CHAPTER 1

Introduction and overview

1.1 Introduction

This study is the latest forward assessment by FAO of possible future developments in world food, nutrition and agriculture, including the crops, livestock, forestry and fisheries sectors. It is the product of a multidisciplinary exercise, involving most of the technical units and disciplines present in FAO, as well as specialists from outside FAO. It continues the tradition of FAO's periodical perspective studies for global agriculture, the latest of which was published in 1995 (Alexandratos, 1995). Earlier editions were Alexandratos (1988), FAO (1981a) and FAO (1970). An interim, less complete version of the present study was published in April 2000. Comments received on the interim report helped shape the study in its present form.

The projections were carried out in considerable detail, covering about 140 countries and 32 crop and livestock commodities (see Appendix 1). For nearly all the developing countries, the main factors contributing to the growth of agricultural production were identified and analysed separately. Sources of productivity growth, such as higher crop yields and livestock carcass weights, were distinguished from other growth sources, such as the area of cultivated land and the sizes of livestock herds. Special attention was given to land, which was broken down into five classes for rainfed agriculture and a sixth for irrigated agriculture. This level of detail proved both necessary and advantageous in identifying the main issues likely to emerge for world agriculture over the next 30 years. Specifically, it helped to spot local production and resource constraints, to gauge country-specific requirements for food imports and to assess progress and failure in the fight against hunger and undernourishment. The high degree of detail was also necessary for integrating the expertise of FAO specialists from various disciplines, as the analysis drew heavily on the judgement of in-house experts (see Appendix 2 for a summary account of the methodology). Owing to space constraints however, the results are mainly presented at the regional level and for selective alternative country groups, which of course, masks wide intercountry differences.

Another important feature of this report is that its approach is "positive" rather than "normative". This means that its assumptions and projections reflect the most likely future but not necessarily the most desirable one. For example, the report finds that the goal of the 1996 World Food Summit – to halve the number of chronically undernourished people by no later than 2015 – is unlikely to be accomplished, even though this would be highly desirable. Similarly, the report finds that agriculture will probably continue to expand into wetlands and rainforests, even though this is undoubtedly undesirable. Therefore, the prospective developments presented here are not goals of an FAO strategy but they can provide a basis for action, to cope both with existing problems that are likely to persist and with new ones that may emerge. It should also be stressed that these projections are certainly not trend extrapolations. Instead, they incorporate a multitude of assumptions about the future and often represent significant deviations from past trends (see Appendix 2). To give an impression of how well previous projections compared with actual outcomes, in Chapters 3 and 4, actual outcomes for some major aggregate variables (e.g. developing country cereal production and net imports) for the latest year for which historical data are available are compared with those implied for that same year by the 1988/90-2010 trajectories projected for these variables in 1992-93 for the 1995 study.

A long-term assessment of world food, nutrition and agriculture could deal with a great number of issues, the relevance of which depends on the reader's interest in a particular country, region or topic. As a global study, however, this report had to be selective in the issues it addresses. The main focus is on how the world will feed itself in the future and what the need to produce more food means for the natural resource base. The base year for the study is the three-year average for 1997/99 and projections are made for the years 2015 and 2030. The choice of 2015 allows an assessment of whether or not the goal of the 1996 World Food Summit (WFS) – to halve the (1990/92) number of chronically undernourished people in developing countries no later than 2015 – is likely to be reached. Extending the horizon to 2030 creates a sufficiently long period for the analysis of issues concerning the world's resource base; in other words, the world's ability to cope with further degradation of agricultural land, desertification, deforestation, global warming and water scarcity, as well as increasing demographic pressure. Naturally, the degree of uncertainty increases as the time horizon is extended, so the results envisaged for 2030 should be interpreted more cautiously than those for 2015.

The analysis is, *inter alia*, based on the long-term developments expected by other organizations. The population projections, for instance, reflect the latest assessment (2000 Assessment, Medium Variant) available from the United Nations (UN, 2001a), while those for incomes are largely based on the latest projections of gross domestic product (GDP) from the World Bank. Most of the agricultural data are from FAO's database (FAOSTAT), as of June 2001. Because these assumptions critically shape the projected outcomes, it is important to note that they can change significantly, even over the short term. For example, the historical data and the projections for the growth of population and GDP used in the 1995 study (Alexandratos, 1995), have since been revised in many countries, often to a significant extent. World population in the 1995 study, for instance, was projected at 7.2 billion for 2010, whereas the current UN projections peg the figure at 6.8 billion, i.e. about 400 million less. Similarly, it is now projected that sub-Saharan Africa's population will reach 780 million by 2010, compared with 915 million in the 1995 study. Also, projections for GDP growth (largely based on the latest projections from the World Bank) are different now from what they were in the 1995 study. Finally, FAO's historical data for food production, demand and per capita consumption were often drastically revised for the entire time series as more up-to-date information became available (for an example, see Box 2.2).

In the chapters that follow, particularly Chapters 2 to 4, reference is made on a number of occasions to conceptual and practical problems that arise in the process of making the projections. Many of these problems result from the approach followed in this study, i.e. the fact that the analyses are conducted in considerable country and commodity detail and that all the projections are subjected to a process of inspection, evaluation and iterative adjustment of the numbers by country and discipline specialists. This means that more data problems are encountered than if the analyses were conducted at a more aggregate level. It also means that an alternative scenario cannot be derived without repeating a good part of the whole cycle of inspection-evaluation-adjustment. In Appendix 2 some of these problems and the way they are or are not dealt with are highlighted, so that that the reader can better form an opinion as to how to view and evaluate the statements in this study.

The report is structured as follows. The remainder of this chapter gives an overview of the main findings of the report. The first part of the report (Chapters 2 to 7) presents the main perspective outcomes for food, nutrition and agricultural production and trade, as well as for forestry and fisheries. Chapter 2 presents and discusses expected developments in food demand and consumption and the implications for food security and the incidence of undernourishment. Chapter 3 discusses expected developments in demand, production and trade of total agriculture (crops and livestock) and for the major commodities. Chapter 4 presents the underlying agronomic projections for growth in crop production, including expected developments in crop yields, and resource (land, water) and input (fertilizer, farm power) use in the developing countries. It includes revised and updated estimates of land with rainfed crop production potential, estimates of irrigation potential and possible expansion of irrigated areas and, for the first time, an estimate of the volume of fresh water withdrawals needed to sustain irrigated agriculture in developing countries as projected in this report. Chapter 5 deals with projections of livestock production and related issues. Chapters 6 and 7 present the current state of and plausible developments in world forestry and fisheries.

The second part of the report (Chapters 8 to 10) continues with a discussion of the main issues raised by these developments. Issues of poverty (including international targets for its reduction), nutrition-development interactions, the role of agriculture in the development of the rural and overall economy, and macroeconomic policies and agriculture are the subjects of Chapter 8. Chapter 9 deals with trade policy issues, focusing on lessons from the implementation of the Uruguay Round Agreement on Agriculture (URAA), the possible implications of further liberalization and issues relating to further reforms during the follow-up negotiations in the context of the broader round of multilateral trade negotiations launched by the World Trade Organization (WTO) at its Fourth Ministerial Conference (Doha, November 2001). Chapter 10 then places agricultural trade in the broader context of globalization and discusses the possible effects of globalization on trade and on the concentration and location of the food processing industry.

The final part of the report (Chapters 11 to 13) deals with perspective issues concerning agriculture and natural resources (land, water, air and the genetic base). Chapter 11 examines the potential of existing and incipient agricultural technologies (including modern biotechnology) to underpin further growth in production while conserving resources and minimizing adverse effects on the environment, and the needed directions of agricultural research in the future. Chapter 12 presents an assessment of the environmental implications of agricultural production based, to the extent possible, on the quantitative projections presented in the preceding chapters, and examines options for putting agriculture on a more sustainable path. Finally, Chapter 13 deals with the interactions between climate change and agriculture, the role of agriculture as source of greenhouse gases but also as a carbon sink of potentially growing importance in the context of the Kyoto Protocol, and the broad impact of climate change on agriculture and food security.

1.2 Overview

1.2.1 Prospects for food and nutrition

Historical developments. The 2001 FAO assessment of food insecurity in the world (FAO, 2001a) estimates the incidence of undernourishment in the developing countries at 777 million persons in 1997/99 (17 percent of their population). The estimate was 815 million (20 percent of the population) for the three-year average 1990/92, the base year used by the 1996 WFS in setting the target of halving the number of the undernourished in the developing countries by 2015 at the latest. Obviously, the decline between 1990/92 and 1997/99 has been much less than required for attaining the target of halving undernourishment by 2015 (see further discussion in Box 2.5).

In a longer historical perspective of the last four decades, considerable progress has been made in raising the average world food consumption (measured in kcal/person/day), a variable that is a close correlate of the incidence of undernourishment. The world average kcal/person/day grew by 19 percent since the mid-1960s to 2 800 kcal. What is more important, the gains in the world average reflect predominantly those of the developing countries whose average grew by 31 percent, given that the industrial countries and the transition economies had already reached fairly high levels of per capita consumption in the mid-1960s. This progress in the aggregate of the developing countries has been decisively influenced by the significant gains made by the most populous among them. Of the seven countries with a population of over 100 million (China, Indonesia, Brazil, India, Pakistan, Nigeria and Bangladesh), only Bangladesh remains at very low levels of per capita food consumption. A significant number of countries however failed to participate in this general thrust towards improved national average food consumption levels and, by implication, towards reduced incidence of undernourishment. There are currently still 30 countries with per capita food consumption under 2 200 kcal, most of them in sub-Saharan Africa.

Population, incomes and poverty in the future. The latest assessment of world population prospects by the UN (UN, 2001a) indicates that there is in prospect a rather drastic slowdown in world demographic growth. In the time horizon of this study, the world population of 5.9 billion of our base year (the three-year average 1997/99) will grow to 7.2 billion in 2015, 8.3 billion in 2030 and 9.3 billion in 2050. The growth rate of world population, which had peaked in the second half of the 1960s at 2.04 percent p.a. and had fallen to 1.35 percent p.a. by the second half of the 1990s, is projected to fall further to 1.1 percent by 2015, to 0.8 percent by 2030 and to 0.5 percent by 2050.

This deceleration in demographic growth and the gradual saturation in per capita food consumption for parts of the world population are important factors that will contribute to slow the growth of food demand and, at the world level, also of production. Despite the drastic fall in the growth rates of both population and aggregate demand and production, the absolute annual increments continue to be large. For *population*, 79 million persons are currently added to world population every year. The number will not have decreased much by 2015. Even by 2030, annual additions will still be 67 million. Practically all of the increases in world population will be in the developing countries. Within the developing countries themselves there will be increasing differentiation. East Asia will be reaching a growth of under 0.5 percent p.a. towards the later years of the projection period. At the other extreme, sub-Saharan Africa's population will still be growing at 2.1 percent p.a. in 2025-30. For *demand and production,* the world cereal totals must increase by almost another billion tonnes by 2030, from the current level of 1.9 billion tonnes, an increase almost equal to that of the period since the mid-1960s (see Chapter 3, Table 3.3).

The growth of incomes is the other major determinant of the growth of food demand and of changes in food security and nutrition. The outlook for income growth is mixed. The latest World Bank assessment for the period 2000-15 foresees higher growth rates in per capita GDP than in the 1990s for all regions and country groups (particularly the reversal of declines in the transition economies) with the exception of East Asia. However, for several countries that have low food consumption levels and significant incidence of undernourishment, the economic growth rates that may be achieved are likely to fall short of what would be required for significant poverty reductions. In particular, there is great contrast as regards the prospects of the two regions with high relative concentrations of poverty and food insecurity, South Asia and sub-Saharan Africa. In the former region, a continuation of the relatively high GDP growth holds promise of positive impact on poverty alleviation and increases in per capita food consumption. However, progress in sub-Saharan Africa may be very limited and far from sufficient to make a significant dent on poverty and food insecurity.

