# Prospects by Major Sector

## Crop production

### *Cereals: an extra billion tonnes needed*

The 1990s saw a decline in the growth of world cereal consumption. This was due not to limits in production capacity but rather to slower growth in demand, partly caused by exceptional and largely transient factors. Growth in consumption will resume, leading to growing dependence on imports in developing countries. The potential exists for traditional and new exporters to fill this gap, but problems of food security and environmental degradation will need to be addressed.

Cereals are still by far the world's most important sources of food, both for direct human consumption and indirectly, as inputs to livestock production. What happens in the cereal sector is therefore crucial to world food supplies.

Since the mid-1960s the world has managed to raise cereal production by almost a billion tonnes. Over the next 30 years it must do so again. Is the task within its capabilities?

#### Growth of cereal demand slows down

The growth rate of world demand for cereals fell to 1 percent a year in the 1990s, down from 1.9 percent in the 1980s and 2.5 percent in the 1970s. World annual cereal use per person (including animal feeds) peaked in the mid-1980s at 334 kg and has since fallen to 317 kg (1997-99 average).

This rapid decline was thought by some to herald a new world food crisis. It was interpreted as a sign that the world was hitting the limits of its capacity for food production and would soon experience serious threats to food security.

In fact, average cereal consumption per person in developing countries has risen steadily throughout the past four decades. The slowdown in the growth of world consumption was due not to production constraints but to a series of factors that limited demand. Among these factors, some are ongoing and widespread:

- World population growth has been slowing.
- Many large countries, especially China, are reaching medium to high consumption levels, such that further rises will be much less rapid than in the past.
- Persistent poverty has prevented hundreds of millions of people from meeting their food needs.

Other factors, however, are largely transient. These include:

- A fall in demand in the transition economies. This was the strongest factor during the 1990s, when both consumption and imports in these countries fell from the very high levels they had reportedly reached earlier.
- The use of cereals for animal feeds in the EU declined until the early 1990s, as high domestic prices favoured cereal substitutes, which were largely imported. Growth in feed

use resumed after EU policy reforms lowered domestic prices.

- Consumption grew more slowly in oil-exporting countries after the effect of the initial boom in oil prices on incomes and cereal imports had largely dissipated.
- Demand grew more slowly in the second half of the 1990s in the East Asian economies, which were hit by economic crisis.

The influence of these transient factors is already on the wane. Over the next 15 years they will gradually cease depressing the growth in cereal demand, which is projected to recover, rising to 1.4 per cent a year by 2015.

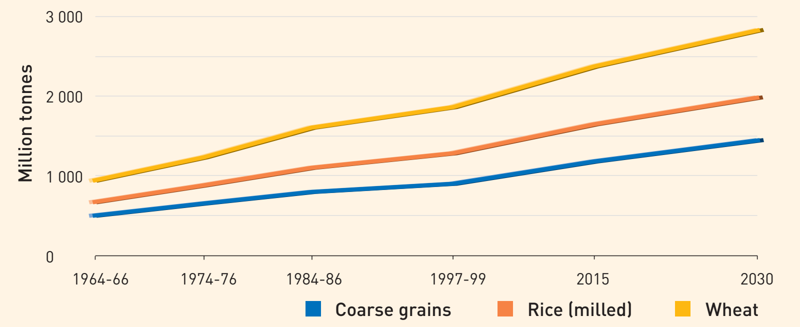
Looking further ahead, slower population growth and the levelling off of food consumption in many countries will continue to dampen demand, the growth of which is expected to slow to 1.2 percent a year over the period 2015 to 2030. Nevertheless, the production task facing world agriculture is massive. By 2030, an extra billion tonnes of cereals will be needed each year. Unforeseeable events such as oil price booms, dramatic growth spurts or crises could, of course, alter effective demand over short periods, but will not greatly change the big picture.

### Developing countries will become more dependent on imports

In the developing countries the demand for cereals has grown faster than production. The net cereal imports of these countries rose from 39 million tonnes a year in the mid-1970s to 103 million tonnes in 1997-99, representing a move from 4 percent of their annual cereal use to 9 percent. This dependence on imports is likely to increase in the years ahead. By 2030 the developing countries could be importing 265 million tonnes of cereals, or 14 percent of their consumption, annually.

Though this increase may seem massive, it represents a lower rate of growth over the next three decades than since the mid-1970s. If real food prices do not rise, and industry and services grow as previously, then most countries will be able to afford to import cereals to meet their needs. However, the poorest countries with the worst food security also tend to be least able to pay for imports.

**World demand for cereals, 1965 to 2030**




Source: FAO data and projections

> The developing countries will become increasingly dependent on cereal imports. By 2030 they could be producing only 86 percent of their own needs, with net imports amounting to some 265 million tonnes annually — almost three times present levels.

### Exporters can fill the gap

Can the rest of the world produce the export surpluses needed to fill the gap? It is worth examining the experience of the past quarter century. Between the mid-1970s and 1997-99 the net annual imports of all cereal-importing countries almost doubled, from 89 million tonnes to 167 million tonnes.

Cereal exporters coped well with the spurt in demand, doubling their export levels. Traditional exporters such as Australia, North America, Argentina and Uruguay played their part. They have the potential to continue to do so. But about half the total increase in exports came from a new player, the EU. From being a net importer of 21 million tonnes of grain a year in the mid-1970s, the EU became a net exporter of 24 million tonnes a year in 1997-99. Initially, much of this turnaround depended on heavy price support and protectionist policies. Various EU policy reforms have since brought domestic prices broadly into line with international prices, but the EU is likely to remain a significant net exporter even if its trade is further liberalized.

The transition economies are another possible source of future exports. Indeed, they are already moving into surplus. Spare land is plentiful in parts of Eastern Europe and Russia, and the scope for increasing productivity by reducing losses and raising yields is high. FAO's projections suggest that the transition countries could be net exporters of 10 million tonnes of cereals a year by 2015 and 25 million tonnes by 2030.

The transition countries became large net importers of cereals over the two decades to the early 1990s. They have since reversed this trend and could be net exporters of 10 million tonnes annually by 2015 and 25 million tonnes by 2030.

# *Prospects for key crops*

## Food staples

*Wheat*. The world's major cereal crop accounted for 31 percent of global cereal consumption in 1997-99. A growing share of wheat is used for animal feed in the industrial countries — 45 percent of total use in the EU. Wheat use per person in developing countries, overwhelmingly for food, has continued to rise, and most developing countries are increasingly dependent on imports. Among the net importers are some major wheat producers, such as Egypt, Islamic Republic of Iran, Mexico and Brazil. Over the coming years wheat consumption is expected to increase in all regions, including the transition countries as their consumption revives. In several rice-eating countries, increases in wheat consumption go hand in hand with constant or declining consumption of rice. The import dependence of developing countries (excluding exporters Argentina and Uruguay) should continue to grow, with net wheat imports expected to rise from 72 millions tonnes a year in 1997-99 to 160 million tonnes in 2030.

*Rice*. This crop is overwhelmingly used for direct human consumption, and made up 21 percent of the world's cereal consumption by weight in 1997-99. Average consumption per person in developing countries has been levelling off since the mid-1980s, reflecting economic development and income growth in major East Asian countries. It has, however, been growing in some regions, including South Asia, where it is still low. Consumption is expected to grow more slowly in the future than in the past. Indeed, average consumption per person in developing countries may well start to decline during the period 2015 to 2030. This will ease pressures on production, but given the slow yield growth of recent years, maintaining even modest increases in production will be a challenge to research and irrigation policy.

