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# LAND USE AND LAND POTENTIALS FOR FUTURE WORLD FOOD SECURITY[1]

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## *1. Introduction*

This paper is, in the first place, about developments in world food security, with particular reference to the developing countries. We first review historical developments during the period from the early sixties to the mid-nineties (Section 2), as a prelude to presenting one possible view of the future (Section 3)[2], drawing on relevant work in FAO. In this context, the future is mainly the year 2010. The possible outcomes for that year are derived from work carried out in the early nineties (14), including minor revisions made on the occasion of the preparation of the technical documentation for the World Food Summit (WFS) of late 1996. The discussion here incorporates preliminary finding from currently ongoing work for revising the projections and extending them to 2015 and 2030. The year 2015 has been chosen in order for this work to be a contribution to the debate concerning the prospects for progress towards meeting the WFS target of halving undernutrition by that year. The extension to 2030 is meant to provide the basic skeleton quantifications of demand, production and trade for that year within which broad issues of agricultural resources, climate change, environment and sustainability can be examined and analysed in the context of a longer term framework of world food security.

Section 4 addresses issues of land use and land adequacy in the developing countries in the context of the overall projection framework. The data for analysing issues of land resources come from the Global Agroecological Zones Assessment" (GAEZ) of FAO and the International Institute of Applied Systems Analysis (IIASA). In Section 4.1 we present briefly the land yield combinations that may prevail in 2010, together with an evaluation of how well the actual outcomes to 1998 (ie, 9 years into the 21–year projection period 1988/90-2010 of the projections study of the early 1990s, ref. 14) are tracking the projections. This is followed by a brief exposé of the issues arising in the process of evaluating the crop production suitability of land in the context of the GAEZ. The intention here is to make the reader aware of the relative and often subjective nature of the concepts of suitability of land for food production and of carrying capacity, which can vary with the socioeconomic context and the time dimension within which they are defined and estimated. Finally, the issue is raised whether the widely held perception that land for food production is getting scarcer, at least in per person terms, and that this threatens the future food security, is supported by the historical evidence and by the conclusions about future trends coming out of global projection studies (Section 4.4). We shall argue that the emphasis being put on growing land scarcities for food production in public debates is not wholly justified and perhaps it is outright misplaced when it refers to the world as a whole. However, there is scope for further research here to capture and analyze the extent to which global aggregate indicators of the conventional economic type may conceal as much as they reveal about scarcity and abundance of natural resources in relation to human welfare.

We are still in the process of examining, critically evaluating and "digesting" the huge amount of quantitative material produced by the current round of GAEZ revisions. Therefore, our

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[2] Sections 2-3 come largely from a recent paper presented to a colloquium of the US National Academy of Sciences (22).

discussion here of issues of land adequacy and land scarcity in the context of the GAEZ (sections 4.3-4.4) is no more than a first rough draft which may change, even radically, after further work.

## 2. *Key Historical Developments In World Food Security*

### 2.1 Improvements in Food Supplies

In the last three decades the world as a whole made significant progress in the food and nutrition area. Progress is measured in terms of the per-person availability of food products for direct human consumption as a national average in each country, expressed in Kcal/day. This is an admittedly imperfect yardstick. However, it comes much closer to what we need to measure and monitor – the degree of satisfaction of human food needs – than the commonly used one of gross production of food commodities per person. It nets out post-harvest losses and all uses of food commodities other than for direct human consumption, e.g. for seed, animal feed, ethanol production (from maize in the USA, from sugar cane in Brazil), etc[3]. By accounting fully for food imports and exports, it makes possible the monitoring of changes in the apparent food consumption of individual countries, which the production statistics alone cannot do.

As a world average, the per-person[4] food availability for direct human consumption grew 19% to 2720 Kcal/day in the three and a half decades to the 3-year average 1994/96, while that of the developing countries[5] grew 32% to 2580 Kcal/day. Meanwhile world population grew from 3.0 billion in 1960 to 5.7 billion in 1995. Naturally, world averages have limited value for tracking changes in the welfare of persons (see below). Use of the national averages of individual countries goes some way towards accounting for distributional dimensions, since it makes possible the analysis of inter-country distribution of gains. As such, the national averages provide a better, though far from satisfactory, basis for monitoring changes in welfare. They show that the part of world population living in countries where per-person food supplies are still very low (under 2200 Kcal/day) decreased considerably to only 10% in the mid-nineties, down from 56% thirty years earlier. At the other extreme, 60% of world population lives now in countries with per-person food supplies over 2700 Kcal/day, up from 30% thirty years ago. China, with its huge population and rapid economic and agricultural growth after the late 1970s, accounts for a significant part of this massive upgrading in the food availability of the developing world.

Excluding China, the gains of the developing countries have been much less impressive, 22% rather than 32%. The detailed country-level data indicate that progress has been very uneven and bypassed a large number of countries and population groups. Many countries in sub-Saharan Africa and South Asia and assorted countries in other regions either made little progress or suffered outright declines from levels that were grossly inadequate for good nutrition to start with. Thus, sub-Saharan Africa still has food availability of only 2150 Kcal/day, compared with 2050 Kcal 30 years earlier. The comparable figures for South Asia are 2350 Kcal and 2000 Kcal, respectively. The per-person food availabilities of the other developing regions (Latin America/Caribbean, East and South-east Asia, Near East and North Africa) are in the range 2700-3000 Kcal, while those of Western Europe and North America are 3370 Kcal and 3570 Kcal, respectively (see footnote 3).

[3] It is, however, inclusive of post-retail waste and non-food uses at the household level, e.g. food fed to pets – hence the very high levels of food availability generally found in the statistics of many high-income countries, often over 3500 Kcal/person/day.

[4] The use of variables expressed in per caput terms to interpret the past and project the future makes such interpretation and projections subject to the errors and uncertainties in the demographic data and projections. The example of Nigeria (see fn 10) illustrates the impact of errors in the historical population data on the diagnosis of the evolution of the food security situation. The example of the developing countries as a whole illustrates the uncertainties about the future emanating from the revisions of the population projections (see Table 1 and relevant text in section 3.2).

[5] The term developing countries comprises all the countries of the world except those of Europe (both east and west) and North America, all the countries of the former USSR, Japan, Australia, New Zealand, the Republic of South Africa and Israel. This classification reflects above all traditional practice and is useful for historical comparisons. However, it leaves much to be desired when it comes to grouping countries by levels of development currently prevailing, a problem that has been intensified in recent years with the new low-income countries created in the wake of the collapse of many economies formerly centrally planned.

The extremely low levels of food availability still prevailing in several developing countries imply that undernutrition is widespread. It is estimated that there are currently over 800 million persons undernourished in the developing countries, with high concentrations in South Asia and sub-Saharan Africa (1). Progress in reducing these numbers has been painfully slow, with reductions in East Asia being compensated to a large extent by increases in sub-Saharan Africa.

## 2.2 The Role of Food Trade

The bulk of the increases in the consumption of the developing countries were met by increase in their own production. In the case of cereals, their production grew at 3.0% p.a. in the three decades to the mid-1990s and provided 87% of the increase in their consumption. However, in a considerable number of countries, gains in food availability depended to a significant degree on rising food imports, particularly during the 1970s. In that decade, the net imports of cereals of the developing countries as a whole tripled, following the growth of incomes and foreign exchange earnings of the oil-exporters, as well as the conditions of easy foreign borrowing and debt accumulation of other countries. For example, in North Africa the per-person consumption of cereals (all uses) increased from 232 kg in the mid-sixties to 322 kg in the mid eighties and per-person net imports skyrocketed from 44 kg to 167 kg in the same period. North Africa's cereals self-sufficiency (production as percentage of consumption) fell from 76% to 51% in the two decades to the mid-eighties and has remained in the range 50%-55% in subsequent years. Many other countries experienced similar precipitous declines in their self-sufficiency associated with improvements in consumption over the same period, e.g., Saudi Arabia, Republic of Korea, Taiwan Province of China, Congo, and Gabon.

