Population, Resources & Food: The World Between Today & Tomorrow

Farrer Memorial Oration, 1987

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FARRER MEMORIAL ORATION 1987

Population, Resources and Food: The World between Today and Tomorrow.

John L. Dillon

Department of Agricultural Economics and Business Management
University of New England
Armidale, 2351

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ABSTRACT

After taking tens of thousands of years to reach 2.5 billion in 1950, world population has doubled to five billion in the last 37 years. In this context of unprecedented population growth, the world situation with regard to likely future resources and food needs is reviewed. Consideration is given to such questions as: What will the world's future population be? What are the likely consequences of rapid population growth in poor countries and incipient population decline in rich countries? What are the limits that a finite Earth imposes on population expansion and social progress?

Current indications are that the world's population will stabilize around the end of the 21st century at a level of about 11 billion or somewhat over twice that of today's level. About 85 percent of the people then in the world will be in today's developing countries. It is argued that the resources and technology to sustain such a population at a reasonable standard of living and without the spectre of Malthusian misery and vice are available or achievable. What is far less certain is whether this technical capacity for sustenance will be matched by political capacity to ensure the institutional and policy framework necessary to achieve equity in sustenance and welfare. Without such equity, the world will continue to be divided economically and socially with consequent turmoil and chaos.

POPULATION, RESOURCES AND FOOD: THE WORLD BETWEEN TODAY AND TOMORROW

William Farrer was a great benefactor to Australia and the world. Born in England in 1845, he came to Australia in 1870 when ill-health forced him to abandon his medical studies after completing a BA in mathematics at Cambridge. In 1886 he resigned his position as a surveyor with the NSW Department of Lands and began working a 400-acre property, which he called Lambrigg (Hill of Lambs) after his mother's home and on which he built a beautiful residence which is now part of the National Trust. The property had been part of his father-in-law's station, Cuppacombalong, near Queanbeyan.

As a country surveyor, Farrer had seen the ravages of rust in wheat and, in 1882 and 1883, wrote letters to the press suggesting the rust problem could be overcome by breeding wheat that was resistant. It seems his inspiration for this came from an appreciation of Charles Darwin's 1868 book The Variation of Animals and Plants under Domestication which, like Darwin's other works, was not very well received by most Australian scientists of the time. We were lucky that The Australasian, in editorial comment, was twice scathing of Farrer and his ideas. His ire was raised and in 1889, after observing a large number of wheat varieties that he grew in a small paddock at Lambrigg from 1886 to 1888, he began his breeding work - using his wife's hairpins as tweezers. Official recognition and support came in 1898 when he was appointed as Wheat Experimentalist of the NSW Department of Agriculture (Evans 1980; Wrigley 1981).

Farrer was eminently successful in his breeding work which, within a few years, he broadened to accommodate not only rust but other diseases, plant type, growing conditions, gluten content, milling and baking quality. He bred and named some 220 wheat cultivars including Federation which, from 1901 to 1925, was our leading variety and was still grown abroad until 40 years after his death in 1906. In his work he was an internationalist, conducting a voluminous correspondence and exchange of seeds with those few breeders active overseas, a correspondence which (fortunately held by the National Library) well shows his scientific brilliance, openness to ideas, recognition of others and an all-consuming dedication to his self-set task. To him we owe the development of our wheat industry. It is no coincidence that the wheats he bred still figure in the pedigree of many of our wheats today, as they do too in many of the wheats used throughout the world, not least in the Veery lines - the wonder wheats of the 1980s - which have Farrer's Federation in their pedigree and are raising bread wheat to new levels of yield and stability across the range of diverse environmental conditions confronting millions of Third World farmers (CIMMYT Wheat Staff 1986).

Both directly through his work and indirectly through his example, Farrer did much to establish Australia's scientific reputation. Worldwide, he was one of the first to recognize and use the potential of hybridization for the improvement of plants, making use of the attributes to be found in varieties of diverse geographic origins. He appreciated and made use of Mendelian principles of genetics at least ten years before their rediscovery in 1900. Too, he was probably the first to breed explicitly for rust resistance and was certainly a pioneer in breeding for milling and baking quality.

