INTERNATIONAL
JOURNAL OF
AGRARIAN AFFAIRS
Vol. V, No. 6, March 1973

Contemporary Issues

Produced by the
University of Oxford Institute of Agrarian Affairs
in conjunction with the International Association
of Agricultural Economists

Price 75p net

OXFORD UNIVERSITY PRESS
LONDON

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THE GREEN REVOLUTION—AN APPROACH TO AGRICULTURAL DEVELOPMENT AND SOME OF ITS ECONOMIC IMPLICATIONS

I. *Introduction*

THE objectives of this paper are:

1. To point out the main aspects of the approach which has been used to initiate the green revolution.
2. To discuss the prospects for initiation of agricultural revolutions and more rapid economic development through successful use of this approach.
3. To urge that agricultural economists around the world join with agronomists in a strong effort to use the opportunities offered by the new technology:
   (*a*) to expand the green revolutions already initiated,
   (*b*) to initiate new ones,
   (*c*) to solve the economic and social problems which result from rapid agricultural development, i.e. so-called 'second-generation' problems.
4. Finally, to stress that even the strongest food production effort is no substitute for effective population control and can buy a breathing space of only twenty to thirty years.

A green revolution which produces a bountiful golden harvest is spreading across vast agricultural areas of Asia. Already well under way in Pakistan, India, and the Philippines, it is now beginning to spread to other Asian countries, as well as to Africa and Latin America. Many of the less developed countries of Asia may become self-sufficient in grain or even exporters, within a few years, even with marked increases in local consumption.

Spectacular breakthroughs in the production of wheat and rice have provided the impetus for these dramatic changes in the agricultural sector. Rapid increases in these basic grains have been made possible by the introduction or transplant of high-yielding, fertilizer-responsive, day-length insensitive varieties of wheat and rice, together

with a new package of improved cultural practices which must be applied to permit these varieties to express their high-yield potential.

The rapid spread of the green revolution has shattered the hypothesis of the economists and planners, who believed that an agricultural development characterized by rapidly rising yields per acre could only be achieved after a gradual improvement over several decades. At present the green revolution is far advanced and has reached the economic pay-off stage, and stage of second generation problems, in Pakistan, India, the Philippines, and Turkey; it is in various stages of development in Afghanistan, Iran, Iraq, Lebanon, Tunisia, Morocco, Indonesia, Malaysia, and Thailand. The introduction of the new varieties in the former countries took place over a period of only three to four years, as can be seen from Table 1.

Both the high-yielding wheat varieties and the new production technology required for their effective utilization were developed largely through research done at the International Center for Maize and Wheat Improvement (CIMMYT)[1] in Mexico. Consequently the new wheat varieties have become commonly known as Mexican varieties. The International Rice Research Institute (IRRI)[2] developed the so-called 'wonder rice' variety IR-8. The transplant or introduction of the new wheats and their technology preceded by about two years the introduction of the new IRRI rice varieties.

It has been demonstrated that introduction of the Mexican wheat varieties has a strong multiplier effect. In suitable areas it paved the way for an even more rapid adoption of new rice varieties. For example, once a farmer is convinced of the huge benefits which can be obtained from the use of improved wheat varieties and the use of chemical fertilizer and other production technology, he rapidly transfers the experience gained to other crops.

How did this rapid introduction of the new high-yielding varieties take place? It resulted from a new approach, which we may call the 'Kick-Off Approach' (Borlaug, 1968). This approach has been developed not from behind the desk, but through practical application of the new technology in the dusty wheat fields of Mexico, Pakistan, and India, and through meetings with planners and top administra-

[1] The International Center for Maize and Wheat Improvement is located in Mexico D.F., Mexico and is a joint dependency of the Mexican Ministry of Agriculture, the Rockefeller Foundation, the Ford Foundation, and US/AID.

[2] IRRI (the International Rice Research Institute) is located at Los Banos, the Philippines and is a joint dependency of the Philippines Government, the Ford Foundation, the Rockefeller Foundation, and US/AID.

tors in connection with national production campaigns. There were no blueprints ready for the introduction of the new varieties at the start; their introduction was not even indicated in any country's five-year development plan. Many persons and institutions have, however, contributed. The farmers were ready, as soon as the top politicians and administrators could be convinced, and deserve most of the credit