Not all developing countries went through this experience of growing dependence on imports, certainly not the largest ones. The two most populous countries of the world, China and India, illustrate this point. China, widely discussed in recent years as a potential source of huge increases in import demand in the future (2, 3, 28), had net imports of cereals exceeding 5% of its aggregate consumption only in exceptional years during the period of quantum gains in its domestic demand. More often it was close to 100% self-sufficiency and an occasional net exporter. India, which was dependent on cereal imports for a crucial 14 percent of its consumption 30 years ago and was widely believed to be on a path of growing dependence on such imports, became virtually 100 percent self-sufficient and indeed an occasional net exporter. India's apparent consumption of cereals grew at about the same rate as that of China (2.8-2.9% p.a. in the 20 years to 1996), but its gains in per-person consumption have been much more modest than those of China and undernutrition remains widespread. India had started with much lower levels of per-person consumption and also had a higher population growth rate than China (2.1% p.a. compared with 1.4% p.a.). Obviously, India's path of declining dependence on food imports reflected not only the production gains from the green revolution but also the little headway made in reducing poverty and the consequent inadequate growth in the effective demand. Had India achieved gains in per-person consumption comparable to those of China, it is an open question whether it would have achieved nearly 100% self-sufficiency. More generally, avoidance of drastic declines in self-sufficiency by the many countries which still have very low levels of consumption often reflects not so much success in their agriculture but rather failure to make sufficient progress towards raising consumption levels to nutritionally satisfactory levels.

In conclusion, food imports played an important role in making possible the quantum jumps in consumption of numerous developing countries which could pay for such imports, though the behaviour of the very large countries contributed to avoiding large declines in the cereals self-sufficiency of the developing world as a whole. The latter declined from 95% in the mid-sixties to 93% in the mid-80s and to 90% by the mid-nineties. By about the early 1980s the era of rapid import growth of the developing countries had come to an end and their net imports moved in the range 70-110 million tons in the subsequent years to the present. These developments notwithstanding, the possibility that there might be further spurts in their import demand is an issue that remained very much alive. It reflects perceptions that there is now much less scope than in the past for further production gains from the green revolution, while sustained economic growth may lift significant numbers of people out of poverty and boost demand at rates high enough to cause a significant part of it to appear as solvable demand for imports (4). From here, it is a short step to worry about the capability of the rest of the world to increase production and generate the necessary export surplus. What does the historical evidence show?

By and large, the traditional cereal exporters (North America, Argentina, Australia and, in more recent years, also Western Europe) coped quite well with spurts in import demand. Between themselves, they export currently (average 1994/96) some 160 million tons of cereals net annually[6]. This is just over 3 times their net exports of 30 years earlier. About one half of the total increment in these net exports was contributed by Western Europe. It is a very significant development for the world food system that this region turned from a net importer of 27 million tons in the mid-1960s to a net exporter by the early 1980s and was exporting 21 million tons net in the mid-1990s. In practice, the other, more traditional, exporters have had (or, perhaps one should say, were constrained by Western Europe's policies) to increase their net export surplus rather modestly, from 77 million tons in the mid-1960s to about 138 million tons 30 years later. Had Western Europe remained a net importer of 27 million tons, the more traditional exporters would have had to increase their net export surplus to 185 million tons.

We do not have a counterfactual scenario to answer the question how the different variables of the world food system (in particular the per-person food availability of the poor countries and those that became heavy importers) would have actually fared if Western Europe had not followed a policy of heavy support and protection of its agriculture. Such policy led to the region's import substitution and then subsidised exports, all accompanied by polemics and friction in the trade policy area. The resulting lower and more volatile world market prices (compared to what they would have been otherwise) are thought to have adversely affected the food security of the developing countries because of the negative effects on the incentives to their producers. However, the positive effects on the consumption of the poor of the lower import prices and increased availability of food aid must also be factored in when evaluating the impacts of such policies on food security. In the end, such policies of Western Europe resulted in the emergence of an additional major source of cereal export surpluses to the world markets and diversified the sources from which the importing countries could provision themselves. This is a structural change that is probably here to stay even under the more liberal trade policy reforms of recent years and the further ones to come (5).

### 2.3 Slowdown in World Agricultural Growth

In the 1990s, there has been a slowdown in the growth of world agricultural production. World cereals output stagnated and fluctuated widely in the first half of the decade. In per-person terms, it fell from the peak of 342 kg achieved in the mid-1980s to a low 311 kg in the 3-year average 1993/95, before recovering to 323 kg in the latest 3-year average 1996/98. In parallel, production of capture fisheries seems to have hit a ceiling of just over 90 million tons and much of the increase in fish production is coming from aquaculture, a development likely to continue in the future. In the face of these developments, it would appear that the world food situation has been worsening. However, the evidence we presented earlier points in the opposite direction. As noted, world average indicators have limited value for welfare analysis and the variables must be observed at a more disaggregated level for a correct interpretation. Progress in food security need not manifest itself in rising world averages (i.e., with aggregate production or consumption rising faster than world population), but it is possible for progress to occur when the world average stagnates or even falls[7].

[6] 118 to the developing countries other than Argentina, 33 to Japan and Israel and 6 to the area former USSR/Eastern Europe.

[7] Simpson's paradox, meaning that the world can get poorer on the average even though everyone is getting richer, simply because the share of the poor in the total grows over time. This can be illustrated as follows (example based on approximate

Thus, in the ten years to the mid-1990s which witnessed the declines in the world averages, there has been no decline, but rather an increase, in the per-person production and consumption of cereals in the developing countries while that of all other food products (roots and tubers, pulses, bananas and plantains, livestock, sugar, oilseeds, fruit and vegetables, etc.) grew even faster than in the preceding ten years. The problem for the developing countries remains one of too low production and consumption per person.

The declines in world cereal output per person have been interpreted by some as beginning an era when the natural resource and technology constraints have become all of a sudden so much more binding (6). In reality, this slowdown has been due, in the first place and up to quite recently, to policy reforms and supply controls[8] coinciding with weather shocks in the main industrial exporting countries. The longer term deceleration in the growth rate of cereal production in these countries has reflected above all the inadequate growth of demand (both domestic and external) for their produce and the associated decline in real prices. For example, the real price of wheat in constant 1990 US$ per metric ton was in the range US$200-240 (annual averages) in the first half of the 1980s and in the range US$125-150 in the following ten years to 1995. For maize, the ranges were US$150-200 and US$85-105, respectively (7). In more recent years, the decline reflected also the collapse of production (as well as of consumption and net imports) in the countries of Eastern Europe and the former USSR following the drastic systemic reforms in their economies. While recovery may be long in coming, the collapse of agriculture in this group of countries will likely prove to be a transient phenomenon. What may prove to be a more enduring structural change in the world food system is the impact of policy reforms, in part linked to the new policy environment for international trade. These reforms may lead to the cessation of generation of quasi-permanent structural surpluses and the holding of large stocks in the major exporting countries by the public sector, which in the past were readily available for interventions in case of abrupt shortfalls in supplies.

## 2.4 World Production and Food Insecurity: an Uncertain Link

The preceding discussion indicates that, by and large, the production system of the world as a whole has been generating food supplies at a rate which was more than sufficient to meet the growth of effective demand. The evidence is the secular declining trend of the real price of food in world markets (8). It is equally true that food insecurity and undernutrition have persisted at high levels. The combination of these two facts certainly suggests that undernutrition is not due to a lack of global capability to produce the additional food required to eliminate undernutrition, which is a very small amount (2-3%) compared to current or future world food output (9).

