

Lessons for the World from US Agriculture: Unbundling Technology

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Summary. — Take as a goal the adequate nourishment of all human beings by the middle of the next century, when the human population will be near double its 1980 level, with much of the increase occurring in the poorest areas of the world. There is a great need to keep food prices low. However, we must consider the additional goal of sustainability. Can agricultural sustainability be achieved while producing the required volume of food at low cost?

This paper will argue that economic development does not require that food be as cheap, or agricultural practices be as labor saving, as is often assumed.

1. INTRODUCTION

In about the year 1850 the human population reached one billion. During the next eight decades it doubled to two billion; the third billion was added by 1960. Fifteen years sufficed to add the fourth billion, and 11 more years brought our numbers, in 1986, to five billion. We had multiplied ourselves fivefold in 136 years. The wonder was that so many of our systems were thriving and so few were in evident collapse.

The name of Thomas Malthus was widely invoked in the early 1970s by those who predicted that the limit of the earth's capacity to produce food would soon be reached, and the terrifying phenomenon of exponential population growth would be stopped by that most to-be-avoided limiting mechanism, famine. Few of the predictions of those times, however, have held up well. On the one hand, population has continued to rise even faster than most estimates, and resources use has soared at a greater rate than that anticipated by even the most gloomy prognosticators. On the other hand, the specific expectations of the Malthusian pessimists continue to be wrong. They were wrong, as they had been for almost 200 years, ever since the *Essay on the Principle of Population* first appeared, because of technology.

The earth's dwindling supplies of mineral deposits and other raw materials have not, as it turned out, set the binding limits on industrial production and consumption; such possibilities as recycling, miniaturization, and substitution of material inputs result in continual improvement

— not deterioration — in the relation between the availability of most basic materials and human requirements thereof. In agriculture, the Green Revolution arrived in time to multiply the world's output of the essential cereal and feed grains by a factor of 2.6 in a little under a quarter-century — keeping so well ahead of population growth that, during 1950–84, global per capita grain availability increased by 40%.¹

At the same time, the world's human population has not stopped growing, and it is not expected, even by the most optimistic prognosticators, to level off until the 10 billion mark is reached, at the soonest. That number is variously projected to be reached by as early as 2050, or as late as 2080. Demographers generally expect around 90% of this increase to appear in the areas now collectively known as the Third World.

The finite supply of raw materials has not proven to be the binding constraint that was predicted, so that from this point of view it seems possible to continue without difficulty to increase production and consumption of industrial goods. Another constraint may, however, be arising. The "throughput" of materials and energy involved in much consumption and production puts strains on the capacity of the environment to

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absorb the effects thereof (often generally referred to as "pollution"). We may even now be pressing this capacity dangerously close to its limits.

This dilemma is the backdrop for the question which we must ask regarding modern agriculture: will human ingenuity, in the form of technological and institutional innovations, be able to accommodate the next population doubling as it did the last, when the number of human beings went from 2.5 billion in the mid-1940s to five billion in 1986? Such an accommodation, to be adequate on humanitarian grounds, must be accomplished in terms of three goals for the global agricultural system:

- (a) Agricultural output must increase so as to feed the rapidly growing human population at a level which will not only maintain but improve the standards of nutrition. This is the requirement for more food.
- (b) Agriculture must not only produce enough food; its product must be able to reach all those who need it. This is usually, and most simply, interpreted as a requirement for cheap food.
- (c) The third requirement is for sustainability, where sustainable agriculture is defined as any collection of agricultural practices which leaves the productive potential of the resource base at least as great as it was when those practices were initiated.

There are reasons (which will only be summarized, not argued, in this paper) to believe that there may be serious conflicts among these three goals. Which one, then, must give way?

Clearly, the first goal is the most critical; it is the one that we are most likely to feel cannot, must not, be abandoned.

If one of the three is to be ignored, it is most likely, in the short run, to be the goal of sustainability. What this means is that, in the long run, goal (a) will no longer be able to be met; our productive capability, instead of growing, will shrink. To fail on goal (a) for the long run (a long run that may not be very far off) is only slightly less bad than failing in the short run; either failure spells terrible misery, deprivation, ruined lives and premature deaths.

With these thoughts in mind, we return to goal (b). The requirement that food reach the hungry is, clearly, just as absolute as the requirement that enough food be produced; however, there is room to consider the possibility of achieving this in ways other than through "cheap food."

One premise of this paper is that there exist preconceptions that make it hard to consider

some alternatives, while other alternatives present themselves forcefully for our consideration. There are immediate and obvious reasons why many people should regard cheap food as a good thing. That fact, in itself, is not sufficient to explain why the literature on agricultural economics has given relatively little attention to the question of whether cheap food is altogether desirable. The explanation for this neglect is probably to be found in the avoidance of normative issues in economic writings.

The next two sections of this paper will be devoted to the fashions of thought that influence our perception of facts and our drawing of conclusions on agricultural issues, both on what is likely, and on what is desirable.

2. WAYS OF THINKING ABOUT AGRICULTURE

One theme of this paper will be that perceptions matter: the choices and decisions which are made, in agriculture as in other areas, depend upon what is believed, and what is believed depends upon what is perceived. This does not imply irrationality; individuals may work as hard as any economist could wish at rationally maximizing their utility, but what they do will still turn upon what they believe will promote their welfare, and upon their beliefs as to which actions are likely to bring about the welfare-promoting consequences they have identified.

These beliefs are not based upon absolute, Platonic knowledge of what exists in the world and of how the world works. They are based, instead, upon each individual's limited set of perceptions of what exists, and upon his or her beliefs (these might also be called "theories") about causes and effects. None of us have the time, or the ability, to invent new theories to suit every different circumstance that we face. Therefore we all depend upon the theories that generally prevail among the people we respect. For this reason, fashions of thought — including the academic theories that are currently "in the air" — are as important a determinant of human behavior as any other "facts" which we may adduce.

Over the last half-century there has existed a fashion of thought — it will be referred to here as "the Old American Model" (OAM) — which has achieved a special kind of dominance in the field of agriculture. The OAM has been viewed, by many, as *the* direction in which agricultural practices should, and inevitably would, develop. Almost nowhere has this dominance, however, been absolute. Even in the United States, a

variety of alternatives has existed, though in an underground fashion (so to speak) for much of the period since the 1930s. Those alternatives have recently been pulled together in a model that its US proponents refer to as the Alternative Agriculture Model (AAM).

Sections 5 and 6 of this paper will outline these two models. First, however, we will see more of the context within which they are important.

3. AN HISTORICAL/ECONOMIC CONTEXT

It is hard to learn from history: it is harder yet not to. It is nearly irresistible to apply the lessons of the immediate past to everything new that comes along. It is worth reflecting, in the early years of a new decade, that the lessons of the two decades just past differ sharply from each other. With this in mind, we might ask ourselves: If we are to choose the lessons of either the 1970s or the 1980s as a basis for teaching us what we need to know about the future of global agriculture, which would make the better basis for prediction?

As observed earlier, the lesson drawn by some observers in the 1970s was that we are using up our resources (of land, minerals, water, etc.); Malthus was right; population will outstrip food production; and we must mobilize all efforts to grow enough food.

The lesson of the 1980s was a completely contrary one, that the Malthusian pessimists are wrong again; technology, along with price incentives, can produce any amount of food that humanity can demand, regardless of the pace of population growth.

If the problem of the 1970s was the threat, and sometimes the reality of famine, the 1980s had problems, too. One that might be cited is that the industrialized world had developed a greater tolerance for famine in the less-developed countries (LDCs): there were not actually fewer deaths from starvation in the 1980s than there were in the 1970s (and the incidence of chronic, debilitating malnutrition has risen over the period), but they had progressively less shock value.