TABLE 1. *Diffusion of the high-yielding, semi-dwarf wheat and rice varieties*

Country	*1964/5*[1]	*1965/6*[1]	*1966/7*[1]	*1967/8*[1]	*1968/9*[1]	*1969/70*[1]	*1970/1*[1]
			Estimated acreage of high-yielding wheat varieties				
W. Pakistan	10	12,000	150,000	2,365,000	5,900,000	6,626,000	7,288,000
India	15	7,400	1,270,000	7,270,000	11,844,000	12,133,000	14,559,000
Turkey	..	..	1,500	420,000	1,444,000	1,343,000	1,184,000
Afghanistan	..	..	4,500	54,000	301,500	360,000	574,300
			Estimated acreage of high-yielding rice varieties				
W. Pakistan	..	..	200	10,000	761,000	1,239,000	1,548,000
India	200	17,700	2,195,000	4,408,000	6,625,000	10,729,000	13,593,000
Philippines	..	..	204,100	1,733,400	2,500,000	3,345,600	3,868,100

[1] *Source*: Imports and Plantings of High Yielding Varieties of Wheat and Rice in the Less Developed Nations. Foreign Economic Development Service, U.S. Department of Agriculture in co-operation with U.S. Agency for International Development, February 1972–FEDR–14.

According to estimates as of June 15, 1972, the Indian acreages for wheat and rice respectively for 1971/2 were 18·5 million and 17·8 million acres. The figures show that the diffusion for both wheat and rice continues. For wheat the production has increased from 12·3 million tons in the bumper crop year 1964/5 to an estimated 26·0 million tons for 1971/2.

for the rapid introduction. In some countries progressive farmers, after trying the new varieties on their farms, brought about considerable pressure from the bottom for large seed imports.

In the following section we will try to point out the main aspects of the approach which has been used to initiate the green revolution. Specific details have, of course, varied from country to country.

II. *The main aspects of the kick-off approach*

Most economists today will agree that in traditional agriculture there is a condition of economic equilibrium at a low level (Schultz, 1965). Yields are stagnant at near-starvation levels. Man, animals, plants, and pests are struggling for survival. Under these conditions, until the technology or price relationships are changed, the peasant farmer is an artist in using the production factors at his disposal in an economically rational way within the limitations and risk involved.

Through his native skill and persistence he extracts a meagre subsistence living from the soil. External attempts to help the farmer improve himself and all types of self-help programmes usually fail.

Under these circumstances a general attitude of defeatism and pessimism often permeates the agricultural sector, including the people planning for agricultural development. There is generally a shortage of agricultural scientists. The few qualified scientists who are available often isolate themselves in laboratories or on government agricultural experiment stations. They prefer to work on theoretical problems rather than on the difficult task of revolutionizing agricultural production. There is insufficient attention to the problems actually faced by farmers and the adaptive research required as a basis for change in production methods. Scientists are satisfied with producing only minor improvements in plant types and cultural practices, instead of attempting dramatic breakthroughs in production. The results of local plant breeding work, as well as imported varieties, usually are tested under the average primitive farming conditions. Until quite recently this meant without fertilizer, or with very small doses of fertilizer, and without plant protection. The new high-yielding genetic materials cannot show their potential under these conditions and are discarded; the result is the continued breeding of traditional varieties.

This *status quo* philosophy of agricultural research adds to the tendency for inertia in the agricultural sector. It seems to be based on the two premisses: (1) that agriculture is primitive and (2) that it will remain primitive. Scientists, instead of being engineers of change, become engineers of stagnation. Consequently, there is insufficient new experimental data as a basis for attempts to launch a revolution in agricultural production.

It was from this background that Brown's concept of 'yield take-off' was postulated. This theory states that a long period of education (higher percentage of literacy), accompanied by a gradually increasing *per capita* income, etc., is needed to trigger a 'yield take-off' in a traditional agriculture (Brown, 1965). This position was adapted by the President's Science Advisory Committee in 1967. 'Since yield take-offs in the past have required educated alert farmers, capital, and a commercial system of agriculture, they will be extremely difficult to achieve in the developing nations' (PSAC, 1967). This led also to the gloomy conclusions in *Famine—1975* and other books which have predicted long periods of famine, during which whole nations would

have to be excluded from external food assistance because of a world-wide food deficiency (P. and W. Paddock, 1967).

The Kick-Off Approach is based on an outright rejection of the hypothesis that agricultural development must necessarily be slow. Rather it is based on manipulation of the following factors in such a way as to achieve rapid development: (1) the technical factors, (2) the psychological factors, and (3) the economic factors. Strong national accelerated production campaigns are necessary for one product at a time as new technology becomes available and is tested. The approach is characterized by the way these factors are aggressively manipulated and subsequently built into production campaigns.

