# ACCELERATED TECHNOLOGICAL CHANGE IN AGRICULTURE AND ITS RELATION TO ENVIRONMENT

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November 1970 No. 21

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## Introduction

In this paper I wish to delimit in four related points the requirements for agricultural development as a prelude to discussion of the relationship between agricultural development and environmental problems. First, without technological change in agriculture and its attendent rapid growth in production, economic development will be slow and the benefits of growth will be badly distributed. More specifically, rates of growth of income of currently low income people are likely to be exceedingly small or nonexistent. There will, of course, be a few exceptions to this generalization, but they will not include a major portion of the worlds population.

Second, technological change in the agriculture is a biological activity and is virtually certain to change the biological and physical environment.

Third, at the present time there appear to be no options to the basic form of certain aspects of technological change needed to increase agricultural production. In these cases, if there is conflict, the adaptations will have to be made elsewhere than in agriculture. On the other hand, several parts of the total process do present options in which cases conflicts can be avoided by choices within the agricultural sector.

Fourth, in view of this situation, the need is not for prophets of doom with respect to the environmental problems associated with rapid expansion in agricultural production. Rather the need is for intelligent analysis of long-term social costs and returns of various alternatives, assistance in choosing among the alternatives, and allocation of research resources to widen the range of alternatives.

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*/ Paper presented to the Conference on Economic Development and Environmental Problems, September 18-19, 1970, Williams College, Williamstown, Massachusetts.

Some Aspects of the Relationship of Economic Growth and Agricultural Production

Although economic development is possible without rapidly increasing agricultural production, a number of problems arise in attempting this process. At the most elementary level, if there is no aggregate increase in food supplies, it is obviously difficult if not impossible to raise the incomes of low income people who spend the bulk of their income on improved food supplies. Thus if economic growth brings about improved welfare of lower income people either there must be a substantial increase in domestic agricultural production or the manufacturing sector must have become so efficient that it can expand exports rapidly in exchange for imported food. Obviously in such a situation the latter simply transfers the problem of increasing agricultural production and any accompanying environmental problems from one country to another.

At a more theoretical level growth of the industrial sector in a situation of stagnant agriculture is likely to be hindered if increased quantities of consumer goods are not available to attract labor to industrial employment. It is conceivable that a system of taxes on the agricultural sector could transfer enough food from existing production to support a large increase in the industrial labor force. In practice we rarely find such an effort succeeding. Thus where economic development is attempted without enlarging food supplies industrial growth tends to emphasize the use of large quantities of capital relative to labor. This process itself appears to be subject to diminishing returns. Therefore, acceleration of growth to achieve a given rate of growth requires substantial acceleration in the rate of savings. The expanded savings rate in turn requires shifts in the consumption function. Such shifts are normally achieved by favoring either high income people or government, but not relatively low income people, in the distribution of income.

Thus we find that economic growth without rapid increase in agricultural production is likely to be slow, to give a poor distribution of income, and to be basically unacceptable in most modern economies. The resultant political tensions are probably irresistible for popularly based government.

Rapid increases in agricultural production accelerate substantially the overall rate of growth. First because the agricultural sector dominates the total production pattern and, second, because increased agricultural production frees an increasing labor force for the industrial sector thereby accelerating the rate of industrial growth.

In most parts of the world technological change is virtually essential to increase agricultural production. This is primarily because the basic inputs of a traditional agriculture have very inelastic supply schedules so that rapid increase in their supply is practically impossible. Thus if agricultural prices rise in most parts of the world there cannot be a corresponding increase in the land supply. We find empirically that in general the elasticity of response to price of the aggregate supply of agricultural commodities in low income countries is highly inelastic and on the order of -.1 or -.2. It takes as much as a ten percent increase in agricultural prices to bring about a one percent increase in aggregate agricultural production.

Increasing agricultural production without technological change requires large increases in agricultural prices and large net transfers of resources to the agricultural sector. Such transfers will stifle industrial development, stagnate population in the agricultural sector, and produce little or no economic growth. That in essence is the case for increasing agricultural production through processes of rapid technological change.

## Elements of Technological Change in Agriculture

The basic element of technological change in agriculture is the development of new crop varieties and new production practices which make use of inputs characterized by elasticity of supply. The supply elasticity is important because it means that technological change does not just increase the quantity of production at all input levels. Rather, it increases the rate of return to much higher levels of use of inputs and allows a switch to inputs which can be supplied in greater quantity at little or no increase in price. Thus the production function is changed in agriculture and large increases in production at decreasing costs per unit of output can occur.