It is now widely accepted, if there ever was any doubt, that food insecurity and undernutrition are above all due to the persistence of abject poverty, development failures (often linked to war and unsettled political conditions) and lack of appropriate social policies. This, however, does not absolve us from the need to address the question of the links between food production and the food welfare status of the population, particularly of those countries and population groups with very inadequate consumption levels. Obviously, a *prima facie* case can be made that such links exist when production failures, particularly where they are endemic, are

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relative magnitudes for the developing and the developed countries): in a population of four persons, one is rich, consuming 625 kg of grain, and three are poor, each consuming 225 kg. Total consumption is 1,300 kg and the overall average is 325 kg. Thirty years later, the poor have increased to five persons (high population growth rate of the poor) but they have also increased consumption to 265 kg each. There is still only one rich person (zero population growth rate of the rich), who continues to consume 625 kg. Aggregate consumption is 1,950 kg and the average of all six persons works out to 325 kg, the same of 30 years earlier. Therefore, real progress has been made even though the average did not increase. Obviously, progress could have been made even if the world average had actually declined. Thus, if the consumption of the poor had increased to only 250 kg (rather than to 265), world aggregate consumption would have risen to 1875 kg but the world average would have fallen to 312.5 kg.

[8] Thus the European Union (EU) production of cereals fell from 191 million tons in the 3-year average of 1989/91 to 178 million tons in 1993/95, before growing again to 207-208 million tons in 1996 and 1997 following the high world market prices and the relaxation of supply controls. Production grew further in 1998 to an estimated 212 million tons.

somehow a causal factor in overall development failures and the perpetuation of poverty. In such cases, it is quite legitimate to hold that persistence of undernutrition is due, at least in part, to inadequate growth of production.

Such a statement may not apply to the world as whole but it would be certainly valid in the socioeconomic and natural resource environments in which production failures (or more generally failure to develop agriculture), poverty and undernutrition coexist. Such a link is indeed present in the many low-income countries with high dependence on agriculture (50-80% of the population depending on agriculture as the main source of living). In such situations, failures in agricultural development often lie at the heart of failures in overall development and the persistence of poverty (10). It follows that one of the main thrusts of national and international policies to solve the problem must be the promotion of local food production and broader agricultural and rural development in these countries, so as to simultaneously increase incomes of the rural poor and food supplies as well as stimulate overall development (29, see also 30 for an overview of issues and estimates of the growth multipliers of agriculture).

In conclusion, the widely-held view that the persistence of food insecurity and undernutrition is not a problem of production (or production potential) but rather one of distribution (or access, or entitlements) can be both true and false at the same time. It is largely true if it refers to the world as a whole, but this is not a very helpful conclusion. It can be grossly misleading if it induces us to ignore the stark reality that it is often failures to develop agriculture and increase food production locally that lie at the heart of the local food insecurity problem. This is certainly not equivalent to saying that countries in that condition (undeveloped agriculture, often poor natural resource endowments and large parts of their population dependent on them for a living) have the potential to develop towards middle-income status with an internationally competitive agricultural sector. It rather underlines the need for the path to less poverty, better food security and eventually freedom from heavy economic dependence on poor agricultural resources to pass precisely through an initial phase of improved agricultural productivity (11).

What are the prospects that progress may be made in the foreseeable future (15-30 years)?

## *3. Future Prospects*

### 3.1 Demographics, Incomes, Poverty

One of the key variables determining future outcomes, the growth rate of world population, has been on the decline since the second half of the 1960s. The UN demographic assessment of 1996 (12) has a medium variant projection indicating further deceleration, from 1.4% p.a. currently (1995-2000) to 1% p.a. in 2020 and to 0.4% p.a. by the middle of the next century[9]. However, the absolute increments in world population are currently very large, about 80 million persons p.a., over 90% of who are added in the developing countries. Such high annual increments (in the range 70-77 million in the new projections of 1998) may persist for another 15-20 years, but with declines in prospect for the longer term future, falling to some 40 million p.a. (30 million in the new projections) by 2050. Demographic growth in sub-Saharan Africa will increasingly dominate the total additions to world population: it will account for one half of the world increment by 2050, compared with only one fifth currently.

On the economic side, the most recent (December 1998) assessment of world economic growth prospects (13) implies that the rate of poverty reduction in the developing countries will be much slower compared with the past, when it was essentially fuelled by the rapid economic growth of East Asia. The growth of this region has been interrupted and the average of the next ten years

[9] The 1996 medium variant projection was for world population to reach 9.4 billion by 2050, up from the 5.7 billion in 1995. The just released new UN assessment of 1998 shows even more steep deceleration, leading to a world population of 8.9 billion in 2050, about 0.5 billion below that projected in 1996. However, over one half of this reduction (270 million) is in the projected population of sub-Saharan Africa, in part due to the revised estimates of the impact of the AIDS epidemic. As such, this further reduction in projected population is partly associated with negative rather than positive developments in human welfare.

1998-2007 may be only 2.9% p.a. compared with 7.2% p.a. in the preceding ten years 1988-97 (East Asia not including China; the fall is much less pronounced if China is included in the region, from 8.8% to 5.8%). On the other hand, South Asia may nearly maintain its past growth rate at the respectable level of 5.4%, a prospect that goes some way towards compensating the loss of poverty reduction momentum emanating from East Asia. At the other extreme, in sub-Saharan Africa, the growth rate of per-person income is expected not to exceed 1.0% p.a. This outcome does not augur well for the reduction of poverty and hence undernutrition in the region, even if it reverses the trend of the negative growth rates of the past.

### 3.2 Food and Agriculture

These overall economic and demographic prospects form the background against which we must assess the prospects for future progress in food and agriculture. One can say right from the outset that the average world indicators of food availability will register only modest gains. This is because the overall demographic and economic outlook implies that the share of the poor, or rather those with lower-than-average food consumption levels, in the world population is set to continue rising. The food insecurity and undernutrition problems will persist, at somewhat attenuated levels, in the medium term future and perhaps well beyond, in many countries starting with very unfavourable initial conditions (mainly in sub-Saharan Africa and, to a smaller extent, in South Asia and selected countries in other regions). One does not need sophisticated analytics to prove this point: any country starting with per-person food supplies of 2000 Kcal/day (and some countries start with less) and a population growth rate of 2.5%-3.0% p.a. would need a growth rate of aggregate food demand of about 5% p.a. for 15 years if, by 2010, it were to have 2700 Kcal/day, a level usually associated with significantly reduced undernutrition (provided inequality of distribution is not too high). Obviously, this kind of growth rates of aggregate demand for food can only occur in countries with “Asian-tiger” rates of economic growth sustained over decades. Few of today’s poorest countries with very low food consumption levels face such prospects. As noted, the recent crisis that hit several economies of East and South-east Asia will also take its toll. The rapid pace of progress of the recent past, particularly in diet diversification towards livestock products, is being interrupted and some countries (e.g. Indonesia) are suffering outright reversals.

These prospects, particularly the demographic ones, are somewhat different from those used some five years ago to produce FAO’s assessment of world food and agriculture prospects to 2010, with particular reference to the developing countries, in the study “World Agriculture: Towards 2010” and subsequent modifications used in the technical documentation of the World Food Summit of 1996 (1, 14). However, the essence of our findings as concerns key variables of food security at the level of large country groups and the world as a whole remains largely valid, particularly if the per caput variables are adjusted for the revisions made in the population data and projections[10]. The main findings, including selected preliminary findings from ongoing work to update the study and extend the time horizon to 2015 and 2030, are summarized below:

- The per-person food availability of the developing countries as a whole will continue to increase from the current (1994/96) 2580 Kcal/day to about 2750 Kcal/day by 2010 (but much higher if the lower population now projected for 2010 were to translate mainly into increases in per caput consumption – see note 1 to Table 1). However, there will be only very modest gains in the currently very low average food availability of sub-Saharan Africa, while South Asia may still be

[10] The revisions of the demographic data and projections have been very drastic for some countries. For example, in the base year data of the FAO Study (ref. 14), the 1990 population of Nigeria was given in the 1990 UN population assessment as 108.5 million. Four years later (in the 1994 assessment), the population for the same year was given as 96.2 million. The most recent (1998) assessment reduced the 1990 population further to 87 million. One can easily imagine what these revisions imply for the estimates of the key variable of per-person food availability and the incidence of undernutrition. The latter estimate is very sensitive to even very small variations in per caput food availability, when the latter is very low. The implication is that we shall have to re-evaluate where we stand now and where we stood in the past, before we can start talking about the future.

in a middling position by 2010. The other developing regions, already starting from better levels now, are expected to be near, or above, 3000 Kcal/day.