The technical factors

A traditional agriculture cannot be transformed into a productive agriculture without new and more efficient technology in crop and animal production. An agricultural revolution for the developing countries must begin here. Highest priority must be given to agricultural experimentation and research, aimed at significant production function shifts. This is an expensive and time-consuming process which requires teamwork among scientists from various disciplines. A new philosophy of research is needed, based upon the premisses that agriculture in the developing countries has been stagnant far too long and that dramatic and rapid development is possible. Until the recent green revolution, the world agricultural situation represented a great disequilibrium between agricultural productivity in the developed and underdeveloped world, mainly as a result of the relatively insignificant amount of efficient and effective research done on agricultural problems in the latter area. This situation is now changing and the production advantage in favour of the tropical and subtropical regions is being slowly redressed. The green revolution may have the potential to alter the global pattern of agriculture (Brown, 1970).

Production levels that have taken centuries to reach in the developed countries can be achieved in decades in the developing countries. The possibility for this acceleration is based on present resources of technology and inputs, the global research network for the developing countries which is being organized through international institutes, and the increasingly strong regional and national programmes. New high-yielding, fertilizer-responsive varieties and supporting technology for efficient wheat production have been

developed and transferred with great efficiency and only minor modifications from Mexico directly to Pakistan, India, and other countries. The same holds true for new rice varieties from the Philippines. In the field of animal production the new high-yielding technology in poultry production has been successfully transferred to many developing countries. The doubling of wheat production, which has taken generations in many developed countries, took fifteen years in Mexico and may take about six to seven years in Pakistan and India.

The agronomic factors which must be manipulated astutely and harmoniously to stimulate rapid change in crop production include: (1) development of high-yielding fertilizer-responsive varieties; (2) improvements in soil fertility (fertilizer); (3) improvements in cultural practices (land levelling, seed-bed preparation, planting time, planting depth, etc.); (4) improvements in water management; (5) improvements in weed control; (6) improvements in disease control; and (7) improvements in insect control (Wright, 1968).

The transplant possibilities

A lengthy research programme was necessary to develop the dwarf Mexican-type wheat varieties which are now being used successfully in many countries in Asia and Africa to revolutionize wheat yields and production. The same process took place at the IRRI for rice. Local improvements of the imported prototypes (phenotypes) (which provide improved resistance against local races of rust and other diseases, improved quality for local dishes, etc.) are now being released in many developing countries from strong national plant breeding programmes. These countries deserve credit for an amazing achievement. The Indian wheat research programme is now the largest single wheat programme in the world; the Canadian, Australian, American, and Russian programmes are all modest in comparison. The contributions of these national research programmes are very important in order to keep the green revolution going. Research must be continuous. It is an investment in future progress.

The first big step towards the modernization of primitive agriculture was to develop new high-yielding and broadly adaptable varieties, which, together with a package of new cultural practices introduced simultaneously, resulted in dramatic yield increases and higher output in relation to input than for the traditional varieties. For example, the new wheat and rice varieties not only permit many times higher yields by use of high doses of fertilizer, but give twice the

amount of grain yield per unit of nutrient compared with the traditional varieties. The marginal social cost for increasing grain production in this way usually has been found to be amazingly low (Borlaug, Narvaez, Aresvik, Anderson, 1969).

The second step was adaptive testing of these varieties and the package of improved practices, and the formulation of sound recommendations. The testing had to be carried out over a number of years in the various countries. Usually it was found that some practices had to be modified and adapted to the weather and soil conditions of the country in question. The local governments assigned competent and well-motivated young scientists to this work, some of whom went to the relevant international institute (CIMMYT in Mexico for wheat and maize and IRRI in the Philippines for rice), to receive on-the-job practical and production-oriented training. After several years of research experience in their own countries, a selected élite of the scientists who had gone through this training and experience were sent for Ph.D. degree programmes in the United States and other countries. These scientists are being prepared to become the leaders of national research programmes. Without the training programmes at CIMMYT and IRRI, which have created a reserve of skilled personnel in many developing countries, it would have taken a much longer time for adoption of the new technology. To complement these overseas training opportunities, there is also a tremendous need for strengthening the agricultural educational institutions in the developing countries themselves.

The psychological (human) factors

The importance of psychological factors has often been overlooked by planners in the formulation of programmes for transforming traditional agriculture. Our experience during the initiation of the green revolution has convinced us that certain psychological aspects are of great importance.