That I should be a recipient of the award commemorating Farrer's contribution seems out of all proportion. I have, however, found one common feature in our lives. In congratulating a fellow breeder in the USA who had recently married he said "I am deeply thankful that it [marriage] was so well, or shall I say, so fortunately taken by myself. It has been the good fortune of my life, and as much of good fortune as is my fair share" (Farrer 1898). I can only say "Me too".

My aim in this address is to overview the world's situation with regard to population, resources and food: where we are, how we got there and where we might be heading. It is a topic which fits well with Farrer's work. Were he alive today, it would, I am sure, have been of great interest to him - not least because there are no sure answers to such questions as: What will the world's future population be? Or: What are the likely consequences of rapid population growth in poor countries and of incipient population decline in rich countries? Or: What are the limits that a finite Earth imposes on population expansion and social progress? We can, however, be sure of two things. First, that after taking tens of thousands of years to reach 2.5 billion (i.e., 2,500 million) in 1950, world population has this year - just 37 years later - reached double that number; and, second, that those of us lucky enough to be in the world today hold a monopoly over the existence of those who might be here in the future.

BACKGROUND

Concern about population size is longstanding. Plato, for example, argued that the ideal Greek state to meet needs of security and self-sufficiency would have 5,040 landholding households (Keyfitz 1972). The Reverend Thomas Malthus, however, is the person we all think of in the context of population growth and its limits. His famous <u>Essay on the Principle of Population as It Affects the Future Improvement of Society, with Remarks on the Speculations of Mr Goodwin, M. Condorcet and Other Writers</u> was first published in 1798. The essay was in reaction to the views of mercantilist writers of the 16th to 18th centuries such as Jean Bodin (1955, p. 159) who in 1576 wrote "One should never be afraid of having too many subjects or too many citizens, for the strength of the commonwealth consists in men" - a statement which, translated to the personal level, is somewhat akin to my recognition that the world needs my genes.

Malthus began by stating his postulates: "first that food is necessary to the existence of man and secondly that the passion between the sexes is necessary and will remain nearly in its present state" - a sentiment to which the elegance of Mrs Malthus was seemingly no impediment. He then stated: "Assuming these postulates as granted, I say that the power of population is indefinitely greater than the power of earth to produce subsistence for man. Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio." He then argued that to achieve population stability "implies a strong and consistently operating check on population from the difficulty of subsistence". He saw this check as twofold: first a "positive check ... which in any degree contributes to shorten the natural duration of life", i.e. the dead are both dead and not very passionate, and second, a "preventative check" which included all those factors that prevent or persuade the living from having children. He went on to say "It is difficult to conceive of any check on population that does not come under the description of misery and vice".

Writers such as William Cobbett and William Hazlitt took Malthus to task, giving him the soubriquet "the gloomy clergyman" and ridiculing him through restatements of his principle as what was dubbed "the dismal theorem": that population equilibrium is only achievable through misery and vice; and "the utterly dismal theorem": that any increase in the world's level of food production must increase the sum total of human misery because population will increase until misery becomes great enough to curtail it (Blaxter 1986).

Despite his notoriety, Malthus was not the first to express the view that food production possibilities were the ultimate limitation to population size. For example, 30 years before Malthus first published his essay, James Steuart had written "The numbers of mankind must depend on the quantity of food produced by the earth for their nourishment, from which as corollary: That mankind have been as to numbers and must ever be in proportion to the food produced; and that food will be in the compound proportion of the fertility of the climate and the industry of the inhabitants" (Skinner 1966).

As yet Malthus' principle has been neither proved nor disproved. As a matter of logic, it does not follow from his postulates. Rather, it is but an opinion. Nor is it true, as would be implied by steady exponential growth of population, that the number of people alive at any time has been more than the number who ever lived before them. Thus, while there were some 4.5 billion people alive in 1984, it is estimated that between then and 40,000 BC some 58 billion had died (Blaxter 1986). Nor do projections of population based on Malthus' work perform well. Taking the American Colonies as representative of a situation unlimited by food production constraints, he found a growth rate (exclusive of migration) of 2.8 percent implying a doubling of population there every 25 years (in contrast to a figure of about 50 years which he derived for Ireland, England and Europe). In fact, to today, US population has grown at a rate only about a quarter of that Malthus suggested as unfettered and there is no evidence that this has been caused by lack of food or other misery and vice of the nature propounded by Malthus.