- The per-person consumption of cereals (all uses) of the developing countries may rise from the 246 kg of 1994/96 to some 255 kg in 2010, or, again, to a higher level due to the lower projected population[11]. The preliminary projections to 2030 suggest a further rise to about 280 kg, while the world average will likely reverse its trend towards decline and rise again – from the about 320 kg in the mid-1990s to about 340 kg in 2030. Important in this reversal will be, in addition to the rise of the developing country average, the change of two trends that in the past contributed to its decline: (a) the bottoming out of the declines and the eventual upturn of per-person consumption in the formerly centrally planned economies; and (b) a similar process (already under way) in Western Europe following the policy reforms that lowered domestic cereal prices and re-established the competitiveness of cereals vis-a-vis cereal substitutes in the feeding of animals.
- The incidence of undernutrition in the developing countries may decline in relative terms (from 21% to 12% of the population) but, given population growth, there will be only modest declines in the numbers undernourished. The current level of over 800 million persons is expected to decline to about 680 million by 2010 (1). A high incidence of undernutrition will persist in sub-Saharan Africa, and a somewhat reduced one in South Asia. These two regions could account for 68% of the developing country total, up from 56% currently. Naturally, the latest (1998) revisions of the UN population projections suggest that the decline in the numbers undernourished could be more pronounced than indicated here, particularly if account is taken of the fact that part of the decline in the projected population is due to expected developments in sub-Saharan Africa.
- Local production increases will be by far the main source of the growth in the food supplies of the developing countries. Their cereals production was projected to grow at 2.1% p.a. from the 3-year average 1988/90 (the base year of the study) of 845 million tons to 1.32 billion tons in 2010 (wheat, rice in milled form, coarse grains). Nine years into the 21-year projection period, the production of the developing countries had risen to 1015 million tons (3-year average for 1996/98, see Table 2) and the growth rate from 1989 to 1998 was as projected, 2.1% p.a.
- The net food imports of the developing countries from the rest of the world should continue to grow, though not at very high rates, i.e. we do not expect major structural surges in the demand for imports like those that occurred in the seventies (see above). In an earlier version of the study completed in the mid-eighties with time horizon 2000 (15), we had projected net imports of cereals of the developing countries to grow to 112 million tons by the year 2000. The evolution to date indicates that the year 2000 outcome will likely be fairly close to this projection, as net imports have been in the range 100-110 million tons in recent years, while the current crisis affecting key developing countries does not augur well for an upturn in their import demand. It is expected that there will be some upswing in imports in the next decade, reaching 162 million tons by 2010 (Table 1)[12].
- The rest of the world should face no major constraints in generating this additional export surplus of cereals, given that (a) the domestic demand of the main exporting countries grows very slowly and below the potential of their agriculture to increase output, and (b) part of the additional

[11]The 246 kg of 94/96 are fairly close to the 245.5 kg interpolated for the same years along the 88/90-2010 projection path as adjusted for the lower population outcome for 1995, as explained in Table 1. It is noted that the adjustment for the lower population brought the interpolated value close to the actual outcome. This closeness does not by itself suggest that the higher gains made in per caput consumption (compared with the path of the original projection) are to be ascribed wholly, or even predominantly, to the lower population growth rate. Nor does it mean that per caput consumption in the remaining years of the projection period will evolve along this implicit higher path. Accounting for the impact of changes in the population growth rate on consumption and other variables raises a number of important issues which lie at the heart of the population-development debate (see ref. 27).

[12] The latest (February 1999) projections of the US Dept. of Agriculture (32, Tables 36, 40, 41) imply net imports of the developing countries of about 155 million tons for the year 2008 (computed as the sum total – with opposite sign – of the net trade projections of the USA, Canada, Australia, European Union, Japan, former Soviet Union and Eastern Europe plus an allowance of 5 million tons for the net imports of the other developed countries - other W. Europe, New Zealand, Israel and South Africa)

import requirements of the developing countries is being offset by declining import demand of the region of Eastern Europe and former USSR. This latter region was a heavy net importer in the pre-reform period (some 35 million tons in 1989/91), but may be a modest net exporter by 2010. The region's net imports had already been drastically reduced by the mid-1990s, while in the trade year July 1997-June 1998 the region is estimated to have been a net exporter of some 3.5 million tons. For the longer term, it is possible to visualize this region emerging as a major additional source of cereal export surpluses in the world (16), just as Western Europe did in the 1980s, though for very different reasons. In the case of the former centrally planned economies, an export surplus will likely be generated from the eventual recovery of agriculture from the status of near-collapse that accompanied radical systemic reforms, rather than from high agricultural support and protection of the type applied in Western Europe.

- For the longer term beyond 2010, the preliminary findings of the above mentioned work to update the study and extend its time horizon to 2015 and 2030 indicate that the net cereals exports of the major exporters (North America, Western Europe, Australia, Argentina) would need to increase from the mid-1990s level of 160 million tons to about 300 million tons by 2030[13]. The required growth rate of their production for generating this export surplus and also meeting the growth of their own demand (including that part of their domestic demand for feed cereals going to produce more meat for export) would be around 0.8 percent p.a. in the 33 years from average 1996/98 to 2030. This growth rate is well below that achieved in the preceding 33 years (1.7 percent p.a. in 1965-98). However, the growth rate of their combined production has been on the decline over time, from 2.9 percent p.a. in the two and a half decades to the mid-80s to an average of 1.1 percent p.a. in 1985-98. As noted, this slowdown was mainly the result of lack of demand, falling real prices and policies put in place to control the growth of production and avoid the accumulation of excessive surpluses (see below for environmental issues).

**Table 1. Developing Countries: Consumption and Net Imports, Actual and Projected**

| **Apparent Consunmption[1]** | **Unit** | **Base Year: Aver. 88/90** | **Projected** | | **Actual Outcome: Aver. 94/96[3]** |
|---|---|---|---|---|---|
| | | | **2010** | **Interpolated Aver. 94/96[2]** | |
| Calories, all food | Kcal/person/day | 2470 | 2730 | 2542 | 2580 |
| " Adjusted | Kcal/person/day | 2487 | | 2597 | |
| Cereals[4], all uses | kg/person/year | 235 | 254 | 240 | 246 |
| " Adjusted | kg/person/year | 236 | | 245.5 | |
| **Net Imports of Cereals[4]** | Million Tons | 90 | 162 | 106 | 106 |

Base year data (before revisions) and 2010 Projections from ref. 14, Alexandratos (1995):83, 145, 426

[1]The revisions in the population data and the projections to 2010 between the UN demographic assessments of 1990 (used in the study, see ref. 14: 426) and 1996 (used to derive the currently available data per caput) influence the data and projections of per caput consumption. In this table, the first rows of calories and food cereals show the original numbers as reported in the study and the resulting interpolation for 1994/96. The second rows show the updated base year data as they are known now as well as the interpolations adjusted for the new population data. For example, the interpolated value of per caput consumption of cereals for 94/96 (240 kg) is adjusted upwards by 2.2% (to 245.5 kg), i.e., for the percentage by which the population of the developing countries for 1995 was lowered between the UN Assessments of 1990 and 1996. This adjustment is made in order to derive an interpolation for 94/96 that can be compared with the actual outcome for 94/96 (246 kg), as the latter is known only for the new revised population data..

