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## FOOD AND ENERGY

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### Abstract

Possible impacts of the changing energy situation on agricultural production in the developed, developing, and stagnating parts of the world are considered. Compared with traditional trends in the developed countries, higher yields are expected and less pressure on the arable use of land, achieved by using more energy per surface unit, but less per farm product unit, and by more care by the farmer for the timeliness of his operations and in disease control. As more by-products of processing are used for fuel production, less will be available as concentrates and more marginal land will then be used for grazing.

Some knowledge of improved means of production has been filtering slowly down from developed to developing nations, resulting in moderate yield increases but with much yet-unrealized potential. With rising energy prices, however, the terms of trade may deteriorate, with these modest gains being lost. It is imperative, therefore, that the developed nations stabilize at a fair level, the international market for the main agricultural products of the developing world.

Development advantages do not reach the world's poorest, stagnating countries. Of special concern are countries with poor soils and an unfavorable climate, but largely landlocked without much of an infrastructure or mineral deposits, but with a burgeoning population. As the terms of trade have become intolerable for these countries and the magnitude of development aid has been decreasing in real terms, it seems as if the world at large is operating on the "lifeboat earth" principle, jettisoning the weak to save the strong.

Food security for these stagnating countries can only be obtained through direct support in either the consumptive or productive sphere. The first, through food aid, disrupts local development and should be restricted to disaster situations. In several countries, support in the productive sphere seems possible through phosphate fertilization programs, without jeopardizing the local social and economic structure.

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In agriculture, plants and animals produce useful organic materials with the sun as a source of energy. The needed resources are few in number: land with some sun, rain, and labor. It appears that many soils and climates enable subsistence in food, clothing, shelter, and energy for the family but not much more, provided of course that a large enough area is available. Man, however, is an animal species with concrete as its natural habitat; the development of civilization having been concentrated in urban centers. To maintain a substantial urban population, the productivity of the rural population has to be much larger than the subsistence level. This is only possible if the urban, industrialized sector supplies a substantial portion of the means of production to farmers.

Although a sharp distinction is not possible, these means of production may be classified as labor-saving, yield-increasing, and yield-protecting, as with machines, fertilizers, and pesticides. Only yield-protecting inputs require little energy for their manufacture and use, although their development would hardly have occurred independent from the bulk chemical industry. With quite some exaggeration, modern agriculture could be defined as the human activity that transforms inedible fossil energy into edible energy by means of the sun, plants, and animals.

Up to World War II, the emphasis in U.S. agriculture was on the improvement of the productivity of labor by mechanization; yield increases of, for instance, small grains were in the order of only three kilograms per hectare per year. In Europe, the emphasis was more on increasing the productivity of the land by the use of fertilizers, but yield increases were also not impressive: about four, ten and 18 kilograms per hectare per year for small grains in England, Germany, and the Netherlands, respectively.

Only a few years after World War II, several ways of increasing productivity came together, resulting in a spectacular boost in the annual increase in yields for most arable crops; small grain yield increases jumped to values between 50 and 80 kilograms per hectare per year. The yield increases were accompanied by a rapid reduction in the number of persons working the land. A similar sudden yield increase took place in Russia and China around 1965.

It is striking that the absolute yearly yield increases in these vastly different regions are about the same, an observation which is obscured by the bad habit of expressing yield as a percentage.<sup>1</sup> The similarity cannot be attributed to any similarity in soils and climate or in economic and social structure. It may have to do with the speed that plant breeders are able to adapt varieties to changing production conditions, but this is mere speculation.

In many wheat growing regions, low absolute yield levels result in annual percentage increases of over 2 per-

<sup>8</sup>This is a situation in which energy balance considerations are of crucial importance. If it is the purpose to make alcohol, the difference between alcohol produced and gasoline, diesel oil, liquified petroleum gas, and alcohol used should be positive since all these fuels can readily be used in the internal combustion engine. How the other direct and indirect energy additions should be counted, depends on opportunity costs. If, for instance, nitrogen fertilizer is made from natural gas which is otherwise flared away, its energy cost should not be counted at all. If, on the other hand, it is made from electricity, then it depends on how badly alcohol is needed in comparison with electricity.