The fact is that the rate of natural increase of population is not a constant but varies over both time and space for reasons apart from food, misery and vice. Historically, it has fluctuated on a global basis from century to century but, until a decade ago, it was generally increasing. Put another way, until very recently, the historical pattern has been for the world's rate of population growth to be increasing over time and for the implied doubling time of population to be decreasing. At the time of Christ, doubling time was nearly 3,000 years; in Malthus' time it was around 200 years; in 1970 it peaked at 35 years. Luckily, doubling time has never reached its ultimate minimum of about six years as would occur if every woman had a child every year from the age of 15 to 45. As at tonight, doubling time is 41 years.

ECONOMIC PERSPECTIVES

Classical economists such as Malthus, writing at the start of the 19th century, saw a scarcity of land and inevitable diminishing returns in food production. They also saw a tendency for population to rise with any widespread betterment of living standards due to improved health and earlier marriage. In contrast, 20th century neo-classical economists in their views reflect the diminished importance of agriculture in modern industrial economies and the impact of a century of rapid technical progress with declining relative prices for resource-based commodities. They emphasise the adaptability of modern economies to population pressure on resources through the mechanisms of market-induced substitution and innovation. As long as market pressure induces new technology that makes substitution possible, it is argued that income per capita can be sustained with a rising population even if the resource initially used is ultimately exhaustible (Stiglitz 1979).

Modern economists also recognize that there are limits to market mechanisms. Prices can give guidance only if resources can be bought and sold. For many important resources this is not possible. Known as common property resources, such resources are owned by everyone and cannot be reserved for individual use. The point is well illustrated by Chief Seattle's response to President Pierce in 1855 when the US government wanted to buy his tribe's land: "The idea is strange to us. If we do not own the freshness of the air and the sparkle of the waters, how can you buy them?" (Repetto 1987). Without collective control over their use, common property resources tend to be depleted or destroyed. Users assume that if they use less in order to save the resource, others will take more; if they find ways to enhance the resource, others will benefit unfairly; or, like the air and the ocean, their impact on it - whether positive or negative - is so small as to insignificant and irrelevant.

Market processes are also myopic about future needs. Even if returns on alternative investment of tied-up capital were no more than seven percent per year, the value of a resource would have to be expected to increase by a factor of 800 if deferral of its use for 100 years were to be economically justified.

NATURAL SCIENCE PERSPECTIVES

Natural science brings different perspectives to the appraisal of population growth possibilities. In particular, scientists see limits to substitution possibilities. Substituting greater yield per unit of land for extra land requires more energy (in the form of fertilizer, pesticides, fuel, etc) per unit of output. Once available energy sources were depleted, this could no longer be done. And what would we substitute for space once there was standing-room only? Assuming today's growth rate of 1.67 percent per year, this would occur in the year 2674 when the earth's land area would be packed solid with 480,000 billion people, or 96,000 times more than today's population of five billion. Nor is the year 2674 a long way off - only 687 years, which is just how long ago Marco Polo returned to Venice from China. Standing-room only, however, is not an eventuality; long before then, assuming the spread of AIDS is halted, motor cars would have exhausted all available space!

Biologists and agriculturalists have also applied the concept of sustainable carrying capacity to human population. Global estimates of such capacity range from 7.5 to 150 billion people depending on the assumptions made about dietary needs and food production possibilities (Revelle 1976; Gilland 1983; Blaxter 1986). A particular study of this type was recently completed by the United Nations' Food and Agriculture Organization (FAO 1983). This study appraised the population-sustaining capacity of land in 117 developing countries. Climate, soil and three alternative levels of technology were taken into account. The study concluded that, with low technology (as mainly used now), of the world's developing regions only South West Asia was unlikely to be able to support its projected population in the year 2000 on a sustainable basis. On a country rather than a regional basis, some 65 countries would not be able to provide the minimum level of nutrition for their expected population in the year 2000; food imports would be needed for 440 million people. With the best of technology (assuming it could be afforded), the number of countries unable to feed their people fell to 19. The study, however, can be criticized (Mahar 1985). It made no attempt to assess what technology might be affordable; it assumed that all land that could be brought under cultivation (including much of the Amazon) would be cultivated and that none would be lost to degradation; further, that no land that could be cropped for direct human consumption would be used to feed livestock. Too, it was assumed that only minimum nutritional standards would be satisfied and all food would be evenly distributed within a country. And beyond 2000 it had nought to say.

