The importance of agriculture and a stable adequate food supply to the well-being of humankind

Norman E. Borlaug
1970 Nobel Laureate - Peace

Human rights is a complex many faceted issue, involving biologic, moral, social and political aspects. The ranking of the importance of its various components is usually adjudged subjectively rather than objectively through the eyes of the beholder. The ranking varies with time and with the position, prerogatives and standard of living of the beholder.

Agriculture - which currently produces 98% of the world's food supply - illustrates this paradox. The vast majority of the population in industrialized food abundant nations take agriculture and food production and distribution for granted. Most of them have never suffered from hunger nor have they lived in close contact with poverty-stricken hungry people. They are victims of urbanization. Few people today stop to reflect on the fact that civilization, as we know it today, could not evolve until there was a stable food production surplus which permitted many people formerly involved in subsistence agriculture to specialize and divert their talents and skills to producing other goods and services to meet human needs.

Fossilized foot-prints in Leitoli Tanzania indicates **Homo sapiens** or near cousins have been treading the planet Earth for at least three and a half (3 1/2) million years. Until some 12 000 to 14 000 years ago they depended on hunting and gathering for their food supply. About that time, as the herds of wild game dwindled and food became scarce, neolithic women came to the rescue. For untold tens of thousands of years palaeolithic/neolithic women (and children) had been collecting seeds (grains), nuts, roots, tubers and fruits or wild plants to supplement their largely wild game meat diet. With the worsening food shortage neolithic women begun to plant seeds of some of these same wild species they had been collecting for untold millennia and so agriculture was born ! Present archaeological evidence indicates that these events probably first took place in the foothills of the Zagros Mountains in what is today Iraq and Iran. But the yield and production of this rainfed agriculture, employing primitive hand tools, was low and required the collective effort of the entire population to produce enough food for the clans/tribes to survive. Even after the domestication of animals and their use as a power source with primitive tillage equipment, yields and production apparently barely met human needs. It was not until irrigated agriculture was developed along the margin of the Tigris and Euphrates rivers (in what is now Iraq) that stable food surpluses

were produced, which in turn permitted the diversion and specialization of labor to produce other goods to meet changing human needs - which hence gave rise to the first civilization - the Sumerian - only some 7000 to 8000 years ago. Within a few hundred years, other irrigated agriculturally based civilizations sprung up along the Indus (Harrapan) and the Nile (Egyptian) and soon resulted in the establishment of trade between these civilizations. Trade and commerce resulted in improvements in the standards of living. These fundamental changes initiated only after there was an adequate stable food supply catalyzed the formation of these early civilizations and all subsequent civilizations.

But there is evidence that many civilizations of the past have evolved and collapsed, in many cases, almost certainly because of failure of their food production system (e.g. Teotihuacan in Mexico) with or without the disruption of war. Each has been replaced by more recent civilizations in some other areas of the world. Within the past two hundred years, and especially within the past century, however, massive population growth has coalesced much of the world into one complex large interdependent civilization, placing enormous pressure on the world agricultural food production system.

Up until about 50 years ago as more food was needed more land was opened to cultivation. For up until about 1940 there was much land suitable for cultivation in many countries of the world. During the past five decades, however, most of the increase in demand for food has been met by the widespread use of improved technology to increase yield per hectare on land already under cultivation. This technology has involved the use of a package of improved crop management practices employing :

1. the use of high yielding disease-resistant crop varieties,

2. improved agronomic practices employing proper rates, dates and methods of planting to assure good stands of seedlings and efficient use of soil moisture,

3. the proper use of fertilizer to restore soil fertility,

4. timely control of weeds, insects and diseases combined with

5. government economic policies that encourage and permit farmers to adopt and employ the improved technology to increase yields and food production.

During my lifetime (79 years) the world's human population has increased by 3.9 billion - from 1.6 billion to the current 5.5 billion. Currently, one billion more people are being added to the world's population each decades.