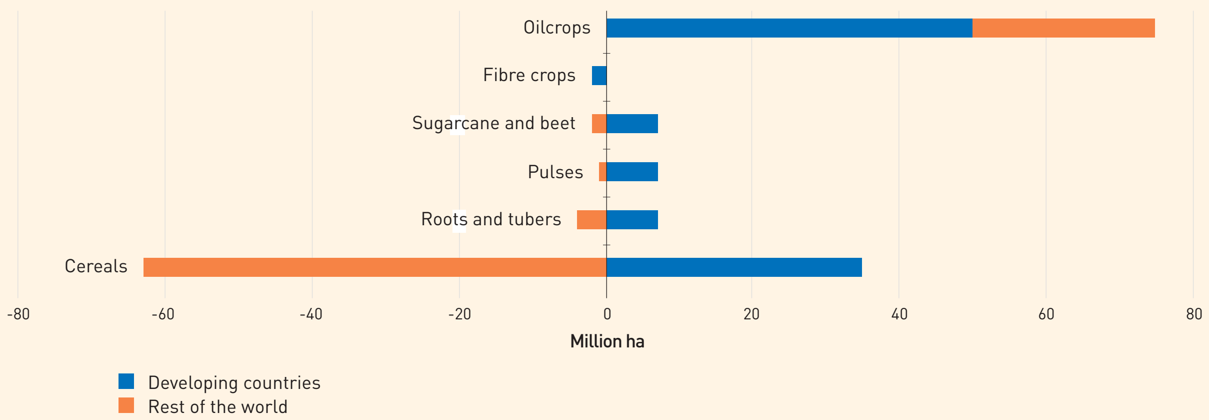
*Coarse grains*. These include maize, sorghum, barley, rye, oats and millet, and some regionally important grains such as tef (Ethiopia) or quinoa (Bolivia and Ecuador). About three-fifths of world consumption of coarse grains is used for animal feed, but where food insecurity is high these crops remain very important in direct human consumption: in sub-Saharan Africa, 80 percent of the grain harvest is used in this way. Consumption of coarse grains has been rising fast, driven mainly by growing use as animal feed in developing countries. In the future, consumption may well grow faster than that of rice or wheat, in line with the growth of the livestock sector. Developing countries will account for a rising share of world production, from less than half at present to just under three-fifths by 2030.

*Oilcrops*. This sector has been one of the world's most dynamic in recent decades, growing at almost double the speed of world agriculture as a whole. It covers a wide range of crops used not only for oil but also for direct consumption, animal feeds and a number of industrial uses. Oil-palm, soybean, sunflower and rapeseed account for almost three-quarters of world oilseed production, but olive oil, groundnut, sesame and coconut are also significant. The rapid expansion of production has meant that oilcrops have accounted for a huge share of the expansion of the world's agricultural land, with a net increase of 75 million ha between 1974-76 and 1997-99 — this at a time when the area under cereals shrank by 28 million ha.

With their high energy content, oilcrops have played a key role in improving food energy supplies in developing countries. Just over one out of every five kilocalories added to consumption in the developing countries in the past two decades originated in this group of products. This trend looks set to continue and indeed intensify: 45 out of every 100 additional kilocalories in the period to 2030 may come from oilseeds. The rapid growth in consumption over the past few decades was accompanied by the emergence of several developing countries — China, India, Mexico and Pakistan, among others — as major and growing net importers of vegetable oils. The result has been that the traditional surplus of the vegetable oils/oilseeds complex in the balance of payments of the developing countries has turned into a deficit in recent years. This has happened despite the spectacular growth of exports from a few developing countries that have come to dominate the world export scene, namely Malaysia and Indonesia for palm oil and Brazil and Argentina for soybean. In most other developing countries, the trend towards increased imports can be expected to continue.

*Roots, tubers and plantains*. World consumption of these crops as human food has been on the decline, but for 19 countries — all of them in Africa — they still provide more than a fifth, and sometimes as much as half, of all food energy. Cassava predominates in humid Central and West Africa and in the United Republic of Tanzania and Madagascar, while plantains are most important in Rwanda and cassava and sweet potato in West Africa and Burundi. Since most of these countries have low food consumption overall — less than 2 200 kcal per person per day — these crops play a crucial role in food security. In the period to 1997-99, Ghana and Nigeria made considerable advances in food security through the increased production of these crops, but in most of the other 17 countries per capita consumption stagnated or declined. The decline in world consumption of traditional roots and tubers has

**Expansion of area cultivated by crop, 1974-76 to 1997-99**




Source: FAO data

been accompanied by a gradual shift towards potato in some areas. A large part of this trend is explained by China, where millions of farmers and consumers have switched from sweet potato to potato.

Average demand for roots, tubers and plantains is projected to rise again in developing countries, with sweet potato and potato becoming particularly important as animal feeds. During the 1990s the use of imported cassava as feed in the EU skyrocketed because of high domestic prices for cereals, only to fall as reform of the Common Agricultural Policy reduced cereal prices. Cassava production for export as feed has been a major factor in expansion of the area cultivated in such countries as Thailand, a trend that is often associated with deforestation.

### Traditional export crops

Beyond these basic food crops, the agriculture and often the whole economy of many developing countries depend to a high degree on the production of one or a few commodities destined principally for export. In this category are commodities such as banana, sugar, natural rubber and tropical beverages (tea, coffee and cocoa).

The distinction between export crops and those for the domestic market is not always neat, either across or even within the developing countries. For example, sugar is the export crop *par excellence* for Mauritius and Cuba but a major import for Egypt, Indonesia and several other countries. Vegetable oils and oilseeds (especially palm oil and soybean) are major and rapidly growing export crops for several countries (including Malaysia, Indonesia, Argentina and Brazil), but are heavily imported by countries such as India and China. Coffee and cocoa share the characteristic of being produced exclusively in the developing countries but consumed predominantly in the industrial ones. Natural rubber used to belong to this category, but more of it is now consumed in the developing countries (half of world consumption, up from a quarter in the mid-1970s) as they industrialize. Cotton is in the same class, but more so, with the developing countries having turned into large net importers following the growth of their textiles industries and exports.

The economies of countries dependent on exports of these commodities are subject to changing conditions in the world market. Slow growth in world demand, combined with increasing supplies from the main producing and exporting countries, which compete with one another, have led to declining and widely fluctuating prices in the markets for several commodities. This has been particularly marked for coffee in recent years: per capita consumption in the industrial countries, accounting for two-thirds of world consumption, has been nearly constant for two decades, at around 4.5 kg, while production has increased, with several new countries, such as Viet Nam, entering the market. The result is that the price of Robusta coffee has nosedived, falling to US$0.50 per kg by January 2002, one-fifth of what it was in the mid-1990s.

For sugar and a few other commodities experiencing faster growth in consumption, mainly in the developing countries, the earnings of developing country exporters have been curbed by policies restricting access to markets, including policies favouring substitute sweeteners such as corn syrup. Such policies are very common in the main industrial countries that are, or used until recently to be, large importers. The EU used policies of this kind to turn itself from a large net importer, which it was until the second half of the 1970s, into a large net exporter today.

