another way of looking at this is that only one-sixth of a hectare is necessary to feed one person per year with corn. The hours needed then would be about 190 hours per person per year or only about 5 weeks work.

When man started harnessing fossil fuel for crop production, agriculture became revolutionized. Great changes occurred in agricultural production and these are discussed in a later section dealing with energy used in food production.

Arable crop land is in short supply. Of the total of 13 billion hectares of land area in the world (9), only an estimated 7 to 10% is suitable for cultivation (9-13). As Paddock and Paddock (14) point out, "a desert may have fine soil, but it has no rain; the Arctic has moisture but not the right temperature; mountains are too up and down. And so it goes." We are fortunate in the U.S. where about 22% of our land is suitable for cultivation (9). However, South America has only 6% arable land suitable for cultivation (9), for approximately the same number of people. Furthermore, nearly all the arable land of the world is in cultivation (14); bringing the remaining arable hectares in the United States, Canada, and elsewhere in the world into production only an estimated 1% might be added. Even in the United States, which has the greatest amount of arable land of any nation, nearly all the land resources already have been put into use.

To complete the picture on the use of land, mention should be made that about 22% of the land area of the world is used for livestock production and is in pastures, ranges, and meadows (13). Another 30% of the land area is in forests (13).

Although our land resources are vital to us for crop production, these lands are rapidly deteriorating. For example, each year in the U.S., about 3.6 billion metric tons of soil are washed into our streams and ponds, and into the oceans (15). This valuable top soil is lost from our cropland, home building sites, and other areas where soil is left with insufficient plant cover. On bare soil such as construction sites, about 1,120 metric tons of soil per hectare may be lost (16). The average loss of top soil per hectare of corn production is 44.1 metric tons (17). In the corn state of Iowa, the loss averages 36 metric tons annually and the aim is to reduce this loss to 11 metric tons annually (18). We in the U.S. are literally mining our soils for crop cultivation. How long can we continue to abuse our valuable soils?

Water is another vital resource in crop production. The 1974 drought in the Midwest emphasized the importance of water to us. Tremendous quantities of water are necessary to raise a crop. About 122 cc of water per cm^2 are needed to raise corn in the subtropics. This is about 12.2 million liters of water per hectare of corn. One hectare is about 2½ acres.

Only about 13% of the world's cultivated land is now irrigated (13). The use of irrigation could significantly increase the arable crop land in the world (19), but this type of alteration of the ecosystem requires energy. A liter of water weighs 1.0 kg. To pump from a depth of a little over 90 m in order ot supply 122 cc of water/cm^2 to a crop hectare would require about 2,060 liters of fuel (ca. 19.7 million kcal) (20). Because of the high energy-demand of irrigation, it is doubtful that irrigation will be used extensively to increase the arable land of the world (21, 22).

Earlier I mentioned that man has utilized fossil energy resources to increase his population numbers. In fact, the use of energy has been increasing faster than population numbers. For example, while it took about 60 years for the U.S. population to double, the U.S. doubled its energy consumption during the past 20 years. More alarming is that fact that while the world population doubled in the last 30 years, world energy consumption doubled within the past decade.

Energy use in food production has been increasing faster than in many other sectors of the world economy. For example, using corn as an average crop, Pimentel et al. (23) documented that energy inputs in corn production more than *tripled* (Tables 3 and 4) during the last 25 years. Note that the quantity of energy used to produce nitrogen fertilizer during 1970 nearly equalled all the energy inputs for 1945. The other large inputs of energy come from machinery (1,037,400 kcal); fuel (1,971,420 kcal); drying (296,400 kcal); and electricity (765,700 kcal).

Drying corn was one of the factors that increased significantly