Up to now, the world has been able to produce sufficient food to meet human requirements but the problem of inequity of distribution - because of

poverty and lack of purchasing power - results in hunger and sometimes famine in some food-deficit nations while at the same time there are food surpluses, depressed prices and farmers facing bankruptcy in food surplus countries.

Let me take a minute to illustrate the world food production/distribution dilemma. Had the 1990 total world food production of all types of food - totalling 2,390 million metric tons of edible matter at zero moisture content (4,615 million tons of gross weight) been distributed evenly it would have provided an adequate diet (2350 k.calories per day, principally from grain) for 6.2 billion people, nearly one billion more than the actual population. However, had the people in the Third World countries attempted to obtain 30 per cent of their calories from animal products - as in the U.S.A., Canada and EEC countries - a world population of only 2.5 billion people could have been sustained - less than half the present world population.

These statistics point out two key problems to feeding the world's people. The first is the complex task of producing sufficient quantities of the desired food to satisfy needs, and to accomplish this Herculean feat in environmentally and economically sustainable ways. The second task, equal or even more daunting, is to distribute food equitably. The impediment to equitable food distribution is poverty and lack of purchasing power resulting from unemployment or underemployment which, in turn, is made more severe by rapid population growth.

At best, the governments of most low-income food-deficit developing nations only have the foreign exchange to import the minimum amount of food to avoid famine and social unrest in the cities. Yet the problems of hunger and famine are usually greatest in the rural areas, where 70% to 85% of the people live. Even if the governments had the resources to import food for distribution in rural areas, they would be confronted with the enormous problems of physically transporting and distributing such commodities among dispersed rural populations in areas often devoid of roads. Clearly then, if the problems of world hunger is to be solved it must come through expanding food production in the low-income food-deficit countries where the majority of the world's hungry people live. Moreover, without the development of domestic agriculture and achievement of an adequate and reliable food supply - the development of commerce and industry will be forever retarded.

Progress Achieved in Expanding the World Food Production Over the Last Half Century

For the past forty-nine years I have been involved in foreign technical agricultural assistance programs trying to help increase food production in more than forty food-deficit nations of Latin America, Asia and Africa. Surprisingly, the technology developed to assist the developing nations expand their food production in some cases has also had an unexpected *spillover* effect to increase yield and production in some developed nations as well. Over these

five decades I have had the unique experience of working in food production problems with :

1. governments covering the entire spectrum of political ideologies,

2. many different racial, ethnic and linguistic groups and

3. a wide range of religious groups.

I have found that my involvement in producing bread for the hungry has been an acceptable and effective passport to understanding with all of these groups - including political, educational and religious leaders, scientists and farmers. It has been both a gratifying and frustrating experience. I will take a few minutes to indicate some of the changes in food production I have been privileged to participate in and in other cases have seen unfold from the *side-lines.* Generally, when a dramatic change in yield is introduced into a traditional agriculture on one crop it soon also indirectly impacts, to a certain extent, on other crops as well.

In the so-called **Quite Wheat revolution** developed by the Cooperative Mexican Government - Rockefeller Foundation Program in Mexico in the 1950's and 1960's I had the pleasure of seeing Mexican wheat yields increase from 750 kg/ha to more than 4500 kg/ha, a six fold increase; in the process production increased from 360,000 metric tons annually to 5,000,000 tons, a more than 13 fold increase; in the process Mexico became self-sufficient in wheat production in 1956. The success of the Mexican program was the catalyst and model that led to the establishment of the first truly international agricultural research center - namely the International Rice Research Institute (IRRI) in the Philippines, sponsored and financed jointly by the Ford and Rockefeller Foundations. Since then this initiative has been expanded into an international network of 17 international centers engaged in developing research information materials and policy capable of increasing yield and production of crop, animal and forest products.