Looking into the future, the scope for growth in world demand and in the exports of developing countries is greatest for those commodities whose consumption is growing fairly rapidly in the developing countries themselves, several of which are likely to become large importers. In this category belong sugar and vegetable oils and, to a lesser extent, natural rubber and tea. Banana and cocoa are also becoming substantial import items in several developing countries, a trend that should intensify in the coming decades. In these two commodities, but also in others such as citrus and fruits and vegetables in general, there is still scope for growth in consumption

## The scares that went away

Two countries, China and India, have been the focus of fears that the world might run into serious food shortages. Together they are home to over a third of the world's population.

Some analysts feared that China would become a permanent importer on an ever-increasing scale. This would raise food prices on the world market, reducing the ability of other poor countries and people to buy food.

China (not including Taiwan Province) was a large importer of cereals in most years up to 1991, with typical net imports of 5 to 15 million tonnes a year. However, in the 1990s the country turned this situation around. In all but two of the eight years from 1992 to 1999, China was a net exporter of cereals, even while domestic use rose from 295 to 310 kg per person per year.

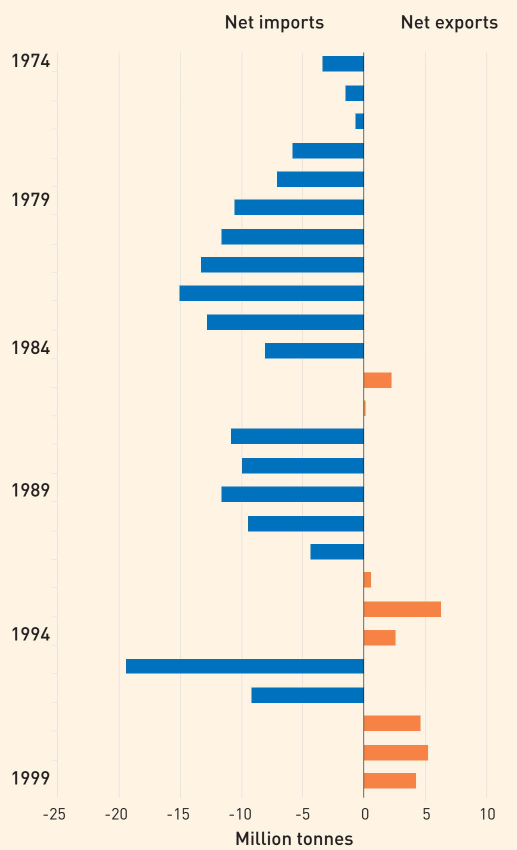
In the 1960s and early 1970s it became commonplace to warn of impending famine in India and in South Asia as a whole. In the mid-1960s the region imported 10 million tonnes of cereals a year — 11 percent of its consumption — but even so its cereal use per person was low, only 146 kg per year.

Thirty-three years on, the region's population had doubled and cereal use had risen to 163 kg per person per year. Yet thanks to the green revolution, imports were only a third of their mid-1960s levels, running at less than 2 percent of consumption. India had become a small net exporter in most years since the late 1970s. However, per capita use is still low in the region, reflecting, among other things, the persistence of widespread poverty and the very low use of cereals as feed, given the low consumption of meat. If consumption had grown faster, it is an open question whether imports would have been contained at such low levels.

and imports in the industrial countries. In parallel, the transition economies will play a growing role as importers of tropical products, a process already under way. In contrast, the high concentration of coffee markets in the industrial countries, together with negligible growth in population and per capita consumption here, do not augur well for the expansion of production and exports in this commodity: a continuation of the current slow growth, of no more than 1.2 percent yearly, seems the most likely outcome.

In conclusion, the agriculture, overall economy and food security of several developing countries will continue to depend on several crops for which the world market conditions are not only volatile but also, on balance, on a declining trend as regards real prices. These characteristics of the market could be highly

### China: from net importer to net exporter of cereals




Source: FAO data

detrimental to the development prospects of these countries. Countries that have failed in the past to diversify their economies and reduce their dependence on these traditional export crops have had a growth record well below average. Their challenge is to change this scenario in the future. The experiences of countries such as Malaysia suggest that this can be done.

### The environmental issues must be addressed

A frequently voiced concern is that the additional production required to meet world demand will be unsustainable, involving deepening levels of environmental damage that will undermine the natural resource base.

In the developed countries this concern relates mainly to the increased use of fertilizers and other chemical inputs. Past increases have led to serious problems of water and air pollution, and so will future ones unless counter-measures are taken.

Although the overuse of pesticides and other chemical inputs is a problem in some high-potential areas, increasing production in the developing world for the most part entails environmental risks of a different kind:

- In extensive farming and ranching systems, the major risks are soil erosion, soil mining and deforestation, leading to declining yields and desertification.
- In intensive irrigated farming systems, the major risks are salinization, waterlogging and water scarcities.

Some methods for increasing and sustaining crop production while minimizing environmental damage are already known and practised in some areas. Such methods need to be researched and extended for all environments, with appropriate policies that will encourage their rapid spread also being devised and implemented.

# Land, water and crop yields

Although future demand for food and cash crops will grow more slowly than in the past, meeting this demand will still require the continued expansion of farmland, together with improvements in yield based on new plant varieties and farming technologies.

Questions have been raised about all of these factors. Is there enough suitable land and water to expand the rainfed and irrigated area as much as will be needed, or is the world running short of these vital inputs? Is there scope for the higher yields that will be required, or are yields approaching limits that cannot be breached? Can biotechnology deliver a new generation of higher-yielding crops better suited to difficult environments? And are there approaches to farming that can increase and sustain production while improving conservation? The following sections will examine these questions.

## *The sources of production growth*

Increases in crop production derive from three main sources: expansion of arable land, increases in cropping intensity (the frequency with which crops are harvested from a given area) and improvements in yield.

Since the early 1960s, yield improvements have been by far the largest source of increase in world crop production, accounting for almost four-fifths or 78 percent of the increase between 1961 and 1999. A further 7 percent of the increase came from increased cropping intensity, while a mere 15 percent came from expansion of the arable area.

Yield improvement was by far the largest factor not just in the developed world but also in the developing countries, where it accounted for

70 percent of increased production. Expansion of the area cultivated accounted for just under a quarter of production growth in these countries. However, in areas with more abundant land, area expansion was a larger contributing factor. This was especially the case in sub-Saharan Africa, where it accounted for 35 percent, and in Latin America, where the figure reached 46 percent.

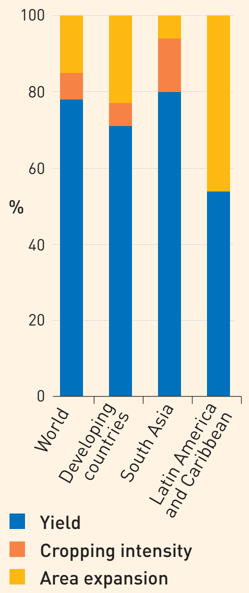
The projections suggest that these broad trends for the developing countries will continue, at least until 2030: land expansion is expected to account for 20 percent of production growth, yield improvements for about 70 percent and increased cropping intensity for the remainder. In sub-Saharan Africa and Latin America, land expansion will still be important, but it is likely to be increasingly outweighed by yield increases.