Other opportunity costs are related to land use. In a country like the Netherlands, opportunity costs for land are so high that Dutchmen are not likely to go into gasohol production. Neither will Dutch scientists develop into experts on this kind of energy-accounting, since for traditional agricultural crops, it is nonsense to compare the amount of energy fixed with the amount of energy used. After all one cannot drink diesel oil and does not grow wheat for burning. Neither are roses grown in hot-houses for fuel, they are used to kindle passion. To make another comparison, whoever is so crazy as to burn a transistor radio in order to conclude that the energy efficiency of its production is next to nothing? Of course, it is always good to know which nonrenewable resources are used where and in what quantities, but this is something else.

<sup>9</sup>The energy balance of energy-producing complementary processes cannot be calculated, because there is no sensible rule to impute the energy used during production of the bulk product and during part of the processing to the various end-products. Using relative prices only shifts the problem in an exercise which is supposed to be of a physical nature. The individual entrepreneur should not be interested in such energy accounting but only in the question how to operate his plant with good economic perspectives.

<sup>10</sup>Much information may be found in F.W.T. Penning de Vries and M.A. Djiteye, eds., *Productivité des Pâturages Sahélien*, Pudoc, Wageningen, 1981. It is noted that the dry matter yield potential of natural annual grasses is the same as that of cultivated coarse grains. Selection during ages and modern plant breeding did not improve at all the photosynthetic capacity of grain crops nor their water use efficiency, but it did improve the grain yield, the harvestability, and the yield stability (see also de Wit *et al.*, *op. cit.*).

<sup>11</sup>Extreme lack of nutrients was also common on the more sandy soils of northwestern Europe at the end of the 19th century. The so-called "Atlantic desert area" was increasing rapidly. Recognition of phosphate deficiency and the availability of ground, basic slag from the iron-smelting works saved the land the farmers from ruin.

<sup>12</sup>H.A. Luning. "Technologische Veranderingen en Inkomstenverdeling," *Landbouwkundig Tijdschrift*, 91:154, 1979.

<sup>13</sup>It is claimed that in Indonesia, rice production increased more than 3 percent per year since the end of the 1960s. Production in 1977 was 15 million kilograms, but 2 million kilograms had to be imported. Thus, rapidly increasing production did not sufficiently keep up with the rapidly increasing demand, but without technological innovation the situation would have been much worse for the country as a whole. Any improvements, however, bypassed the landless and nearly landless families, which make up more than one-third of the rural population on the main island, Java. Commercialization led to less demand for their labor on the farm, but this was partly offset by less rapidly rising food prices. Hence, technological innovation may be a necessary condition for improvement, but it is certainly not a sufficient condition to help the poor.

<sup>14</sup>Data from OECD and the International Monetary Fund.

<sup>15</sup>To put more emphasis on the precarious trade balance, farming in these countries could be defined as the activity which transforms untradable land and untradable labor into tradable agricultural products. That a large portion of the foreign exchange is spent on consumption goods is only natural — after all a transistor radio satisfies an obviously basic need. Another basic need is fuel for cooking, with wood becoming more and more scarce. Firewood-schemes take a long time to mature and are high in terms of labor cost; solar-based systems require considerable capital, which is even more scarce for poor farmers than time. Anaerobic bio-gas installations may be the most promising for the future, all the more so because fewer nutrients are lost than from dung burning.

<sup>16</sup>There are always practically unavoidable phosphate losses. Moreover, during cultivation the amount of phosphate that is bound organically decreases and that is bound inorganically increases. In the latter form it is less available for the crop. The nitrogen-phosphate ratio of plant tissue is at a maximum at 20 to one so that the nitrogen-fixation of leguminous crops is limited by the amount of phosphate that can be taken up (see Penning de Vries and M.A. Djiteye, *op. cit.*, note 11).

<sup>17</sup>Soil science is sufficiently advanced to locate without much further field work, regions and soil-types where phosphate would be sufficiently beneficial. Comparison with the situation in 19th century northwestern Europe shows that the wheel is being invented again. The difference with the European situation is that a cheap by-product of industry is not available to improve soils in the phosphate-poor countries. On the other hand, in the 19th century, there were no rich neighbours around the corner.

<sup>18</sup>Desert-locust control programs are a good example. They are of low-impact because they do not interfere with local social and economic structures, but are obviously useful.

production cannot be enhanced much above the present level. With nitrogen, full recirculation is even theoretically impossible, but its supply could be enhanced by stimulating biological fixation of nitrogen out of the air which would put high demands on the phosphate availability.<sup>16</sup>

Given the rapid increase of population as a result of the input of medical knowledge, more direct support is needed, either in the consumptive sphere or in the productive sphere. Structural support in the consumptive sphere by supplying food may be attractive for regulating western markets, but it is a serious setback for local development and should be reserved only for disaster relief.