More recently the World Bank has analyzed carrying capacity in terms of food and fuelwood supplies in seven countries of the Sahelian and Sudanian zones of West Africa (World Bank 1985). The study showed the region's rural population of 27 million in 1980 was still significantly below the 36 million who could be sustained agriculturally but it was well beyond the 21 million who could be supplied with fuelwood on a sustainable basis. The result, of course, is rapid deforestation and possible desertification as what use food if it cannot be cooked?

The carrying capacity approach is, however, open to criticism. Agricultural resources are not everything, as countries such as Kuwait and Singapore illustrate. Too, in its analogy to non-human species, the carrying-capacity approach ignores man's ability to modify both his environment and his way of using it. This ability is well illustrated by man's development of agricultural technology which, in its fullest expression to date, has changed in turn from hunting to shifting cultivation with long fallow periods, to short fallow and rotations with organic manuring and multiple cropping, to intensive monocultures using improved varieties, chemicals, machinery and irrigation, and possibly, in tommorrow's world, to use of genetically engineered species and aquaculture (Boserup 1981; Pingali and Binswanger 1984; Wolf 1987). There are also social and other mechanisms - such as sexual taboos, inheritance laws, birth control and migration - that regulate population growth. These are found in both traditional and modern societies. However, they provide no surety against stress, particularly relative to environmental damage. Population impinges on both local and global ecosystems. Witness the current scientific uncertainty about the greenhouse effect caused by disruption to the carbon cycle through the burning of fossil fuels and other man-made effects on the global atmosphere (Mintzer 1987). Worst of all, by the time their consequences are evident, the ecosystem changes that have occurred, whether local or global, may be irreversible. Nor are the threatened resources - such as climate, forests, woodlands and biological diversity - protected by rising prices since they are largely in the public domain.

POPULATION OUTLOOK

Compared to Malthus' time, recent years have seen dramatic changes in the population scene. The scale of current population growth is unprecedented. Every year some 83 million people - more than five times Australia's population or as many people as existed in 1000 BC - are added. Unique too is the shift in this growth to the developing countries. Until the 1930s, population growth was more rapid in the industrialized countries than in their colonies. Today, however, innovations in health care have dramatically reduced death rates in the developing world while birth rates have fallen more slowly. Worldwide, as Evelyn Waugh put it, "Medical science has oppressed us with a new huge burden of longevity" (Gallagher 1983, p. 576). Since 1950, 85 percent of total population increase has been in the Third World. Yet, as the demographers tell us, no one in the world today is more than a 52nd cousin of anybody else.

Too, world population has become far more mixed as the technology of courtship has progressed from walking, to the bicycle, to the car and now the aeroplane.

Most dramatic has been the auspicious reverse in the world's population growth rate that occurred in the early 1970s when it started falling from the two percent per annum reached in the 1960s to reach 1.67 percent today, an effect due not to Malthus' positive checks of famine and pestilence but to the preventative check of controlling fertility. For the first time, the progression of ever-shortening doubling times of world population has been reversed. It seems the flood crest of population growth, though not of absolute numbers of people, has passed. World population is still expected to double before it stablizes at about the end of the 21st century. Based on extrapolation of current trends in fertility control, the World Bank (1984) has estimated this stabilized population to be 11 billion. The United Nations estimates the figure at 10.2 billion (Merrick 1986). The assumptions underlying these estimates are, of course, crucial; uncertainty abounds as to at just what level or when world population will stabilize. For example, the United Nations' estimate of 10.2 billion in 2100 assumes world fertility will fall to replacement level by 2035. A 30-year delay in this would imply a population plateau not at 10.2 billion but at somewhat over 14 billion. It is sure, however, that when stability is reached, less than 15 percent of the world's population will be in today's developed countries.