Even more startling and impressive (and gratifying) than the success of the *quite wheat revolution* in Mexico, was its impact on wheat production in Pakistan, India and Turkey during the hunger/famine crisis of the 1960's and 1970's and subsequently in many other countries. In the period from 1966 to 1991, Pakistan wheat yields increased from 760 kg/ha to 2000 kg/ha while production increased from 3.9 million metric tons to 14 million tons. Employing the IRRI improved rice varieties and production technology, rice production, in the same period, increased from 1.32 million tons to 3.43 million tons. The country became self-sufficient in both wheat and rice production, for the first time, in 1968, and has remained so up to the present time despite its large increase in population. India's accomplishments in the 1966 to 1991 period are even more impressive, especially when recalling the widespread famine of 1965 and 1966 which led many authorities to state that India's population had

outgrown its food supply and a disastrous 'die-off' of the population was inevitable. Employing the Mexican wheat production technology, modified to make it more suitable to Indian conditions, Indian wheat yields have more than doubled, increasing from 830 kg/ha to 211 kg/ha, while production has increased nearly five fold, from 11.4 million tons to 55 million tons. India became self-sufficient in wheat production in 1972, employing modified IRRI rice varieties and production technology, it became self-sufficient in rice and all cereals in 1974 and remains self-sufficient, despite population having increased from approximately 450 million to 860 million in the same period. The larger and more appropriate question now is how much longer can it remain self-sufficient under the relentless pressure of the human population monster ?

Similarly, there has been impressive increases in yield and production of cereals during the last two decades in the Philippines, South Korea, Taiwan, Indonesia, Turkey, Egypt, Chile, Argentina, and Brazil. The most impressive increase in cereal yield and production over the past 15 years, however, has not been in India but rather in the People's Republic of China (P.R.C.). In 1961, the average yield and production of all cereals in the P.R.C. was 1.4 metric ton/ha and 147 million tons respectively. By 1980 it had approximately doubled to 2.8 tons/ha with a production of 285 million tons. By 1990, yield had increased to 4.2 tons/ha and production to 389 million tons, thereby replacing the U.S.A. as the leading cereal producer in the world. Moreover, over the last three decades (and especially during the last decade) the P.R.C. has greatly reduced its yield/ha gap compared with that of the U.S.A. Cereal yields in the P.R.C. have increased progressively from 1.4 to 2.8 and 4.2 tons/ha for the years 1961, 1980 and 1991, respectively, while over the same years, U.S.A.'s cereals yields have increased from 2.5 to 3.4 and 4.8 tons/ha respectively. The difference in yield/hectare in 1991 was 1.1 ton/ha in favor of the U.S.A., whereas by 1991 the gap in yield differences had been narrowed to 0.60 tons/ha.

The fantastic increase in both yield and production of cereals in P.R.C. is primarily the result of the large increase in utilization of chemical fertilizers, especially nitrogen and phosphates. Yields of grains doubled from 1.9 to 3.8 tons/ha in the 1975 -1985 year period when the twelve large anhydrous ammonia plants came on stream. Although the P.R.C. is the world's model country in using recycled crop residues, animal and human composted wastes the fantastic achievements in increasing food production could not have been achieved without the huge investments that were made in the ammonia/urea complexes that were made during 1974-75 at the height of the petroleum energy crisis. The P.R.C.'s decision, implementation and results of investment in synthetic fertilizer production capacity leaves a loud, clear message that should be heard and learned by those poorly informed environmentalists that are giving out mis-information to the press, television and to the political leaders in many countries to the effect that the world need not use scarce fossil fuels to produce fertilizer for food production.

This year Dr. Ha Kang will be awarded the seventh annual World Food Prize for the multi-pivotal role he has played as a scientist, policy-maker and cabinet minister in revolutionizing Chinese agriculture.

Meeting Future Food Demands

During the 1990's the world population will increase by about one billion and then again by another one billion people during the first decade of the 21st century. The medium projection is for world population to reach 6.2 billion by the year 2000 and about 8.3 billion by 2025, before **hopefully** stabilizing at about 10 billion by the end of the 21st century. Where will the food come from ?