[2]Exponential interpolation

[3]FAOSTAT data, Commodity Balances CBS domain (see fn. 1), extraction of 11 March 1999.

[4]Cereals and cereal products, including beer, in grain equivalent.

[13] The above-mentioned USDA projections of February 1999 indicate combined net exports of these major exporters of 218 million for the year 2008 (32, Tables 36, 40, 41)

## *4. Land for Agriculture: Issues of Future Use, Availability and Scarcity*

### 4.1 Land-Yield Combinations in the Future

In our work, the projections of production are derived, in the first place, as part of the consumption, production and trade balances generated for each country or country group and each one of the 26 crop and 6 livestock products covered in the study. In a second step of the analysis, the production projections for 34 crops[14] are unfolded into, and tested against, what "experts"[15] think are "feasible" land-yield combinations by agroecological environment (irrigated, rainfed subhumid, rainfed semiarid, fluvisols/gleysols, etc) taking into account whatever knowledge is available. A major input into this evaluation (in practice introduced as constraints to land expansion but also as a guide to what can be grown where) are the "data" relating to the availability of land suitable for growing crops in each country and each agroecological environment. The latter data come from the FAO Agroecological Zones work. The latter is currently being revised in cooperation with IIASA to produce the new "Global Agroecological Zones Assessment"(GAEZ).

Our findings indicate (certainly to nobody's surprise) that, as in the past, and more so in the future, the mainstay of production increases will be the intensification of agriculture in the form of higher yields and more multiple cropping and reduced fallows, particularly in the countries with appropriate agroecological environments and little or no potential of bringing new land in cultivation. As noted, we projected the land-yield combinations for each crop and each developing country (other than China[16]) for several agroecological environments. The end result of the detailed projections indicates that the growth of the average yields of the developing countries will be slower than in the past. Thus, the average yield of cereals was projected to be 1.5% p.a. (from 1.9 tons/ha in 88/90 to 2.6 tons/ha in 2010), compared with 2.2% p.a. in the preceding 20 years (average yield of wheat, rice paddy and coarse grains). Nine years into the projection period (1989-98), the average cereal yield grew as predicted at 1.5% p.a., though rice yield grew by less than predicted, that of maize by more and that of wheat as predicted, as shown in Table 2.

The predominant weight of contributions of yield increases to the growth of agricultural production notwithstanding, land expansion will continue to be a significant factor in those developing countries and regions where the potential for expansion exists (many countries in sub-Saharan Africa, Latin America and South-east Asia) and the prevailing farming systems and more general demographic and socio-economic conditions favour land expansion. One of the frequently asked questions in the debates on world food futures and sustainability is how much land there is that could be used to produce food to meet the needs of the growing population. The rough and ready answer is: plenty, but very unevenly distributed in relation to the distribution of the population on the surface of the planet. Much of it also suffers from constraints (e.g., ecological fragility, low fertility, toxicity, high incidence of disease, lack of infrastructure) so that it cannot be considered to be a resource that is usable for food production on demand. In addition, account must be taken of the fact that "food" comprises a bundle of very heterogeneous products as regards their agronomic

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[14] The commodities sugar and vegetable oil are unfolded for the analysis of production into their constituent crops (sugar cane, beet, soybeans, sunflower, groundnuts, rape seed, oil palm, coconuts, sesame seed, cotton seed, etc), so that in the end land-yield combinations are generated for 34 crops.

[15] Ideally, "experts" combine knowledge of the discipline involved together with knowledge of the conditions in the field of the individual countries being analysed, e.g., for generating "feasible" combinations of land and yields prospects for semi-arid millet/sorghum farming systems we need to consult with agronomists with experience in, mainly, Africa's semi-arid tropics and sub-tropics - Sahelian zone countries and similar.

[16] Problems with the land and yield data of China (3, 31) made it necessary to project the country's production directly, not in terms of land-yield combinations as it was done for the other developing countries. The resulting projection of China's production of cereals implies a growth rate of 2.0% p.a. from 1988/90 to 2010 (14: 141). The actual outcome to 1998 has been 2.2% p.a.

requirements for growth, so that, for example, plenty of land in the humid tropics with potential to produce bananas or cassava may not be a great asset if what we need is really wheat (see below). Finally, land which can produce food is also an input into the production of other services to humanity (e.g. those provided by forests) so that, again, its opportunity cost can be high and it should not be considered as a ready and costless resource available for food production. Consideration of trade-offs between more food (or improved food security) and other services of land must always be an integral part of any decision-making calculus.

**Table 2. Developing Countries: Cereals Yields and Production, Actual and Projected**

| **Yields (kg/ha, excl. China[1])** | **Base Year: Aver. 88/90** | **Projected** | | **Actual Outcome: Aver. 96/98[3]** |
|---|---|---|---|---|
| | | **2010** | **Interpolated Aver. 96/98[2]** | |
| Wheat | 1900 | 2700 | 2172 | 2170 |
| Rice(paddy) | 2800 | 3800 | 3145 | 3050 |
| Maize | 1800 | 2500 | 2040 | 2100 |
| All Cereals | 1900 | 2600 | 2140 | 2144 |
| **Production (million tons, incl. China[1])** | | | | |
| Wheat | 224.9 | 348 | 265.6 | 279.9 |
| Rice(milled) | 324.3 | 461 | 370.8 | 363.1 |
| Maize | 197.0 | 358 | 247.3 | 262.4 |
| Other Cereals | 100.9 | 151 | 117.6 | 110.3 |
| All Cereals | 847.1 | 1318 | 1001.4 | 1015.7 |

Base year data and 2010 Projections from ref. 14, Alexandratos(1995):145, 169
[1]China's production was projected directly, not in terms of areas and yields (see 14: 141, fn. 5)
[2]Exponential interpolation. [3]FAOSTAT data (see fn. 1), extraction 10 March 1999.

Subject to these qualifications, in the agroecological zones assessment we used at the time of the Study (early 1990s), the developing countries outside China[17] were estimated as having some 2.5 billion ha of land of varying qualities which has potential for growing at least one of several crops in rainfed conditions and at yields above an "acceptable" minimum level. Of this land, some 720 million ha (plus another 36 million ha of desert land reclaimed through irrigation) were already in cultivation (roughly, what in the statistical sources is called arable land and land in permanent crops). Most of the remaining 1.8 billion ha is in Latin America and sub-Saharan Africa. At the other extreme, there is virtually no spare land available for agricultural expansion in South Asia and the Near East/North Africa region. Even within the relatively land-abundant regions, there is great diversity among countries and sub-regions as concerns land availability per person, both quantity and quality. For example, in sub-Saharan Africa land is scarce in East Africa and relatively abundant in Central Africa.

Land expansion may add some 90 million ha to the above estimates of cultivated land of the developing countries (other than China). Such expansion will account for about 20% of the increase in their aggregate crop production. These projections of areas and yields were arrived at through an examination of the agricultural growth needs and the potentials for land expansion and for technology development and adoption in each country, as well as in the context of the historical experience. It would appear that the widely held view that land in agricultural use is not (or will not be) growing any more is probably unduly influenced by the experiences of the industrial countries, and indeed by that of their cereals sector in which area has indeed been on the decline. As noted, the industrial countries' growth of the cereals sector has been constrained by lack of demand, so that the decline in area under cereals does not reflect the onset of binding land constraints to agricultural

[17] China was not included in the estimates of land suitable for rainfed production because, in addition to the above-mentioned problems of reliability of the current land-use data, there was at the time inadequate knowledge of climatic conditions and crop growth requirements in certain zones. These problems have been largely resolved in the current update of the GAEZ.

expansion. The situation is very different in the developing countries, particularly those which combine the above-mentioned characteristics (availability of land, need to expand output, and farming systems and more general socioeconomic conditions favouring land expansion rather than intensification). Otherwise, why should we worry about tropical deforestation caused by, among other things, expansion of agriculture?