Support in the productive sphere concerns the supply of means of production to the farmer. Any scheme of support should not require simultaneously difficult technological, social, and economic changes, should have a controlled impact, and be negotiable on a governmental level. Admittedly as a technocrat, I arrived by a process of elimination at the possibility of the distribution of phosphate. The advantages of such a scheme are indeed numerous. Many soils in poor countries that have been exploited for some time are poor in phosphate.<sup>17</sup> Some augmentation of its level would mean that some more of the natural is available and the cultivation of nitrogen-fixing leguminous crops is facilitated. This is especially important because all farmers know how to utilize these methods. Moreover, yield increases are not so spectacular that the introduction of phosphate would require rapid changes of traditional agricultural systems or disrupt the social structure. Finally, it is important to remark that no harmful side effects of phosphate have ever been noticed and that once introduced, the element recirculates for some time in the system.

Of course there is the problem of distribution. Not only the infrastructure for transportation is bad, but distribution through conventional channels could easily have the result that benefits end up in places other than with the farmer. The radical solution would be distribution by air. The phosphate could then be spread directly on the land where it is needed with a minimum of social and economic interference. Although this seems far fetched and the costs large, it can be placed in the proper perspective by a comparison with the distribution of food. When each unit of triple super phosphate generates at least 100 times its weight in food, the transport problem is made orders of magnitude smaller. Thus the cost of structural relief for many could very well not exceed the cost of disaster relief for a few.

Obviously, this or similar low-impact programs<sup>18</sup> should not replace, but be complementary to other programs on the national, regional, and local level which are intended to relieve some of the immediate pressure and to give more food security in the 1990s — which is what this symposium is about.

<sup>1</sup>Expressing yield increases as percentages suggests an exponential growth rate over a long period of time; whereas yearly absolute increases in small grain yields, for example for the U.S. and the U.K. are distinctly linear; with the post-war trend line sharply steeper than the pre-war one.

On average, the absolute growth rate in yield for developing countries appears to be about 13 kilograms per hectare per year; in the industrialized countries, Russia, and China, about 75 kilograms per hectare per year.

<sup>2</sup>Under the assumption that fertilizers and adequate varieties are available and pests and diseases are controlled, P. Buringh, H.D.J. van Heemst, and G.J. Staring, (*Computation of the Absolute Maximum Food Production of the World*, Agricultural University of Wageningen, Netherlands, Publication of the Department of Tropical Soil Science, 1975) calculated potential world food production in kilogram grain equivalents. Areas of the world's potentially arable land were estimated and are shown on maps in C.T. deWit, H.H. van Laar, and H. Van Keulen, "Physiological Potential of Crop Production," In *Plant Breeding Perspectives*, J. Sneep and A.J.T. Hendriksen, eds., Pudoc, Wageningen, 1979.

<sup>3</sup>Including processing, packing, and retailing, the figure amounts to 16 percent. For information on energy in agriculture see D. and M. Pimentel, *Food, Energy, and Society*, Edward Arnold, London, 1979.

<sup>4</sup>See, for example, OECD, *Facing the Future: Mastering the Probable and Managing the Unpredictable*, Paris, 1979. Although their figures on energy availability may seem overly optimistic, it should be realized that the limits are not so much technical as they are self-imposed by mankind. Stating that it is not necessary to return to the land, is therefore a political choice on my part.

<sup>5</sup>Since energy costs of post-harvest handling are strictly proportional to the amount of grain, and since the capacity of a combine is limited by its digestion rate of straw not of seed, the trick is to leave more straw on the land.

<sup>6</sup>Because of better air-water relations, better rootability, improved timeliness of operations, and other conditions, the higher the reclamation level of the land, the higher the nitrogen uptake level of the plants and the higher the recovery rate for the applied fertilizer. Thus, increasing returns to fertilizer can be achieved as land is improved. For more information on these relationships see:

C.T. deWit, *A Physical Theory on Placement of Fertilizers*, Agricultural University of Wageningen, Agricultural Research Report No. 59.4, 1953;

H. Van Keulen, *Nitrogen Requirements of Rice with Special Reference to Java*, Research Institute of Agriculture Contract Center, Bogor, 1977; and

C.T. deWit, "On Efficient Use of Labour, Land, and Energy in Agriculture," *Agricultural Systems*, 4:279, 1979.