As in the past, humankind will rely on plants - and especially cereals - to supply virtually all of our increased food demand. Even if per capita food consumption remains constant, population growth would require that world food production increases by 2.6 billion gross tons - or 57 % - by 2025, as compared to 1990. However, if diets improve among the hungry poor - estimated to about one billion people - annual food demand would increase 100%, requiring an annual harvest of 9 billion gross by 2025 compared to 4.5 billion gross tons at present. South Asia, and sub-Saharan Africa are the regions with the most poverty. By the year 2000 South Asia will still have the largest number of poor people although sub-Saharan Africa will have the highest percentage - 50% of the total population - in such dire conditions.

Increasing Food Production Through Further Increase in Yield/Hectare

Using the population growth rates indicated above and the expected changes in per capita cereal demand I come up with the following projection for cereal crop needs through the year 2025. To meet the projected food demands, the average yield of all cereals must be increased by 80% between 1990 and 2025, this is a formidable difficult challenge ! Fortunately, there are still many improved agricultural technologies already available and only being partially used at present - as well as others well advanced in the research pipeline - that can be employed in future years to raise crop yields. There are also large gaps between actual yield and potential yield in virtually all low-income, food-deficit developing nations, as well as in the ex-Soviet Union, Eastern European countries, India, Argentina and Brazil.

It is my belief that with growing demand for food and economic policies better attuned to stimulating production, yield can be increased by 50-100% in many areas of Asia, Latin America, the former Soviet Union and Eastern Europe and by 100-200% in African countries south of the Sahara, excluding the Sahel. To achieve this productivity there must be improved efficiency all along the crop production line : better land preparation to assure optimum crop stands, more timely planting of the best available varieties and hybrids, proper

fertilization, improved timely control as needed of weeds, insects and diseases and finally reduction in post harvest losses. This yield and crop production projection target assumes that there will be peace and reasonable social and political stability policies will prevail to stimulate food production, expand education and public health programs, rather than in the vast wasteful expenditure on armaments as has been the case in much of the world over the past three decades.

Increasing Food Production by Expanding the Cultivated Area

Most of the opportunities for opening new agricultural lands suitable for cultivation have already been exploited in most regions of the world. This is certainly true for densely populated Asia and Europe. Only in sub-Saharan Africa and South America do large unexploited tracts exist. Much of the area in some regions is, however, covered with tropical rain-forests - and should be left in forest. Other large tracts are problem soils, that until recently, were thought to have been worthless for agriculture, but with appropriate new technology based on four decades of research are gradually being transformed into important productive agricultural lands. One such large tract is the **Cerrado** in Brazil.

One of the Last Frontiers : the Brazilian Cerrado

Bringing the world's potentially arable problem soils area under cultivation is a formidable challenge. It cannot be achieved without strong aggressive interdisciplinary research. The Brazilian **Cerrado**, or savanna, is a case in point.

The **Cerrado** is a vast expanse of mostly flat to rolling grassland savanna, in some areas covered with a fire-induced semi-climax bush-stunted tree-grass cover. The total area of the **Cerrado** in Brazil is about 205 million hectares, approximately equivalent to the combined land area of Spain, France, Italy and Britain. It spans a geographic area from latitudes 24° to 4° s. and varies in elevation from 500 to 1800 m with a unimodal precipitation (October-March) that varies from 900 to 1,800 mm annually. The so-called **Central cerrado** with 175 million hectares in one contiguous block forms the bulk of the savanna lands. About 112 million hectares of this block is considered to be potentially arable. Most of the remainder has potential value for improved pastures for livestock production or for forest plantations with eucalyptus spp. or southern pine (e.g. pinus eliottii or pinus carabea). The soils are deep highly leached strongly acidic oxisoils with high levels of soluble aluminum with most of the phosphate fixed and unavailable. The soils in general have excellent physical texture.

In pre-colonial times, the area was sparsely inhabited by a number of Amerindian tribes dependent on a culture based upon hunting and gathering of wild plants. During the colonial period, and continuing from the time of

independence up until 20-25 years ago, the **Cerrado** was considered to be essentially worthless for agriculture (except for strips of alluvial soils along the margin of streams, where there had been an accumulation of nutrients). Until recently, most of the **Cerrado** was used for extensive low productivity cattle production - based on the native savanna/brush flora of poor digestibility and low carrying capacity.