The FAO study indicates that, for the world as a whole, there is enough unused productive potential, in terms of land, water and yield improvements, to meet the expected growth in effective demand. However, this is a global conclusion and there are several strong qualifications to bear in mind:

- Effective demand expresses people's purchasing power rather than the real need for food: wealthy consumers may indulge to excess, while the very poor may not be able to afford even basic foods.
- Data suggesting that food is getting cheaper may be flawed, because they do not reflect the environmental costs of expanding and intensifying agriculture; moreover, the failure to internalize resource costs may curb investment in agricultural research, holding back the potential for future growth in yields.
- Land or water scarcities and other problems will most certainly continue to arise at country and local levels, with serious consequences for poverty and food security.

> In future, 80 percent of increased crop production in developing countries will have to come from intensification: higher yields, increased multiple cropping and shorter fallow periods.

**Sources of growth in production, 1961 to 1999**




Source: FAO data

# *Land resources*

### Is there enough potential cropland for future needs?

It is often suggested that the world may be heading towards shortages of suitable agricultural land. FAO studies suggest that this will not be the case at the global level, although in some regions and areas there are already serious shortages, and these may worsen.

Less new agricultural land will be opened up than in the past. Over the period 1961-63 to 1997-99 the expansion of arable land in developing countries totalled 172 million ha, an increase of 25 percent. In the next 30 years an increase of only 120 million ha, or 13 percent, will be required. Adding an extra 3.75 million ha

Fears of an imminent crunch between population growth and land availability are unwarranted. Most future growth in crop production will stem from improved yields. In some countries, however, land shortages may bite.

a year may seem a daunting task — but it is less than the rate of 4.8 million ha a year that was actually achieved over the period 1961-63 to 1997-99. A slowdown in expansion is expected in all regions, but this is mainly a reflection of the slower growth in demand for crops.

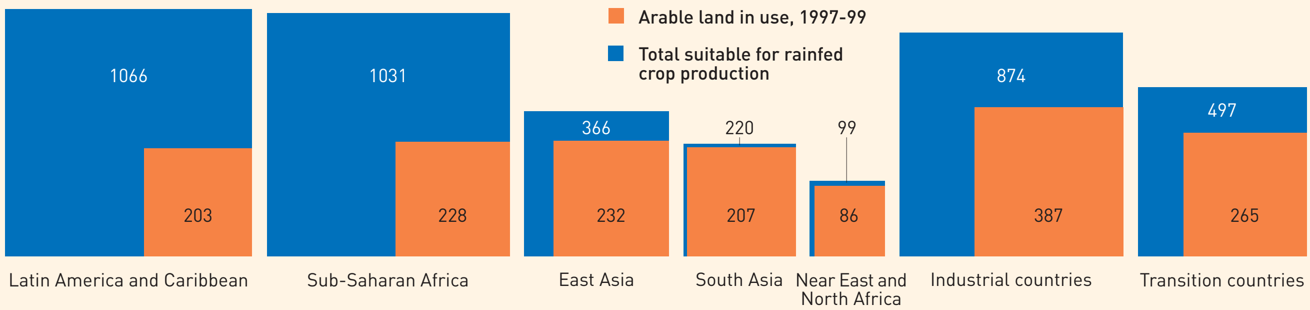
There is still potential agricultural land that is as yet unused. At present some 1.5 billion ha of land is used for arable and permanent crops, around 11 percent of the world's surface area. A new assessment by FAO and the International Institute for Applied Systems Analysis (IIASA) of soils, terrains and climates compared with the needs of and for major crops suggests that a further 2.8 billion ha are to some degree suitable for rainfed production. This is almost twice as much as is currently farmed.

Of course, much of this potential land is in practice unavailable, or locked up in other valuable uses. Some 45 percent is covered in forests, 12 percent is in protected areas and 3 percent is taken up by human settlements and infrastructure. In addition, much of the land reserve may have characteristics that make agriculture difficult, such as low soil fertility, high soil toxicity, high incidence of human and animal diseases, poor infrastructure, and hilly or otherwise difficult terrain.

The pool of unused suitable cropland is very unevenly distributed. By the end of the twentieth century, sub-Saharan Africa and Latin America were still farming only around a fifth of their potentially suitable cropland. More than half the remaining global land balance was in just seven countries in these two regions: Angola, Argentina, Bolivia, Brazil, Colombia, Democratic Republic of Congo and the Sudan. At the other extreme, in the Near East and North Africa 87 percent of suitable land was already being farmed, while in South Asia the figure was no less than 94 percent. In a few countries of the Near East and North Africa, the land balance is negative – that is, more land is being cropped than is suitable for rainfed cropping. This is possible where, for example, land that is too sloping or too dry for rainfed crops has been brought into production by terracing or irrigation.

More than 80 percent of the projected expansion in arable area is expected to take place in sub-Saharan Africa and Latin America. Although there is still surplus land in these regions, the expansion may involve cutting back on long rotation and fallow periods. If fertilizer

## Cropland in use and total suitable land (million ha)




Sources: FAO data and Fischer *et al.* (2000)

use does not rise to compensate, this may result in soil mining and stagnant or declining yields.

In contrast, in South Asia and the Near East and North Africa, where almost all suitable land is already in use, there will be next to no expansion in area. By 2030 the Near East and North Africa will be using 94 percent of its suitable cropland, with a remaining surplus of only 6 million ha. In South Asia the situation will be even tighter, with 98 percent already in cultivation. In South and East Asia, more than 80 percent of the increase in production will have to come from yield increases, since only 5 or 6 percent can come from expansion of the arable area.

> The projections suggest that the arable area in developing countries will increase by almost 13 percent or 120 million ha over the years from 1997-99 to 2030.

Cropping intensities will rise in all developing regions, on average from 93 percent to 99 percent. This will occur through the shortening of fallow periods and increased multiple cropping, made possible partly by growth in the irrigated area.

### Is land becoming scarcer?

There is widespread concern that the world may be running out of agricultural land. The trend towards scarcity associated with population growth is aggravated by the conversion of farmland to urban uses, by land degradation and by other factors.

Certainly, much farmland is being taken over for non-agricultural uses. Assuming a requirement for housing and other infrastructure of 40 ha per 1000 people, then world population growth between 1995 and 2030 implies the need for an additional 100 million ha of such non-agricultural land. Since most urban centres are sited on fertile agricultural land in coastal plains or river valleys, when they expand they take up more of this prime land. In China alone, more than 2 million ha were taken out of agriculture in the ten years to1995.

Despite these losses, there is little evidence to suggest that global land scarcities lie ahead. Between the early 1960s and the late 1990s, world cropland grew by only 11 percent, while world population almost doubled. As a result, cropland per person fell by 40 percent, from 0.43 ha to only 0.26 ha. Yet, over this same period, nutrition levels improved considerably and the real price of food declined.

The explanation for this paradox is that productivity growth reduced the amount of land needed to produce a given amount of food by around 56 percent over this same period. This reduction, made possible by increases in yields and cropping intensities, more than matched the decline in area per person, allowing food production to increase.

Land scarcity and the problems associated with it do of course exist at country and local levels, with serious consequences for poverty and food security. In many places these are likely to worsen unless remedial action is taken.