Famine was not, however, among the problems of agriculture in the 1980s that were most widely recognized in the industrialized countries. The subjects stressed by agricultural economists and other policy advisers in the West (see Miner and Hathaway, 1989) included deteriorating and destabilized commodity prices in world markets; severe economic stress at the farm level; heavy build-up of stocks of key commodities; and

aggressive export competition promoting serious international trade conflicts.

The fashions of thought of the 1980s encouraged blaming many of these problems on the agricultural policies of the governments of the affected nations. Indeed, there is a strong case to be made for holding economic macropolicy responsible for many of the woes that settled on agriculture in the early 1980s. The case is made from two directions — by the proponents of free markets as the most efficient allocators of resources, and by the environmentalists.

The former observe that resource allocation is skewed under systems such as the US commodity program, where prices signal neither the preferences of consumers (as prices reflect the government's decisions of what to support, under a complex set of rules), nor the true costs of inputs.

The environmentalists join the market liberalizers in this instance, pointing to the fact that government programs which reduce the risk of specialization have promoted a decline in diversity at all levels of farm operations and have subsidized ecologically short-sighted agricultural practices and crop choices. Government agricultural policy has shaped technological change in ways that may not be in the best interest of the farmer or of the broader community, especially with regard to the needs of the future.

During the 1980s the view from the industrialized world of the LDCs has emphasized those problems which fit into the same set of beliefs and observations that have focused attention upon the macropolicy errors of the industrialized world. These problems stem from price-distorting macropolicies, though of a different sort than found in the industrialized countries. LDC governments are more apt to bias their trade policies against the agricultural sector than in its favor. The favorite economic explanation of the underlying cause of these problems is that they are the inevitable result of government interference in the free working of markets which has prevented the harmonious balancing of supply and demand.

While emphasizing the mistakes that have been made by governments meddling in agricultural (as in other) markets, today's dominant fashion of economic thought gives scant attention to the realities of market failures — collusion among producers; inadequate translation of environmental stresses that will reduce future productivity into market costs; and failure to internalize other externalities, such as off-farm health effects of pesticide use and water contamination by fertilizer run-off. It similarly fails to build theory upon that fact about market prices which allows glut to coexist the famine: the

"demand" that makes itself felt in the market's balancing of supply and demand is understood to mean economically effective demand; this does not reflect what is actually wanted, or needed, but what people can afford to buy.

The slowing of world economic growth in the 1980s, compounded with the efforts to pay off interest rate inflated debts (diverting LDC resources and efforts from the basic needs emphasis of the 1970s), along with trade barriers that raised consumer prices in importing countries, and support programs that raised consumer prices in exporting countries, all drove a larger than usual wedge between the agricultural products that people would like to buy and what they could afford to buy. The supply-demand gap opened wide when supply was raised relative to what it would have been without artificial price inflation or with appropriate inclusion of the cost of externalities, while demand was depressed relative to what it would have been with greater world prosperity.

The slow-motion depression of the 1980s is the backdrop for the currently popular reading of the lessons of that decade, which is that our technological ability to produce food is significantly greater than the global demand for food — that the greatest need is not for increased overall production, but for freer international trade. The goal of such liberalization would not be a significant lowering of average prices (see Paarlberg, 1989), but rather the reorganization of production toward the commodities more in (effective) demand.

This conclusion is only possible in a situation of worldwide economic distress, in which the most basic indicator of human well-being has remained far below what should be an acceptable level: globally there are now estimated to be 600–800 million people suffering from severe food deficiency. Production, even in the early 1980s, was in excess only of the ability of a world in depression to pay the prices expected: given existing patterns for consumption, it was not significantly in excess of actual need.

4. THE ECOLOGICAL/ECONOMIC CONTEXT

This paper will assume, but will not attempt to prove, that grave ecological dangers exist in today's global agricultural system. For more evidence on the unsustainability of parts of the existing global system, other works (including some mentioned in the bibliography) will need to be consulted. The following is simply a statement of the three overriding issues which have con-

vinced many observers that there is serious cause for alarm.

- (a) Large areas of land are being degraded through poor farming practices, so that the global total of land that can be used for farming with currently known techniques will diminish significantly unless present trends are reversed and damage already done is repaired.
- (b) Usable fresh water resources, essential for farming as well as for industrial and other uses, are deteriorating rapidly — in quantity (where important water tables are dropping) as well as in quality (where water is becoming polluted).
- (c) The prospect of global warming seems, on the whole, to present more negative than positive factors for agriculture. There are, at the same time, a number of aspects of agriculture (both modern and traditional) which are direct contributors to global warming. These include the characteristic substitutions of modern agriculture (e.g., of machinery and chemicals for land and labor), which result in heavy use of fossil fuels; the methane gas produced by animals under a variety of systems of animal production²; and the overall pattern of land use, with accompanying patterns of vegetative cover.³

Some of the strongest statements on the dangers of unsustainable agriculture are to be found in the writings of the Worldwatch Institute — an organization which was a leader in the direful predictions of the early 1970s. While noting that the conclusions of this group have often been too gloomy, it is useful, also, to recall that the facts they have stated have generally been sound; if anything, their statement of trends in human behavior regarding resource use and population growth have been too conservative, on the optimistic side. Their failure has been in not fully anticipating the technological response to those facts, which has changed the outcome — never more dramatically than in the growth of the world's agricultural output in the 1970s.

The following then, is one statement from the Worldwatch Institute on the sustainability of present agricultural systems:

According to [the United Nations Environmental Program's] 1984 assessment, 4.5 billion hectares, or 35 percent of the earth's land surface, are threatened by desertification. Of this total — on which a fifth of humanity already makes its living — three fourths has already been at least moderately degraded. Fully one third has already lost more than 25 percent of its productive potential . . .

Each year, irreversible desertification claims an estimated 6 million hectares worldwide — a land area nearly twice the size of Belgium lost beyond practical hope of reclamation. An additional 20 million hectares annually become so impoverished that they are unprofitable to farm or to graze (Worldwatch, 1989, pp. 21–22).

According to this picture, those who carry from the history of the 1980s a memory which teaches them that the problem in world agriculture is one of glut, not of deficiency, are ill prepared to face the problems that will come with an expanding human population. We face the need at least to double current levels of output in a little over a half-century, but the land base on which this will have to be achieved will not be larger than it is now. Instead, if all the land areas whose economic usefulness is now on the verge of being destroyed were to be removed from cultivation and returned to less productive, but still highly important range or forest uses, there would be a marked reduction in the area available for intensive agriculture.

This paper will focus below on one particular type of modern agriculture — the “Old American Model” (or OAM). The concerns listed so far do not lead to the conclusion that the OAM is solely, or even principally, responsible for the world’s agroecological problems. Some of the unsustainable practices now employed occur in the OAM, some in various “hybrid” systems (mixed scientific/traditional), and some in the context of a variety of models which are lumped together under the name “traditional agriculture.”⁴

It is not because I believe it is the principal culprit in environmental degradation that I will dwell on the OAM. Instead, the OAM will be emphasized because it holds a special role in the world, as a standard against which other systems are compared, especially in terms of “productivity.”

To the extent that the existing systems do not produce enough food for a growing human population, or do not make it available where it is needed, or fail to achieve these goals in a sustainable fashion, there will be growing pressure for change. Where should this change occur — in the countries that now are the largest exporters, so that they double or triple their surpluses? Or in the LDCs, where most of the additional hungry people of the next century will be born? Any attempts to answer these questions will depend upon our mental models of what kinds of agricultural systems and practices are feasible and desirable. Believing that these mental models are strongly shaped by the agricultural forms emanating from the United States, I will

now look at two approaches to agriculture currently available in the United States.