<sup>7</sup>The problem is that energy accounting is even a more dismal science than economics. Adding energy seems straightforward enough because the amounts can all be expressed in joules, but the usefulness of different products and energy carriers is so vastly different that the whole exercise often obscures more than it reveals. It is as if a miser were to place all his pennies, nickles, dimes, quarters, silver dollars, and paper bills on a scale and enjoy himself because he owns more than 1000 kilograms of money.

## **The Food and Energy Situation in Developing Nations**

It is prudent to place this last remark in the proper perspective, for hunger will remain just a few jet-hours away, in the less developed parts of the world. There the yields of small grains are in general much lower, not because of lack of potential, but due to a lack of yield-increasing inputs. For example, the dry-matter yield of annual grasses in the Sahelian region is only about 1500 kilograms per hectare, which is far too often attributable to lack of water. In many cases, the yield of these natural grasses in the 400 millimeter rainfall zone may be increased more than five-fold to 10,000 kilograms per hectare by the use of fertilizer.<sup>10</sup> Indeed, the lack of plant nutrients in many agricultural areas in Africa as well as in South America and Asia can hardly be underestimated.<sup>11</sup> The average annual yield increase of small grains within each of these continents is about 13 kilograms per hectare, low compared with the present yield increase in the industrialized part of the world, but comparable with the yield increase in Europe before World War II. Obviously some knowledge of improved means of production has been filtering down from the rich countries, but not fast enough.

For instance in Africa, with an average small grain yield of 1300 kilograms per hectare, the annual increase of 13 kilograms per hectare amounts to only 1 percent per year, far less than the growth rate of the population. The difference has been made up more or less by further reclamation, but soils which can be reclaimed by simple means are less available now. Western technology is indispensable for further reclamation. Hence, to improve the food situation either machinery has to be used for extending the surface under cultivation or fertilizer to increase the yield per surface unit, but the problem with both is that they are energy-intensive and becoming more and more expensive.

The average yield increases used here for illustration cover up many regional differences. Some regions and countries have a good enough infrastructure that agricultural development is possible. Prices at the farm gate are such that it pays for the farmer to improve the land, to use fertilizers and new varieties, and to apply needed disease control. With rising energy prices, however, the terms of trade for these farmers may deteriorate rapidly, and the gains may be lost in coming years. Perhaps the industrialized nations and OPEC members together have enough common sense to stabilize the international market for the main agricultural products of the developing countries on a fair level. Only then would there be opportunities to further national policies that would make it pay to develop farming.

The so-called "green revolution" has been often criticized because of adverse side-effects. Analysis<sup>12</sup> has shown that more advanced methods of farming have been rapidly accepted by farmers in regions where this was technically and economically possible. Benefits have not depended either on farm size or type of landownership, although landowners tend to profit more from the changes than tenants or laborers. Although producer advantages bypassed the landless or near landless part of the rural population, the new methods resulted in smaller price increases for food, benefiting in this way the poor who spend a large portion of their income on food.<sup>13</sup> On the other hand, it should be realized that some regions have been profiting much more than others, but it is hardly fair to blame an innovation because it cannot be or has not been applied successfully everywhere for everybody.

## **Food and Energy in the Poorest, Stagnating Countries**

What holds for regions within countries, holds even much more among countries — practically all the new developments have not touched the poorest countries. Already in the beginning of the 1970s the external debt of these countries was 130 percent of the value of their exports; this percentage has increased to a staggering 230 percent at the beginning of the 1980s with interest on and repayments of loans claiming more than 20 percent of exports.<sup>14</sup> Since this increase in external debt was not accompanied by an increase of imports, it must be attributed completely to the worsening of the terms of trade, in part because of soaring energy costs. The situation is by now such that organizations like the World Bank which have to operate somehow on a balanced budget must no longer deal with these countries. Even worse, the magnitude of development aid for these countries has decreased in real terms during the last ten years. It seems as if the world at large is operating according to the "life boat earth" principle, jettisoning the weak to save the strong.