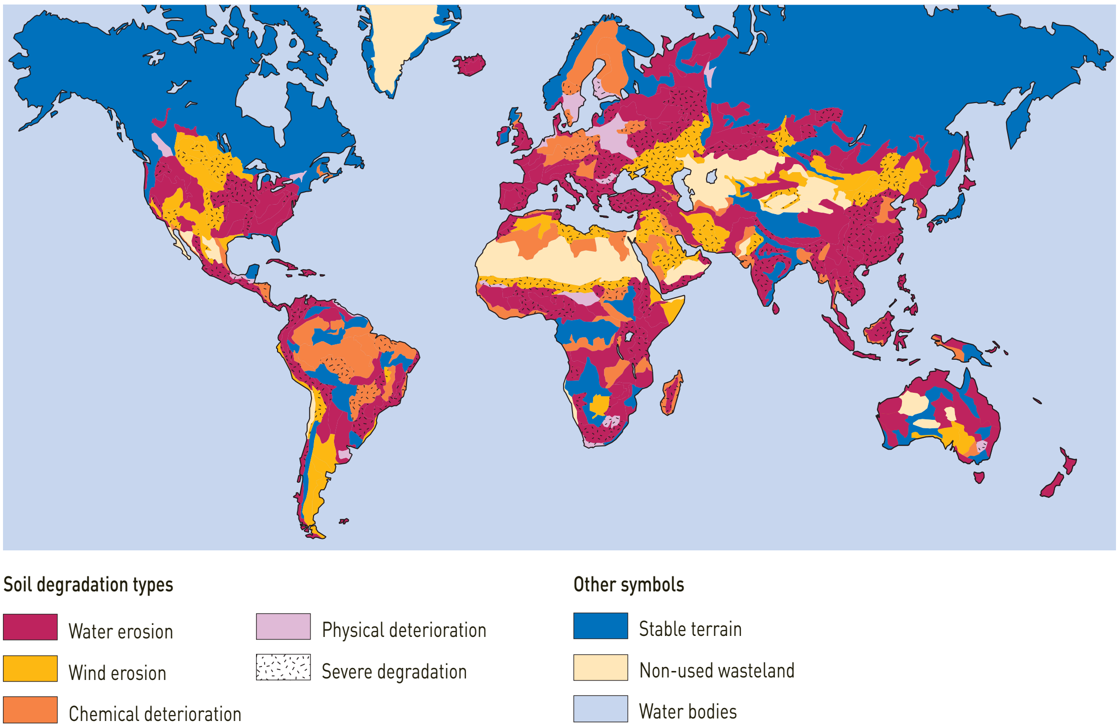
### How serious is land degradation?

Land degradation is the process by which the soil's current or future capacity to produce is lowered by chemical, physical or biological changes. Some analysts claim that accelerating land degradation will offset productivity improvements, while others believe the seriousness of this problem has been greatly overstated.

The truth is that the area of degraded land is not known with much precision. Its assessment is often based on expert judgement rather than objective measurement. For India alone, estimates by different public authorities vary from 53 million ha right up to 239 million ha.

The most comprehensive survey to date, the Global Assessment of Land Degradation (GLASOD), is now over ten years old. GLASOD estimated that a total of 1964 million ha were degraded, 910 million ha to at least a moderate degree (with significantly reduced productivity) and 305 million ha strongly or extremely so (no

## Human-induced soil degradation in the world




Source: Oldeman *et al.* (1991)

longer suitable for agriculture). Water erosion was the most common problem, affecting almost 1 100 million ha, followed by wind erosion, which affected almost 600 million ha.

The impact of degradation on productivity is also hard to assess. Its seriousness varies widely from site to site over even small distances, and at the same site according to local weather, vegetation and farming techniques. Degradation is a slow process that can be masked by applying additional fertilizer or by changing the crops grown. GLASOD reported in 1991 that almost all farmland in China was degraded, yet between the early 1960s and mid-1990s China tripled her rice production and increased her wheat production sevenfold. Some studies suggest annual average losses in cropland productivity may be quite small, averaging only 0.2 to 0.4 percent a year.

Degradation also has off-site costs, such as the siltation of streambeds and dams, flood damage, loss of fisheries and the eutrophication of lakes and coastal waters. These costs are often greater than on-site costs. However, the off-site effects of degradation are not all negative: losses in one place may result in gains elsewhere, as when soil eroded from uplands boosts productivity in the alluvial plains where it is deposited.

Because it is difficult to quantify, the future progress of land degradation was not taken into account in the projections made for this study. However, some projected or foreseeable trends, driven primarily by economic forces, will tend to reduce its extent and impact:

- About a third of the harvested area in developing countries in 2030 is expected to be irrigated land, which is generally flat, protected by bunds and little affected by

## Principal types of land degradation

- *Sloping land* is particularly prone to water erosion, especially in wet areas where slopes exceed 10 to 30 percent and conservation measures are lacking. In Nepal, for example, some 20 to 50 tonnes of soil per ha are estimated to be eroded each year from fields in the hills and mountains, while up to 200 tonnes per ha per year may be lost in some highly degraded watersheds. Crop yields in these areas fell by 8 to 21 percent in the 25 years to 1995. Around 45 percent of the world's agricultural land has slopes of more than 8 percent, and out of this total 9 percent has very steep slopes of over 30 percent.
- *Desertification*, a term referring to land degradation in arid and semi-arid areas, received a great deal of attention during the 1970s and 1980s, when it was believed that deserts such as the Sahara were spreading irreversibly. Estimates suggested that up to 70 percent of the world's 3.6 billion ha of drylands were degraded. Since then remote sensing has established that desert margins ebb and flow with natural climate changes, while studies on the ground are showing the resilience of crop and livestock systems and the adaptiveness of farmers and herders.
- *Salinization* occurs in irrigated areas, usually when inadequate drainage causes salts to concentrate in the upper soil layers where plants root. It is a problem mainly in the arid and semi-arid zones, where 10 to 50 percent of the irrigated area may be affected. Salinization can cause yield decreases of 10 to 25 percent for many crops and may prevent cropping altogether when it is severe. It is estimated that 3 percent of the world's agricultural land is affected. In East Asia, however, the proportion is 6 percent and in South Asia 8 percent. For the arid and semi-arid tropics as a whole, 12 percent of agricultural land may be affected.
- *Nutrient mining* is also a serious problem. Farmers often use insufficient fertilizer to replace the nitrogen, phosphorus and potassium (NPK) harvested with their crops and lost through leaching, while trace elements, such as iron or boron, may also be deficient. A detailed study of Latin America and the Caribbean found nutrient depletion in all areas and for almost all crops except beans. Net NPK losses in the region in 1993-95 amounted to 54 kg per ha per year. Another study suggested net losses of 49 kg per ha per year in sub-Saharan Africa.

erosion. A quarter of the rainfed land by that time will have slopes of less than 5 degrees, also generally not prone to heavy erosion.

- The shift in livestock production to more intensive systems will take some pressure off dryland pastures. However, in the developing countries this will be partly offset by the encroachment of cropland, which will reduce the area remaining for extensive grazing.
- As people leave rural areas for urban centres, and farming for non-farming occupations, steep slopes and other marginal land will tend to be abandoned and will revert to scrub and forest. This process has already occurred rapidly in some European countries. In Italy, some 1.5 million ha were abandoned in the 1960s, 70 percent of which was sloping land. In some provinces, agricultural land decreased by 20 percent.

Other trends tending to reduce land degradation are likely, but their extent and intensity will depend heavily on the spread of improved agricultural and conservation practices, without which land degradation may worsen in many areas. The main practices and their potential impact are:

- No-till/conservation agriculture (NT/CA), which can maintain year-round soil cover and increase organic matter in soils, thereby reducing water and wind erosion.
- Increased fertilizer consumption and more efficient fertilizer use, which will reduce erosion by increasing root growth and ground cover.
- The use of irrigation, water harvesting, drought-tolerant crops and grazing-tolerant grasses, which will improve crop and vegetation cover and reduce erosion in drylands.
- The cultivation of legumes, which can add nitrogen to soils and improve their stability and texture in mixed crop-livestock farming systems.