The OAM has been our dominant representative, and is particularly associated with the spectacular successes of the Green Revolution. The other approach is the Alternative Agriculture Model (AAM). The proponents of the AAM do not propose to do away with what has been learned from the OAM. Rather they hope, while introducing some additional features, to build upon and refine its most productive aspects. Although many of these proponents of alternatives come from within the tradition of the OAM, they generally believe that the most efficient way to achieve what is needed is not to push for incremental reform within the model, but rather to set alongside it a recognizably different model, so that a clear choice will exist.

5. THE CULTURAL CONTEXT FOR TWO “AMERICAN” MODELS

Agriculture is one of the most practical of human pursuits; it is also one of the most symbolically charged. The relation of a farmer to his or her land is often as emotionally loaded as the relation of parent to child. The small farms of a developed country like Italy or of a developing one like Indonesia, the huge private holdings of the United States or Argentina, the communal plots which differ so greatly from Hungary to the Soviet Union to China — each of these forms is highly significant for how the people of these nations see themselves. The significance is for the self-image and sense of identity not only of the farmers, but of the whole people.

Thus, if we are to understand where US models of agriculture come from, and what it will mean for them to change, we will need to go beyond the obvious aspects of technology, and pay some attention to the socio-cultural aspects which are, in turn, crucially founded upon some essential elements of the US self-image.

The US self-image, as described by Mazlish (1990) is most efficiently understood in terms of its contradictions or polarities.⁵ Two pairs of contradictory images are particularly relevant for understanding the place of agriculture in the United States: (1a) the completely independent, self-sufficient frontiersman, versus (1b) the social, interactive, efficient businessman of the city; and (2a) the ruthless master of nature, versus (2b) the friend, or child, of nature.

There are complicated dynamics involved in how these pairs of images play off against one another. The second pair often involves a more clearly and direct internal conflict: an individual

is almost forced to make a choice as to whether he or she will gravitate toward the "friend" or the "ruthless master" of nature end of this spectrum. The first pair, by contrast, can exist within the same individual without raising a conscious awareness of tension. As a society, too, Americans cling to the image of the independent, self-sufficient small farmer (a derivation of 1a) while being simultaneously proud of the fact that US agriculture is a business (fitting into 1b).

It is the combination of (1b) (the efficient businessman) and (2a) (the master of nature) which creates the largest part of the basis for the OAM that has been dominant in US agriculture for the last half-century. At the same time, these dualisms contain other possibilities. One of these has been emerging with increasing force in recent years as a part of the environmental movement in the United States. The temporarily subordinated images of independence, self-sufficiency, and harmony with nature may not persist as a cluster (individual food self-sufficiency, in particular, has long been a romantic ideal with no possibility of realization for the vast majority of North Americans), but these images form a nexus with an important role to play in shaping the next phase of US agriculture.

The publication of *Alternative Agriculture* (Pesek *et al.*, 1989) may prove to be a watershed event.⁶ It has created the possibility that farmers whose practices do not fit within the ethos of the OAM will have another model, the AAM, against which to measure and by which to define themselves.

The AAM is based on an ecological/conservationist tradition which may be summarized in the idea, "What you inherit from nature is likely to be the best you will have — try to preserve it intact." This leads to an emphasis on, for example, the recycling of plant wastes as humus. By comparison, a "technological fix" approach says: "Don't worry about what you use up, you can always replace it." In the instance of agricultural recycling, the technological optimists tend to view chemical additives as perfect substitutes for organic matter. The ecological conservationists stress the complexity of ecological interactions, and the difficulty of understanding what it is that one is trying to replace. More broadly, the ecological view also stresses the importance of not abandoning knowledge of traditional patterns of human resource use before discovering the values which are presumed to be represented in their endurance.

The proponents of the AAM hold that their model is more economically rational than the currently dominant OAM. They argue that this is so even in the short run, and on the basis of

selfish individualism; but their argument is additionally strengthened when a longer-run, more socially-oriented, perspective is used.

In the next section these models will be described in terms of the productivity of the factors they employ. Here, first, we will see how some additional preferences and predilections which can be recognized as other aspects of the "American psyche" combine with the polarities described above to create, for the OAM, an ideal type which I will call "the monolithic solution." The characteristics of this ideal type (not to be confused with a real description of specific decisions) will be sketched, with a contrast drawn to the "diversified solution" approach of the AAM.

(a) *The monolithic solution is large and simple — each problem has a single, easily replicable solution*

"Monolithic" solutions will have a "clean" look; they will implicitly assume that in the average situation there is sufficient understanding so that messy attention to local details is unnecessary. This simplifies the work of that US invention, the extension agent, who can efficiently cover a large territory while referring for relevant knowledge to the scientific community attached to a research center, rather than to the myriad of individual farmers. (Again, we are talking of an ideal type — a caricature — which is acknowledged to be unfair to many individual extension agents.)

Included in this mind set is a US liking for bigness *per se*. The preference for solutions that are large and simple also deemphasizes the on-the-spot decision making which had been characteristic of agriculture since the neolithic revolution, and which comes back into prominence in the "diversified solution" typical of the AAM.

Related also to a preference for specialization, the OAM's large and simple solutions are consistent with the tendency of industrialization to achieve labor productivity by reducing the knowledge, information and skill required of workers ("deskilling").

In contrast to the OAM's achievement of strength in simplification, the AAM accepts and builds upon the reality of nature's complexity. The AAM does not have any inherent bias against bigness: it recognizes that there are many situations where economies of scale exist. It also recognizes other economies, however, some of which may be lost when farming units become too large.

(b) *The monolithic solution is specialized, dealing with only one issue at a time*

This preference for specialization, expressed through commodity programs and other federal interventions, as well as in the choices of individual farmers, has had the effect of favoring single crop farms, promoting farm systems which routinely separate crops from livestock, and decreasing the genetic diversity of many major US crops and livestock species.

By contrast, the AAM values diversity as a positive source of ecological insurance and of interactive synergies.

(c) *The monolithic solution offers certainty and completeness*

These were among the characteristics that were originally expected from the introduction of chemicals and other modern inputs to farming: with pesticides and herbicides, it was once hoped, it was just a matter of finding the right application to be sure of getting rid of *all* the unwanted insects and weeds. With scientific irrigation, chemical fertilizers, and genetically engineered plant varieties, the production function could be made precise.

These ambitions have not been realized, and the reason for this defeat stems from the change over time and space of interactive systems: such change was not built into the model's premises. There is a larger system, perhaps best apprehended in the discipline of ecology, within which any agricultural technology operates. The ecological system includes the long-range effects upon soil and water of irrigation, chemical applications, mechanical tillage, repetitive monocropping, etc., which change the production function over time. It also includes the adaptive responsiveness of wild flora and fauna to the genetic and chemical engineering of modern science.

(d) *The monolithic solution offers control as a consequence of intensiveness*

While this aspect of the OAM is related to specialization and to the single, large solution, it has its own features as well. The following illuminating passage in *Alternative Agriculture* describes an aspect of the OAM:

Intensive animal production tends to have performance characteristics similar to intensive crop production. Capital, technology, and chemicals are

substituted for labor and management, resulting in systems that are productive and profitable under favorable conditions but more vulnerable to routine fluctuations in input and output prices (Pesek, *et al.*, 1989, p. 226).

The tradeoff offered by the AAM is, essentially, a partnership with nature in which the tendency for plants and animals, soil and water to maintain their own health and productivity is allowed and encouraged to operate, while less effort is made to maintain tight control over every aspect of the interactions occurring on the farm.

(e) *The monolithic solution is designed for simple goals that can be analyzed by techniques of neoclassical economics*

Neoclassical economics emphasizes maximization, which can be performed without constraint only over a single function. Thus, the maximization within a single period of output per acre or of output per worker hour are goals that can be readily calculated.

Within the context of such simplified goals, overkill is not seen as inefficiency. There is relatively little account taken of the economic waste or the externalities that may be associated with the use of an irrigation schedule that will ensure enough water for any year, regardless of annual weather patterns; or of a pesticide application schedule that sets a given dose so many times a year, regardless of insects' reproduction cycles, predators, etc.