This projected increase of land in agricultural use (some 90 million ha in 20 years, or 12%, in the developing countries as a whole, excluding China) is a small proportion of the total unused land with rainfed crop production potential (some 1.8 billion ha). What does the empirical evidence show concerning the rate and process of land expansion for agricultural use in the developing countries? Micro-level analyses have generally established that under the socioeconomic and institutional (land tenure, etc) conditions prevailing in many developing countries, increases in output are obtained mainly through land expansion, where the physical potential for doing so exists. For example, in a careful analysis of the experience of Côte d'Ivoire, Lopez (19: 125) concludes that "the main response of annual crops to price incentives is to increase the area cultivated"[18]. Some of this land expansion is taking place at the expense of the long rotation periods and fallows (a practice common to many countries in sub-Saharan Africa) with the result that the natural soil fertility is reduced (19:105). With fertilizer use being often uneconomic, the end-result is soil mining and stagnation or outright reduction of yields in many countries of the region.

At the more aggregate country and regional levels, the quality of the general land use data leaves much to be desired. The data of harvested, or sown, area for the major crops are comparatively more reliable. They show that expansion of harvested area continues to be an important source of agricultural growth, mainly in sub-Saharan Africa, but also in South-east Asia and to a smaller extent in Latin America. Overall, for the developing countries outside China, the harvested area under the major crops (cereals, oilseeds, pulses, roots/tubers, cotton, sugar cane/beet, rubber, tobacco) grew 11% in the last ten years (from average 1986/88 to average 1996/98), or about 1 p.a. This is only slightly higher than the growth rate of 0.9% p.a. we projected for all crops for the 21-year period 88/90-2010 (ref. 14, p.165).

### 4.2 Environmental Issues Related to Land-Yield Increases

Concerning the environmental and sustainability dimensions of the expansion and further intensification of agriculture, we note that (a) the foreseen land expansion need not be associated with the rapid rates of tropical deforestation observed in the past, though there is no guarantee that this will be so; (b) there will be further increases in the use of agrochemicals (fertilizer, pesticides) in the developing countries, though at declining rates compared with the past; (c) increased use of fertilizer is often indispensable for sustainability (to prevent soil mining); and (d) the need to accept trade-offs between production increases and the environment will continue to exist in the foreseeable future and the policy problem is how to achieve such increases while minimizing adverse impacts on natural resources and the wider environment.

The environmental issues related to agriculture are not confined to the developing countries, though they are predominantly related to their growing needs for food, given that the bulk of additional food to be produced on a global scale is destined to the developing countries. But such needs create pressures for increased production also in the developed countries and, in a reversal of "conventional wisdom" contribute to extend the ecological footprint of the developing countries into the developed ones. We noted earlier that a good part of the additional production of the industrial countries[19] will be on account of the export surpluses they must produce for the developing countries

[18] Similar findings (rate of deforestation being positively related to the price of maize) are reported for Mexico by Deininger and Minten (20:313)
[19] In the case of cereals in North America, W. Europe and Australia combined perhaps some 60% of the increment in production between the mid-nineties and 2030 will be on account of export markets.

and that the growth rate required of their production (of the industrial countries) would be lower than that achieved in the last few decades. This prospect (a lower growth rate of production) does not in itself guarantee that it is a feasible proposition. In particular, environmental concerns related to intensive agriculture in the high-income countries (nitrate pollution, soil erosion, perceived risks from genetically modified organisms, etc.) may contribute to slow down the rate at which progress may be made in achieving the required yield increases.

However, the environmental implications of increased production in the industrial countries for export may appear in an entirely different light if examined in a global context, rather than solely in that of the resources and environmental concerns of the exporting countries themselves. The global context is provided by the realization that major increases in the absolute volume of world production are in prospect over the longer term, even if the growth rate of production will be lower than in the past. For example, in the case of cereals we should be thinking in terms of world production growing from the 1.8 billion tons of the mid-1990s to about 2.9 billion tons by 2030 (5). Obviously, trade will contribute to spread the associated environmental pressures across the globe. This raises the issue how trade and the distribution of environmental pressures over the globe are related. Will trade help assign relatively more pressures to countries which can best respond to them, given their resource endowments and technological prowess?

This issue can be addressed schematically with the aid of a simple taxonomy of the combinations of natural resources and technology used in production, on the one hand, and development levels, on the other (examples given in 5, 18). The former determines the extent to which the growth of production enhances the risk of adverse environmental impacts, while the latter is instrumental in determining the value people assign to resource conservation and the environment relative to the more conventional benefits from increased production, e.g. food security, farm incomes, export earnings. Such a taxonomy can help put in a world context the environmental risks of more intensive grain production in the developed exporting countries and make it possible to compare them with those incurred by other countries that would also be raising their grain production. It will also provide useful information for judging the extent to which enhanced production for export in the developed countries may contribute to world food security by making world agriculture as a whole more sustainable, or less unsustainable - if one subscribed to the view that the ever growing volume of overall economic activity is putting the world on an unsustainable path. This is not the place to develop this subject, but raising the issue is certainly an integral part of any debate concerning world food futures and the role of the different countries.

### 4.3 Estimating the Land Potentials for Agriculture

The principal question the above-mentioned current round of work of FAO/IIASA on the GAEZ attempts to answer is: *how much land a country (and eventually the world) has which is suitable for the production of crops useful for human welfare?* Any evaluation starts by taking stock of (a) the biophysical characteristics of the resource (soil, terrain, climate), and (b) the growing requirements of crops (radiation, temperature, humidity, etc). The data in the former set are interfaced with those in the second set and conclusions are drawn as to the amount of land that may be classified as suitable for producing each one of the crops tested (see full discussion in 31).

The following observations apply:

- The two above-mentioned data sets are not immutable over time. Climate change, degradation or the permanent conversion of land to non-agricultural uses all contribute to change the extent and characteristics of the resource – a fact which is of particular importance if the purpose of the study is to draw inferences about the adequacy of the resource in the longer term. In parallel, the growth of scientific knowledge and the development of technology contribute to modifying the growing requirements of the different crops for achieving any given yield level. For example, in the present round of GAEZ work the maximum attainable yield for rainfed wheat[20] in sub-tropical (winter rainfall)/temperate environments is put at about 12 tons/ha in high input farming and about 4.8 tons/ha in low input farming. Some 25 years ago, when the first FAO Population Supporting Capacity study was carried out (ref. 23: 132) these yields were put at 4.9 and 1.2 tons/ha, respectively. Obviously, the land suitable for growing wheat at, say, 5 t/ha in 50 years time may be entirely different from that prevailing today, if scientific advances make it possible to obtain in the future 5 t/ha where only 2 t/ha can be had today, eg through the development of varieties better able to withstand stresses like drought, soil toxicity, pest attacks, etc. This will have repercussions as to whether or not any given piece of land will be classified as suitable for producing a given crop.

- The amount of suitable land will differ from one crop to another. For example, to take extremes, more than 50% of Congo DR's land area is suitable for growing cassava but less than 3% can grow wheat. It follows that we can only speak of "land suitable for growing crop x or y or z". Therefore, before we make statements about adequacy or otherwise of land resources to grow food to feed a growing population we must have a notion of what commodities this population is going to need or to demand. Obviously, for the information about land suitability to be useful, it must somehow be combined with information about demand patterns (volume and commodity composition, both domestic and foreign demand must be considered, both at present and in the foreseeable future). Knowing that Congo DR has a lot of land suitable for growing cassava is not very helpful, unless we knew whether or not there is demand for so much cassava, now or in the future.