## *Irrigation and water resources*

A large share of the world's crops is already produced under irrigation. In 1997-99, irrigated land made up only about one-fifth of the total arable area in developing countries. However, because of higher yields and more frequent crops, it accounted for two-fifths of all crop production and close to three-fifths of cereal production.

This share is expected to increase further in the next three decades. Based on the potential for irrigation, national plans for the sector and the moisture needs of crops, the developing countries as a whole can be expected to expand their irrigated area from 202 million ha in 1997-99 to 242 million ha by 2030. This is a net projection – that is, it is based on the assumption that land lost due, for example, to salinization and water shortages will be compensated by rehabilitation or by the substitution of new areas.

There will be no overall shortage of land or water for irrigation, but serious problems will persist in some countries and regions.

Most of this expansion will occur in land-scarce areas where irrigation is already crucial: South Asia and East Asia, for example, will add 14 million ha each. The Near East and North Africa will also see significant expansion. In land-abundant sub-Saharan Africa and Latin America, where both the need and the potential for irrigation are lower, the increase is expected to be much more modest – 2 million and 4 million ha respectively.

Although the projected expansion is ambitious, it is much less daunting than what has already been achieved. Since the early 1960s, no less than 100 million ha of new irrigated land have been created. The net increase projected for the next three decades is only 40 percent of that. The expected annual growth rate of 0.6 percent is less than a third of the rate achieved over the past 30 years.

The FAO study did not make projections for irrigation in the developed countries, which account for around a quarter of the world's irrigated area. Irrigation in this group of countries grew very rapidly in the 1970s, but by the 1990s the pace of growth had slowed to only 0.3 percent per year.

### Is there enough irrigable land for future needs?

As with land in general, it has been suggested that the world may soon experience shortages of land suitable for irrigation. There is concern, too, that vast areas of presently irrigated land may be severely damaged by salinization. Once again, at global level these fears seem exaggerated, though serious problems may occur at local level.

FAO studies suggest there is still scope for expanding irrigation to meet future needs. However, irrigation potential is difficult to estimate accurately, since it depends on complex data on soils, rainfall and terrain. The figures should therefore be taken only as a rough guide. The total irrigation potential in developing countries is nevertheless estimated at some 402 million ha. Of this around half was in use in 1997-99, leaving an unused potential of 200 million ha. The projected increase by 2030 would take up only 20 percent of this unused potential.

In some regions, however, irrigation will come much closer to its full potential: by 2030, East Asia and the Near East and North Africa will be using three-quarters of their irrigable area, and South Asia (excluding India) almost 90 percent.

## Is there enough water?

Another frequently voiced concern is that much of the world is heading for water shortages. Since agriculture is responsible for about 70 percent of all the water withdrawn for human use, it is feared that this will affect the future of food production. Once again, at global level there seems to be no cause for alarm, but at the level of some localities, countries and regions, serious water shortages appear highly likely to arise.

The assessment of potential irrigated land used for this report already takes into account the limitations imposed by the availability of water. The renewable water resources available in a given area consist of the amount added by rainfall and incoming river flow, minus the amount lost through evapotranspiration. This may vary greatly across regions. For example, in an arid region such as the Near East and North Africa, only 18 percent of rainfall and incoming flows remain after evapotranspiration, whereas in humid East Asia the share is as high as 50 percent.

The water used for irrigation includes, besides that actually transpired by the growing crop, all the water applied to it, which may be considerable in the case of crops that are flooded, such as rice. In addition, there are the losses through leakage and evaporation on the way to the fields, and the water that drains away from the fields without being used by the crop. The ratio between the amount of water actually used for crop growth and the amount withdrawn from water sources is known as water use efficiency.

There are large regional differences in water use efficiency. Generally, efficiency is higher

> The projections for developing countries imply a 14 percent increase in water withdrawals for irrigation by 2030. One in five developing countries will face water shortages.

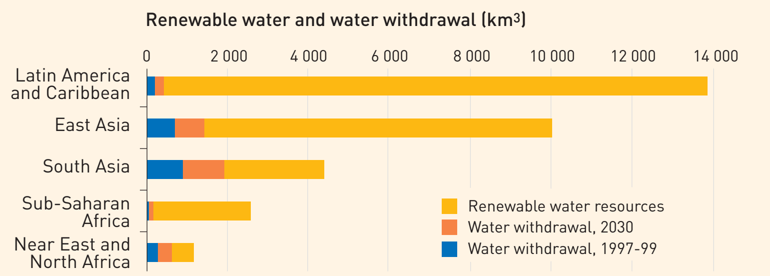
where water availability is lower: in Latin America, for example, it is only 25 percent, compared with 40 percent in the Near East and North Africa and 44 percent in South Asia.

In the developing countries as a whole, only about 7 percent of renewable water resources were withdrawn for irrigation in 1997-99. But because of differences in efficiency and in water availability, some regions were using a much higher proportion than others. In sub-Saharan Africa, where irrigation is less widespread, only 2 percent were used, and in water-rich Latin America a mere 1 percent. In contrast, the figure in South Asia was 36 percent and in the Near East and North Africa no less than 53 percent.

The projections for developing countries imply a 14 percent increase in water withdrawals for irrigation by 2030. Even then, they will be using only 8 percent of their renewable water resources for irrigation. The shares in sub-Saharan Africa and Latin America will remain very small.

Water availability is considered to become a critical issue only when 40 percent or more of

### Irrigation and water resources, 1997-99 to 2030




Source: FAO data and projections

renewable water resources are used for irrigation. This is the level at which countries are forced to make difficult choices between their agricultural and their urban water supply sectors. By 2030 South Asia will be using this level, and the Near East and North Africa no less than 58 percent.

Out of 93 developing countries studied for this report, 10 were already using more than 40 percent in 1997-99 and another 8 were using more than 20 percent — a threshold which can be considered to indicate impending water scarcity. By 2030 two more countries will have crossed this lower threshold and one in five developing countries will be suffering actual or impending water scarcity.

Two countries, Libyan Arab Jamahiriya and Saudi Arabia, are already using more water for irrigation than their annual renewable resources, by drawing on fossil groundwater reserves. Groundwater mining also occurs at local levels in several other countries of the Near East and North Africa, South Asia and East Asia. In large areas of India and China, ground-water levels are falling by 1 to 3 metres per year, causing subsidence in buildings, intrusion of seawater into aquifers and higher pumping costs.

In these countries and areas, policy changes and investments will be needed to improve the efficiency of water use, together with innovations to improve the capture and infiltration of water, such as water harvesting, tree planting and so on.

Growth in wheat and rice yields slowed markedly in the 1990s. Rice yields rose at an average of 2.3 percent per year between 1961 and 1989, but between 1989 and 1999 this figure fell by more than half, to 1.1 percent.

# *Potential for yield growth*

### Growth rates have slowed in the past decade

Most future increases in crop production will be achieved through improved yields. Yield advances have been uneven over the past three decades.