Today, there is a new frontier spirit of enthusiasm sweeping the **Cerrado** as the potential giant begins to awaken. But what has happened to transform this worthless land into valuable arable land ? The beginning of the story goes back to the 1930's and 1940's when bits and pieces of research information on soils and agronomy, as well as some aluminum-tolerant crop plant germplasma, was developed by scientists working at agricultural universities, and at provincial and federal government stations. By the second half of the 1960's, commercial farming was being attempted with very modest success, in some part of the **Cerrado**, with the application of lime to correct acidity and aluminum toxicity and with the application of nitrogenous, phosphatic and potassium fertilizers and minor elements to restore plant nutrients. Newer varieties with aluminum tolerance (forage grasses, soybeans, rice, wheat and maize) were developed in the early 1970's, however, these varieties had low grain yield and were especially susceptible to disease and insect pests.

The creation in 1973 of the Empresa Brasilera de Pesquiza Agropecuaria (EMBRAPA) - the National Brazilian Research Corporation - provided a major impetus aimed at making the **Cerrado** a commercial agricultural area. EMBRAPA scientists initiated a more coordinated systematic program of inter-disciplinary research, integrating past knowledge and generating new research information and plant materials. Much of the soil fertility/toxicity research and the interdisciplinary agronomic research, coordinated by Dr. Wenyusclav Goedert, was centred at the Centro de Pesquiza Agropecuaria del Cerrado, located near Brazilia, while the breeding of aluminum tolerant varieties with higher yield combined with better resistance to the major diseases and insect pests was carried out at the various EMBRAPA commodity - specific national research centers.

In the 1980's EMBRAPA begun collaborating with several of the international agricultural research centers (especially CIAT and CIMMYT) to accelerate the development of a third cycle of crop varieties combining tolerance to aluminum with better yield and agronomic characters and a higher level of resistance to the major diseases. During the past five to eight years, the more recent soil and agronomic information combined with the use of the newer crop varieties has been moved onto farms and is spreading rapidly to increase yields and production of a number of the most important crops. Moreover, improved crop management systems including better crop rotations, the proper use of herbicides and minimum tillage that leaves the crop residues on the surface to facilitate rainfall penetration and reduce run-off and soil erosion are beginning to gain acceptance.

A few of the most progressive farmers are now beginning to put all of the pieces of the new crop production technology together properly with excellent results. The challenge ahead is to extend these skills to all farmers - to assure continued success and to assure further improvements, a vigorous interdisciplinary research effort must be continued to overcome many still unsolved problems.

Despite all the soil toxicity/infertility problems and biological and infrastructure problems that have been encountered, great progress has been made in the last two decades, and especially during the last ten years in converting this once thought to be worthless land into an important agricultural region. The **Cerrado** is already producing 25% of Brazil's soybeans, rice and maize, 14% of the beans, 5% of the wheat and 20% of its coffee. It has vast areas of improved pasture that are producing 12% of the milk production and sustaining 40% of the national cattle herd. Nevertheless, at present, the profitability of agricultural production in much of the **Cerrado** is still seriously constrained by high transportation costs. To haul grain 1500 km by truck costs about us$ 40 per ton. Future development of railroad and river transport and continuing improvement in the road system, will no doubt, greatly improve the economics of production in the region. Finally the rate of expansion of agricultural production in the **Cerrado** will depend upon both domestic and international demand for food and its price and Brazil's progress in developing the transportation and communication infrastructure.

In all probability, much of the information on soil and agronomic management practices and aluminum tolerant crop varieties that have been developed for use in the **Cerrado** will be useful in other areas where there are similar soils such as in the vast plains (llanos) of the Orinoco drainage in Colombia and Venezuela and across the oxisoil belt across south central Africa.

African Agriculture in Crisis

More than any other region of the world, agriculture south of the Sahara is in crisis. High rates of population growth over the last three decades, combined with little application of improved agricultural production technology have resulted in declining per capita food production, escalating food-deficits, and deteriorating nutritional levels, especially among the rural poor. Unless recent production trends are drastically altered, sub-Saharan Africa will only be producing 75% of its basic requirements by the year 2000. It should be remembered that the present food crisis is the result of the long time neglect of agriculture and rural development. It received little attention during the colonial period and the continuing neglect since independence is equally deplorable.