Of the population growth to the end of next century, it is estimated that some 95 percent will occur in what is today's developing world. One likely effect of this during the coming century will be a demographically divided world. On the one hand, in 1986 the developed regions plus China had a population growth rate of 0.8 percent per year (with a range from 0.2 to 1.0 percent) and a population of 2.3 billion while, on the other hand, the rest of the world's regions had a growth rate of 2.5 percent (with a range from 2.2 to 2.8 percent) and a population of 2.6 billion (Brown 1987). The danger is that many countries in the rapid growth group, under the mutually reinforcing influence of rapid population growth and falling per capita income, may become caught in a demographic trap, leading at worst to a downward spiral of economic decline and ecological deterioration with declining food production possibilities. Should that happen, only charity would keep misery and famine at bay until such countries could regroup and again attempt to make the demographic transition to low population growth. Regardless of that extreme possibility, there seems no doubt that for some time the demographic division of the world will reinforce its already existing economic division into rich and poor countries. This is already happening. In the past 20 years, while developing countries as a group have increased their GNP more rapidly than developed countries, most of the gain has been offset by higher population growth. In per capita terms, the relative income gap has narrowed negligibly while in absolute terms it has widened substantially. Thus, while GNP grew faster in India than in the US from 1965 to 1984, because of more rapid population growth real per capita income in India grew only from US$190 to $260 - a gain of only $70 over the period - while in the US it increased from US$11,000 to $15,400 - an increase of $4,400.

Nonetheless, despite all the bestialities of our age, it is a fact that over the recent period of high population growth, living standards have on average risen in almost all countries as measured by such indicators as per capita income, agricultural production, school enrolment, literacy, infant survival and life expectancy. The improvement would doubtless have been greater if population growth had been slower (Clausen 1984; National Research Council 1986). Certainly, despite a reduction in the proportion of the world's population suffering absolute poverty, growth of population has increased their number - which today probably exceeds one billion. However, as a variety of studies has now substantiated, the problem for such people, even under famine conditions, is not the lack of potentially available food but their lack of resources, usually land or money, to obtain it (World Bank 1980; Sen 1981; Mellor and Gavian 1987). In this, as in many other aspects of economic progress, it is not population growth per se which is to blame. Rather it is the inadequacy of economic policies and political institutions, and in some cases doubtless also the ossification of social structure together with the inadequacy of traditional culture relative to needed polity. Without change to these influences, it seems sure that next century will see a greater number still suffering absolute poverty.

RESOURCE EFFECTS

Population growth has impacts on both renewable and non-renewable resources (Repetto 1987). Most transformed of renewable resources has been land, recognising of course that the time required to renew land is very long. Of the world's cropland in use in 1980, almost two-thirds was brought into production after 1850. The cost has been a substantial reduction in the extent of temperate and tropical forests, grasslands and wetlands. One consequence has been the decimation of fuelwood supply. It is estimated that 1.5 billion of the two billion people who rely mainly on fuelwood are using it faster than it grows. A second cost, particularly with the depletion of the forests of the humid tropics, is the imperilment of biological diversity involving millions of as yet unclassified plant, animal and insect species whose value to mankind is as yet unexplored and whose potential, given that 80 percent of the world's current food supply comes from only 24 plant and animal species, must be significant. To give but one example, clearing of the forest on the island of Madagascar over recent decades is estimated to have doomed some 60,000 plant and animal species. A third cost is the loss of grasslands and rangelands with consequent overstocking and degradation of the remainder. Thus more than 60 percent of the world's rangelands are now classified as moderately to severely desertified (World Resources Institute 1987). A fourth cost of intensification is erosion which, unless checked, is estimated by FAO (1983) to cost developing countries 20 percent of potential agricultural production by the end of this century, not to mention erosion's downstream costs of dam siltation reducing irrigation storage and power generation as well as causing increased water treatment costs, abraded turbines and reduced fish populations.

Until the 1950s, the major source of increased agricultural production in the world was additional land. Since then, under the constraint of reduced availability of new land, the situation has been reversed. Additional output has come largely from increasing yields per unit of land through the use of improved varieties, fertilizers, pesticides and irrigation. Thus, while the area of grain harvested in the world increased by a factor of only 1.2 from 1950 to 1986, the amount of grain produced increased by a factor of 2.7.