Global cereal yields grew rapidly between 1961 and 1999, averaging 2.1 percent a year. Thanks to the green revolution, they grew even faster in developing countries, at an average rate of 2.5 percent a year. The fastest growth rates were achieved for wheat, rice and maize which, as the world's most important food staples, have been the major focus of international breeding efforts. Yields of the major cash crops, soybean and cotton, also grew rapidly.

At the other end of the scale, yields of millet, sorghum and pulses saw only slow growth. These crops, grown mainly by resource-poor farmers in semi-arid areas, are ones for which international research has not so far come up with varieties that deliver large yield gains under farm conditions. There have been useful incremental gains, however, and farmers' yields are more stable than they used to be, thanks to the introduction of traits such as early maturity.

Overall growth in cereal yields slowed in the 1990s. Maize yields in developing countries maintained their upward momentum, but gains in wheat and rice slowed markedly. Wheat yields grew at an average of 3.8 percent per year between 1961 and 1989, but at only 2 percent a year in 1989 to 1999. For rice the respective rates fell by more than half, from 2.3 percent to 1.1 percent. This largely reflects the slower growth in demand for these products.

### Is projected yield growth realistic?

The slower growth in production projected for the next 30 years means that yields will not need to grow as rapidly as in the past. Growth in wheat yields is projected to slow to 1.1 percent a year in the next 30 years, while rice yields are expected to rise by only 0.9 percent per year.

Nevertheless, increased yields will be required — so is the projected increase feasible? One way of judging is to look at the difference in performance between groups of countries. Some developing countries have attained very high crop yields. In 1997-99, for example, the top performing 10 percent had average wheat yields more than six times higher that those of the worst performing 10 percent and twice as high as the average in the largest producers, China, India and Turkey. For rice the gaps were roughly similar.

National yield differences like these are due to two main sets of causes:

- Some of the differences are due to differing conditions of soil, climate and slope. In Mexico, for example, much of the country is arid or semi-arid and less than a fifth of the land cultivated to maize is suitable for improved hybrid varieties. As a result, the country's maize yield of 2.4 tonnes per ha is not much more than a quarter of the United States average. Yield gaps of this kind, caused by agro-ecological differences, cannot be narrowed.
- Other parts of the yield gap, however, are the result of differences in crop management practices, such as the amount of fertilizer used. These gaps can be narrowed, if it is economic for farmers to do so.

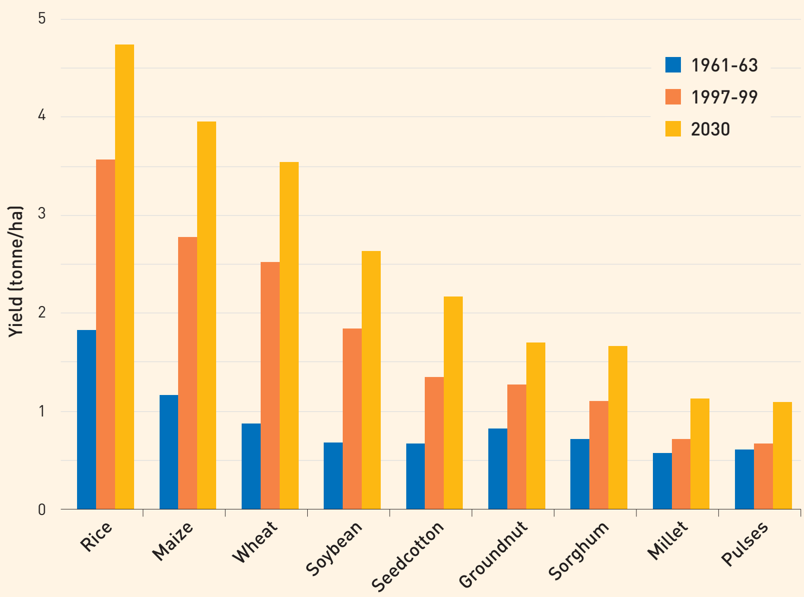
To find out what progress in yields is feasible, it is necessary to distinguish between the gaps that can be narrowed and those that cannot. A detailed FAO/IIASA study based on agro-ecological zones has taken stock of the amount of land in each country that is suitable, in varying degrees, for different crops. Using these data it is possible to work out a national maximum obtainable yield for each crop.

This maximum assumes that high levels of inputs and the best suited crop varieties are used for each area, and that each crop is grown on a range of land quality that reflects the national mix. It is a realistic figure because it is based on technologies already known and does not assume any major breakthroughs in plant breeding. If anything, it is likely to underestimate maximum obtainable yields, because in practice crops will tend to be grown on the land best suited for them.

The maximum obtainable yield can then be compared with actual national average yield to give some idea of the yield gap that can be bridged. The study showed that even a technologically progressive country such as France is not yet close to reaching its maximum obtainable yield. France could obtain an average wheat yield of 8.7 tonnes per ha, rising to 11.6 tonnes per ha on her best wheat land, yet her actual average yield today is only 7.2 tonnes per ha.

Similar yield gaps exist for most countries studied in this way. Only a few countries are

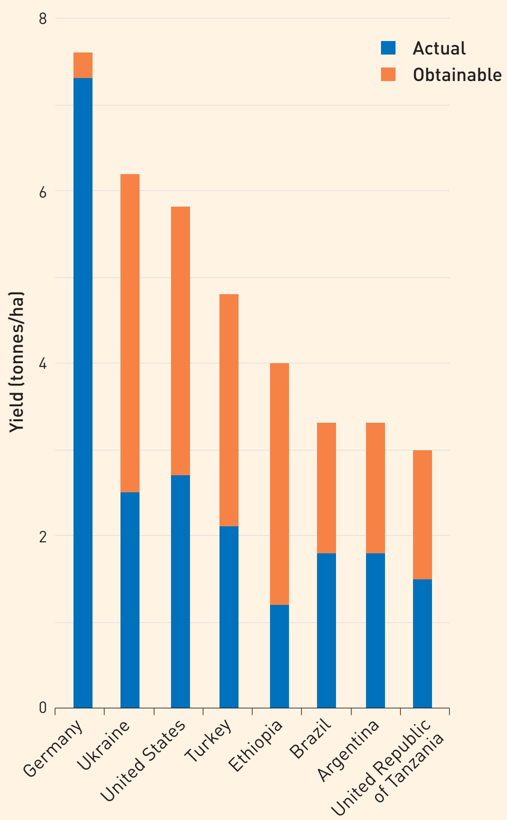
**Crop yields in developing countries, 1961 to 2030**