The World Bank also projects possible developments in the incidence of poverty – the percentage of the population and numbers of persons below the US$1/day poverty line. This is of particular importance for the evaluation of possible reductions in undernourishment, as poverty is a close correlate of food deprivation and insecurity. The Bank assessment concludes that the *proportion* (not the absolute numbers) of the population living in poverty in the developing countries as a whole may fall from the 32 percent it was in 1990 to 13.2 percent in 2015. This fall, if it materialized, would meet the target of halving the proportion in poverty between 1990 and 2015. It is recalled that the target of halving the proportion of the poor is one of the International Development Goals of the Millennium Declaration adopted by the UN General Assembly (see Chapter 8 for details). However, the absolute numbers in poverty in the developing countries (a measure more directly relevant for the target of reducing undernourishment – see below) are not halved, as they are projected to decline from 1.27 billion in 1990 to 0.75 billion in 2015.

Prospects for food and nutrition. The projections of food demand for the different commodities suggest that the per capita food consumption (kcal/person/day) will grow significantly. The world average will be approaching 3 000 kcal in 2015 and exceeding 3 000 kcal by 2030. These changes in the world averages will reflect above all the rising consumption of the developing countries, whose average will have risen from the 2 680 kcal in 1997/99 to 2 850 kcal in 2015 and close to 3 000 kcal in 2030. These gains notwithstanding, there will still be several countries in which per capita food consumption will not increase to levels that would imply significant reductions in the numbers undernourished from the very high levels they have at present. In 2015 there could still be 6 percent of world population (462 million) living in countries with very low levels of food consumption (under 2 200 kcal). At the regional level, sub-Saharan Africa would still have in 2015 medium-low levels of per capita food consumption, 2 360 kcal/person/day, and even less if Nigeria is excluded from the regional total.

These gains in average consumption mean that the great majority of people will be better fed and the incidence of undernourishment should decline. But will it decline sufficiently to achieve the objectives set by the international community? The 1996 WFS set the target that the numbers undernourished (not just the proportion of the population in that condition) should be reduced by half by 2015 at the latest. Improved nutrition, in addition to being a human right and a final objective of development in its own right, is also an essential precondition for societies to make progress towards overall economic and social development within a reasonable time span. This is because undernourished persons are impeded by their very condition (undernourishment) from fully contributing to, and profiting from, the economic activities that are part and parcel of the development process. There is sufficient empirical evidence (reviewed in Chapter 8) establishing how persons in such condition have smaller earnings and fewer opportunities in life than others. Removing the causes of undernutrition is a prime area for public policy interventions (e.g. through public health, sanitation and feeding programmes for pregnant women and children) since economic growth, although a necessary condition, is rarely sufficient by itself to achieve this goal within a reasonable time span.

The implication of the projected higher levels of average national food consumption per person is that the proportion of the population undernourished in the developing countries as a whole could decline from the 17 percent in 1997/99 to 11 percent in 2015 and to 6 percent in 2030. All regions would experience declines in these percentages and, by 2030, all of them, except sub-Saharan Africa, should have incidence in the range of 4 to 6 percent of the population, compared with a range of 9 to 24 percent in 1997/99. Sub-Saharan Africa could still have 15 percent of its population undernourished in 2030, down from 34 percent in 1997/99.

Because of population growth, declines in the relative incidence of undernourishment do not necessarily translate into commensurate declines in the absolute numbers (which is of relevance to the WFS target). Notwithstanding the slowdown in their demographic growth, the developing countries' population will still grow from 4 555 million in 1997/99 to 5 804 million in 2015 and to 6 840 million in 2030. Therefore, the numbers undernourished will decline only modestly: from the 776 million in 1997/99 to 610 million in 2015 and to 440 million in 2030.[1] If these projections came true, it would mean that we might have to wait until 2030 before the numbers undernourished are reduced to nearly the target set for 2015 by the WFS, i.e. one half of the 815 million estimated for 1990/92.

Can faster progress than projected here be made? Empirical evidence suggests that in the countries with high dependence on agriculture, assigning priority to the development of food production holds promise of overcoming the constraint to better nutrition represented by unfavourable overall economic growth prospects. Several countries, mainly in sub-Saharan Africa (Nigeria, Ghana, Chad, Burkina Faso, the Gambia, Mali, Benin and Mauritania) have at times achieved in the past quantum jumps in their food consumption per

1 Numbers refer to the population of the countries for which estimates of undernourishment were made.

capita (over 20 percent) over periods comparable in length to the first subperiod of our projections (17 years or less), at a time when national average per capita incomes were not growing or outright falling. The common characteristic of these experiences has been rapid growth in the production of staple foods (cereals, roots and tubers).

Several empirical studies (discussed in Chapter 8) document the mechanism of how agricultural growth can be a potent factor in initiating a process of development that favours poverty reduction and improved food consumption in rural areas in countries with high dependence on agriculture and poverty profiles that are predominantly rural. The key conditions for this to happen are (i) that agricultural growth be somehow initiated, e.g. through policies that develop and diffuse affordable productivity-raising innovations such as improved seeds; and (ii) that the distribution of the ownership of land or other productive assets of agriculture not be too unequal so that benefits from higher agricultural production are widely spread and do not accrue predominantly to large landowners (who would spend most of their additional income on things other than locally produced goods and services).

If these conditions are met, a virtuous cycle of causation can set in: the initial increases of agricultural production, in addition to providing more food for the producers themselves and for others, create incomes that are spent locally and create demand for produce and services from the non-farm rural sector, thus generating incomes there. These, in turn, feed back into increased demand for food and more goods and services from the rural non-farm sector itself. This "pump-priming" role of agriculture is seen as necessary because the rural non-farm sector produces goods and services that are in the general category of non-tradables. This means that in that particular context and stage of development their production can increase only in response to local demand, otherwise it would not increase. The services that can be produced locally are non-tradable almost by definition, even if most goods may be inherently tradable but become non-tradable in the absence of adequate transport and marketing infrastructure.

Returning to the projections, the slow pace of progress in reducing the absolute numbers undernourished notwithstanding, the considerable overall improvement implied by the projected numbers should not be downplayed. It is no mean achievement that in the developing countries the numbers well-fed (i.e. not classified as undernourished according to the criteria used here) could increase from 3.8 billion in 1997/99 (83 percent of their population) to 5.2 billion in 2015 (89 percent of the population) and to 6.4 billion (94 percent) in 2030.

With the reduction of the relative incidence of undernourishment, the problem will tend to become more tractable through policy interventions, both national and international. This is the consequence of the prospect that the number of persons involved (and possibly needing to be targeted by policies) will be smaller, as will be the number of countries with high incidence (see Table 2.3). In addition, many more countries than at present will have relatively low incidence of undernourishment. For example, 16 countries had less than 5 percent undernourishment in 1997/99. Their number will increase to 26 in 2015 and 48 in 2030. By this latter year, such countries (including most of the largest developing countries) will account for three-quarters of the population of the developing countries and for 178 million undernourished out of the total of 440 million (in 1997/99: 8 million out of 776 million). Thus a growing part of the undernourished will be in countries with low relative incidence. For this reason, it will be easier than at present for them to respond to the problem though national policy interventions.

In parallel, the number of countries with high incidence of undernourishment (over 25 percent) and most in need of international policy interventions will be reduced considerably: from 35 in 1997/99 to 22 in 2015 and to only five in 2030. None of them will be in the most populous class (over 100 million population in 1997/99). They will account for an ever-declining proportion of the undernourished, 72 million out of the 440 million in 2030 (1997/99: 250 million out of the 776 million).

1.2.2 Prospects for aggregate agriculture and major commodity sectors

Total agriculture. The bulk of the increases in world consumption of crop and livestock products has been originating in the developing countries. With slower population growth and the gradual attainment of medium to high food consumption levels in several countries, the growth rate of the demand for food (and at the world level, also of production) will be lower than in the past. These are positive factors from the standpoint of human welfare. On the negative side, there is the prospect that in several countries with severe incidence of undernourishment, the growth of the demand for food will be well below what would be required for significant improvement in their food security. How much lower the growth of aggregate global demand will be in relation to the past depends on a number of factors. Foremost among them are the relative share, in world totals and other characteristics, of the countries that have already attained medium to high levels of consumption per capita, say over 2 700 kcal/person/day. Several developing countries (29 of those covered individually in this study) belong to this class, including some of the most populous ones (China, Indonesia, Brazil, Mexico, Nigeria, Egypt, the Islamic Republic of Iran and Turkey). They have one half of the population of the developing countries and account for two-thirds of their aggregate demand.

In the period from the mid-1960s to 1997/99, this group of 29 developing countries made spectacular progress in raising per capita consumption, from an average of 2 075 kcal to 3 030 kcal (see Table 3.2 in Chapter 3). China's performance carried a large weight in these developments. The group's population growth rate was 1.8 percent p.a. and that of its aggregate demand for all uses was 4.2 percent p.a. In the projections, commodity by commodity, the implied per capita consumption for this group in terms of kcal/person/day rises to 3 155 kcal in 2015 and to 3 275 kcal in 2030, i.e. to levels not much below those of the industrial countries today. The implied annual growth rate for the whole period 1997/99-2030 (in terms of kcal per capita) is only 0.25 percent. In parallel, the group's population growth rate is projected to fall to 0.9 percent p.a. The net result is that a drastic deceleration of the growth of aggregate demand is in prospect for this group of countries, from 4.2 percent p.a. in the preceding three decades to 1.7 percent p.a. in the period to 2030.

Given the large weight of this group of countries in the totals of the developing countries and the world, their drastic deceleration is reflected in all the aggregates. Thus, the growth rate of the developing countries as a whole declines from 3.7 percent p.a. in the preceding three decades to 2.0 percent p.a. in the period to 2030. This happens despite the prospect that the demand of the other developing countries (those below 200 kcal in 1997/99 which have the other half of the population) will not decelerate much (less than the decline in their population growth rate) and that their per capita food consumption would rise from 2 315 kcal in 1997/99 to 2 740 kcal in 2030. At the world level, the impact of the deceleration in the developing countries is muted (the deceleration in aggregate demand, from 2.2 percent p.a. to 1.5 percent p.a., is not very different from that of world population, see Table 3.1). This reflects the fact that in the past the world growth rate was depressed because of the collapse of consumption and production in the transition economies. The cessation (and eventual reversal) of this effect in the future offsets in part the deceleration in world totals caused by the slowdown in the developing countries.

At the world level, production equals consumption, so the preceding discussion about global demand growth prospects applies also to that of global production. For the individual countries and country groups, however, the two growth rates differ depending on movements in their net agricultural trade positions. In general, the growth rates of production in the developing regions have been below those of demand, and as a result their imports have been growing faster than their agricultural exports. These trends led to a gradual erosion of their traditional surplus in agricultural trade. In fact, the developing countries have turned in recent years from net agricultural exporters to net importers. This trend continues in the projections. The net imports of the developing countries as a whole of the main commodities in which they are deficit, mainly cereals and livestock products, will continue to rise fairly rapidly. In parallel, their net trade surplus on account of their traditional exports (e.g. tropical beverages, bananas, sugar and vegetable oils) will either rise less rapidly than their net imports of cereals and livestock products or outright decline. This does not mean that the exporting developing countries will not be expanding their net exports. It rather reflects the fact that several large developing countries are turning into growing net importers of products that are exported mainly by other (exporting) developing countries, e.g. vegetable oils, sugar and natural rubber.

Cereals. The preceding discussion about future slowdown in the growth of demand applies in varying degrees to individual commodities.