We reject the approach of a 'yield take-off' (Brown, 1965) as a means of changing a traditional agriculture. Time is too short for such a long and slow academic approach to solving food production problems. We have to convince the often illiterate farmers in the developing countries to adopt new technology rapidly. We believe that the correct approach to revolutionizing a traditional agriculture calls for a 'kick-off' through dramatic demonstrations of new high-yielding technology and strong production campaigns.

All demonstrations should be made as spectacular as possible in order to overcome the scepticism and inertia of farmers, planners, government officials, and scientists. Yield increases of 15 to 20 per cent will convince no one. Demonstrations showing increases from 100 to 600 per cent, such as those which have been achieved over widespread areas in India and Pakistan during recent years, have caught the peasants' imagination and have triggered an agricultural revolution. Such demonstrations destroy the peasants' attachment to archaic practices, and with them their 'conservatism'. They generate enthusiasm in farmers, scientists, and government officials and usher in an entirely new spirit of hope and aggressiveness at all levels.

In order to mount such an attack, strong food production campaigns should be initiated around one single crop or animal product for which new high-yielding technology is available. It should be a product which is important to the economy of the country and for which the minimum production services, such as roads, market facilities, and sufficient water for substantially higher yields, are available (Hopper, 1968).

We have become convinced from our own experience in many different countries that the peasant farmer is shrewd enough to be receptive to change whenever advances in technology clearly demonstrate that large increases in yields are possible—provided, of course, that the new inputs required are made available and that there is ample margin for reasonable profit.

The revolution in food production in India, Pakistan, the Philippines, and other countries is also establishing mutual confidence and co-operation between peasants and scientists, and between scientists and agricultural economists and planners, where little or none existed previously. It is transforming agricultural scientists by providing them with experience, confidence, pride and new hope. This is particularly true among young scientists. In the past, more often than the farmers, it has been the scientists and planners who have been ultra-conservative.

The agricultural extension service also has an important role to play. If there is no new technology available in a country, there is nothing to extend or to demonstrate, and extension programmes cannot be expected to lead to significant results. The introduction of the improved production technology offers real opportunities to the extension service. Staff must be reoriented to the new methods and trained in their effective utilization. In-service practical field training,

sponsored jointly by the research and extension service, is highly desirable.

The economic factors

Most agricultural economists today agree that farmers in developing countries are acting in a rational, economic way. If rapid change is to be fostered through a production campaign for introduction of new technology, government economic policy must be such that the adoption of new methods and inputs is profitable to farmers. Farmers must be assured of an incentive price for their products, and prices must be stabilized to prevent unreasonable fluctuations and the risk of a sharp price drop resulting from a steep rise in production. On the other hand, rigid price support policies which tend to freeze cropping patterns should be avoided. After some years, when the new cost-reducing technology has been widely adopted, the time will come to consider a price reduction, thereby making other products relatively more profitable and consequently facilitating diversification of agriculture.

The profitability for wheat and rice production has been assured both in India and Pakistan through guaranteed minimum prices. Government grain procurement at the support price level serves a two-fold purpose. First, it protects the farmer at the time of harvest and the consumer later in the season. Second, the approach provides for inputs at reasonable prices and for the timely availability of inputs at the appropriate local level. Huge seed imports by governments for distribution to farmers at reasonable prices were also important in accelerating change in India, Pakistan, and Turkey.

Dr. Theodore W. Shultz has clearly indicated that unwise economic policies, assumed to assure cheap food for the urban consumer, have discouraged agricultural production in many Latin American countries (Schultz, 1965 and 1966). In several countries the use of fertilizer is inhibited because of an unfavourable price relationship. The Argentine farmer, for example, receives a low price for his wheat and must pay a high price for fertilizer. The price ratio of nitrogen to wheat grain has been 9·3 to1 in Argentina, contrasted with 2·6–2·8 to 1 in Mexico, India, and Pakistan. In these latter countries the use of fertilizer has increased very rapidly.

The national production campaigns

The factors listed above can only be properly manipulated through strong national production campaigns. Assuming that new technology

and the necessary inputs are available, the main prerequisites for such campaigns are:

1. A minimum basic infrastructure.
2. A sufficient number of motivated, enthusiastic, and skilled personnel, well versed in the new technology, to guide the campaign and provide the capacity (with limited outside assistance) to adapt and introduce it.
3. A cadre of skilled personnel in the agricultural sector generally and a sufficiently strong institutional base for a successful campaign.
4. A modest, flexible budget with a minimum of administrative red-tape for the co-ordinator of the campaign.
5. A firm commitment by the government to give the campaign high priority. In many countries with successful campaigns enthusiastic support has been given by the head of state (US/AID 1969).