This intensification of production has put pressure on the land base, notably in terms of soil degradation, erosion and, in many irrigation areas, waterlogging and salinization. Chemical pesticides have had substantial ecological impact with previously unimportant pests emerging as the natural balance is disturbed. Conversely, more and more pest species have been developing resistance to pesticides. Too, public regulations on pesticide use are generally lax in the developing world so that pesticide exposure is widespread and consequently a health risk to all.

Relative to non-renewable resources, the major impact of population growth is from the developed world - its industry feeds on fossil fuels, metals and other minerals. These resources, however, are generally subject to the price mechanism which provides a rationing device. The historical record is fairly clear. Non-renewable resources have not become significantly more scarce over the last century during which time their use has burgeoned (Repetto 1987). With possibilities for innovation, substitution and recycling, it seems, paradoxically, that relative to population growth they constitute a second-order problem in comparison with renewable resources.

Overall, in terms of food and resources, it seems that the fivefold increase in population since Malthus wrote has been accommodated with both generally improving living conditions and longer expectation of life. A much larger proportion of the world's renewable resources - water, soils and plant resources - has been pressed into service. They have met the pressure of population to date but not without significant sacrifice to future productivity.

ENVIRONMENTAL QUALITY EFFECTS

While most measures of environmental quality in advanced countries show improvement over recent years, the reverse is true in developing countries (World Resources Institute 1986). Urban areas are the most affected. In the developing world, urbanization is proceeding rapidly. Hundreds of millions live in unauthorized squatter settlements without water and sewage services. Air and water quality in Third World cities are also generally poor because of the lack of infrastructure and effective pollution controls on industry. Population growth, through birth and off-farm migration, has of course contributed to these problems. However, as experience in the developed world shows, enforcement of environmental regulations on pollution can do much to overcome the problem.

More difficult and probably more important worldwide are the as yet largely uncontrolled emissions into the global atmosphere of carbon dioxide and trace gases such as fluorocarbons, nitrous oxide and methane that contribute to global greenhousing and also reduce the level of stratospheric ozone which is crucial to shielding the earth's surface from ultraviolet radiation. Ice-core samples, for example, indicate that the concentration of carbon dioxide has already risen about 25 percent above its preindustrial level. According to some modelling estimates, it is already inevitable that such untoward atmospheric emissions will cause a warming of the earth's surface by two or three degrees (Mintzer 1987). This would be a significant change leading to a sea-level rise of perhaps a metre and shifts in climate with consequent reduced rainfall and crop yields. Again, however, while compounded by population growth, such effects cannot be directly attributable to it. Rather they are the adverse side of what seems like progress - shanks's pony versus the automobile or the less convenient shaving soap stick and brush versus the aerosol foam pressure can with its fluorocarbon emission.

In sum, population growth rates are not the dominant influence on environmental quality though very rapid urbanization in developing countries is a significant factor. More critical are the pace and pattern of industrialization and the effectiveness of environmental controls.

FUTURE PROSPECTS

Clearly, given Earth's finite nature, world population has to reach a limit, preferably at a level which offers wellbeing to all rather than just a few. At what level this might be and when it might be achieved is clearly uncertain - just as, in the final analysis, it is uncertain whether stability will be achieved through rational moderation of fertility or through Malthusian misery. Uncertainty likewise surrounds the capacity of resources to meet population needs. All that can be done is to make a considered judgment.

Perhaps most critical are energy resources. Certainly, at existing prices and with existing technology (excluding nuclear power), oil reserves as currently defined will be under pressure within the next 40 years. But if prices and extraction technology advance, further supplies will become available - the problem is economic and technological rather than geologic. Too, superconductors now on the horizon may - as some physicists predict - transform the productivity of primary energy sources just as transistors and microchips have transformed electronics.

Scarcity of nonfuel minerals is not seen as a problem. Most are available in virtually non-exhaustible quantity. The possible exceptions are phosphorus, which is estimated at 500 years' supply for agricultural use, and some trace elements such as copper and zinc (Goeller and Zucker 1984).