The deceleration of the world cereal sector has been taking place for some time. It will continue in the future, but the difference between past and future growth rates will not be as pronounced as in other sectors, particularly in livestock and oilcrops (see below). Cereals will continue to be by far the most important source (in terms of calories) of total food consumption. Food use of cereals has kept increasing, albeit at a decelerating rate. In the developing countries, the per capita average food use is now 173 kg, providing 56 percent of total calories, compared with 141 kg and 61 percent in the mid-1960s. The level of around 173 kg has been nearly constant since the mid-1980s. We project that it will remain around that level over the projection period. Cereals will continue to supply some 50 percent of the food consumption (in terms of kcal/person/day) in the developing countries, which is projected to reach nearly 3 000 kcal/person/day in 2030. Within the cereals group, per capita food consumption of rice will tend to stabilize at about present levels and will decline somewhat in the longer term, reflecting developments in, mainly, the East Asia region. In contrast, food consumption of wheat will continue to grow in per capita terms and, in the developing countries, such growth will be associated with growing wheat imports. Increases in the demand and trade of coarse grains will be increasingly driven by their use as animal feed in the developing countries.

As noted earlier, world consumption and production of cereals are projected to increase by almost another billion tonnes by 2030, from the 1.89 billion tonnes of 1997/99. Of this increment, just over one half will be for feed, and about 42 percent for food, with the balance going to other uses (seed, industrial non-food use and waste). Feed use, and within it that of the developing countries, will revert to being the most dynamic element driving the world cereal economy, as it will account for an ever-growing share in aggregate demand for cereals. It had lost this role in the decade to the mid-1990s following events and policies that had depressed feed use of cereals in two major consuming regions, the transition economies and the European Union (EU) (see Chapter 3, Sections 3.2 and 3.3).

The dependence of the developing countries on imports of cereals (wheat and coarse grains) will continue to grow, notwithstanding lower growth of demand compared with the past. This follows from the prospect that in the post-green revolution period, and in the face of growing resource scarcities, particularly of irrigation, developing countries' potential to increase production is also more limited compared with the past. Their net cereal imports are projected to rise from 103 million tonnes in 1997/99 (and the forecast 110 million tonnes for the current trade year July 2001/June 2002) to 190 million tonnes in 2015 and to 265 million tonnes in 2030. These numbers imply a resumption of the growth of the world cereal trade after a period of near stagnation. The latter was mainly the result of the virtual disappearance of net cereal imports of the transition economies in the 1990s as well as the slowdown of the economies and oil export earnings in many countries, particularly in the major importing region Near East/North Africa.

These factors that depressed export markets available to the traditional exporters of cereals will be less limiting in the future, but they will not disappear entirely. Not only are the transition economies unlikely to revert to being the large net importers they were in the pre-reform period, but in the longer term they have the potential of transforming themselves into net exporters of cereals. We have made an allowance for this eventuality by estimating their net exports in 2015 and 2030 at 10 and 25 million tonnes, respectively. The traditional cereal exporters in the industrial world (United States, Canada, the EU and Australia) are expected to increase their net exports from the 144 million tonnes in 1997/99 to 224 million tonnes in 2015 and 286 million tonnes in 2030 (see Table 3.8).

The question is often raised whether these traditional exporting countries have sufficient production potential to continue generating an ever-growing export surplus. Concern with adverse environmental impacts of intensive agriculture is among the reasons why this question is raised. The answer depends, *inter alia*, on how much more they must produce over how many years. Production growth requirements are derived by adding the projected net exports to the projections of their own domestic demand, including demand for cereals to produce livestock products. The result is that these countries are required to increase their collective production from the 629 million tonnes of 1997/99 to 758 million tonnes in 2015 and 871 million tonnes in 2030, an increment of 242 million tonnes over the entire period, of which about 80 million tonnes would be wheat and the balance largely coarse grains. The annual growth rate is 1.1 percent in the period to 2015 and 0.9 percent in the subsequent 15 years, an average of 1.0 percent p.a. for the entire 32-year projection period. This is lower than the average growth rate of 1.6 percent p.a. of the past 32 years (1967-99), although the historical growth rate has fluctuated widely, mostly as a function of the ups and downs of export demand, associated policy changes and occasional weather shocks. The overall lesson of the historical experience seems to be that the production system has so far had the capability of responding flexibly to meet increases in demand within reasonable limits. This is probably also valid for the future.

Livestock. The world food economy is being increasingly driven by the shift of diets towards livestock products. In the developing countries, consumption of meat has been growing at 5-6 percent p.a. and that of milk and dairy products at 3.4-3.8 percent p.a. in the last few decades. However, much of the growth has been taking place in a relatively small number of countries, including some of the most populous ones, especially China and Brazil. Including these two countries, per capita meat consumption in the developing countries went from 11.4 kg in the mid-1970s to 25.5 kg in 1997/99. Excluding them, it went from 11 kg to only 15.5 kg. Including or excluding China in the totals of the developing countries and the world makes a significant difference for the aggregate growth rates of meat, although not of milk and dairy products, given the small weight of these products in China's food consumption. However, many developing countries and whole regions, where the need to increase protein consumption is the greatest, have not been participating in the buoyancy of the world meat sector. In this category are the regions of sub-Saharan Africa (with very low per capita consumption reflecting quasi permanent economic stagnation) and the Near East/North Africa where the rapid progress of the period to the late 1980s (oil boom) was interrupted and slightly reversed in the subsequent years, helped by the collapse of consumption in Iraq. Similar considerations apply to the developments in the per capita consumption of milk and dairy products.

The world meat economy has been characterized by the rapid growth of the poultry sector. Its share in world meat production increased from 13 percent in the mid-1960s to 28 percent currently, while per capita consumption increased more than threefold over the same period. In more recent years, the world meat trade has been expanding rapidly. This expansion reflected, among other things, significant moves towards meat trade liberalization, including in the context of regional trade agreements. Some drastic changes occurred as to the sources of imports and destination of exports. Japan became the world's largest net importer (it increased net imports fourfold since the mid-1980s), followed by the countries of the former Soviet Union (mainly the Russian Federation). Australia and New Zealand (together) continue to be the world's largest exporters while, in the last decade or so, the United States turned from a large net importer of meat to a large net exporter, mostly on the growing strength of its poultry sector.

Concerning the future, the forces that made for the rapid growth of the meat sector in the past are expected to weaken considerably. The lower population growth is an important factor, as is the natural deceleration of growth following the attainment of fairly high consumption levels in the few major countries that dominated past increases. For example, if China's growth in the 1990s of about 2.6 kg/person/year (leading to the 45 kg of 1997/99)[2] were to continue for much longer, the country would soon surpass the per capita consumption of the industrial countries. Similar considerations apply to other countries, such as Brazil. Therefore, rather drastic deceleration in at least these countries and, given their large weight, also in the global aggregates, is to be expected.

Other countries may do better in the future than in the past, but their weight in the totals is not suffi-

2 It is thought that these very large increases appearing in the FAO food balance sheet data and the discrepancies from independent consumption data result mainly from an apparent overestimation of China's meat production (see Chapter 3).

cient to halt the expected deceleration in the broad aggregates. India, with its very low per capita meat consumption (4.5 kg in 1997/99) and a population rivalling that of China, could be thought of as a potential growth pole of the world meat economy. This is not likely to be, as its per capita consumption would not exceed 10 kg even by 2030, and this under rather optimistic assumptions. At least this is what a number of studies indicate. The result is that the growth rate of world meat demand and production could grow at rates much below those of the past, 1.7 percent p.a. in the period to 2030, down from 2.9 percent in the preceding 30 years. The deceleration in the developing countries would be more drastic, because of the above-mentioned large-country effect, following the projected slower growth of aggregate consumption in China, and to a smaller extent in Brazil. Remove these two countries from the developing countries aggregate and there is only a modest reduction in the growth of their aggregate demand for meat, reflecting essentially the lower population growth rate.

Unlike meat, we project higher growth in the world milk and dairy sector than in the recent past because of the cessation of declines and some recovery in the transition economies. Excluding these latter countries, world demand should grow at rates somewhat below those of the past but, given lower population growth, per capita consumption would grow faster than in the past.

The structural change that characterized the evolution of the meat sector in the past will probably continue, although at attenuated rates. Poultry will continue to increase its share in world meat output and the meat trade will continue to expand. The trend for the developing countries to become growing net importers of meat is set to continue. This is another important component of the broader trend for the developing countries to turn from net exporters to growing net importers of food and agricultural products. Imports of poultry meat will likely dominate the picture of growing dependence on imported meat. Trade in dairy products will also likely recover with the net imports of the developing countries resuming growth after a period of stagnation from the mid-1980s onwards.

As noted earlier, the world feed use of cereals had slowed considerably in the recent past. It had grown less fast than the aggregate production of the livestock sector, although not in the developing countries. The main reasons were the collapse of the livestock sector in the transition economies, high policy prices in the EU up to the early 1990s, the shift of livestock production to poultry, and more general productivity increases creating more output from a given input of cereals. Growth in the world feed use of cereals will resume thanks to the cessation of the downward pressure on world cereals feed use exerted by events in the transition economies and their eventual reversal; the turnaround of the EU to growing feed use of cereals; the increasing weight of the developing countries in world livestock; and the attenuation of structural change towards poultry.

Oilcrops and products. This category of food products with a high calorie content has played an important role in the increases of food consumption in developing countries. Just over one out of every five calories added to their food consumption in the period since the mid-1970s originated in this group of products. In the projections, this trend continues and indeed intensifies: 45 out of every 100 additional calories in the period to 2030 may come from these products. This projection reflects above all the prospect of only modest further growth in the direct food consumption of staples (cereals, roots and tubers, etc.) in the majority of the developing countries in favour of non-staples such as vegetable oils which still have significant scope for further consumption increases.

On the demand side, the major driving force of the world oilcrops economy has been the growth of food demand in the developing countries, with China, India and a few other major countries representing the bulk of such growth. Additional significant demand growth has been in the non-food industrial uses of oils and in the use of oilmeals for the livestock sector. The growth of aggregate world demand and production (in oil equivalent) would continue to be well above that of total agriculture, although it would be much lower than in the past, 2.5 percent p.a. in the next three decades compared with 4.0 percent p.a. in the preceding three. This deceleration will reflect the factors that were discussed earlier in relation to other commodities, i.e. slower population growth, more and more countries achieving medium-high levels of consumption and, of course, persistence of low incomes in many countries limiting their effective demand.

On the production side, the trend has been for four oilcrops (oil palm, soybeans, sunflower seed and rapeseed) and a small number of countries to provide much of the increase in world output (Table 3.16). With the lower demand growth in the future and changes in policies (e.g. limits to subsidized production), the pace of structural change in favour of some of these crops could be less pronounced in the future. The sector accounted for a good part of cultivated land expansion in the past and in the industrial countries it made up for part of the declines of the area under cereals. The projections of land use in the developing countries indicate that oilcrops will continue to account for a good part of future expansion of harvested area in the developing countries. Being predominantly rainfed crops, the expansion of their production depends on area expansion (rather than yield growth) by more than is the case of other crops, such as cereals.

The rapid growth of demand of the developing countries was accompanied by the emergence of several of them as major importers of oils and oilseeds. If we exclude the five major net exporters among the developing countries (Malaysia, Indonesia, the Philippines, Brazil and Argentina), the others increased their net imports of oils and oilseeds (in oil equivalent) from 1 to 17 million tonnes between 1974/76 and 1997/99. In parallel, however, the five major exporters increased their net exports from 4 to 21 million tonnes, so that the net trade balance of all the developing countries increased slightly (see Table 3.20). In the future, these trends are likely to continue and the net trade balance of the developing countries would not change much, despite the foreseen further rapid growth of exports from the main exporter developing countries. The developing countries have so far been net exporters of oil meals, which have enabled them to maintain a positive, although declining, net trade balance in value terms in their combined trade of oilseeds, oils and meals. With the development of their livestock sector, the prospect is that their net exports of oil meals could turn into net imports. This is yet another dimension of the above-mentioned trend for the developing countries to turn into net importers of agricultural products.