Formal institutionalized services seem to be less important than previously assumed. In West Pakistan, for example, the seed of the new varieties was distributed mainly from farmer to farmer without much institutional backing. There was no effective formal short-term credit programme and the government extension service was not particularly well developed.

Through the successful use of the Kick-Off Approach in many developing countries in recent years considerable experience has been gained. The best review of this experience is given in the papers prepared for the 'Spring Review of the New Cereal Varieties', 13–19 May 1969, organized by the U.S. Agency for International Development. New countries planning to use the Kick-Off Approach for food grains should study this experience in order to plan successfully for their own situation. An evaluation of the economic feasibility and technical requirements, and the consequences of a successful programme for transport, storage, processing, marketing, financial support programmes, etc., will be useful. Research work by agricultural economists in the fields of farm management, production economics, agricultural policy, and marketing is also required. The social consequences of a green revolution have also to be carefully studied.

Countries which have already introduced the new high-yielding wheat or rice varieties should consider how to use the same approach for other crops for which new technology can be made available. The

same approach may also be successfully used for various animal products and possibly in other fields, such as transport, storage, and processing of agricultural products, where new revolutionizing technology is being developed. The success of the approach indicates that future strategy for agricultural modernization in developing countries generally should be based on new technology drawn from dynamic problem-oriented research which can increase productivity in a dramatic way. The hypothesis of slow gradual development for 'take-offs' should be discarded in favour of the hypothesis of rapid development through 'kick-offs'. This approach has important consequences also for planning of sectors supporting agriculture, e.g. manufacture of inputs, storage, marketing, and processing. The central planning organization should maintain good liaison with the production programmes and, as required, expand and modernize these supporting sectors.

III. *Can successful kick-offs lead to an agricultural revolution and rapid economic development?*

The introduction of the high-yielding wheat and rice varieties in India, Pakistan, and the Philippines has resulted in dramatic production increases with a gross value of hundreds of millions of U.S. dollars per annum. The traditional attitudes have changed. There is new hope. The 'kick-offs' will be easier for other crops or animal products for which new revolutionizing technology is available.

Assuming a continuation of a sound agricultural policy the green revolution initiated in these countries will continue. To exploit fully the potential of the new varieties of wheat and rice already introduced will take time, probably a decade or more. New and improved varieties will undoubtedly be released every three to four years. Continuing research will improve the efficiency of current production practices. Average yield and total production will therefore continue to increase after the introduction period of new wheat and rice varieties. For maize some strong national programmes have already been initiated. As soon as the technology is available and tested, production campaigns can be started for other important crops, such as sorghum and millets, cotton, winter oil seeds, soybeans, etc., and for certain livestock products. Such efforts may result in dramatic production increases and diversification of agriculture.

The remaining job in developing new high-yielding technology is an immense and continuing one (Wortman, 1969). Most of the present

Mexican-type wheat varieties are best suited for irrigated or high rainfall areas. Similarly the IRRI rice varieties are best suited for areas with control of the water factor. Promising work is under way, however, to develop new varieties and agronomic practices which will make possible the doubling of yields in the less-favoured areas also. A broad-based agricultural revolution would require new high-yielding technology for every major crop, suitable for every major season, in every main region of every developing nation. Similarly, improved breeds have to be developed for the major animal species. Many knowledgeable scientists are confident that it is now possible to develop such varieties. To produce suitable animal breeds is also possible but may be more difficult and will require a much longer time. Both for crop production and animal production complete packages are needed. For crops these packages must include a variety, fertilizer technique, plant protection technique, and improved cultivation practices; for new animal breeds they must include proper nutrition, management, and disease control.

Well-adapted farm mechanization can play an important role as part of a proper production package, especially in facilitating multiple cropping in the tropical areas where sufficient water is available for the whole year. As demonstrated by Dr. Richard Bradfield at IRRI multiple cropping opens up possibilities for tremendous production increases in such areas. The new varieties with short growing seasons make possible three to four crops per year, taking full advantage of the 365-day growing season (Bradfield, 1969). However, programmes of farm mechanization have to be tailored to the labour-employment situation in each country or area. In many overpopulated countries, with a growing rural population, selective and gradual mechanization is required.

Production breakthroughs lead to a broad spectrum of second-generation problems in provision of farm supplies, storage, transport, processing and marketing facilities, etc. As modern technology applicable to these problems becomes available it should in many cases be introduced through a 'kick-off' (it usually is much easier to transfer directly than farm production technology) and not in a slow or gradual way through introduction of intermediary technology. The latter approach may delay development for decades because of the long life of the investments.