The continuing social and political instability with the neglect of the development of rural infrastructure -roads, railroads, marketing systems for agricultural products, together with the inadequacies of rural education and

public health services continue to be major obstacles to social and economic improvements. Unlike densely populated Asia with its accompanying shortage of arable land, Africa still has vast areas of land potentially valuable for agriculture that is undeveloped. Land tenancy - with much of the land still held by tribal leaders - is another impediment to development in many of the African countries. Moreover, serious human and animal health problems have also held back background agricultural development.

If the African countries south of the Sahara are to become viable parts of the 21st century brotherhood of the United Nations far greater attention must be given to agriculture and rural development. It is in the agricultural sectors of these societies where 70-85% of the people live and struggle to eke out a miserable existence. If these countries are to evolve socially, economically, and politically, governments must abandon their policies of providing cheap food for the politically volatile urban dwellers while neglecting to provide economic production incentives for farmers.

Many of the tropical and semi-tropical environments - especially the forests and transition areas - are fragile economic ecological systems with highly weathered soils that loose fertility rapidly under continuous cultivation. Traditionally, slash and burn shifting cultivation and complex cropping patterns permitted low-yielding, relatively stable, food production systems. Increasing population and food requirements have shortened the bush/fallow previously used successfully to restore soil fertility and often pushed farmers into more marginal lands. With more continuous cropping organic material and nitrogen are being rapidly depleted, while phosphorus and other nutrient reserves are also being depleted slowly but steadily. This is provoking disastrous environmental consequences, such as erosion and weed invasions leading to impoverished post fire climax vegetation.

Since 1986, we have been involved in food production technology transfer projects in sub-Saharan Africa sponsored by the Sasakawa Foundation and its Chairman, Mr. Rioychi Sasakawa , and enthusiastically supported by former President Jimmy Carter. This program known as Sasakawa-Global 2000 currently operates in six African countries : Ghana, Bénin, Togo, Nigeria, Tanzania and most recently Ethiopia. Previously we also operated similar projects in Sudan and Zambia.

The heart of these projects has been dynamic field testing and demonstration programs for the major food crops for which improved technology has been developed by national and international research organizations, but for various reasons was not being adequately extended among farmers. Working with national extension services during the past seven years, more than 150 000 one-acre Production Test Plots (P.T.P.) have been grown by small scale farmers. Most of these P.T.P.s have been concerned with demonstrating sorghum, wheat, cassava and grain legumes. The package of recommended production technology includes :

1. the use of the best commercial variety or hybrids,

2. proper land preparation and seeding to ensure good stand establishment,

3. proper application of appropriate fertilizers and, when needed, crop protection chemicals,

4. timely weed control and

5. moisture conservation and/or better water use if under irrigation.

We also work with participating farmers' families to improve on farm storage of agricultural production, both to reduce post-harvest losses and to allow farmers to hold stocks longer to exploit periods when prices in the market place are most favorable.

Virtually without exception, P.T.P. yields are two and generally three times higher than the control plots employing the farmers traditional methods. Hundreds of field days, attended by thousands of farmers, have been organized to demonstrate and explain the components of the production package. In areas where the projects are operating farmers' enthusiasm is high and political leaders are taking much interest in the program.

It has become clear from the large number of P.T.P.s conducted on farms over the past seven years that sub-Saharan Africa has a large unexploited food production potential. The principal challenge is to find ways to convert this potential to actual production.

It is now becoming apparent that despite the formidable obstacles in Africa, the elements that worked in Latin America and Asia will also work to increase food production in sub-Saharan Africa. If an effective seed and fertilizer supply and distribution system and a marketing system for the crop is developed, sub-Saharan Africa can make great strides toward improving the nutritional and economic well-being of their desperately poor populations.

Geneva, June 11th, 1993.
gm\borlaug.txt