Roots, tubers and plantains. These products (mainly cassava, sweet potatoes, potatoes, yams, taro and plantains) represent the mainstay of diets in several countries, many of which are characterized by low overall food consumption levels and food insecurity. The great majority of these countries are in sub-Saharan Africa, with some countries of the region (Ghana, Rwanda and Uganda) deriving 50 percent or more of total food consumption (in terms of calories) from these foods. In general, high dependence on these foods is mostly characteristic of countries that combine suitable agro-ecological conditions for their production and low incomes. With the exception of potatoes, diet diversification away from these products occurs when incomes and overall food consumption levels improve. In a number of countries (e.g. Nigeria, Ghana and Benin), quantum jumps in the production of these products were instrumental in raising food consumption from low or very low levels.

The evolution over time shows declining per capita food consumption of these products for the developing countries and the world as a whole up to about the late 1980s, followed by some recovery in the 1990s. These developments reflected two main factors: (i) the rapid decline in food consumption of sweet potatoes in China (from 94 kg in the mid-1970s to 40 kg at present), only in part counterbalanced by a parallel rise in that of potatoes, in both China and the rest of the developing countries, and (ii) the rapid rise of food consumption of all products in this category in a few countries, such as Nigeria, Ghana and Peru.

Significant quantities of roots are used as feed, including potatoes (mainly in the transition countries and China), sweet potatoes (mainly China) and cassava (mainly Brazil and the EU). The EU's feed consumption of cassava (all imported) amounts to some 10 million tonnes (fresh cassava equivalent). This is less than half the peak it had reached in the early 1990s, when EU policy prices for cereals were high and rendered them uncompetitive in feed use, leading to a process of substitution of cassava and other imported feedstuffs for cereals. The reversal is mostly the result of the policy reforms in the EU which lowered the policy prices for cereals after 1993 and re-established their competitiveness. In Thailand, the main supplier of cassava to the EU, cassava production and exports followed closely the developments in the EU. The rapid expansion of cassava production for export in Thailand is thought to have been a prime cause of land expansion and deforestation, followed by land degradation in certain areas of the country. This link provides a good example of how the effects of policies (or policy distortions such as the high support prices in the EU) in one part of the world can exert significant impacts on production, land use and the environment in distant countries.

The food products in this category will continue to play an important role in sustaining food consumption levels in the many countries that have a high dependence on them and low food consumption levels overall. The main factor responsible for the decline in the average of the developing countries (precipitous decline of sweet potato food consumption in China) will be much weaker, as the scope for further declines is much more limited than in the past. In parallel, the two factors that made for increases in the average, the increase in demand for potatoes when incomes rise and the potential offered by productivity increases in the other roots (cassava and yams), will continue to operate. It will be possible for more countries in sub-Saharan Africa to replicate the experiences of countries such as Nigeria, Ghana, Benin and Malawi, and increase their food consumption. Thus, the recent upturn in per capita consumption of the developing countries is projected to continue.

The main export commodities of the developing countries. The agriculture and often the overall economy, as well as the incidence of poverty and food security of several developing countries, depend to a high degree on the production of one or a few agricultural commodities destined principally for export, e.g. tropical beverages, bananas, sugar, oilseeds and natural rubber. In such cases the overall economies, and often the welfare of the poor are subject to changing conditions in the world markets, i.e. the rate of expansion of such markets and the prices these commodities fetch. For some commodities, the rate of expansion of world consumption has been too slow. For other commodities, such as sugar, protectionism in the main traditional import markets of the industrial countries has been a prime factor in restricting the growth of exports. In the face of such constraints, competition among exporters to capture a market share has resulted in declining and widely fluctuating export prices.

This has been particularly marked for coffee in recent years. The industrial countries account for two-thirds of world coffee consumption and their consumption per capita has been nearly constant for two decades. Given their low population growth, aggregate demand has been growing very slowly while production has kept increasing, including from recent entrants in world markets such as Viet Nam. The result has been that prices have precipitated and this has worsened poverty in the countries where significant parts of the rural population depend on coffee for a living.

The importing developing countries have been increasingly providing market outlets for the exports of other developing countries. As noted, this has been the case for commodities such as sugar, vegetable oils and oilseeds, and natural rubber. It has been much less so for coffee and, to a lesser extent, cocoa. For these latter commodities the growth of export demand over the projection period will be slow, as it will continue to be dominated by consumption trends in the industrial countries. In contrast, higher growth is foreseen in exports of sugar, vegetable oils and oilseeds, and natural rubber, fuelled by demand generated in the importing developing countries where the scope for expansion of consumption is still considerable. The policies of the industrial countries severely restricted imports of commodities such as sugar in the past (including the turning of the EU from net importer to net exporter). These policies will be less restrictive in the future, following policy reforms already agreed (e.g. the Uruguay Round limits on subsidized exports, the North American Free Trade Agreement [NAFTA] eventually leading to tariff-free access of Mexican sugar to the United States, the EU's Everything but Arms Initiative [EBA]) and the new ones that may come in the future.

1.2.3 Issues of trade policy and globalization

As noted in the preceding section, the traditional agricultural trade surplus in the balance of payments of the developing countries has been diminishing over time and turned into a net deficit in recent years. This gradual erosion has reflected the many factors discussed above that influenced demand and supply and associated imports and exports of the individual commodities in the different countries. Among these factors are the agricultural and trade policies of the main players in world markets, foremost among them the Organisation for Economic

Co-operation and Development (OECD) countries. Most OECD countries have traditionally protected their agriculture sectors heavily, partly through policies granting domestic support and partly, and closely related to the former, through trade policies, such as tariffs, quotas and export subsidies.

The impact of these policies on the trade performance and on the welfare of the developing countries has varied widely. There have been clear losers among the countries exporting products competing with those of the OECD (e.g. Argentina for cereals and livestock products, Brazil and Cuba for sugar), and clear gainers among the countries that had preferential access to the protected markets. Possible gainers (from lower prices and plentiful supplies of cereals in world markets) are to be found among the consumers of the food import-dependent developing countries, including those receiving food aid, but often at the expense of farmers in these same countries. More often, the situation is mixed, e.g. countries in North Africa benefiting from low-priced cereal imports but harmed by barriers to their exports of fresh vegetables.

These support and protection policies affected above all the trade performance (changed market shares) as well as consumers (paying higher prices) and the taxpayers (paying the subsidies) of the OECD countries themselves. For this reason, most studies that examined the possible effects of agricultural trade liberalization conclude that the lion's share of gains in welfare would accrue to the high-income countries, and certainly to some developing countries exporters of competing products, e.g. cereals, livestock, sugar and vegetables. However, some developing countries could be harmed, such as those that enjoy preferential access in protected markets or those that have few agricultural exports but import much of their food.

The late 1980s and the 1990s witnessed intensified efforts to discipline policies that distorted trade. The resulting Uruguay Round Agreement on Agriculture (URAA) enshrined a certain measure of discipline. It mandated reductions in border protection, trade-distorting domestic support and export subsidies. These reductions, however, still left the countries that made heavy use of them in the pre-URAA period, i.e. primarily most OECD countries, with considerable scope for continuing them, albeit at lower levels than before. For countries that made little use of domestic support and export subsidies, overwhelmingly the developing ones, the URAA meant that they were left with very little scope for using such policies in the future, generally within the limits of the *de minimis* clause. In practice, the URAA legitimized and in a sense froze the divide between high-protecting countries and the rest. However, there were some compensations. Developing countries were not required to reduce and could increase, or introduce for the first time, support aimed at their agricultural development, e.g. investment or input subsidies. In addition, the widely diffused practice of binding tariffs at levels well above those effectively applied in the pre-URAA period afforded significant scope for increasing border protection through higher tariffs in the future. These possibilities notwithstanding, some analysts argue that the URAA may have "institutionalized" the production and trade-distorting policies of the OECD countries without addressing the fundamental concerns of developing countries.

Continuing negotiations on agriculture to liberalize trade further are under way. They began in March 2000 and were later subsumed in the broader round of multilateral trade negotiations launched by the WTO at its Fourth Ministerial Conference (Doha, November 2001). In these negotiations the potential exists for the concerns of the developing countries to be addressed more effectively than in the past under the provision for special and differential treatment of the developing countries to reflect their development needs. At the same time, however, further liberalization will tend to erode the gains enjoyed by several developing countries of preferential non-reciprocal access to the protected markets of the major OECD countries (though generally to the benefit of other competing developing countries). Four non-reciprocal preferential arrangements are of particular relevance: the Generalized System of Preferences (GSP) under the WTO; the African, Caribbean and Pacific Group of States (ACP)-EU Cotonou Agreement; the US Trade and Development Act of 2000; and the EBA to provide duty-free and quota-free market access to the EU for the products of the least developed countries (LDCs).

While the importance of "classical" border measures (such as tariffs and quotas) gradually diminishes, the prominence in trade of the safety and quality standards increases. The latter concerns mainly the WTO Agreement on the Application of

Sanitary and Phytosanitary Measures (SPS), but also the quality attributes covered under the Agreement on Technical Barriers to Trade (TBT) and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Recent food safety scares and the advent of genetically modified products have added to the influence of these standards in trade. Their application will be increasingly coming under scrutiny in order to minimize the risk that they will be used inappropriately to protect domestic producers from foreign competition.

The importance of standards in trade has been greatly boosted by the advance of globalization in food and agriculture. What was once a set of national markets linked by raw material trade from land-rich to land-scarce countries is gradually becoming a loosely integrated global market with movements of capital, raw and semi-processed goods, final products and consumer retail services. Intrafirm and intra-industry trade is increasing in importance so that the food trade is assuming certain characteristics of the trade in manufactures. Trade policy with respect to food and agriculture is gradually shifting beyond concentration on issues pertaining to primary farming to encompass issues and interests of the whole food chain, including food processing, marketing and distribution.

The thrust towards a globalized food and agriculture economy is seen as offering opportunities for developing countries to improve the performance of their agricultural and food sectors. This is part of the wider argument that, generally speaking, policies that favour openness of the economy boost economic growth. This has knock-on effects on reducing the numbers below the poverty line, although not necessarily on reducing the income gap between the rich and the poor or, for that matter, between rich and poor countries. These are not arguments in favour of "big bang" liberalization, whether of trade or capital flows. Empirical evidence suggests that openness and outward-oriented policies are not *per se* guarantors of success. More important are the companion policies on the domestic front that facilitate the integration into global markets. These are policies that provide appropriate transition periods towards freer trade; help adapt new, external technologies to the domestic environment; or provide competition policy settings and design contracts that also allow small-scale agriculture to thrive within the operations of transnational corporations (TNCs).

As an important element of globalization in food and agriculture, experience suggests that TNCs can make an important contribution as vehicles of capital, skills, technologies, access to both domestic and export marketing channels, and creation of linkages to the rural economy, for example through contract farming. There are, however, snags such as excessive concentration of market power (and its eventual abuse) in the hands of a few large, sometimes vertically integrated, enterprises operating in many countries. These should be mitigated by appropriate policies, not by closing the economy to the broader benefits and, of course, domestic enterprises are not devoid of monopolistic elements; on the contrary, competition from new entrants, even if foreign, can be a welcome boost to competition.

1.2.4 Factors in the growth of crop production

By 2030, crop production in the developing countries is projected to be 67 percent higher than in the base year (1997/99). In spite of this noticeable increase in the volume of crop production, in terms of annual growth rates this would imply a considerable slowdown in the growth of crop production as compared with the past, for the reasons discussed in Section 1.2.2 concerning the anticipated deceleration in the growth of aggregate demand. Most of this increase (about 80 percent) would continue to come on account of a further intensification of crop production in the form of higher yields and of higher cropping intensities (multiple cropping and reduced fallow periods), with the remainder (about 20 percent) coming on account of further arable land expansion.

The developing countries have some 2.8 billion ha of land with a potential for rainfed agriculture at yields above a "minimum acceptable level". Of this total, some 960 million ha are already under cultivation. Most of the remaining 1.8 billion ha however cannot be considered as land "reserve" since the bulk of the land not used is very unevenly distributed with most of it concentrated in a few countries in South America and sub-Saharan Africa. In contrast, many countries in South Asia and the Near East/North Africa region have virtually no spare land left, and much of the land not in use suffers from one or more constraints making it less suitable for agriculture. In addition, a good part of the land with agricultural potential is under forest or in protected areas, in use for human settlements, or suffers from lack of infrastructure and the incidence of disease. Therefore, it should not be considered as being a reserve, readily available for agricultural expansion.