If the increase in agricultural production in the developing countries is to lead to economic development, there must be an effective

consumer demand for the production increase. With regard to world food supply one has to plan for production sufficient to feed properly double the present world population by the end of the century. About 80 per cent of this population may be living in the regions presently considered as less developed. People expect and have been promised better nutrition and improved living conditions. If their expectations are not met there is a risk of disease, starvation, widespread disorder, and political disintegration. The only hope lies in rapidly improving diets and living conditions (Notestein, 1969).

The problem of world hunger is, however, not only a problem of food production in relation to population; it is also a problem of employment, *per capita* income, effective demand, and education. A high economic growth rate and sound economic and social policies are needed in order that increasing agricultural production can be effectively marketed (Bell, Hardin, and Hill, 1969). According to a report of the President's Science Advisory Committee (PSAC, 1967), the target set for food production to provide average diets that meet minimum calorie and protein requirements about 15 years from now will require the following compound annual growth rate (1965/6–1985/6) for the developing countries in aggregate:

	Per cent
Increase in food demand	4·0
Increase in food production	4·0
Increase in gross national income	5·5

In order to solve the problem of under-employment an annual economic growth rate of at least 6 per cent is essential as part of a general strategy for development, including a policy to maximize output through full utilization of the total labour force (McNamara, 1969). This is a growth rate about one-third higher than that which obtained over the past decade for the developing countries. To achieve this goal, the increase of food production in developing countries would have to be nearly double their historic rates. On the basis of the technological breakthrough in agriculture taking place in many developing countries such a doubling seems to be within reach. An average increase of 6·0 per cent in gross national income may turn out to be more difficult, but can also be reached or surpassed. The achievement of such growth rates can, however, take place only through expanded technical and capital assistance from the developed countries, new world trade patterns allowing the developing countries to

export their surpluses, and expansive economic policies by all countries.

The introduction of new, efficient production technology will lower the production costs of important food products and facilitate the nutritional revolution which should follow the production breakthrough. Malnutrition and protein deficiencies, especially among children, are to a high degree the result of ignorance and superstition and maldistribution within the family. The spread of knowledge about proper nutrition is therefore of fundamental importance. A nutritional revolution would improve the quality of the labour force. A satisfactory protein intake for children during the first years of their lives would avoid irreparable mental retardation because of protein deficiency.

Through a rapid increase in production at profitable prices, agriculture *per capita* income will reach higher levels. This again will facilitate a higher standard of living for the rural population, including increased use of industrial products and modernization of villages through new types of housing, running water, electric power, sewerage systems, etc. The demand for rural infrastructure will increase rapidly. The intensification of agricultural production, the investment in rural infrastructure, and the modernization of villages will create employment. This can also help to reduce the present overrapid rate of urbanization and provide a better market for the growing industrial sector.

An expansive economic policy in developing countries is greatly facilitated by the Kick-Off Approach, making it possible to increase agricultural production at decreasing costs per unit of output more rapidly than population rises (Hardin, 1970). This removes a major constraint on a policy aiming at increasing employment and income per family among the masses, since the resulting rise in demand for food can be met by the rapid increase of production at constant or even falling prices. A full employment policy may be possible through a labour-intensive growth path in the agricultural and consumer goods industries, plus labour-intensive public works programmes. Such an approach has been successfully tested in Pakistan for provision of rural infrastructure, such as roads, schools, dispensaries, irrigation and drainage, etc. Under an assumption of continuing strong technological advance in agriculture, the structure of demand will change towards agricultural supplies, rural infrastructure, and domestically produced consumer goods. The pressure on foreign exchange under

an expansive economic policy will be less through growth in the agricultural and consumer goods industries than would be the case with primary emphasis on heavy industry. Rapid agricultural growth, based upon technological change in agriculture, can thus help to solve many of the most urgent problems in the developing countries, including underemployment, excessive urbanization, and the low income level for the masses. Consequently, agricultural development can assist with the alleviation of serious social and political problems. However, widespread expansive economic policy in the developing countries can succeed only if parallel policies are adopted in the developed parts of the world also, and in conjunction with expansion of mutually beneficial trade on a global basis. The full potential benefits of increased food production in the developing countries can only be realized as part of an expanding world-wide economy, industrial as well as agricultural.