It will be objected that the statements just made cannot be true: a competitive market will ensure efficient use of resources. The answer to this, of course, is that the OAM has not grown up within the perfectly competitive market hypothesized by economists, but instead has been significantly molded by the environment of US federal farm policies.⁷

The OAM's adoption of simple goals may be contrasted with the far more complex set of goals associated with both the more traditional and the most modern, ecologically oriented kind of farming. This more complex set of goals compares the total output with the entire input package, rather than measuring success only on the denominator of acres sown or of labor inputs. It includes the long-term health and productivity of the land among its objectives. These objectives require attention to factors which can be measured by current approaches with difficulty, if at all.

Perhaps even more fundamental than its goals is the AAM's approach of "fine tuning" rather

than "overkill." This is achieved by the substitution of one scarce and costly factor for another — that is, of human attentiveness and skill for excess inputs of water, chemicals, or fossil-fuel energy.

(f) *The monolithic solution is amenable to reductionistic analysis which assumes that components can be examined one by one without loss of essential understanding*

The OAM assumes that one can adequately understand the possible effects of a switch to a more "organic" type of farming by an analysis, or an experiment, in which only one technique or input is changed, with the rest held constant (closely related to the *ceteris paribus* assumption).

The criticism of the reductionistic analysis employed in the OAM is that it misses some important interaction effects which are characteristic of biological systems. It has also given little or no guidance on the issue of how to make a transition from the OAM to an alternative model.

As a final example of the beliefs which support a preference for a "diversified solution", we may consider the following:

The primary advantages of diversification include reduction or elimination of certain diseases and weeds, reduced erosion, improved soil fertility and tilth, increased yields as a result of rotational effects, reduced need for nitrogen fertilizer (in cases using legumes in crop rotation), and reduction of financial risks from changing crop prices. . . .

Disadvantages can include increased machinery requirements and expense (for example when forage crops are needed); need for additional buildings, fences and watering facilities when livestock or poultry are added; increased complexity of the farmer's management of production and marketing; and reduction of acreage planted with government-supported crops (Pesek, *et al.*, 1989, p. 230).

Note that the advantages cited for diversity are strong in social benefit: diseases and weeds are not only costly to the individual farmer, but are also negative externalities when they spread to neighbors' fields; soil fertility and tilth help, and erosion harms, the farmers of the future, while erosion also threatens off-farm water supplies; reduced need for fertilizer also may aid in maintaining water quality well beyond the farm. At the same time, some of the disadvantages refer to a loss of what had been a private benefit at public cost (reduction of acreage planted with government-supported crops), or to a requirement for more inputs of education of workers (arguably, a public good).

6. THE PRODUCTIVITY OF THE OAM

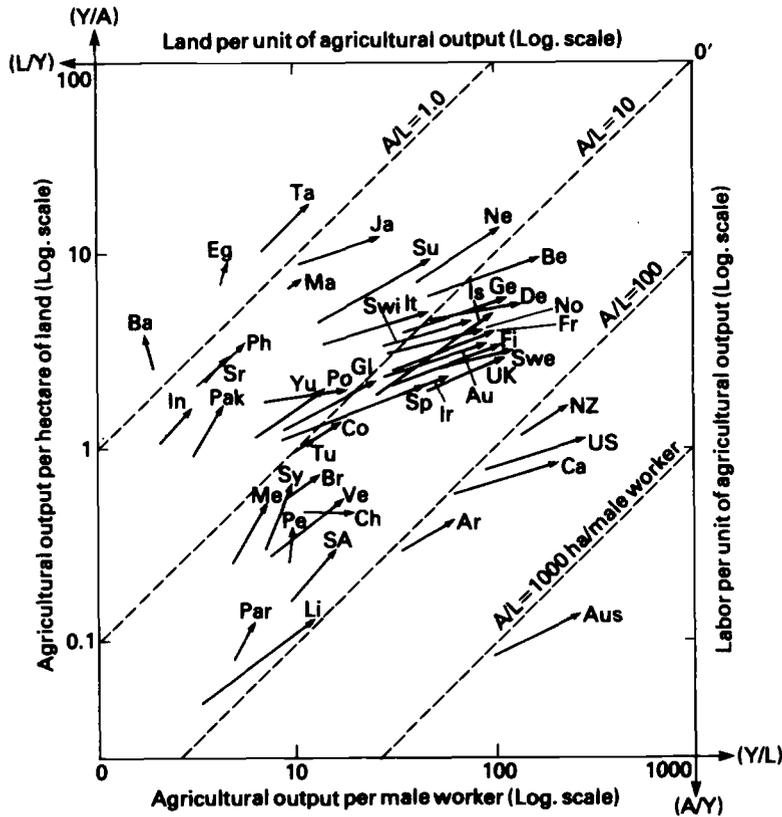
The most striking aspect of US agriculture is its labor-saving character. One hears stories, for example, of Soviet agricultural experts visiting a US farm, unable to believe that the majority of the agricultural laborers are not being hidden from them. Only Australia can boast a comparable agricultural output per worker.

What about land productivity in US agriculture? In this respect, US agriculture compares favorably with countries with a similar factor endowment. Among the five great wheat exporters, only New Zealand produces more agricultural output per hectare of land than does the United States, while Canada, Argentina and Australia produce less — Australia very significantly so, with little better than one-tenth the land yield of the United States. Evidently, Australia has made a tradeoff, achieving the world's highest labor productivity (in wheat production) at the cost of being among the world's lowest in land productivity. However, when we look, not only at major wheat exporters, but at a group of 44 countries spanning the range of North and South, we find that the United States does not lead in land productivity: in fact it is among the bottom third. The United States, too, appears to have made the land productivity versus labor productivity tradeoff.

Figure 1, drawn from Hayami and Ruttan (1985), shows the relation among three factors: land inputs, labor inputs, and agricultural output. As with any graph, it is important to understand not only what it includes, but also what it leaves out. Figure 2 provides a context in which we can place the Hayami-Ruttan graph, to see what it does not include.⁸

Level (a) in Figure 2 depicts the classical economic view of agriculture, wherein the perceived tradeoff was between land and labor: the productivity of one of these two inputs could only be enhanced by adding more of the other. Since both were characterized by diminishing marginal returns, the factor whose use was increased would suffer a productivity decline: hence the pessimism of such classical economists as Malthus and Ricardo.⁹

During the two centuries of the industrial revolution, a more dynamic, third element was added to the tradeoff, appearing to refute the premises for the classical pessimism. It became possible to apply technological inputs to enhance the productivity of both land and labor. There have continued, however, to be Malthusian pessimists who proclaim that we are about to run up against some global system of diminishing marginal returns such that technological progress



Key:

Argentina	Ar	Finland	Fi	Mexico	Me	Sri Lanka	Sr
Australia	Aus	France	Fr	Netherlands	Ne	Surinam	Su
Austria	Au	Germany, F.R.	Ge	New Zealand	NZ	Sweden	Swe
Bangladesh	Ba	Greece	Gr	Norway	No	Switzerland	Swi
Belgium	Be	India	In	Pakistan	Pak	Syria	Sy
(& Luxembourg)		Ireland	Ir	Paraguay	Par	Taiwan	Ta
Brazil	Br	Israel	Is	Peru	Pe	Turkey	Tu
Canada	Ca	Italy	It	Philippines	Ph	United Kingdom	UK
Chile	Ch	Japan	Ja	Portugal	Po	United States	USA
Colombia	Co	Libya	Li	South Africa	SA	Venezuela	Ve
Denmark	De	Mauritius	Ma	Spain	Sp	Yugoslavia	Yu
Egypt	Eg						

Source: Hayami and Ruttan (1985), p. 121. Used with permission.