Taking into account availability of and need for land, arable land in the developing countries is projected to increase by 13 percent (120 million ha) over the period to 2030, most of it in the "land-abundant" regions of South America and sub-Saharan Africa, with an unknown but probably considerable part of it coming from deforestation. In terms of harvested land, the land area would increase by 20 percent (178 million ha) on account of increasing cropping intensity. The latter will reflect, *inter alia*, the growing role of irrigation in total land use and crop production.

Irrigation is expected to play an increasingly important role in the agriculture of the developing countries. At present, irrigated production is estimated to account for 20 percent of the arable land (but about 30 percent of harvested area because of its higher cropping intensities) and to contribute some 40 percent of total crop production (nearly 60 percent of cereal production). This share is expected to increase to 47 percent by 2030. The developing countries are estimated to have some 400 million ha of land which, when combined with available water resources and equipped for irrigation, represent the maximum potential for irrigation extension. Of this total, about one half (some 202 million ha) is currently equipped in varying degrees for irrigation and is so used. The projections conclude that an additional 40 million ha could come under irrigated use, raising the total to 242 million ha in 2030. In principle, by that year the developing countries would be exploiting for agriculture some 60 percent of their total potential for irrigation. Naturally, the harvested area under irrigation will increase by more (33 percent), following fuller exploitation of the potential offered by controlled water use for multiple cropping.

Expansion of irrigation would lead to a 14 percent increase in water withdrawals for agriculture. This latter result depends crucially on the projected increase in irrigation water use efficiency (from 38 to 42 percent on average). Without such efficiency improvements it would be difficult to sustain the above-mentioned rates of expansion of irrigated agriculture. This is most evident in regions such as the Near East/North Africa (where water withdrawals for irrigated agriculture account for over 50 percent of their total renewable water resources) and South Asia where they account for 36 percent. In contrast they account for only 1 percent in Latin America and 2 percent in sub-Saharan Africa, with East Asia being in the middle (8 percent).

Naturally, these regional averages mask wide intercountry differences in water scarcities. Countries using more than 40 percent are considered to be in a critical situation. There are ten developing countries in that class, including countries such as Saudi Arabia and the Libyan Arab Jamahiriya which use more than 100 percent of their renewable resources (mining of fossil groundwater), and another eight countries are using more than 20 percent, a threshold which could be used to indicate impending water scarcity. By 2030 two more countries will have crossed this threshold and by then 20 developing countries will be suffering actual or impending water scarcity. Within-country differences can be as wide as intercountry ones. Large regions within countries can be in a critical situation even if the national average withdrawals for irrigation are relatively modest. China is in that class with the north facing severe constraints while the south is abundantly endowed with water.

As already mentioned, yield growth will remain the mainstay of crop production growth. For most crops, however, the annual growth rate of yields over the projection period will be well below that of the past. For example, the growth rate of the average cereal yield of the developing countries is projected to be 1.0 percent p.a., as compared with the 2.5 percent p.a. recorded for 1961-99. This deceleration in growth of yields has been under way for some time now. For example, in the last ten years (1991-2001) it was already down to 1.4 percent p.a. Intercountry differences in yields are wide and are projected to remain so. They reflect in part differences in agro-ecological conditions and in part differences in agricultural management practices and the overall socio-economic and policy environment. To the extent that the latter factors change (e.g. if scarcities developed and prices rose), or can be made to change through policy, yields could grow in the countries where the agro-ecological potential exists for this to happen under changed agronomic practices, e.g. better varieties and fertilization.

Chapter 11 provides some illustrative evidence on the existence of such potential in the different countries. It does so by comparing the prevailing yields with those that are attainable under advanced (or high-input) agriculture in those parts of the land that are evaluated as being suitable for the individual crops from the standpoint of agro-ecological conditions. Naturally, the existence of such gaps in yields in no way suggests that countries with yields well below their agro-ecologically attainable ones are less efficient producers economically. Often, the contrary is true. For example, the major exporters of wheat (North America, Argentina and Australia) have low to medium yields well under their attainable ones under high input farming. Yet they are competitive low-cost producers compared with some countries attaining much higher yields, often near their maximum potential, e.g. many countries of the EU.

In conclusion, the yield growth foreseen for the future, although lower than in the past, can still be the mainstay of production increases and need not imply a break from past trends in the balance between demand and supply of food at the world level. This could be so precisely because the demand will also be growing at lower rates. The issue is not really whether the yield growth rates will be slower than in the past. They will. Rather the issue is if such slower growth is sufficient to deliver the required additional production.

Naturally, this slower yield growth may not happen unless we make it happen. In particular, the higher yields of the future cannot come only, or even predominantly, from the unexploited yield potential of existing varieties in the countries and agro-ecologies where such potential exists. It will need also to come from countries and agro-ecologies where such potential is very limited. This requires continued support to agricultural research to develop improved varieties for such environments (including those coming from modern biotechnology, see Section 1.2.5 below).

The preceding discussion may have created the impression that we are saying that there is, or there can be developed, sufficient production potential for meeting the increases in effective demand that may be forthcoming in the course of the next three decades. The impression is correct so long as it refers to the world as a whole. But this is not saying that just because such global potential exists, or can be developed, all people will be food-secure in the future. Far from it, as already discussed. Food security and food production potential are however closely related in poor and agriculturally dependent societies. Many situations exist where production potential is limited (e.g. in the semi-arid areas given existing and accessible technology, infrastructure, etc.) and a good part of the population depends on such poor agricultural resources for food and more general livelihood. Unless local agriculture is developed and/or other income-earning opportunities open up, the food insecurity determined by limited production potential will persist, even in the middle of potential plenty at the world level. The need to develop local agriculture in such situations as the often *sine qua non* condition for improved food security cannot be overemphasized.

In the same vein, the above-mentioned need to continue the agricultural research effort (including in biotechnology) to improve yields, even if yield potentials of existing varieties are not fully exploited in many countries, finds its justification in these same considerations. For example, the existence of significant unexploited yield potential for wheat in Ukraine or Argentina does not obviate the need for research to raise yield ceilings for the agro-ecological and other conditions (e.g. salinity and water shortages) prevailing in the irrigated areas of South Asia. The bulk of the additional demand for wheat in South Asia will not be for the wheat that could be potentially produced in Ukraine or Argentina. It will materialize only as part of the process of increasing production locally for the reasons discussed earlier (increased production stimulates the local rural economy).

Behind all these statements, of course, looms large the issue of whether the continuing intensification of agriculture that proceeds even under decelerating yield growth rates is a sustainable proposition. That is, is the capacity of agriculture to continue to produce as much as is needed for all people to be well-fed now and in the future being put in jeopardy, e.g. because of land degradation, depletion or otherwise deterioration of water resources. Would the externalities generated in the process of agricultural expansion and intensification (e.g. water and air pollution, disturbance of habitat, loss of biodiversity, etc.) not impose unacceptable costs to society? An overview of these issues is given in section 1.2.9 below, and the issues are treated in more detail in Chapter 12. The technological options to minimize risks and transit to a more environmentally benign and resource-conserving agriculture, while still achieving the needed production increases, are explored in Chapter 11. Here suffice to say that we foresee a rather drastic slowdown in the use of mineral fertilizer.

Fertilizer use (nutrients NPK) in the developing countries is projected to increase by 1.1 percent p.a. from 85 million tonnes in 1997/99 to 120 million tonnes in 2030 (at world level from 138 million tonnes to 188 million tonnes). This is a drastic slowdown as compared with the past (e.g. 3.7 percent for 1989-99). The slowdown reflects the expected continuing deceleration in agricultural production growth, the relatively high levels of application that prevail currently, or will be gradually attained, in several countries, and the expected increase in fertilizer use efficiency, partly induced by environmental concerns. Fertilizer use per hectare in the developing countries is projected to grow from 89 kg in 1997/99 to 111 kg in 2030 (near the current level of use in the industrial countries). East Asia would continue to have the highest consumption, reaching 266 kg per ha, while sub-Saharan Africa would still have under 10 kg/ha in 2030, well below what would be required to eliminate nutrient mining and deterioration of soil fertility in many areas.

Significant changes are expected to occur in the mechanization of agriculture which will change the role played by the different sources of power in land tilling and preparation: human labour, draught animals and machines. There is currently wide diversity among countries and regions as to the role of these three power sources. Human labour predominates in sub-Saharan Africa (some two-thirds of the land area is cultivated by hand) and is significant also in Asia, both South (30 percent) and East (40 percent – the estimate for East Asia excludes China). In contrast, it is mostly tractor power in Latin America and the Near East/North Africa. Draught animals account for shares in total power supply comparable to those of human labour in all regions except sub-Saharan Africa, where their use is much less common.

The future is likely to see further shifts towards the use of mechanical power substituting for both human labour and draught animals. The driving forces for such changes are part of the development process (e.g. urbanization and opening of alternative employment opportunities) but also reflect more specific factors pertaining to agriculture and particular socio-economic contexts. These include changes in cultivation methods (spread of no-till/conservation agriculture, change from transplanting to broadcast rice seeding, etc.), in cropping patterns and in some factors affecting the rural workforce such as the impact of HIV/AIDS (an important factor in several countries of sub-Saharan Africa). Only in sub-Saharan Africa will human labour remain the predominant source of power. This is also the only region where draught animals are likely to increase their share, with tractors cultivating no more than about a quarter of the total crop area even in 2030. This compares with shares of 50-75 percent that will have been reached in the other regions.

1.2.5 Agricultural research and biotechnology in the future

The spread of science-based agriculture emanating from the significant past investments in agricultural research underpinned much of the growth of agriculture in the historical period. The need for further increases in production in the future while conserving the resource base of agriculture and minimizing adverse effects on the wider environment, calls for ever greater contributions from agricultural research. The research agenda for the future will be more comprehensive and complex than in the past because the resource base of agriculture and the wider environment are so much more stretched today compared with the past. Research must increasingly integrate current advances in the molecular sciences, in biotechnology and in plant and pest ecology with a more fundamental understanding of plant and animal production in the context of optimizing soil, water and nutrient use efficiencies and synergies. Effective exploitation of advances in information and communication technology will be necessary not only to facilitate interactions across this broad spectrum of scientific disciplines but also to document and integrate traditional wisdom and knowledge in the planning of the research agenda and to disseminate the research results more widely.

Much of the additional production must originate in the developing countries and at least part of it must originate in the agriculture practised by the poor in ways that will also contribute to raising their incomes and food demand as well as those of the wider rural economy. It follows that the research effort must be increasingly oriented in three directions, namely, that it must:

- enhance the capability of world agriculture to underpin further substantial growth in production and also improve nutritional attributes of the produce;
- raise the productivity of the poor in the agro-ecological and socio-economic environments where they practise agriculture and earn a living; and
- maintain the productive capacity of resources while minimizing adverse effects on the wider environment.

These considerations, particularly the last two, suggest a growing role for public sector research. Yet support for public sector research (both national and international) has declined significantly over the past decade at a time when private sector investment in biotechnology research has been growing fast. By now the private sector has built up expertise, technologies and products that are considered essential to the development and growth of tropical agriculture based on rapidly advancing biotechnologies and genetically engineered products. It follows that potential synergies between the private sector and public research offer significant scope for directing more of the research effort in the above-mentioned directions. In particular, such synergies can lead research to underpin a new technology revolution with greater focus on the poor by putting special emphasis on those crop varieties and livestock breeds that were largely ignored throughout the green revolution, but that are specifically adapted to local ecosystems. These include crops such as cassava and the minor root crops, bananas, groundnuts, millets, some oilcrops, sorghum and sweet potato. Indigenous breeds of cattle, sheep, goats, pigs and poultry and locally adapted fish species must also receive much greater priority. A particular focus in the new research agenda should be on plant tolerance to drought, salinity and low soil fertility since nearly half of the world's poor live in dryland regions with fragile soils and irregular rainfall.