The effects of 'kick-offs' have been demonstrated in India and other countries. In India during the past three years the cumulative increment in the gross sale value of wheat at the procurement level (which represents the lowest price paid to the farmers), above that of the 1965 record crop, was $1,850 million. To this increment must be added the increased gross sale value of rice and coarse grains. This increase in gross income has affected both agriculture and general economic development. About 300,000 pumps are installed annually and about 70,000 tube-wells dug. About 55,000 tractors are bought annually with a waiting-list for about double that number of units. A large number of mechanical threshers are being sold. The consumption of fertilizers has doubled since 1965/6. In 1969 radio production increased by 60 per cent, sewing machines by 16 per cent, bicycles by 13 per cent, partly as a result of increased demand from the rural sector. In many areas there is a notable increase in the number of improved homes in the villages, with brick construction replacing mud structures. The new varieties have also had the effect of increasing employment in agriculture (Anderson, 1970).

The conclusion must be that the chances for a broadly based agricultural revolution, and for sound economic and social development generally, will be much higher through successful kick-offs than through slow evolution towards take-offs.

As with the industrial revolution in the nineteenth century there are some undesirable repercussions from the agricultural revolution. In this connection mention should be made of a tendency towards

increased social and economic inequality in agriculture, i.e. between large and small farms, between landholders and landless peasants, and between irrigated areas and rainfed areas. These negative repercussions are often exaggerated. On the other hand the positive effects are often widely overestimated. A common example is in connection with the estimates of the number of people which can be properly taken care of on this planet in future years. These tendencies to over-pessimism and over-optimism should be avoided in favour of a balanced realistic view. It should be the duty of every government concerned to try to minimize the negative repercussions and to maximize the positive effects through sound research and wise economic and social policies.

The one factor which can create the most serious future problems is an unchecked population explosion. This represents a monster which may destroy the hope of a bright future for the developing countries. The green revolution can only provide the needed breathing space for the implementation of effective population control programmes and should, of course, never be used as an excuse for slowing down such programmes.

Some irresponsible commentators have done a great disservice to all who are struggling to produce more food and hence buy time. To state that we now know how to produce food for a nearly unlimited number of people is ridiculous and dangerous. Moreover, to state that the green revolution is contributing directly to a so-called 'red-revolution' or to the Indian 'land-grab' is preposterous.

The most unfair of all criticisms are those generously put forward from the side lines, and which hold that we who have been involved in the green revolution have created more problems than we have solved. Let us remember that change always brings new problems, but with new problems come new opportunities. We have bought twenty to thirty years of time for others to come to grips with all of the multiple aspects of the population problem and the rest of the economic and social problems of the world. And many of these problems have become easier to solve than they would have been without the increases in agricultural production.

Every objective observer must admit that the new technology is not the primary cause of the social imbalances in the countryside in many developing countries. The imbalances are the result of all the social, religious, economic, and political forces which have governed villages for centuries. It is not the fault of the green revolution that because

of the power structure in Indian villages the distribution of credit is very much in favour of the affluent, that the land reforms approved by law about two decades ago have not been implemented, that security of tenure has not been given, that ceilings on land ownership are often still nominal, that the multitude of landless labour is growing because of lack of family planning and increasing population pressure, etc.

Every objective observer must admit that the new technology in itself is a positive factor for an attack on poverty and on the social imbalances which are man-made issues of long standing. We have always stressed that modernization of agriculture should include a combination of new technology, geared to higher productivity and production, and policies for improvements in the institutional framework to benefit the rural under-privileged. But agronomists alone cannot solve the problems of distributive justice in agriculture and cannot be made responsible for shortcomings in this regard. This is a field where agricultural economists should play an important role. Let us join hands and see what we as a team can do during the coming decades.

The seriousness or magnitude of the world food problem should not be underestimated. Recent success in expanding wheat, rice, and maize production in Asian countries offers the possibility of buying twenty to thirty years of time—representing only a few seconds on the clock of human occupancy of the earth—in which to bring population growth into balance with food production, and the total resources for human life.

After the year 2000 world population will approach its ceiling. A new doubling will likely represent the definite maximum of the number who can expect to have a human life on this planet. Shall the next period of doubling be thirty years or 300? Shall it be a period of peace and prosperity or of war and destruction? It depends upon all of us.

REFERENCES

Agency for International Development (1969), *Spring Review of the New Cereal Varieties. Implications for AID.* AID Washington WOH/PPO, June 1969.

ANDERSON, R. G. (1969), 'Can the New Production Levels be Maintained in Wheat?', *World Science News*, vol. 8, no. 3, Mar. 1969.

—— (1970), *Wheat Improvement and Production in India.* The Rockefeller Foundation, New Delhi, May 1970.