Figure 1. International comparison of labor and land productivity in agriculture.*

*On the 45 degree lines (called uni-A/L lines by Hayami and Ruttan) the land/labor ratio remains constant over the 20 year period represented in this graph: one man's output grows only as much as the output of an average piece of land of the size he worked in 1960. If the slope is steeper than 45 degrees, the land/labor ratio decreased — output per male agricultural worker increased less than output per hectare.

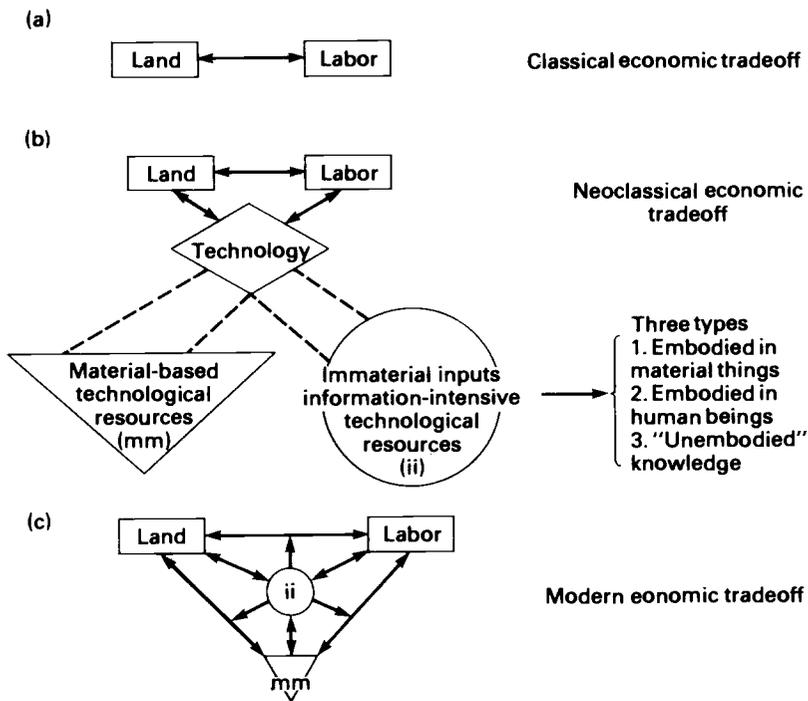


Figure 2. *Productivity of agricultural inputs: Theoretical degrees of freedom in three stylized historical periods.*

*The periods in history which may be described as belonging to phase (a) are those long stretches of time when, in particular places, no important new agricultural technology was being introduced. For the West, this means that the only periods appropriately described in terms of the classical economic tradeoff are various (not all) times prior to the 18th century.

†Phase (b) is outstandingly, but by no means uniquely, exemplified by the industrial revolution as it has occurred starting at different times in different parts of the world.

will come to an end. Economists who perceive that this will throw us back upon the severe limitations of the classical land/labor tradeoff prefer to listen to the technological optimists who insist, instead, that the ingenuity of humankind will continue to find technological inputs that can maintain the momentum of ever greater productivity of all critical factors.

It may be that both the Malthusian pessimists and the technological optimists are right. We may "unbundle" the concept of technological inputs to agriculture to consider two types.

— "mm" (for the mostly material inputs) is the group of technological resources whose marginal returns are declining most markedly in modern agricultural systems such as the OAM. They include chemicals, machinery, imported (i.e., off-farm) energy, and other purchased material inputs.

— "ii" (for the information-intensive, im-

material inputs) is the group of technological resources that appear to retain significant potential to enhance the productivity, and reduce the intensity of use, of most or all other factors.

Examples of technologies which emphasize "ii" inputs include:

- pest control strategies that employ natural interactions of plants and pests;
- crop rotation and diversity;
- the selection and creation of improved animal and plant varieties;
- complex farming systems, including, with the staple grains, legumes, fodder and, importantly, livestock;
- recycling of animal and vegetable waste products;
- agroforestry and other types of three-dimensional design to maximize utilization of sunlight in plant "layers"; and
- "fine-tuning" of inputs, e.g., in timing as

well as quantity of applications of water, fertilizer, etc.

The Old American Model has, over the decades, increased inputs of both information (including the skilled management, consultants, etc., in which it is embodied) and materials, relative to its inputs of land and unskilled labor. The greatest increases so far, however, have been in the "mm" inputs of machinery and chemicals. The data are not at present available that would allow calculation and comparison of the productivity of these two types of technological factors. However, it is a reasonable hypothesis that, in increasing land productivity by about 50% from 1950 to 1975, while labor productivity more than tripled, the productivity of the "mm" inputs was greatly reduced, including the productivities of machinery, fossil fuel, fertilizer, and other chemicals.¹⁰

The Alternative American Model, building on the OAM, continues the intensification of requirements for knowledge, skills, and information — the "ii" inputs.

Alternative farming is not easy. Grain farmers who add livestock to their farms may find it more difficult to balance demands on their time during certain peak work seasons. Labor needs, particularly for trained personnel, typically increase on farms using alternative systems. Marketing plans take more time to develop and implement. Alternative farming practices also require more attention to unique farm conditions. Scouting for pests and beneficial insects, using biological controls, adopting rotations, and spot spraying insecticides or herbicides require more knowledge and management than simply treating entire fields on a programmed schedule (Peseck, *et al.*), 1989, pp. 9–10).

It may be expected that the total labor requirements of the AAM will climb, along with the increase in the skill, knowledge, and information components of technologies that have to be instilled in workers. At the same time, the AAM appears to have begun a trend in decreasing the overall intensity of "mm" inputs. Its impact on land productivity is, as yet, unclear.

7. THE MEANING OF THE TWO "AMERICAN" MODELS FOR THE INDUSTRIALIZED WORLD

If one were to ask, in Argentina, Mexico, Canada, India or Russia, why US agriculture is so widely admired and imitated throughout the world, the answer would be, very simply, "Because it is so productive."

Relative to other countries, US labor produc-

tivity is very high; land productivity varies by crop, but tends toward the low end of the spectrum; and the productivity of the traditionally defined technological inputs is, on the whole, very low. The admiration accorded to the OAM clearly rests, then, upon a belief that a level of labor productivity which can release 98% of the workforce to off-farm activity is a desirable achievement. This belief deserves some examination, especially with regard to the future directions to be taken by the agricultural systems of the world.

The US experience is most obviously meaningful for the rest of the industrialized world, where factor endowments (at least the relative availability of labor and capital) and factor prices are more like those in the United States than are those in developing regions. What lessons, then, can be drawn for the industrialized world from the discussion so far?

In the United States, we may be seeing a transition from the Old American Model to some form of Alternative Model. The motivations for change may be found in a comparison of the OAM's performance with the three goals initially set out. While the OAM produced a great quantity of food (goal a), its claims to low-cost production (goal b) are put in some doubt by the environmentalists' claims that, in fact, significant societal costs have been left out of the accounting. Similarly, the OAM is criticized as inadequately meeting goal c, sustainability.¹¹

A transition from OAM to AAM may be expected to be characterized, first by a substitution of "ii" for "mm" inputs. This implies a marked increase in the levels of education, skill, and knowledge required in the agricultural sector. These qualities will have to be supplied by an upgrading of the education/skill level of the average agricultural employee, along with a large increase in the number of highly educated employees of various kinds. Given the types of practices advocated by the proponents of the AAM, this is also likely to be accompanied by an increase in unskilled and in mid-level as well as in highly skilled employees. In relation to the almost continuous trend in US agriculture over the last century, this direction of change is regressive. Given the cost of labor (a major motivator for the direction of factor substitution we have seen to date), it is likely to be expensive.