Of concern especially are countries with poor soils and an unfavorable climate, largely landlocked without much of an infrastructure and without mineral resources, with a population that numbers in the millions and of an age structure promising still more rapid growth. The only way for these unfortunate countries to make some foreign exchange is to export agricultural staple products, at the expense of growing food for their own use. Transport costs of exports and imports are staggering and increasing. Schemes of market stabilization and price support, however useful in more fortunate countries are here hopelessly inadequate.<sup>15</sup>

## **Conclusion and the Suggestion of a Phosphate Relief Program**

But what else? Without external inputs, any improvement requires a better recirculation of plant nutrients, but even with full recirculation of phosphate, the availability of this plant nutrient is so low on many soils, that crop

cent, outstripping the percentage increase in population. Any slack thus created is taken up by an increased use of grain for animal production and by taking marginal lands out of arable production. In most regions, the difference between the present and potential yields is still so large that the trend of yield increase and accompanying changes could continue into the next century.<sup>2</sup>

### **Possible Impacts of the Changing Energy Situation in Agricultural Production in the Developed World**

The question to be addressed is whether potential yield increases can be realized in view of the changing energy situation. It is well to realize that less than 5 percent of the total energy consumption is used in agricultural production,<sup>3</sup> and it does not seem likely that energy will become so scarce that many of us would have to return to the land to grow our own food.<sup>4</sup> Whether we like it or not, the world will look very much the same around the year 2000, barring any holocaust, of course.

Within this rather conservative frame of thinking, three issues arise: (1) yield level and acreage use, (2) the availability of concentrates for animal production, and (3) biomass as a source of energy. In addressing these matters, there is the danger of falling into the trap of applying the well-known law of diminishing returns to the relation between yield and the total of direct and indirect energy use. The law applies only when one growth factor, like water or nitrogen, is varied, keeping all other growing conditions the same. Energy, however, is not a growth factor as such, but something needed for their manufacture. Since the relative contribution of different factors changes with increasing yields, it is not a matter of course that more and more energy is needed to bring about increasing yields.

On the contrary, considerable amounts of energy are needed for basic operations like plowing, seedbed preparation and sowing, but these amounts are not higher at higher yield levels. Even the energy needed for harvesting increases less than proportionally with increasing yield levels.<sup>5</sup> It appears that the application of the energy-rich input, nitrogen, can be much better controlled in situations where capital is diverted to reclamation activities that increase the yield level because then considerably less loss occurs through violation, denitrification, and leaching.<sup>6</sup> At high yield levels, attention to the timeliness of all operations and more effort on the control of diseases and other acts of God, pays great dividends. It is not so much more energy that is required for these rewards, but time and care by the farmer.

There is not time to elaborate the arguments in a more quantitative fashion,<sup>7</sup> but the conclusion is obvious. The better controlled the growing conditions are and the more efficiently the farmer can operate, the higher the yield. Although energy use per surface unit may still increase, the energy use per product unit will decrease, albeit at the expense of more care and time on the part of the farmer and the extension service.

Continued yield increase, accompanied by a relative decrease in the use of energy, however, does not seem very probable on marginal soils — that is, on soils where large reclamation efforts are needed to approach potential growth situations. It is likely, therefore, that marginal lands will be taken out of production as relative energy prices increase. If this is not recognized in time, the danger exists that too much capital is used for reclamation activities which do not pay in the long run. Of course, one may argue that these soils could then be used for energy-farming, but soils that are marginal for food production are likely to be marginal for other agricultural operations as well. Even in cases where the energy balance from cultivation to end-use of the fuel is positive, elaborate gasohol schemes remain hazardous because the net-production of energy is small compared with the gross production.<sup>8</sup>

Consider the situation in Brazil. A good energy crop, sugarcane, sufficient land, and many poor people are available to make gasohol; the positive effect of the operation on the trade balance may well be impressive. An infrastructure would be created, however, that relies on the continued availability of farmers poor enough not to use much machinery. Any change in these conditions would place the net return on energy under considerable stress.

Fuel production from biomass will be mainly from near-waste products, such as manure and straw, sawdust and wood clippings, molasses, and other by-products that are at present diverted to animal food. Many by-products could become so valuable as a fuel source that during processing less effort would be given to the efficient recovery of the primary products.<sup>9</sup> Scarcity of concentrates could then make roughage on marginal lands so valuable, that cows and other ruminants would once again be used as the most clever harvesting machines ever invented.

Thus, possible consequences of rising energy prices are: (1) less pressure on the arable use of land, (2) higher yields, (3) more energy use per surface unit, (4) less energy use per unit farm product, (5) more care by the farmers for timeliness and disease control, (6) more by-products of processing used for fuel production, less available for concentrates, and more grazing on marginal land. Surely, therefore, the food security of the developed world is not threatened by rising energy costs.