The experience to date suggests that biotechnology, if well managed, can be a major contributor to all three objectives. Modern biotechnology is not limited to the much publicized (and often controversial) activity of producing genetically modified organisms (GMOs) by genetic engineering, but encompasses activities such as tissue culture, marker-assisted selection (potentially extremely important for improving the efficiency of traditional breeding) and the more general area of genomics.

The GM crops most diffused commercially at the moment incorporate traits for herbicide tolerance (Ht) or insect resistance (Bt, from *Bacillus thuringiensis*), while maize and cotton combining both Ht and Bt traits (stacked traits) have also been released recently. Ht soybeans dominate the picture (they account for 63 percent of total area under GM crops and for 46 percent of the global area under soybeans), followed by maize, cotton and canola. Diffusion has been very fast although concentrated in a limited number of countries. The United States accounts for over two-thirds of the 53 million ha under GM crops globally. These first-generation GM crops have not been bred for raising yield potential, and any gains in yields and production have come primarily from reduced losses to pests. They have proved attractive to farmers in land-intensive and labour-scarce environments (primarily the developed countries) or those with a high incidence of pests because they save on inputs, including labour for pest control.

The interest for the developing countries even of these first-generation GM technologies lies in the fact that they embody the required expertise for pest control directly into the seeds. This is particularly important for environments where sophisticated production techniques are difficult to implement, are simply uneconomic or where farmers do not command the management skills to apply inputs at the right time, sequence and amount. The spectacular success of Bt cotton in China (higher yields, lower pesticide use and overall production costs, greatly reduced cases of human poisoning) may bear witness to the usefulness of these GM traits for the agriculture of the developing countries.

The potential benefits can be enhanced by further innovations currently in the pipeline in the general area of pest control. These include herbicide tolerance and insect resistance traits for other crops such as sugar beet, rice, potatoes and wheat; virus-resistant varieties for fruit, vegetables and wheat; and fungus resistance for fruit, vegetables, potatoes and wheat. Even more interesting could be the eventual success of current efforts to introduce into crops new traits aimed at enhancing tolerance to abiotic stresses such as drought, salinity, soil acidity or extreme temperatures. Attempting to raise productivity in such situations using GM varieties can be the cheaper, and perhaps the only feasible, option given the difficulties of pursuing the same objective with packages of interventions based on existing technology.

The transition from the first to the second generation of GM crops is expected to shift the focus towards development of traits for higher and better quality output. Many of these new traits have already been developed but have not yet been released to the market. They include a great variety of different crops, notably soybeans with higher and better protein content or crops with modified oils, fats and starches to improve processing and digestibility, such as high stearate canola, low phytate or low phytic acid maize, beta carotene-enriched rice ("golden rice"), or cotton with built-in colours. First efforts have been made to develop crops that allow the production of nutraceuticals or "functional foods", medicines or food supplements directly within the plants. As these applications can provide immunity to disease or improve the health characteristics of traditional foods, they could become of critical importance for an improved nutritional status of the poor.

However, not all is bright with the potential offered by biotechnology for the future of agriculture in its main dimensions (enhancing production, being pro-poor, conserving resources and minimizing adverse effects on the environment). With the present state of knowledge, there persist significant uncertainties about the longer-term impacts and possible risks, primarily for human health (e.g. toxicity, allergenicity) or for the environment, e.g. fears of transmission of pest resistance to weeds, buildup of resistance of pests to the Bt toxins or the toxic effect of the latter on beneficial predators (see Chapter 11 for details). There is, therefore, a well-founded *prima facie* case for being prudent and cautious in the promotion and diffusion of these technologies.

However, the degree of caution any society will have about these products depends on societal preferences about their perceived risks and benefits. Certain segments of high-income societies with abundant food supplies (and occasional problems of unwanted surpluses) are unwilling to take any risks in order to have more and cheaper food, particularly when it comes to staples such as grains, roots and tubers. In contrast, poor societies with high levels of food insecurity can be expected to attach more weight to potential benefits and less to perceived risks. Obviously, the solution cannot be to let each society make its own choices, because the potential risks affect the global commons of environment, biodiversity and human health. All humanity has a stake in the relevant developments. Moreover, not all stakeholders are equally well informed about the pros and cons of the new technologies. In addition, the absence of a widely shared consensus risks segmenting the world food economy. It may raise obstacles to trade in products that may be acceptable to some countries and not to others.

Finding a solution calls for wide-ranging, well-informed, transparent and fully participatory debate. This is not an easy proposition, because the wealthiest and most risk-adverse societies (or significant segments of such societies) have a disproportionate command over scientific knowledge (including proprietary rights to the technologies) and over the media that can decisively influence the debate. If these distortions remain uncorrected, one cannot feel confident that the debate will lead to optimal results from the standpoint of world welfare. Hence the need for a stronger role of the public sector research system, particularly of the international one, in the generation and diffusion of technologies and related knowledge about the pros and cons.

Besides these possible retarding factors relating to the need for prudence and caution in the face of scientific uncertainties, there are other factors from the socio-economic and institutional spheres, often interacting with the former, that may act in the same direction. The principal among them have to do with the growing control by a small number of large firms of the availability and cost of inputs and technologies farmers will be using and of the use of scientific discoveries for the further development of technology. A whole array of issues pertaining to the establishment and enforcement of intellectual property rights (IPRs) and genetic use restriction technologies (GURTs) are relevant here (see Chapter 11).

1.2.6 Growth in livestock production

Livestock production accounts globally for 40 percent of the gross value of agricultural production (and for more than half in developed countries). Developing countries will continue to increase their part in world production, with their share in meat going up to two-thirds of the world total by 2030 (from 53 percent in 1997/99) and in milk to 55 percent (from 39 percent). The past trend for the livestock sector to grow at a high rate (and faster than the crop sector) will continue, albeit in attenuated form, as some of the forces that made for rapid growth in the past (such as China's rapid growth) will weaken considerably (see discussion above).

The contribution of the increase in the number of animals will remain an important source of growth, but less so than in the past. In the meat sector, higher carcass weights will play a more important role in beef production and higher offtake rates (shorter production cycles) in pig and poultry meat production. The differences in yields (meat or milk output per animal) between developing and industrial countries are, and will likely remain, significant for bovine meat and milk, but much less so for pork and poultry, reflecting the greater ease of transfer and adoption of production techniques. However, factors making for a widening technology gap are also present and may become more important in the future. Among them, the most important is the development and progressive application of biotechnological innovations in the developed countries. The developing countries are not well suited to benefit; in the first place because they often lack the essential human, institutional and other infrastructure, and second because large private companies do not produce such innovations for small farmers in tropical countries.

The broad trends that are shaping the production side of the livestock sector evolution may be summarized as follows:

- an increasing importance of monogastric livestock species compared with ruminants, together with a shift towards increased use of cereal-based concentrate feeds;
- a change, at varying rates according to the region, from multiple production objectives to more specialized intensive meat, milk and egg production within an integrated global food and feed market. The trend for industrial livestock production to grow faster than that from mixed farming systems and, even more, from grazing will continue;
- the spread of large-scale, industrial production with high livestock densities near human population centres brings with it environmental and public health risks, as well as livestock disease hazards. The latter will be enhanced as increasing proportions of world livestock production will be originating in warm, humid and more disease-prone environments;
- animal health and food safety issues associated with these developments are further intensified by the growing role of trade in both live animals and products as well as in feeds;
- increasing pressure on, and competition for, common property resources, such as grazing and water resources, greater stresses on fragile extensive pastoral areas and more pressure on land in areas with very high population densities and close to urban centres.

Policies to address all these issues are required if society is to benefit from the high-growth subsector of agriculture. For the developing countries, besides improved nutrition from higher consumption of animal proteins, the potential exists for livestock sector development to contribute to rural poverty alleviation. It is estimated that livestock ownership currently supports and sustains the livelihoods of 675 million rural poor. Benefits to the rural poor from the sector's growth potential are not, however, assured without policies to support their participation in the growth process. If anything, experience shows that the main beneficiaries of the sector tend to be a relatively small number of large producers in high-potential areas with good access to markets, processors and traders, and middle-class urban consumers. Desirable policy responses are discussed in Chapter 5, as are those relating to the all-important area of health (both animal and human) and food safety.

1.2.7 Probable developments in forestry

During the last two decades, pressures on diminishing forest resources have continued to grow. Traditionally, forestry outcomes were determined by demands for wood and non-wood forest products and the use of forest land for expansion of agriculture and settlements. However, in more recent years there has been a growing recognition of the importance of forestry in providing environmental goods and services such as protection of watersheds, conservation of biodiversity, recreation and its contribution to mitigating climate change. This trend is expected to persist and strengthen during the next 30 years, and increasingly the provision of public goods will gain primacy. In parallel, the expansion of forest plantations and technological progress will greatly help to match demand and supply for wood and wood products and contribute to containing pressures on the natural forest.

FAO's Forest Resources Assessment 2000 estimates the global forest area in 2000 at about 3 870 million ha or about 30 percent of the land area. Tropical and subtropical forests comprise 48 percent of the world's forests, with the balance being in the temperate and boreal categories. Natural forests are estimated to constitute about 95 percent of global forests and plantation forests 5 percent. Developing countries account for 123 million ha (55 percent) of the world's forests, 1 850 million ha of which are in tropical developing countries. During the 1990s, the net annual decline of the forest area worldwide was about 9.4 million ha, the sum of an annual forest clearance estimated at 14.6 million ha (a slight decline from that of the 1980s) and an annual forest area increase of 5.2 million ha. Nearly all forest loss is occurring in the tropics. Population growth coupled with agricultural expansion (especially in Africa and Asia) and agricultural development programmes (in Latin America and Asia) are major causes of forest cover changes.

In most developed countries, deforestation has been arrested and there is a net increase in forest cover. Such a situation is seen also in a number of developing countries, largely because of reduced dependence on land following the diversification of the economies. By 2030 most agriculture-related deforestation in Asia and to some extent also in Latin America could have ceased. In parallel, however, economic growth puts additional pressures on the forest by stimulating the demand for forest products, especially sawnwood, panel products and paper. Things may not move in that direction in Africa, where population growth, combined with limited changes in agricultural technologies and the absence of diversification, could result in continued forest clearance for agricultural expansion.

Current efforts towards wider adoption of sustainable forest management are expected to strengthen, although such efforts may not be uniform and are critically dependent on political and institutional changes. Inadequate investment in capacity building and persistent weaknesses of the political and institutional environment may limit the wider adoption of sustainable forest management in several countries, especially in sub-Saharan Africa.

Industrial wood demand is expected to grow, but this is estimated to be lower than in earlier forecasts. As noted, the area in forest plantations has been growing at a fast rate: it grew from 18 million ha in 1980 to 44 million ha in 1990 and to 187 million ha in 2000. Plantations are now a significant source of roundwood supply and they will become more so in the future. They could double output to some 800 million m^3 by 2030, supplying about a third of all industrial roundwood. There will be substantial involvement of the private sector, including small farmers in the production of wood, also coming from "trees outside forests" (trees planted around farms, on boundaries, roadsides and embankments). The probable further growth of legally protected forest areas should be feasible without too much impact on future wood supplies. On the demand side, technological improvements in processing would help to reduce raw material requirements per unit of final product. Overall, the longer-term outlook for the demand-supply balance looks now much less problematic than in the past.

An estimated 55 percent of global wood production is used as fuelwood. Tropical countries account for more than 80 percent of global fuelwood consumption. Wood will continue to be the most important source of energy in the developing countries, especially for the poor in sub-Saharan Africa and most of South Asia. No significant changes in fuelwood consumption are likely over the period to 2015. Wood will remain a readily accessible source of fuel for millions of poor people throughout the world. Forests close to urban centres may continue to be subjected to heavy exploitation to meet the growing demand for charcoal. Notwithstanding localized shortages, demand will more or less be met, and demand for fuelwood may trigger planting in farmlands and other areas not used for agricultural purposes. The shift towards alternative fuels may accelerate beyond 2015, depending on changes in access to such fuels.