Americans now enjoy the cheapest food in the world relative to their incomes and to the rest of their expenses, spending only about 15% of their total disposable income on food, in contrast to "Western Europeans, who spent an average of 23.8 percent of household disposable income on food in 1983. Families in many less developed

countries spend well over 50 percent."¹² An increase in the cost of producing food does not have alarming implications for the United States, where the cost of unprocessed food is a relatively small part of what consumers pay for what they eat. In the United States a \$1.00 loaf of bread contains only about five cents worth of wheat; the other 95 cents goes to transportation, processing, packaging, advertising, merchandising, and the overhead and profits of the "middlemen" involved in each of these steps. If the price of wheat doubled in the United States, the price of the \$1.00 loaf would increase only to about \$1.05 (Worldwatch, 1989, p. 14).

Much of the rest of the industrialized world possesses another sort of insulation that can also prevent some cost increases from being directly transformed into significantly increased food prices. Western Europe and Japan have maintained institutional arrangements that have greatly inflated the price of food. The cost of production has also been raised above what it would presumably be without government intervention; however, in many cases the price of food has been inflated more than production cost. If these regions choose to move their agricultural systems in the direction of more costly, "greener" practices, internalizing externalities and sustaining fertility for the future, the perceived cost of food production could rise for some time, at least in some areas, before bumping into current "artificially high" food prices.

The simplest summary, then, of what may be expected if US agriculture moves in the alternative direction, and if Western Europe and Japan follow suit, is that labor intensity will cease to drop, and may in some cases increase; the absolute number as well as the proportion of workers employed in agriculture will rise; the cost of production will increase; and the result will be a not very painful price increase in the United States, and a rationalization of already existing high food prices in some other industrialized countries.¹³

Given the role of some of these countries as major exporters, we must keep in mind the possible effect of raising the price of internationally traded foodstuffs. This is an issue which should be considered within an overview of the yet more perplexing question of what the Third World should now be learning from developments in US agriculture.

Having looked at two US models, it is not to be assumed that these are the only conceivable options. The AAM has, indeed, evolved in the context of commendable efforts to look throughout the world for techniques, plant and animal varieties, and institutional arrangements that can

be combined with modern science to meet the three goals set out at the beginning. Nevertheless, the AAM remains a model that is of particular applicability to the possibility of an agricultural transition in the United States and other highly industrialized countries. To make specific recommendations for the South, it would be necessary to go beyond what is possible in this paper, examining the models offered by China, Bali, the ancient Inca cultivators, etc. It would also be necessary to disaggregate crops and local experiences vastly more than has been possible here.

The investigation at hand is necessarily of smaller scope. We have seen an hypothesis that a move toward sustainable agriculture in the North will entail increasing the skill and education mix of the agricultural labor force, as well as its overall size, with increased production costs a likely result. The next section focuses upon another hypothesis: that economic development in the South does not absolutely require that food be as cheap, or agricultural practices be as labor saving, as the standards held up by the OAM.

8. THE MEANING OF THE "AMERICAN" MODELS FOR THE THIRD WORLD

Let us start by surveying factor productivity in traditional as compared to modern agricultural practices. First of all, "traditional" farming systems are most often characterized by low labor productivity; this is the aspect that causes modernizers to argue that as long as the production of food for the nation requires the majority of the people to work in the agricultural sector, living standards cannot materially improve.

With regard to the productivity of other factors, one, at least, is easy to generalize about; namely, the "mm" type of technological inputs. It is, above all, the intensity of use of the "mm" inputs which differentiates modern from traditional farming methods. In the former, using the OAM as the archetype, we know that the use of power and machinery may effectively substitute for much human labor. In this process, land also is substituted for labor, "because higher output per worker through mechanization usually requires that the worker cultivate a larger land area" (Hayami and Ruttan, 1985, p. 75). Chemical inputs, e.g., fertilizers and pesticides, generally enhance the productivity of both land and labor, especially when they are used in conjunction with improved genetic varieties (inputs which I would tend to characterize, in themselves, as "ii") and with irrigation systems (which may involve either "ii" or "mm" inputs).

In the OAM, intensity of use of "mm" inputs has been pushed to a point where additional increments yield a low return. By contrast, in many traditional situations, where virtually no "mm" inputs are in use, a small dose of, e.g., chemical fertilizer may have an enormous impact.

The productivity of "ii" inputs in traditional farming is almost impossible to calculate at this time. Such an estimation will have to wait for more precise definition of particular "ii" inputs. Some material inputs and capital improvements (e.g., creation of terraces or drainage ditches, planting of windbreaks, etc.) also should be defined as "ii" embodiments. Guidelines should be developed on how to determine the type and the proportion of the labor input which should be classified as "ii". My own expectation is to find that, while there is a wide variation in this respect among traditional systems, on average the "scientific" nature of modern systems tends to increase their "ii" intensity, while at the same time keeping the size of the returns that can reasonably be assigned to these inputs higher than the average returns to "ii" factors in traditional systems.

Finally, we come to land productivity. Here, as noted earlier, the OAM record is not especially strong. Referring again to Figure 1, however, we may note that the nations with the highest land productivity are Taiwan, Japan, and the Netherlands, followed by Egypt (with very low, and declining, labor productivity), Mauritius (also with very low labor productivity, but better than Egypt), Surinam, and most of Western Europe. The European countries are in a cluster which combines out-standing performance in both land and labor productivity. Behind them in both, but still above the United States in land productivity, we find the Second World countries of Yugoslavia and Poland; and then, still above US land productivity but with miserably low output per male worker, Bangladesh, Sri Lanka, the Philippines, India and Pakistan.¹⁴

As suggested by this survey, land productivity in traditional systems varies widely, with the most productive still below the performance of a few highly industrialized countries, but well above most other practitioners of modern agriculture. This is worth noting. For the LDCs facing continued rapid population growth, land productivity is especially important, given the limitations most face on increasing land area under cultivation.¹⁵ Where tradeoffs have to be made, the land-productivity choices of the OAM, designed for a country with vast land holdings and a relatively expensive labor force, are not likely to provide a good model.

Another important point with regard to factor

productivity in Third World agriculture may best be made by citing the example of India.

Indian farming practices are a mixture of modern and traditional. Of the total Indian workforce, about two-thirds are now listed as primarily employed in agriculture. Upon closer inspection, however, it may be found that the average Indian agricultural laborer works fewer than half the number of days a year that he or she would wish to work. Thus one may deduce that the technologies employed in Indian agriculture as a whole are such that one-third of the workforce would be sufficient to feed the whole country; indeed, if all of India adopted practices that are common in the most modernized areas, even fewer workers would be needed.

Why, then, do two-thirds of the workforce stay in agriculture? Because they have no other jobs to go to: industry has not expanded as fast as agriculture has shifted to labor-saving technologies. Indian society has found a myriad ways of institutionalizing the sharing of poverty and the rationing of jobs in the agricultural sector: wages and employment practices are tailored so as to provide a bare subsistence to many, rather than a good living to a few, under circumstances where the rest would otherwise starve.

The Indian example is only one of many that could be cited to emphasize that in the Third World the hope that industrialization would create productive work for surplus agricultural workers has been frustrated as industrial jobs have failed to increase as fast as the population. Huge numbers of rural people in the South are in need of productive jobs now; given projected population growth, in many places this problem will only increase for the foreseeable future.¹⁶

This stark reality casts doubt upon an assumption that has for long been deeply embedded in development economics: that labor productivity in agriculture and in industry must both continue to rise indefinitely if economic development is to continue and to be shared by all in the society. To suggest why this assumption may be invalid, imagine a simplified economy of three families: one engaged in farming, and two working in the production of nonagricultural goods and services. (For simplicity, the nonagricultural sector will be called "industrial," though it must, of course, include financial and other services, education, government, etc.) Each family can, on average, consume one-third of the output of the agricultural family's production, and two-thirds of the output of a family in the industrial sector. It is assumed that agricultural labor productivity is such that one family's labor is sufficient to produce food for all three families.