The rapid increase in agricultural production through technological change requires, one, a set of infrastructure factors including research and trained manpower, transportation, and power, and, two, a vast increase in the supply of production inputs such as fertilizer, water, and possibly pesticides.

### 1. The Infrastructure of Technological Change in Agriculture

Large investment in publicly supplied resources is particularly necessary because of the small scale nature of agricultural production units. Such small units are not disadvantageous at the production level, but many services for these production units have economies of scale, require large scale efforts, and for reasons of difficulties in charging for the services, of custom, and of need for innovation must be publicly supplied. Three elements of this infrastructure are particularly important to agricultural development and have substantial implications to the physical and biological environment.

Development of greatly improved agricultural technologies including high yield crop varieties suited to a high proportion of a nation's production conditions is number one and a key part of the infrastructure. Such agricultural technology is a product primarily of research and of higher educational institutions. The diversity of physical conditions for agricultural production reduce the transferability of research results so that a widespread system of research institutions is necessary to produce a stream of varied research results which, in turn, will require a large number of trained technicians to develop, modify, and apply as new technologies.

Despite substantial strides over the last several years the development in agriculture of both the research structure and the systems of higher

education are still in a rudimentary stage. Growth in this area is one of the most important infrastructure investments which can be made in low income countries. If high rates of return on investment in transportation, irrigation, fertilizer, and many other elements are to be achieved, the research institutions and the higher education institutions necessary to developing new technologies must be created. These investments are often thought of as long-term pay-off investments. But the three to five years for initial pay-off is not long by normal investment standards. By contrast, the more rapid returns to irrigation and other inputs are illusory because they occur only when the new technologies from research raise the returns from such investment. Thus, pay-off to such investment is rapid only after research has succeeded.

The necessity to agricultural development of widespread systems of research has important implications for the protection of the environment. Research in the agricultural sciences is concerned with raising yields per acre subject to a series of restraints provided by the physical environment, economic costs and returns, and cultural conditions. In principle man's desires concerning the physical and biological environment can reasonably be added to those restraints. On the one hand adding such restraints may simply recognize real costs as defined by the population affected. On the other hand such restraints may represent alien values, particularly if they serve to preserve the environment for the rich of the world by denying increased food supplies and economic growth to the poor. Many research restraints designed to conserve the environment are so restrictive that they prevent growth-inducing processes. In sum, a vast research system helps the search for means of growth which do the minimum violence to the environment. But specific concerns must be: one, to what extent objectives of growth and conservation of the environment conflict; and, two, who decides between competitive allocations to growth and to conservation of the environment.

Improved transportation is the second element of the infrastructure to be considered because of its importance to rural development. The returns to transportation investment will be relatively low under traditional economic conditions. Rapid increase in agricultural production so that larger quantities of agricultural commodities have to be transported out and inputs be transported into the agricultural sector plus rapid increase in industrialization will all greatly increase the returns to investment in transportation. In turn cheap effective transportation will be necessary to those improvements. At present, only 20 to 30 percent of food grain production is marketed in most low income countries. New high yield varieties may double the marketed surplus of food grains, placing much heavier burdens on the transport system. A wide-range series of marketing studies show that the single most important source of market imperfections is imperfections in the transport system.

Improvement in the transport system has special advantages in low income countries because transport development can be very labor intensive. Experience suggests, however, that if currently underemployed labor is to be used, there must be a large increase in the availability of food to supply the added consumption needs generated by the increase in their incomes.

In the long run improved agricultural technology should supply this food. In the short run it may be desirable to supplement domestic production with imports of PL 480 food grains from the United States. Such imports, of course, do not depress local agricultural prices and discourage local agricultural production if increased demand is generated for them.

Development of widespread systems of transportation have important environmental influences in terms of the choice of transportation systems, the secondary effects of enlarged travel and market contact, and the implications to the choice of consumption patterns. Again, rapid development of improved transportation must be taken as one of the givens of technological change in agriculture and economic growth and concern with environment must operate within that given requirement.

Third of the considerations is the importance of investment in power for rural development which is often greatly understated. This mistake is made because of a misunderstanding of the role of labor in development, the requisite of raising labor productivity as part of the development process, and the advantage of mechanical power in many types of operations.