Improved access to manufactured products would reduce the dependence on several of the non-wood forest products traditionally used for subsistence consumption. There will however be an increased demand for certain items, especially medicinal and aromatic plants, ethnic foods and industrial products. While unsustainable exploitation from natural forests could result in a substantial decline in the supply of some of the valuable non-wood forest products, this may eventually lead to domestication and commercial cultivation of some of the more valuable ones. Although there will be significant improvements in the processing technologies, the producers of raw material are unlikely to be the main beneficiaries. This largely stems from persistent weakness in the research and development capacity of the producers.

During the next 30 years, one could witness an increase in the non-consumptive uses of forests, especially for protection of biodiversity, conservation of soil and water, mitigation of global climate change and recreational uses. In fact the cultural and recreational uses of forests will gain prominence, although in many developing countries consumptive use of forest products will remain important. Environmental standards in forest resource management will be widely adopted. Although the expansion of protected areas may not be rapid, protection objectives will be growing in importance as determinants of forest land uses. Increasingly there are efforts to enhance the scope for action by the private sector, communities, non-governmental organizations (NGOs) and civil society at large. These latter changes, coupled with technological improvements, will bring about significant qualitative changes in forestry.

1.2.8 Plausible developments in fisheries

Fish remains a preferred food. Average world per capita consumption continued to increase to 16.3 kg in 1999, up from 13.4 kg in 1990. This development was heavily dominated by events in China. Excluding China, the apparent consumption per person in the rest of the world actually declined from 14.4 kg in 1990 to 13.1 kg in 1999. There are very wide intercountry differences. Reported per capita consumption ranges from less than 1 kg in some countries to over 100 kg in others. The global average per capita consumption could grow to 19-20 kg by 2030, raising total food use of fish to 150-160 million tonnes (97 million tonnes in 1999).

Marine capture fisheries have in the 1990s shown annual catches of between 80 and 85 million tonnes. Inland catches increased slowly to 8.3 million tonnes in 1999. While the gross volume of marine catches has fluctuated and does not show any definite trend, the species composition of the catch has changed, with high-value species (bottom-dwelling, or demersal species and large pelagics) gradually being substituted by shorter-lived surface dwelling (pelagic) and schooling fish.

By the end of the 1990s, an estimated 47 percent of major marine fish stocks were fully exploited, about 18 percent overfished, and another 9 percent depleted. Only a quarter of the fish stocks were moderately exploited or underexploited. The long-term yearly sustainable yield of marine capture fisheries is estimated at approximately 100 million tonnes. This assumes more efficient utilization of stocks, healthier ecosystems and better conservation of critical habitats. Increased landings also depend on improved selectivity of fishing gear, leading to less discarding of unwanted fish, and on sustained higher levels of catch from fisheries on restored stocks. However, this increase will be slow in materializing. Moreover, the estimated potential yield of capture fisheries (100 million tonnes) includes large quantities of currently minimally exploited living aquatic resources in the oceans, of which the most well known are krill, mesopelagic fish and oceanic squids.

The bulk of the increase in supply will therefore have to come from aquaculture. During the 1990s, aquaculture has shown a spectacular development (most of it in Asia, with China accounting for 68 percent of world aquaculture production), and by 1999 aquaculture accounted for 26 percent of world fish production (even 34 percent of fish food supplies). This growth could continue for some time, although constraints (lack of feeding stuffs, diseases, lack of suitable inland sites, environmental problems, etc.) are becoming more binding. Unless these constraints are relaxed, the long-term growth prospects of aquaculture, and hence of fish consumption, could be seriously impeded.

On the feed side, fishmeal producers expect that within a decade or so the aquaculture industry will use up to 75 to 80 percent of all fish oil produced, and about half of the available white fishmeal, while the prospects for growth in supplies are not encouraging. Although considerable research efforts have been undertaken, a satisfactory replacement for fish oil in aquaculture feed has still to be found. The proportion of fish reduced to fishmeal and oil (at present some 30 million tonnes) is likely to fall. In spite of an increasing demand for fishmeal following the intensification of livestock production and further expansion of aquaculture, an increasing share of small pelagic species (normally used for reduction) is likely to be used for food. The fishmeal industry will therefore be forced to find other sources, the most likely of which is zooplankton (initially Antarctic krill).

The single most important influence on the future of wild capture fishery is one of governance. Although in theory renewable, wild fishery resources are in practice finite for production purposes. They can only be exploited so much in a given period; if overexploited, production declines and may even collapse. Hence total fishery production from the wild cannot increase indefinitely. Resources must be harvested at sustainable levels, and access must be equitably shared among producers. So far only very few managers have succeeded in creating sustainable fisheries. As fish resources grow increasingly scarce, conflicts over allocation and sharing are becoming more frequent.

The principal policy challenge is to establish rules for access to fish stocks. Fisheries based on explicit and well-defined rights of access will need to become more common; when rights are well defined, understood and observed, allocation conflicts tend to be minimized. These issues are the subject of an increasing body of international and bilateral agreements dealing with legal access rights.

Another major policy challenge is to bring the global fishing fleet capacity back to a level at which global fish stocks can be harvested sustainably and economically. Past policies have promoted the buildup of excess capacity in the fishing fleet and incited fish farmers to increase the catch beyond sustainable levels. Policies have to react fast to unwind the overcapacity that has been built up over the past to ensure a return to a steady-state fish stock. This process is already under way and has, among other things, led to a contraction of the capture fisheries labour force in developed countries.

A third important policy consideration is the increasing pressure from various quarters in society to reduce environmental damage associated with both capture and culture fisheries. This has also led to a set of national and international rules and laws, some voluntary in nature, regulating fishery methods.

A major factor, affecting both the sustainability of capture fisheries and the expansion of aquaculture, will be the expected improvements in the understanding of the marine ecosystem. Improved knowledge will encompass the working of ecosystems, including the dynamics of fish stocks, and the effects of human intervention on such ecosystems. This knowledge would increase fisheries productivity, facilitate improved fisheries management and enable monitoring of fisheries operations, to ensure compliance with rules and regulations and to assess their impact on the environment.

1.2.9 Environmental aspects of natural resource use in agriculture

The quantum gains in agricultural production and productivity achieved in the past were accompanied by adverse effects on the resource base of agriculture that put in jeopardy its productive potential for the future. Among these effects are, for example, land degradation; salinization of irrigated areas; overextraction of underground water; growing susceptibility to disease and buildup of pest resistance favoured by the spread of monocultures and the use of pesticides; erosion of the genetic resource base when modern varieties displace traditional ones and the knowledge that goes with their use. Agriculture also generated adverse effects on the wider environment, e.g. deforestation, loss or disturbance of habitat and biodiversity, emissions of greenhouse gases (GHGs) and ammonia, leaching of nitrates into waterbodies (pollution, eutrophication), off-site deposition of soil erosion sediment and enhanced risks of flooding following conversions of wetlands to cropping.

The production increases in prospect at the world level for the period to 2030 (in terms of the absolute quantities involved) will be of an order of magnitude similar to those that took place in the comparable historical period (e.g. for cereals and sugar) or even higher (e.g. for meat and vegetable oils). Thus, almost another billion tonnes of cereals must be produced annually by 2030, another 160 million tonnes of meat, and so on. It follows that pressures on the resources and the environment will continue to mount. The challenge facing humanity is how to produce the quantum increases of food in sustainable ways (preserving the productive potential of the resource) while keeping adverse effects on the wider environment within acceptable limits. A *priori*, the task looks more difficult than in the past because:

- resources are more stretched today than they were 30 years ago (e.g. water shortages are more severe, GHG concentrations are higher, etc.), hence the risk that further deterioration will act as a break to development is much more present;
- the growing share of the developing countries in world production means that pressures will be increasingly gathering in the agro-ecological environments of the tropics which are more fragile than the temperate ones and contain much of the world's biodiversity;
- in most of these countries, conventional objectives of agricultural development (food security, employment and export earnings) can easily take precedence over those of sustainability and environmental conservation, no matter that for them the preservation of the productive potential of their agriculture is much more crucial for their survival than it is for the industrial countries where agriculture is a small part of the economy;
- the research and technology capabilities for finding solutions to respond to the problems reside predominantly in the industrial countries and less so in the developing ones where they are most needed.

The preceding considerations and the magnitudes involved suggest that the increases in production and associated progress in food security cannot be achieved at zero environmental cost. The issue is whether any threats to the resource base of agriculture and the generation of other environmental "bads" associated with more production and consumption can be contained within limits that do not threaten sustainability, that is the ability of future generations to have acceptable food security levels within acceptable more general living standards, including a clean environment. Often the choices present themselves in the form of what are acceptable trade-offs, rather than whether we can have something for nothing. There are trade-offs over time, among the different dimensions of sustainability and over space (e.g. among countries or regions within countries).

An example of trade-offs over time is the eventuality that deforestation (including more general disruption of wildlife habitats) of the past as well as the one now taking place could be reversed in the future when the pressures for further increases in output will be eased and the advancement of yields could lead to less land being needed for any given level of output. Europe's experience seems to point in this direction.

Trade-offs between different dimensions of sustainability include, for example, the higher herbicide applications that could accompany efforts to increase water use efficiency and/or reduce methane emissions by shifting rice cultivation from flooded and transplant to direct seeding. Similarly, the shift to no-till/conservation agriculture in order to reduce soil erosion risks and increase the carbon sequestration capacity of soils (see below), favours the development of weeds that may provoke increased use of herbicides. In like manner, combating the effects of saltwater intrusions into irrigation aquifers in coastal areas (because of overextraction or sea level rise) may require the acceptance of genetically modified salt-tolerant crops together with some as yet unknown risks. In livestock, the shift from ruminant meat to pork and poultry may slow down the growth of methane emissions from ruminant livestock but will aggravate the problem of livestock effluent pollution from large pig and poultry industrial units. Similarly, grazing restraints on extensive rangelands have their counterpart in the increase of feedlot-raised cattle with, as a result, enhanced point source pollution as well as eventual effects on arable land elsewhere, including in other countries, generated in the process of producing more cereals for the feedlots.

Trade-offs among countries relate primarily to the potential offered by international agricultural trade to spread across the globe the environmental pressures from increased production. The individual countries differ as to their capabilities to withstand adverse effects associated with increasing production because they differ in the relative abundance of their resource endowments; they possess agro-ecological attributes that make their resources more or less resilient; or they are at present more or less stretched from past accumulation of environmental damages. Countries also differ as to their technological and policy prowess for finding solutions and responding to emerging problems.

Trade can contribute to minimizing adverse effects on the global system if it spreads pressures in accordance with the capabilities of the different countries to withstand and/or respond to them. Whether it will do so depends largely on how well prices in each country reflect its “environmental comparative advantage”. This requires that, in addition to absence of policy distortions that affect trade, the environmental “bads” generated by production be embodied in the costs and prices of the traded products, which is not normally the case when externalities are involved. If all countries meet these conditions, then trade will contribute to minimizing the environmental “bads” globally as they are perceived and valued by the different societies, although not necessarily in terms of some objective physical measure. This latter qualification is important because different countries can and do attach widely differing values to the environmental resources relative to the values of other things, such as export earnings and employment. In the end, the values of environmental resources relative to those of other things are anthropocentric concepts and countries at different levels of development and with differing resource endowments are bound to have differing priorities and relative valuations.

An additional mechanism through which trade can contribute to spread pressures across the globe in ways that minimize adverse effects on sustainability has to do with the enhanced degree of product substitutability afforded by trade, e.g. substituting imported palm oil for locally produced oil from sunflower seed or soybeans. Producing a tonne of palm oil in East Asia requires only a fraction of the agrochemicals (fertilizer and pesticides) used to produce a tonne of oil from sunflower seed or soybeans in Europe, for example.