(A reminder: labor productivity is often de-

financed by economists in terms of the value — price times quantity — of output. If a worker makes three widgets every day, but the price of widgets, relative to other prices, doubles tonight, then tomorrow that worker's productivity will be said to have doubled. When the price rise is not relative to other prices, but part of a general price increase, then of course there is simply inflation — the value of money goes down, instead of productivity rising. However, when a price increase in one sector is combined with real increases in labor productivity in another, some interesting possibilities emerge.)

Suppose, in our three-family community, there are \$300 circulating annually, accounted for in the national income and product accounts by the fact that each industrial family annually produces \$100 worth of industrial goods, and the farm family produces \$100 worth of food. Now let three things change (and it will be important that they happen together, with the correct timing).

First, some combination of new technological applications and past capital investments (both fully paid for, so as not to complicate the story with returns to other factors) results in a doubling of "real" labor productivity for the industrial sector: each individual employed there can now produce exactly twice as much, per day, as was previously possible.

Second, and at the same time (for reasons we will not yet try to explain), the price of farm products doubles.

Third, central bankers cleverly manage to keep the growth in money supply in step with these two kinds of labor-productivity growth, so that, by the time the first two changes are complete, there are \$600 circulating in the society.

What has happened? First, there has been inflation (of 20%) during the period of change. Second, since only two-thirds of the change is real, and one-third is monetary, the residents, on average, are not twice as well off as before; they are only one and two-thirds times as well off. But they are, in fact better off, in terms of their average consumption opportunity set. Third, the inflation has achieved something like a redistribution of income; while it did not change relative incomes, it cushioned that sector whose labor productivity was growing relatively less rapidly, or not at all.¹⁷

The point of this example is to dramatize the fact that it is possible to achieve economic development — defined, here, as a process whereby average incomes rise relative to the average price of consumption goods, so that each family can increase its standard of living by purchasing more of what is sold on the market¹⁸ — without increasing labor productivity in all

sectors. To be sure, such development will be very slow if it depends upon a very small industrial base. However, once as many as two-thirds of the workforce are actually employed outside of agriculture, additional transfers of workers into industry will have increasingly less effect upon the pace of industrialization.

When there is no mechanism for achieving such an increase in the price of farm output as was assumed in the second step, if industrial labor productivity rises while the output per agricultural worker is relatively stagnant, the prices of farm products may be expected to rise somewhat (assuming that the growing affluence, hence growing demand, in the industrial sector is not entirely absorbed by imports), but the sector as a whole will receive a progressively smaller share of society's total product. This is one of the dynamics which has contributed, since the start of the industrial revolution, to pushing workers out of agriculture.

Several developments may now be combining to create for the future the missing mechanism for raising agricultural prices so as to maintain for the sector something closer to a steady share in a country's net national product. One is the demand-supply dynamic: unless the growth in world population is accompanied by severe recession or depression, the demand for food can be expected to continue to grow strongly. On the supply side, given the difficulty which we can expect Southern agricultural systems to encounter in keeping up with LDC population expansion, international markets will continue to play a crucial role. The conclusion of the previous section was that internationally traded food grown in the North is likely to become more expensive. Additionally, LDC governments and farmers may pay attention to environmental requirements, and this concern may translate, as in the AAM, into emphasis upon "ii" inputs as a way of increasing land productivity. If this projection becomes a reality, it will contribute a cost-push factor (relating to the cost of education) which can work with international prices toward maintaining a high market price for food in the developing as well as in the industrialized worlds.

This is not a cheerful conclusion. In thinking about the North, the observation was made that a rise in the cost of agricultural production could be accompanied by a much smaller rise in the price of food. There is little reason to think that the same could be true in the South — except where some kind of subsidy puts a wedge between cost and price. A rise in the price of food in poor countries has a very stark meaning indeed: misery and starvation. The noble experi-

ment of Bangladesh in the 1970s, when the government undertook to insure the basic needs of all, regardless of ability to pay, was a rare instance of the kind of commitment that will be required if cost-increasing technologies are to be introduced into Third World agriculture without causing unacceptable hardship. Not surprisingly, the Bangladeshi experiment collapsed because the government ran out of funds to support it.

If the technologies for a sustainable agricultural revolution can only produce enough food for the populations of the 21st century by increasing production costs, then for those regions which cannot find ways to make more expensive food sufficiently available to large poor populations the next best fallback position is one that does not seem especially likely: the provision of funds from the First World to cushion the poor from the effects of achieving sustainable food increases through increased production costs. If such funds are not forthcoming, then it is probable that economic development will take precedence over sustainability in the LDCs, with long-run consequences that are distressing to contemplate.

9. CONCLUSION

A sustainable revolution in agriculture is needed for the 21st century. Some outlines of its nature for the North are to be found in an examination of the Alternative American Model. It is harder to say what technological and institutional changes may emerge to support a sustainable revolution for the South: however from our survey of the AAM we can project at least some of the desirable characteristics. As a part of an overall approach to development, it would have to emphasize the combination of rapidly growing industrial labor productivity with rapidly growing agricultural land productivity. It would give a relatively low priority to the goal of reducing the agricultural labor force to anything near the proportional size it is the United States, and would give a high priority to education.

These projections are based upon the premise that sustainable agricultural technologies of the future will depend heavily upon "ii" inputs. While they will also use more "mm" inputs than do the traditional technologies, they will use fewer of these than does the OAM. They will continually aim to find ways of substituting away from the "mm" toward the "ii" inputs.

This approach to development makes a virtue of two necessities which, in other scenarios,

could be regarded as serious drawbacks.

First, if sustainable agriculture is relatively labor absorbing (compared, for example, to the OAM), this, for the foreseeable future, can be a boon to labor-surplus LDCs.

Second, if sustainable agriculture's requirements for increased skill and education of farm workers pushes up agricultural wages, this may help to divert a fair share of society's wealth to agricultural employees, even if labor productivity does not grow as rapidly in agriculture as in industry.

This scenario can only succeed as a prescription for the development of entire societies (including their farm sectors) if it is accompanied by a significant rise in the global price of food, over the level at which it has been held by the technologies and the government programs which have prevailed over the last 40 years. The goals implicit in this conception of a sustainable agricultural revolution may be summarized as the simultaneous raising of two ratios:

$$\frac{\text{average wage}}{\text{average } P \text{ (food)}} \quad \text{and} \quad \frac{\text{average } P \text{ (food)}}{\text{average } P \text{ (all else)}}$$

The weakness of dealing with averages is sharply illustrated by the grave drawback that the sustainable agriculture revolution, as described, still requires a safety net for those members of society whose incomes do not rise in step with the other changes.

The other most serious difficulty with this scenario is that it assumes an industrial takeoff which is less dependent upon low-cost agricultural production, as compared with many proposals now being made for developing countries.

These two problems are not to be underestimated. Cheap food is the most direct attack on cycles of misery, malnutrition and low productivity. We have few enough ideas for how to make poor countries rich without readily abandoning the strategy of agriculture-led development, as currently conceived.

Nevertheless, if technology does not save us by pointing the way to sustainable, highly productive, low-cost agriculture, none of our remaining options are free of serious problems. The path then most likely to be taken is that the world will opt, by default, for highly productive, low-cost agriculture that is not sustainable. If that is what we face, then the scenario suggested here, for a sustainable agricultural revolution that includes the goal of improving on present levels of global nutrition without assuming cheap food, will be worth considering.

NOTES

1. This paper will focus on grain production and consumption because the trend, over the past half-century or more, has been for these crops to assume an ever greater importance in human nutrition, whether consumed directly, or by being fed to animals. However, figures on grain alone may be somewhat misleading; for example, the above cited growth in per capita grain production is to some extent offset by reduced final calorie value of grain, as increasing amounts of it are turned into meat; 40% of the world's grain output is now used to feed animals. (The calories present in the end product of beef are approximately one-tenth what they are if consumed directly as grain.) It is also the case that in some places rising grain output has been accompanied by reduced production of other crops.