- Declaring a piece of land as suitable for crop production implies that we consider that people find it (or will find it) worth their while to exploit it for this purpose. In other words, land must not only possess minimum biophysical attributes in relation to the requirements of the crops for which there is, or there will be, demand, but also exist in a socioeconomic environment in which people assign to it the characteristic of an economic asset. For example, in low income countries, people will exploit land even if the yields (or rather the returns to their work) are relatively low, given that the urgency to secure access to food is high (meaning that the price of food is high relative to their income) and the opportunities of earning higher returns by doing something else are limited. Thus, what qualifies as land with acceptable production potential in a poor country, may not be so in a high-income one (except, of course, if poor quality is compensated by larger area per person cum mechanization[21]) where returns to one's work in farming must generate income not far below what people can earn in other work. Obviously, the socioeconomic context within which a piece of land exists and assumes a given value/utility changes over time: what qualifies today as land suitable for farming may not be so tomorrow.

It is no easy task to account fully for all these factors in arriving at conclusions concerning how much land with crop production potential there is. For example, if food became scarce and its real price rose, more land would be worth exploiting, hence classified as agricultural, than would otherwise be the case. Depending on the kind of use one intends to make of such information, one may want to use different criteria and generate alternative estimates. This objective would be served by having access to the raw primary results of the land evaluation exercise in as much detail as possible. What determines the amount of detail that the evaluation produces?

[20] The yield achievable by the best existing varieties in climates with radiation and temperature regimes giving LGPs in the range 180-240 days.

[21].Relatively low-yield rainfed but internationally competitive agriculture (wheat yields of 2.0-2.5 tons/ha compared with double that in W. Europe) is practised in such high income countries as the USA, Canada and Australia but in large and fully mechanized farms so that a person can exploit lots of it to earn sufficient income even if earnings per ha are low.

Given the biophysical characteristics of land, the number of answers (concerning how much of the land is suitable) generated by the evaluation will be a function of (a) the number of crops tested, and (b) the technology variants under which the crops are supposed to be produced (eg whether or not fertilizer is used, etc), (c) the crop varieties taken into account (or assumed to exist at a future date) for determining land/climatic suitability for producing a given yield, and (d) the yield levels used as cut-off points for accepting a piece of land as suitable, eg land yielding less than 500 kg/ha under the low technology variant (or say 1200 kg under the high technology) may not be considered suitable, or worth exploiting. But, as noted, what is worth exploiting or suitable for crops is very much a socioeconomic aspect of our problématique.

Table 3 illustrates the variety of results, depending on the crops, technology variants and yield acceptability thresholds, obtained for the developing countries other than China (see footnote 17). For example, it shows that there are 330 m. ha suitable for growing wheat under the high input technology (260 m. ha if we exclude the marginally suitable land category), but in the range 1.3-1.5 billion ha for the other 4 crops shown (rice, maize, soybeans, cassava). Also shown is an estimate, corresponding to a *maximum maximorum* concept, of 2577 million ha, or 2365 million ha if the marginally suitable category is excluded. This is obtained as the sum total of the evaluation results of the individual grid cells by taking for each cell the largest area resulting as suitable under any crop and technology variant.[22]

There is another sense in which this is a *maximum maximorum* estimate: it ignores land uses other than for growing the crops for which it was evaluated. Thus, forest cover, protected areas and land used for human settlements and infrastructures, or otherwise built-up, are not accounted for. At the same time, a correct estimation of land potentials for growing food requires that we account for the state of land as is at present rather than as the soil maps and climatic inventories show it to be (in principle in its natural condition). It is well known that land used for agriculture is as much a product of nature as of human intervention. Land which is not productive in its natural state ha been made so, e.g. through irrigation. Indeed, in the countries considered here, some 36 million ha of desert land (arid and hyper-arid in GAEZ terminology which evaluates such land as not suitable for agriculture) have been rendered productive, some of them highly so (Egypt, etc), by irrigation. Thus, the GAEZ results include an element of underestimation of the food production capability of the world's land resources (for more discussion see ref. 25). Naturally, human intervention also leads to deterioration of the productive potential of the resource, e.g. through soil erosion, salinization of irrigated areas, etc. In this sense, the GAEZ evaluation may contain an element of overestimation, though the extent of deterioration from human intervention can be easily exaggerated (26).

[22] For example, in a two-cell, two-crop, two-technology set, there result 8 estimates of suitable land areas (4 per cell). The maximum is obtained by taking for each cell the highest of the four values and summing them up.

**Table 3. Estimates of Land with Rainfed Crop Production Potential, Selected Crops, Developing Countries, excl. China (million ha; yields in tons/ha)**

| | Land Class | Length of Growing Period (LGP[1]) | Land quality[2] | Area suitable for growing specified crops under rainfed conditions and high inputs | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | WHEAT | | RICE (paddy) | | MAIZE | |
| | | | | Area | Av.Yield | Area | Av.Yield | Area | Av.Yield |
| 1 | Dry semi-arid | 75-119 | VS,S,MS, mS | 7 | 2.9 | 19 | 1.9 | 59 | 4.3 |
| 2 | Moist semi-arid | 120-179 | VS,S,MS | 22 | 4.0 | 38 | 2.9 | 286 | 7.5 |
| 3 | Sub-humid | 180-269 | VS,S,MS | 83 | 4.2 | 379 | 3.6 | 414 | 7.0 |
| 4 | Humid | 270+ | VS,S,MS | 123 | 4.2 | 588 | 3.9 | 167 | 6.1 |
| 5 | mS Land in Classes 2,3,4. | 120+ | mS | 56 | 1.8 | 235 | 1.8 | 391 | 2.9 |
| 6 | Fluvisols/Gleysols | Naturally flooded | VS,S,MS | 30 | 4.0 | 144 | 3.8 | 111 | 7.1 |
| 7 | mS Land in Class 6 | Naturally flooded | mS | 8 | 1.8 | 36 | 2.0 | 42 | 3.0 |
| | **Total for High Inputs** | | | **329** | **3.7** | **1439** | **3.4** | **1470** | **5.7** |
| | **- of which mS** | | | **69** | **1.8** | **288** | **1.8** | **470** | **3.0** |
| | **Total for Low Inputs** | | | **384** | **1.3** | **1327** | **1.0** | **1461** | **1.7** |
| | **- of which mS** | | | **115** | **0.7** | **454** | **0.7** | **602** | **1.0** |

| | | | | SOYBEANS | | CASSAVA | | Maximum for all crops[3] |
|---|---|---|---|---|---|---|---|---|
| | | | | Area | Av.Yield | Area | Av.Yield | Area |
| 1 | Dry semi-arid | 75-119 | VS,S,MS, mS | 49 | 1.3 | 1 | 4.5 | 177 |
| 2 | Moist semi-arid | 120-179 | VS,S,MS | 256 | 2.4 | 38 | 8.2 | 436 |
| 3 | Sub-humid | 180-269 | VS,S,MS | 423 | 2.3 | 395 | 10.3 | 697 |
| 4 | Humid | 270+ | VS,S,MS | 108 | 2.2 | 473 | 9.5 | 868 |
| 5 | mS Land in Classes 2,3,4. | 120+ | mS | 336 | 1.0 | 267 | 4.3 | 136 |
| 6 | Fluvisols/Gleysols | Naturally flooded | VS,S,MS | 105 | 2.4 | 85 | 9.3 | 239 |
| 7 | mS Land in Class 6 | Naturally flooded | mS | 35 | 1.0 | 42 | 4.3 | 24 |
| | **Total for High Inputs** | | | **1310** | **1.9** | **1301** | **8.5** | **2577** |
| | **- of which mS** | | | **406** | **1.0** | **310** | **4.3** | |
| | **Total for Low Inputs** | | | **1070** | **0.6** | **1006** | **2.3** | **212** |
| | **- of which mS** | | | **421** | **0.3** | **475** | **1.6** | |

Source: Computer files of the GAEZ project, FAO and IIASA.
1. Number of days in which climatic conditions (temperature, radiation, soil moisture) permit crop growth
2. VS=Very Suitable (achievable yields over 80% of maximum achievable in the cell evaluated if the only constraints were temperature and radiation); S=Suitable (60-80%); MS=Medium Suitable (40-60%); mS= Marginally Suitable (20-40%)
3. Taking for each grid cell on the map the largest area resulting as VS, S, MS, or mS for any crop and any input level.