In considering the prospects for the future, we must be aware that history need not repeat itself as concerns the extent to which the continued growth of production will be associated with adverse effects. The projections to 2030 suggest that some effects will be different from those of the past simply because their determinants will be changing, e.g. the lower growth of rural population will tend to slow down the rate of deforestation. Others will be different because of policy changes; for example, the EU, having paid the environmental cost of transforming itself from a large net importer of sugar to a large net exporter, now has policies that do not favour further expansion of exports. Finally, history need not repeat itself because of the wider adoption of more environmentally benign technologies and of policies that favour them and/or remove incentives for unsustainable practices, e.g. for expansion of ranching into forested areas. Approaches to agricultural production that offer scope for minimizing adverse impacts include those described in the following paragraphs.

Integrated pest management (IPM) promotes biological, cultural, physical and, only when essential, chemical pest management techniques. Naturally occurring biological control is encouraged, for example through the use of alternate plant species or varieties that resist pests, as is the adoption of land management, fertilization and irrigation practices that reduce pest problems. If pesticides are to be used, those with the lowest toxicity to humans and non-target organisms should be the primary option. Precise timing and application of any pesticides used are essential. Broad-spectrum pesticides are only used as a last resort when careful monitoring indicates they are needed according to pre-established guidelines. Given that chemical pesticides will continue to be used, the need for rigorous testing procedures before they are released on to the market (as well as sharing of the relevant information among countries) cannot be overemphasized. The same applies for the need to have comprehensive and precise monitoring systems to give early warning of residue buildup along the food chain, in soils and in water.

Integrated plant nutrient systems (IPNS). The depletion of nutrient stocks in the soil (nutrient mining), which is occurring in many developing countries, is a major but often hidden form of land degradation, making agricultural production unsustainable. In parallel, overuse or inappropriate use of fertilizers creates problems of pollution. IPNS hold promise of mitigating such adverse effects by recycling all plant nutrient sources within the farm and use of nitrogen fixation by legumes to the extent possible, complemented by the use of external plant nutrient input, including manufactured fertilizers.

No-till/conservation agriculture (NT/CA) involves planting and maintaining plants through a permanent cover of live or dead plant material, without ploughing. Different crops are planted over several seasons, to avoid the buildup of pests and diseases and to optimize use of nutrients. NT/CA has positive effects on the physical, chemical and biological status of soils. Benefits include reduced soil erosion, reduced loss of plant nutrients, increase in organic matter levels of soils, higher rainfall infiltration and soil moisture holding capacity and, of course, savings in fossil fuel used in soil preparation.

Organic agriculture. Although the growing demand for organic foods is to a large extent driven by health and food quality concerns, organic agriculture is above all a set of practices intended to make food production and processing respectful of the environment. It is not a product claim that organic food is healthier or safer than that produced by conventional agriculture. Organic agriculture is essentially a production management system aiming at the promotion and enhancement of ecosystem health, including biological cycles and soil biological activity. It is based on minimizing the use of external inputs, representing a deliberate attempt to make the best use of local natural resources. Synthetic pesticides, mineral fertilizers, synthetic preservatives, pharmaceuticals, GMOs, sewage sludge and irradiation are prohibited in all organic standards. Naturally, this by itself does not guarantee the absence of resource and environmental problems characteristic of conventional agriculture. Soil mining and erosion, for example, can also be problems in organic agriculture.

In conclusion, future agro-environment impacts will be shaped primarily by two countervailing forces: mounting pressures because of the continuing increase in demand for food and agricultural products mainly on account of population and income growth; and decreasing pressures via technological change, institutional and policy responses to environmental degradation caused by agriculture, and structural change in the sector. On balance, the potential exists for putting agriculture on a more sustainable pathway than a continuation of past trends would indicate. The main requirement is increasingly to decouple agricultural intensification from environmental degradation through the greater exploitation of biological and ecological approaches to nutrient recycling, pest management and soil erosion control.

1.2.10 Climate change and agriculture

Climate change: agriculture's role in climate change. Agricultural activities contribute to climate change through the emission of GHGs. They also contribute to climate change mitigation through carbon sequestration in cropland and the provision of biofuels that can substitute for fossil fuels. Globally, they generate some 30 percent of total anthropogenic emissions of GHGs. The main ones are carbon dioxide (CO_2 – agriculture accounts for about 15 percent of total anthropogenic emissions); methane (CH_4 – about 50 percent coming from agriculture); and nitrous oxide (N_2O – agriculture accounting for about two-thirds). Both CH_4 and N_2O are gases with warming potentials many times higher than that of CO_2. The main source of CO_2 emissions is tropical forest clearance, related biomass burning and land use change. For methane the chief sources are rice production and livestock through enteric fermentation of ruminants and animal excreta. For nitrous oxide it is mineral fertilizer and animal wastes – manure and deposition by grazing animals.

Future emissions from agriculture will be determined by the evolution of the main variables (land use, fertilizers and numbers of animals) and their qualitative changes, as presented in the preceding sections and discussed in more detail in individual chapters. Thus, carbon dioxide emissions could be stable or even less than in the past because of slower deforestation and land cover change. Likewise, methane emissions from rice cultivation will slow down or possibly even decrease (through changes in paddy field flooding and rice varieties), but annual methane emissions from livestock could increase by 60 percent by 2030. Also, growth of nitrous oxide emissions from fertilizers will be slow (slow growth in consumption combined with a more efficient use of fertilizers) but, as for methane, emissions from livestock (animal waste) could increase by some 50 percent by 2030.

Agricultural land sequesters carbon in the form of vegetation and soil organic matter (SOM) derived from crop residues and manure. The potential exists for it to sequester much more carbon than it actually does under most current cropping practices. This potential is assuming growing economic, political and environmental importance in the context of the Kyoto Protocol. The crop production projections of this study imply an increase in total biomass production and unharvested residues, hence an increase in gross carbon sequestration. Cropland can be made to increase carbon sequestration if managed for this purpose. The above-mentioned no-till/conservation agriculture is a major approach to increasing carbon in the soil, and it also contributes to lower GHG emissions through the reduced use of fuel. Better residue management and changes in cropping patterns can also contribute to carbon sequestration. Even greater gains per hectare could be achieved where marginal cultivated land is taken out of crop production and replaced by grass or legume forages. Permanent set-aside of agricultural land would sequester large amounts of carbon if forested or left to revert to tree scrub. Finally, degraded land that has gone out of production, e.g. saline soils, could be restored to sequester carbon.

In conclusion, managing agricultural land to sequester more carbon could transform it from a net source to a net sink. The rate of sequestration gradually declines before reaching a limit and can be especially high during the first few years. Some of the carbon sequestration will not be permanent and eventually the gains will level off. This notwithstanding, managing agricultural land for carbon sequestration will extend the time available to introduce other measures with longer-term benefits.

Climate change: impacts on agriculture. The main parameters of climate change with potential effects on agriculture and food security are as follows:

- Global average temperatures are projected to rise by about 1°C by 2030. Higher latitudes will warm more quickly than lower ones, land areas will warm more quickly than the oceans, and polar sea ice will decrease more in the Arctic than in the Antarctic. Consequently, average temperatures in the higher latitudes may rise by 2°C.
- Broadly speaking, climate change is projected to increase global mean precipitation and runoff by about 1.5 to 3 percent by 2030. There will be greater increases in the higher latitudes and the equatorial region but potentially serious reductions in the middle latitudes. Parts of Central America, South Asia, northern and southern Africa and Europe may suffer appreciable falls in available water resources.
- Sea levels are rising at about half a centimetre per year, and are likely to continue at this rate for several decades even if there is rapid implementation of international agreements to limit climate change. Thus sea levels could be about 15 cm higher by 2030.
- There is likely to be an increase in the frequency and intensity of relatively localized extreme events including those associated with El Niño, notably droughts, floods, tropical cyclones and hailstorms.

Recent research has suggested that some impacts of climate change are occurring more rapidly than previously anticipated. For example, average sea temperatures in northern latitudes are rising rapidly (in particular in the North Sea), ocean currents are being disrupted and phytoplankton populations altered.

The main effects of these changes on food and agriculture are foreseen to be the following:

- Temperature and precipitation changes will affect the extents of land that is suitable for growing crops. Suitable areas will increase in higher latitudes because of milder and shorter winters, and will decline in arid and semi-arid areas.
- The effects on yields follow the same pattern as land suitability, with gains in middle to higher latitudes and yield losses in lower latitudes, but with some gains in tropical highlands where at present there are cold temperature constraints.
- Larger changes are predicted in the availability of water from rivers and aquifers because of reductions in runoff and groundwater recharge. Substantial decreases are projected for Australia, India, southern Africa, the Near East/North Africa, much of Latin America and parts of Europe. Thus, irrigation capacity will be negatively affected precisely in the countries where climate change will enhance dependence on irrigation, e.g. because of more frequent and more severe droughts. The main decrease in water availability will be after 2030 but there could be negative effects on irrigation in the shorter term.
- On the positive side, the rise in atmospheric concentrations of carbon dioxide (CO_2), stimulates photosynthesis (the so-called CO_2 fertilization effect) and improves water use efficiency. Up to 2030 this effect could compensate for much or all of the yield reduction coming from temperature and rainfall changes.

- Effects on livestock will be partly through deterioration of some grasslands in developing countries (mostly after 2030). Of more significance to livestock production is the rise in temperature over the period to 2030, and the CO_2 fertilization effect. These will favour more temperate areas through reduced need for winter housing and for feed concentrates (because of better pasture growth). Many developing countries, in contrast, are likely to suffer production losses through greater heat stress to livestock and lower fodder and forage yields, but this may be compensated by the CO_2 fertilization effect.
- The substantial rise foreseen for average sea temperatures may have serious effects on fisheries. It could disrupt breeding patterns, reduce surface plankton growth or change its distribution, thereby lowering the food supply for fish, and cause the migration of mid-latitude species to northern waters. The net effect may not be serious at the global level but could severely disrupt national and regional fishing industries and food supplies.
- Impacts from sea level rise will take the form of progressive inundation of low-lying coastal areas and saltwater intrusion. Increased frequency and intensity of tropical cyclones will also increase the frequency of extreme high-water events as more severe storm surges penetrate further inland.
- There could be substantial changes in the distribution of major pests even under the small changes in average temperature likely to occur by 2030. Fewer cold waves and frost days could extend the range of some pests and disease vectors and favour the more rapid buildup of their populations to damaging levels. The importance lies both in the larger pest populations *per se* that may arise because of higher temperatures, and in their role as carriers of plant viruses, as in the case of aphids carrying cereal viruses, which are currently held in check by low winter or night temperatures.
- Finally, greater temperature extremes seem likely to give rise to higher wind speeds, and there may be increases in the occurrence of hurricanes. So, in addition to impacts on plant growth, there may be greater mechanical damage to soil, plants and animals, for example from greater wind erosion, sand blast damage to crops and drowning of livestock.

The main impacts of climate change on global food production capacity are not projected to occur until after 2030, but thereafter they could become increasingly serious. Up to 2030 the impact may be broadly positive or neutral at the global level. However the regional impacts will be very uneven. Food production in higher latitudes will generally benefit from climate change, whereas it may suffer in large areas of the tropics. Over the period to 2030, the most serious and widespread agricultural and food security problems related to climate change are likely to arise from the impact on climate variability, and not from progressive climate change, although the latter will be important where it compounds existing agroclimatic constraints.

Naturally, the prospect that global production potential may not be much affected by climate change, or may even rise, is poor consolation to poor and food-insecure populations with high dependence on local agriculture and whose agricultural resources are negatively affected. Even small declines in the quantity and quality of their agricultural resources can have serious negative impacts on livelihoods and food security. Among the obvious responses to these emerging risks are accelerated economic growth and diversification of economies away from heavy dependence on vulnerable agricultural resources, and promotion of technologies and farming practices to facilitate adaptation to changing agro-ecological conditions.