2. At one end of the spectrum, animals fed a low-quality diet or suffering from poor health — such as may be found in many underdeveloped areas — are serious offenders; at the other end are the anaerobic composting processes in the large concentrations of manure which accompany confinement systems of animal care. There is reason to hope that the progress of the science of animal husbandry will have answers for the problems which occur all along this spectrum from poor to rich farmers; however, as with other solutions which will be discussed, these may be costly.

3. On this subject, new combinations of modern science with older traditions of agroforestry are quite promising.

4. For example, with respect to the four principal sources of land degradation (Worldwatch, 1989, p. 22) we may note that:

— The OAM cannot be held responsible for *overgrazing on rangelands*, as this is antithetical to its approach to animal husbandry, which confines animals, rather than allowing them to range.

— *Deforestation* occurs because people need to cut wood for fuel, or else because those who possess the power to clear forests believe that an alternative use of the land is in their self interest. In those cases where the OAM is intended to be applied as the alternate use, it is only partially and indirectly the cause of this choice.

— *Overcultivation of croplands* can and does accompany any agricultural model, when economic/population pressures mount, or when knowledge or concern about the relation between current actions and long-term land fertility is lacking.

— *Salinization of irrigated lands*, too, can occur within a variety of agricultural models; however, the spread of irrigation practices has increased rapidly with the spread of Green Revolution technology — closely linked to the OAM.

5. This section will draw heavily on Mazlish's (1990) work in describing "the American psyche."

Properly speaking, of course, "America" includes all parts of both North and South America. The Old American Model of agriculture is used throughout

much of this part of the world; however, it emanates very specifically from the United States. In spite of an attempt to avoid this more generally, in this section I will accept the too-common habit of speech which refers to the United States when speaking of "America" or using the adjective, "American."

6. This book was written by The Committee on the Role of Alternative Farming Methods in Modern Production Agriculture of the Board on Agriculture of the National Research Council, the members of whose Governing Board are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

7. Thus, "High target prices, deficiency payments, and disaster provisions that compensate farmers for crop losses are principal causes of inefficient input use. Current farm programs base payment on historical per acre yield levels, multiplied by a per bushel deficiency payment rate. The per bushel deficiency payment is the difference between the government-set target price and loan rate or the market price, whichever difference is less. When deficiency payments are large, during periods of protracted low crop prices, farmers have greater incentive to apply fertilizers and pesticides in greater amount to produce the most bushels per acre and collect the highest payments" (Pesek, *et al.*, 1989, pp. 205–207).

8. It may be noted that the tradeoffs implicit in Figure 1 fit within the mind set suggested as appropriate to phase (b) in Figure 2, where technologies are not seen as substituting for one another, but only for land and labor.

9. Capital was sometimes cited as a third factor, but it could also be regarded as "congealed labor" (Alfred Marshall later stressed this view), or as the super-category under which land was to be subsumed. In neither case was capital identified closely enough with machinery and other aspects of technology so as to loosen the just-cited limitations on perceived opportunities for productivity growth.

10. In corn production labor productivity increased by a factor of 12.5 during 1940–80 (Hayami and Ruttan, 1985, p. 221). "Between 1954–60 and 1971–80 the marginal physical product of nitrogen fertilizer in corn production declined from 0.80 bushels to 0.15 bushels of corn per pound of nitrogen applied" (Hayami and Ruttan, 1985, p. 222, note 40). These authors follow the above observation with the question, "How will increases in U.S. corn yields be generated in the future?" Their answer is very much in line with the proposed shift toward "ii" technologies: "A combination of scientific advance and enhanced concern about sources of productivity growth has induced intensified efforts to explore new approaches to the development of less energy-intensive and more environmentally compatible biotechnologies for corn production. These include biorational and biological approaches to pest

control, photosynthetic enhancement, plant growth regulation, cell and tissue culture, biological nitrogen fixation, and cellular-level gene transfer" (Hayami and Ruttan, 1985, p. 222).

11. The standard economic response to this criticism is that what is here called lack of sustainability is simply the relative depletion of formerly common factors (e.g., fertile soil and cheap sources of usable water, as well as some purchased inputs); the argument is that what we are now seeing is a rational substitution away from factors as they become scarcer and therefore more expensive. The environmentalist twist which is given to the explanation in the text is the implication that the market has not done an adequate job of foreseeing the impacts of resource degradation and depletion, so that costs to the future which should have been included within the production function were ignored, as externalities. Neoclassical economics, in eschewing normative positions, has a harder time recognizing the possibility that there is something which markets "should" have done which is different from what they have done (see Goodwin, 1991).

12. Worldwatch (1989), pp. 34–35. It is important to remember what these averages hide: that each of the areas mentioned includes a spread, so that the poor in the United States spend considerably more than 15%, and the poor in the LDCs are likely to spend something like 70% of their incomes on food.

13. The papers collected in Part III of this special issue address the institutional difficulties that would be encountered in problems similar to that which is raised here: namely, the difficulty of coordinating the policies of different nations so that those who adopt socially responsible policies are not penalized by the free-riding of others who continue, for example, to benefit from export competitiveness because they have not internalized externalities of production.

14. The sub-Saharan tropical African nations, not represented here, would be found in the lower left-hand quadrant, and the arrows showing their progress would slope slightly down and head rapidly to the left, if drawn to cover the years 1973–84 (Timmer, 1987).

15. Regarding land area as a possibly binding constraint, we might imagine a technological optimist arguing that we should not be very worried about land degradation, or about the costs to the future of trying to produce on degraded land:

"The issue" (the optimist might say) "involves different time-periods. Let T_0 be the original time, when the land was at its maximum, pre-farming

fertility. Let T_1 be a later time — say the present — when farming practices have degraded the land to some degree. There has been technological progress between T_0 and T_1 ; in most cases the productivity gains accompanying technological progress will outweigh the productivity losses of land degradation."

The salient phrase in this argument is: "in most cases." It is a matter of opinion and debate whether, on average, the effects of technological progress can be expected to continue (as they have clearly done in the past, in most cases) to outstrip the effects of environmental degradation. Obviously, the technological optimists think so, and the environmental pessimists think not.

The optimists cite the possibility of new solutions to, e.g., soil and ground water salinization, or global warming — such solutions as genetic engineering of rice to make it salt tolerant, even able to grow in salt marshes by the oceans; or of wheat to make it able to tolerate the wetter coasts and dryer midcontinental regions expected to result from global warming. The environmentalists cite the danger to several critical food chains of introducing intensive rice farming into salt marshes. They point, also, to the race which we cannot assume we are winning, between our genetic manipulation of plants and animals and the genetic responsiveness of wild pests and parasites.

16. If we look at the 30 poorest out of the 138 nations reporting 1986 GNP per capita to the United Nations (those that did not report it were largely, but not exclusively, communist countries), only five had rural population below 70% of total population; of these only one (Zambia, at 57%) was below 60%. By contrast, of the 30 with highest GNP per capita, only four had more than 30% of total population listed as rural (World Game Institute Global Data Disk, Philadelphia, PA, 1989).

17. In a simplified economic world where prices are assumed fully flexible, the same could be achieved without inflation, simply by having the price of "industrial" goods and services fall while agricultural prices hold steady. However, the assumption of fully flexible prices, though convenient, is not necessary, and is a large step toward such unrealism as to approach irrelevance.

18. A social objective of development should be, but is not always, mentioned along with this economic one: that a result of development should be that people receive more, not less, satisfaction, both from what they purchase and consume, and from that part of their existence that is devoted to paid or unpaid work.

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