## 4.4 Is Land for Agriculture Becoming Scarcer?

Land in agricultural use in the world as a whole (arable land and land in permanent crops) has increased by only 150 million ha (to about 1.5 billion ha) or by 11 percent in the last few decades, though there have been very significant changes in specific regions: the increase was 50 percent in Latin America and this accounted for 37% of the global increase. Over the same period, world population grew by several billion and it nearly doubled from 1960 to 1995 (from 3.0 billion to 5.7 billion). By implication, land per person declined by 42%, to 0.26 ha/person. In parallel, there is growing preoccupation that agricultural land is being lost to non-agricultural uses, while the ever more intensive use of land in production (multiple cropping, reduced fallow periods, excessive use of agrochemicals, spread of monocultures) is perceived as leading to its degradation (soil erosion, etc) and undermining its long-term productive potential.

These developments are perceived by many as having put humanity on a path of growing scarcity of land as a factor in food production, with the implication that it is, or it will be in the near future, getting increasingly difficult to produce the food required for feeding the ever growing human population. Are these concerns well founded? We first note that any discourse about the future requires that we be as precise as possible concerning the magnitudes involved: how much land there is (quantity, quality, location) and how much more food, what type of food and where is required, now or in any given point of time in the future. The brief *tour d' horizon* of historical developments and, in particular, of future prospects in world food and agriculture presented in sections 2 and 3 provides a rough quantitative framework which can serve the purpose of evaluating such perceptions.

The evidence presented earlier concerning historical developments does not lend support to the notion that it has been getting increasingly difficult for the world to extract from the land an additional unit of food; rather the contrary has been happening, as evidenced by the secular decline in the real price of food. This secular decline just tells us that it has been getting easier for humanity to produce an additional unit of food relative to the effort required to produce an additional unit of an "average" non-food product. This statement applies to the world as a whole, not necessarily to particular locations, and is valid only under particular conditions (essentially, absence of market failures and ethical acceptability of the resulting distribution of access to food by different population groups).

The notion that resources for producing food (in which land is an important constituent) have been getting more abundant rather than scarcer (in relative terms, ie in relation to the aggregate stocks of resources of the global economy) appears counterintuitive. How can it be reconciled with the stark fact that world population has been growing fast (eg from the 3.0 billion of 1960 to the 5.7 billion in 1995) while land in agricultural use increased only by 11%, meaning that land per caput declined by some 42 percent (from .45 ha in 61/3 to .26 ha in 94/6)? The answer is to be found in the fact that over the same period yields per ha of cropped area increased, as did the cropping intensity (reduced fallows and increase in the number of crops per year) in the areas where a combination of irrigation and agroecological conditions permitted it and the growth of the demand for food made it necessary. For example, over the same period world average grain yields doubled (from 1.4 t/ha in 61-63 to 2.8 t/ha in 94-96) and the cropping intensity probably increased by some 20 percent on the average (this is a guess), resulting in the amount of arable land required to produce any given amount of grain (say, that required to feed one person at a given level) having fallen by some 60 percent. This is a deeper decline than the above-mentioned 42 percent fall in the arable land per person.

In this comparison of physical quantities, land for food production is seen to have become less scarce, not scarcer. The economic evidence (declining real price of food) corroborates in a general sense the conclusion that it has also become less scarce relative to the evolution of the demand for food and relative to what has been happening in the other sectors of the economy. However, as noted, such economic evidence properly refers to the decreasing relative scarcity of the aggregate resource base for food production (in which land is only one component along with capital, labour, technology, etc) rather than to land alone[23]. In practice, what we call land today is a composite of land in its natural and capital investments embodied in it, e.g., irrigation infrastructure, levelling, fencing, soil amendments, etc. It follows that any further discussion of the prospective role of land in meeting future food needs has to view it as just one component, indeed one of changing and perhaps declining relative weight, in the total package of factors that constitute the resource base of agriculture which, the historical record shows, is flexible and adaptable.

Concerning the future, a number of projection studies, in addition to the one presented here, have addressed, and largely answered in the positive, the issue whether the resource base of world agriculture (including its land component) can continue to evolve in a flexible and adaptable manner as it did in the past and continue to exert downward pressure on the real price of food (see 27). This largely positive answer means essentially that for the world as a whole there will be enough, or more than enough, food production potential to meet the growth of effective demand, ie the food demand of those who can afford to pay the farmers to produce it.

The preceding discussion refers to the evidence about land scarcities that can be deduced from the evolution of global magnitudes, whether aggregates (e.g., world population), averages (eg world per caput values of key variables), or food price trends observable in world markets. However, observing, interpreting and projecting the evolution of global aggregates can go only part of the way towards addressing the issues often raised in connection with role of land in food production, essentially the issues pertaining to the broader nexus of food security and the environment. A more complete consideration of the issue requires that we examine it at a more disaggregated level and also go beyond the use of conventional economic indicators of scarcity or abundance. Concretely, is land availability for food production likely to be (or has it been so far) a significant constraint to solving problems of food insecurity at the local level? And, is it possible that the market signals which tell us that the resources for producing food (land among them) have been getting less scarce (in relative terms) are seriously flawed because they fail to account for the environmental costs and eventual future risks associated with the expansion and intensification of agriculture? These are some of the questions we intend to address in our further work on the GAEZ and the projections of world food and agriculture to 2030.

## *5. Conclusions*

The fears of impending food crisis that dominated the thinking of some observers up to about mid-1997 have subsided following the reversal of the signals of scarcity (rising prices in world markets[24]). It is now well accepted that, at least over the medium term, there appear to be no major global constraints to expanding world food production at a rate sufficient to match the growth of the effective demand for food (see, for example, 17). The deceleration over time of the effective demand for food contributes materially to this "happy" state of affairs, which, however, is less "happy" than it appears. This is because the deceleration results from both positive and negative developments from the standpoint of human welfare. The positive ones are the slowdown in population growth due to voluntary reductions in fertility around the world and the fact that an ever-growing proportion of world population gradually achieves sufficient levels of nutrition beyond which there is only limited scope for further increases in per-person food demand. The negative aspects are the contributions of higher mortality (than it would be otherwise – see footnote 9) to the slowing of global population growth, and the role of poverty in depressing demand for food. Demand for food would not de

[23] The role of agricultural land as a resource contributing to human welfare, as the latter is conventionally measured by GDP, has been on the decline. Johnson (24) says that "agricultural land now accounts for no more than 1.5 percent of the resources of the industrial nations".

[24] The latest (early March 1999) quotation for wheat (US No 1 H.W., fob Gulf) is US$114/ton, compared with about US$210/ton in late 1996.

decelerating as much, if at all, at least for some time, if the significant part of world population with still very inadequate consumption levels had purchasing power to express as solvable demand in the marketplace the need to increase consumption. This is why the problems of food insecurity afflicting many countries and population groups remain as severe as ever, regardless of the fact that price trends in world markets indicate once again an overabundance of food relative to effective demand at the global level. World market prices do not reflect adequately the problems of the poor and the food insecure.

Our findings leave no scope for complacency concerning the prospects that progress during the period up to 2010, and perhaps also well beyond it, will be of a pace and pattern such as to eliminate, or significantly reduce, food insecurity. Simply put, the prospects that there will be an elimination in the foreseeable future of the significant incidence of poverty now prevailing are not encouraging. So long as there will be poverty, there will also be food insecurity. This is a pragmatic and far from optimistic assessment, even if we conclude that the world as whole has sufficient food production resources to meet the expected growth in the effective demand for food and some more. Naturally, those who think that the world is going to end tomorrow will find unduly optimistic any notion that further progress, slow and uneven as it may be, can be made, but this not our concern here.

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