When returns to investment in irrigation increase substantially through agricultural research, it becomes economic in many areas to institute a widespread system of tube well irrigation. Electric powering of such systems is likely in the long run to be one of the most efficient means of operating them. Electric power has great flexibility in that it can be turned readily to many other uses. Finally, and in the long run perhaps most important, a widespread electric power distribution system is likely to pave the way for many modern small-scale industries which can, once the food bottleneck is broken, provide a much more rapid expansion of employment than can more centralized large-scale industry. Such small scale industries very often tap substantial previously untapped potentials for savings and investment thus giving further impetus to growth of employment opportunities.

Strong arguments are often made against further investment in power on the basis that past investment is not being fully utilized. Underutilization is, however, often the result of unavoidable inefficiencies. Power often does not get used because it has been distributed in the wrong places. That error can usually only be rectified by expanding into other areas. Power is often unutilized because it is expensive due to unreliability. Treatment of this problem may also call for expansion of the availability. In addition the high returns to power investment come only after the rest of the infrastructure is in place. It is usually impossible to have such close coordination of infrastructure investment that high returns are realized to all parts early in the process. Thus again one should not be reluctant to have a substantial overexpansion of power facilities in early stages of development.

As in the case of transport, a widespread system of electric power generators and distribution must be taken as a given of the environmental problem, and its ramifications analyzed and dealt with as effectively as possible short of restraining its development.

## 2. The Inputs of Technological Change in Agriculture

Of greater direct concern to the environment than the above infrastructure elements of development is the tremendous increases in requirements of production inputs. Technological change in agriculture is much more a matter of increasing the capacity to use more inputs at high levels of productivity than it is of increasing the average productivity of those inputs. The most important inputs from an ecological point of view are fertilizer, water, and pesticides.

Extremely large increases in plant nutrients are needed if there are to be large increases in agricultural production. So far it appears that there is no choice but to use large quantities of inorganic fertilizers. There may be room for some increase in efficiency in the use of fertilizers particularly in the tropics where heavy rainfall causes rapid leaching. For example, pellitizing and more sophisticated application techniques could result in making nutrients available relatively slowly and thereby reducing the leaching, and increasing the percentage which is effectively used by economic plants. No doubt scientific research can also bring about some changes in the nature of fertilizers which will cause less ecological damage. The basic restraint, however, is almost certain to be a vast increase in the quantity of nutrients needed. One of the most important features of yield increasing technological change is its potential for increased use of fertilizers at relatively high rates of return and to use fertilizers in forms which can be supplied in very large quantities. It is the latter problem which basically rules out an agriculture dependent on organic forms of fertilizer such as animal manures and the plowing under of green crops.

Well controlled water supplies are another prerequisite of rapid technological change in agriculture. Introduction of irrigation into new areas, the lifting of ground water, and the reduction of stream flow particularly in tidal areas all may bring about major ecological changes. Again it must be recognized that if agricultural production is to be increased substantially supplies of water to many areas must be increased and the supply of water to other areas must be placed under greater control.

One of the most complicated problems with respect to technological change in agriculture and its relationship to the environment is the use of pesticides. These include herbicides, insecticides, and many other chemical controls of various types of plant pests.

The problem of pests is undoubtedly much greater in the tropics than in more temperate latitudes. The year round warm temperatures and highly moist conditions are conducive to rapid pest increase. In addition, the development of high yield varieties with much greater plant populations and vegetation density bring about changes in the micro-environment which are conducive to the increase of many insect and disease pests. If these pests are to be controlled by chemical means the total chemical applications are likely to be much greater in the tropics than elsewhere. On the one hand this suggests a much greater problem for the tropics. In practice it may well be a blessing in disguise.

The huge quantity of chemicals needed to control pests in the tropics may force the development of other means of control. There appears to be considerable concentration on questions of biological control of pests including the breeding of plants which are resistant to the particular pests of a particular area. It may well be that the very high cost of chemical control will make many new crop varieties unprofitable to farmers and force further modification in those varieties to reduce their vulnerability to various pests. This may be one of the most productive places in which simultaneously a contribution to economic growth and environmental control may be introduced.

It would be irresponsible to divert scarce scientific resources to a hopeless quest for means of reducing the assault on the environment in countries in which those same resources could bring about major increases in production. Where we find, however, that increases in production may occur more rapidly if nonchemical means are found to control pests, we may achieve two advantages simultaneously of economic growth and improvement in the environment. It is this search for a system to have the cake and eat it which must be encouraged if the lot of the poor is to be improved through economic development and with minimal damage to the environment.