The most direct and immediate effect of population growth will be on agricultural resources. A stabilized world population twice that of today, as predicted by the World Bank and United Nations, and having improved nutrition in today's developing countries, would mean a threefold increase in the demand for basic calories. If grain were the only source of these calories, 10 billion tonnes would be needed each year. This would imply that all of the world's current cropland would have to yield about seven tonnes of foodgrain per hectare per year - which, although only half of the world record yield, is about what farmers currently achieve in the US Cornbelt with all its advantages of climate, soil and modern technology. It compares with a current world average yield of 2.3 tonnes per hectare. Obviously additional land, generally of lower quality and for which crop varieties and agronomy are not yet adequately developed, will have to be brought into production. Studies by FAO suggest the land is available in North and South America, Australasia and parts of Africa (Hrabovszky 1985). These are not, however, the regions of expected population pressure. Trade and the ability to finance it by exports of manufactures from food-deficit countries will be necessary.

Thus experts are generally agreed that, with adequate support for research, wise husbandry and the appropriate provision of input supplies, technical information and farmer incentives, world food needs at a stabilized population of around 11 billion can be met using standard technology that is either currently available, in the research pipeline or sure to come from research investment (Schultz 1981; Bale and Duncan 1983; Hanrahan, Urban and Deaton 1984; Mellor and Johnston 1984). This assessment is complemented by favourable expectations about the potential revolutionary contribution of genetic engineering - for example, the development of nitrogen-fixing capacity in cereals and of plant varieties with greater photosynthetic efficiency and resistance to disease (Brill 1986; Elkington 1986).

Overall, admitting the uncertainties involved, so far as one can draw a line through considered assessments, the expert consensus seems to be: first, that world population will stabilize around the end of next century at a level not too much above twice that of today; and second, that the resources and the technology to accommodate such a population at a reasonable level of sustenance and welfare are available or achievable. What is far less certain, however, is whether this physical capacity will be matched by the requisite political capacity to ensure the institutional and policy framework needed to achieve equity in sustenance and welfare. In the future, as now, those suffering hunger will do so not because sufficient food cannot be grown but because, through lack of political recognition, their right to it has not been established.

To have equity in sustenance and welfare, each member of society must have a sufficient entitlement or resource endowment to enable him or her to acquire the food and other goods and services needed for reasonable existence (Sen 1986). At base this implies each person must either have command over sufficient physical resources or possess sufficient human capital or possess sufficient of both to earn his or her keep. Having command over sufficient physical resources implies either a massive redistribution of wealth to achieve equity, or a State guarantee of access to sufficient resources or their output. Possession of sufficient human capital implies a vast increase in the provision of education and training. Neither of these necessary changes to give equity in entitlement appears easy to achieve. Both are sure to have to overcome all the difficulties imposed by man's capacity for inhumanity to his fellow man as so often expressed through prejudice, ignorance, tradition, emotion and self-interest.

The risk is that without the profound changes needed in policies and institutions in order to achieve reasonable equity in most of the societies of the developing world, the division between rich and poor will not only continue but become far worse with consequent social conflict, turmoil, chaos and misery. Current conflicts over entitlements in Nicaragua, the Philippines and South Africa give a foretaste of possibilities. Likewise, the need for an equity orientation and the difficulty of achieving it is well illustrated by Brazil's recent history as sketched in the respected US journal The New Yorker: "Brazil's dictatorship began in 1964, with a coup d'état and the blessings of Lyndon Johnson who sent down an aircraft carrier, a helicopter carrier, four oil tankers, six destroyers and a hundred tons of arms and ammunition for moral support and encouragement. By the time it ended, in 1985, Brazil had "developed" - to the eighth industrial power in the world from around the fiftieth - and a handful of bankers, businessmen and managers had what amounted to slavers' rights over a hundred and thirty million people. It was a regime noted, even in Latin America, for sadism, social terror and corruption" (Kramer 1987, p. 40).

Yet, one can only remain optimistic that what Jacob Bronowski has called the Ascent of Man will continue. As Bronowski (1973, pp. 19-20) put it:

> Among the multitude of animals which scamper, fly, burrow and swim around us, man is the only one not locked into his environment. His imagination, his reason, his emotional subtlety and toughness, make it possible for him not to accept the environment but to change it. And that series of inventions by which man from age to age has remade his environment I call ... The Ascent of Man.

Let us hope that Homo sapiens is sapient and that his reason and inventiveness can serve him as well in the socio-political sphere over the next century and beyond as it has and can in the technical sphere. If it does not, Malthusian misery will pervade much of the world - generated not because of a lack of physical resources but because of political incapacity to ensure equity in entitlement.

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