BELL, DAVID E., HARDIN, LOWELL, and HILL, F. F. (1969), 'Hope for the Hungry. Fulfilment or Frustrations?' in *Overcoming World Hunger.* The American Assembly. Columbia University, 1969.

BORLAUG, NORMAN E. (1968), 'Wheat Breeding and Its Impact on World Food Supply', *Proceedings 3rd International Wheat Genetics Symposium.* Canberra, 1968. Aust. Acad. Sci., Canberra, pp. 1–36.

—— NARVAEZ, M. I., ARESVIK, ODDVAR, and ANDERSON, GLENN (1969), 'A Green Revolution Yields a Golden Harvest', *The Columbia Journal of World Business,* Sept./Oct. 1969 issue.

BRADFIELD, RICHARD (1969), *Opportunities for Increasing Food Production in Tropical Regions by Intensive Multiple Cropping.* The International Rice Research Institute, 1969.

BROWN, L. R. (1965), *Increasing World Food Output. Problems and Prospects.* U.S. Department of Agriculture. Foreign Agric. Economic Dept. Rpt. No. 25.

—— (1970), *Seeds of Change. The Green Revolution and Development in the 1970's.* Published for the Overseas Development Council by Praeger Publishers Inc. 1970.

ENSMINGER, DOUGLAS (1962), 'Overcoming the Obstacles to Farm Economic Development in the Less-Developed Countries', *Journal of Farm Economics. Proceedings,* Issue vol. xliv, no. 5, Dec. 1962.

Expert Committee on Assessment and Evaluation (1969), *Modernizing Indian Agriculture. Report on the Intensive Agricultural District Program (1960–68),* Vol. i. Ministry of Food Agriculture, Community Development and Co-operation. Government of India, May 1969.

HARDIN, LOWELL S. (1970), 'Agricultural Development Employment and Growth', *Memorandum* of 15 Apr. 1970.

HARRAR, GEORGE J., and WORTMAN, STERLING (1969), 'Expanding Food Production in Hungry Nations. The Promise. The Problems', in *Overcoming the World Hunger.* The American Assembly, Columbia University, 1969.

HOPPER, DAVID W. (1968), 'Investment in Agriculture. The Essentials for Payoff', in *Strategy for the conquest of hunger.* Proceedings of a symposium convened by the Rockefeller Foundation, 1 and 2 Apr. 1968.

LIEFTINK, PETER (1968), *Water and Agricultural Development in West Pakistan.* The World Bank, Washington D.C., 1968.

MCNAMARA, ROBERT S. (1969), *Address to the Board of Governors.* Washington D.C. 29 Sept. 1969.

NARVAEZ, MORALES IGNACIO (1969), *The Accelerated Wheat Improvement Program in West Pakistan.* Lahore, Feb. 1969.

NOTESTEIN, FRANK W. (1969), 'Population Growth and Its Control', in *Overcoming World Hunger.* Edited by Clifford M. Hardin. The American Assembly, Columbia University, 1969

PADDOCK, P. and W. (1967), *Famine 1975!* Weidenfeld & Nicolson, London.

President's Science Advisory Committee (1967), *The World Food Problem,* vol. ii, p. 378. The White House, May 1967.

SCHULTZ, T. W. (1965), *Economic Crisis in World Agriculture.* The University of Michigan Press, 114 pp. Ann Arbor. Mich.

—— (1966), 'Increasing World Food Supplies. The Economic Requirements', in *Prospects of the World Food Supply,* pp. 18–23. A symposium, National Acad. of Sci. Washington D.C.

U.S. Department of Agriculture (1969), *The Impact of New Grain Varieties in Asia.* ERS-Foreign 275. Washington D.C. July 1969.

WHARTON, JR., CLIFTON R. (1969), 'The Green Revolution. Cornucopia or Pandora's Box?' *Foreign Affairs,* vol. 47, no. 3. New York, Apr. 1969.

WORTMAN, STERLING (1969), *The Technological Bases for Intensified Agriculture.* A discussion paper prepared for consideration by representatives of assistance agencies, Villa Serbelloni, 23–25 Apr. 1969.

WRIGHT, B. C. (1968), 'Critical Requirements of New Dwarf Wheats for Maximum Production'. Food and Agricultural Organization and Rockefeller Foundation. *International Seminar on Wheat Improvement and Production*. Ayub Agric. Res. Inst. Lyallpur, Pakistan. Available from the Ford Foundation P.O. Box 1043, Islamabad, Pakistan.