Source: FAO data and projections

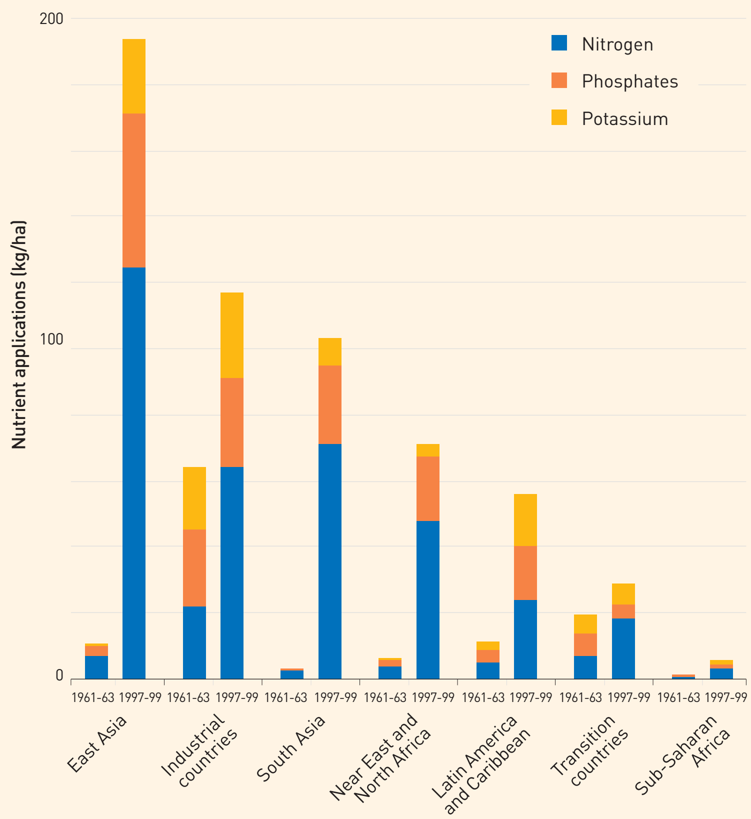
The slower growth in production projected for the next 30 years means that yields will not need to grow as rapidly as in the past. Growth in wheat yields is projected to slow to 1.1 percent and in rice yields to only 0.9 percent per year in developing countries.

## Exploitable yield gaps for wheat: actual versus obtainable yield




Sources: FAO data and Fischer *et al.* (2000)

## Fertilizer use, 1961 to 1999




Source: FAO data

actually achieving their maximum obtainable yield.

When real prices rise, there is every reason to believe that farmers will work to bridge yield gaps. In the past, farmers with good access to technologies, inputs and markets have responded very quickly to higher prices. Argentina, for example, increased her wheat production by no less than 68 percent in just one year (1996), following price rises, although this was done mainly be extending the area under wheat. Where land is scarcer, farmers respond by switching to higher-yielding varieties and increasing their use of other inputs to achieve higher yields.

It seems clear that, even if no more new technologies become available, there is still scope for increasing crop yields in line with requirements. Indeed, if just 11 of the countries that produce wheat, accounting for less than two-fifths of world production, were to bridge only half the gap between their maximum obtainable and their actual yields, then the world's wheat output would increase by almost a quarter.

The outcome of research is always uncertain, particularly if it is strategic or basic in nature. However, if new technologies do become available through the genetic and other research currently under way, this could raise yield ceilings still further, while possibly also reducing the environmental costs of crop production.

Given the right economic incentives, world agriculture will respond to the demand expressed in the marketplace, as it has done in the past. Of course, many poor farmers in marginal environments will be in a position to respond only if they gain access to inputs, markets and technologies, and if the policy environment is favourable. In addition, research must develop the varieties and techniques needed to raise yields in difficult environments. These measures are essential if poor farmers and their families are not to find themselves trapped in poverty.

### Fertilizer: use will continue to rise, but slowly

One of the major ways in which farmers can increase yields is by applying more fertilizer. A third of the increase in world cereal production in the 1970s and 1980s has been attributed to increased fertilizer use. In India this figure rises to half.

The level of fertilizer use varies enormously between regions. North America, Western Europe and East and South Asia accounted for four-fifths of world fertilizer use in 1997-99. The highest rates, averaging 194 kg of nutrients per ha, were applied in East Asia, followed by the industrial countries with 117 kg per ha. At the other end of the scale, farmers in sub-Saharan Africa applied a mere 5 kg per ha.

World fertilizer consumption grew rapidly in the 1960s, 1970s and 1980s, but slowed considerably in the 1990s. The slowdown in industrial countries was due mainly to reduced government support for agriculture and increased concern over the environmental impact. In transition countries, fertilizer consumption also fell rapidly, but for different reasons, namely recession and restructuring. Even in developing countries, the growth rate of fertilizer use in the 1990s was less than half of that seen in earlier decades.

This slower growth is projected to continue. Global fertilizer consumption is expected to grow by an average 1 percent per year over the next three decades (a little faster in developing countries and a little slower in developed). The fastest growth rates are expected in sub-Saharan Africa. Here fertilizer use is currently very low, so fast growth rates can still mean only small absolute increases.

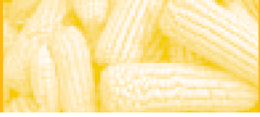
# The role of technology

The development and dissemination of new technology is an important factor determining the future of agriculture. The FAO study investigated three areas that are particularly critical, namely biotechnology, technologies in support of sustainable agriculture, and the directions that should be taken by future research.

## *Biotechnology: issues and prospects*

### What is the current role of biotechnology?

For thousands of years, human beings have been engaged in improving the crops and animals they raise. Over the past 150 years,



Biotechnology promises great benefits for both producers and consumers of agricultural products, but its applications are also associated with potential risks. The risks and benefits may vary substantially from one product to the next and are often perceived differently in different countries. To reap the full potential of biotechnology, appropriate policies must be developed to ensure that the potential risks are accurately diagnosed and, where necessary, avoided.

scientists have assisted their efforts by developing and refining the techniques of selection and breeding. Though considerable progress has been achieved, conventional selection and breeding are time-consuming and bear technical limitations.

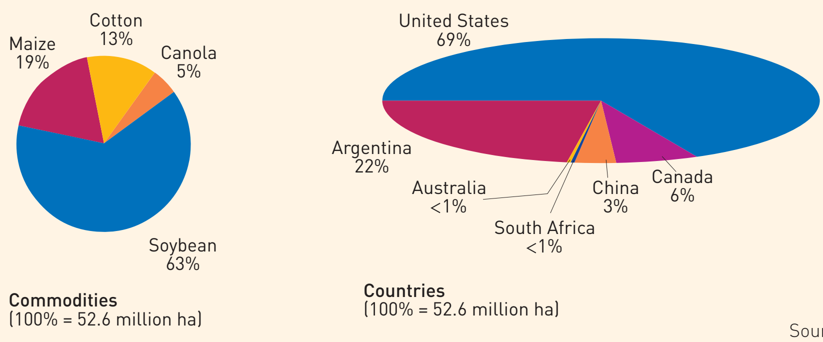
Modern biotechnology has the potential to speed up the development and deployment of improved crops and animals. Marker-assisted selection, for instance, increases the efficiency of conventional plant breeding by allowing rapid, laboratory-based analysis of thousands of individuals without the need to grow plants to maturity in the field. The techniques of tissue culture allow the rapid multiplication of clean planting materials of vegetatively propagated species for distribution to farmers. Genetic engineering or modification — manipulating an organism's genome by introducing or eliminating specific genes — helps transfer desired traits between plants more quickly and accurately than is possible in conventional breeding.

This latter technique promises considerable benefits but has also aroused widespread public concerns. These include ethical misgivings, anxieties about food and environmental safety, and fears about the concentration of economic power and technological dependence, which could deepen the technological divide between developed and developing countries.

The spread of genetically modified (GM) crops has been rapid. Their area increased by a factor of 30 over the 5 years to 2001, when they covered more than 52 million ha. Considerable research to develop more GM varieties is under way in some developing countries. China, for instance, is reported to have the second largest biotechnology research capacity after the United States.

However, the spread so far is geographically very limited. Just four countries account for 99 percent of the global GM crop area: the United States with 35.7 million ha, Argentina with 11.8 million ha, Canada with 3.2 million ha

### Area of GM crops for different commodities and countries




Source: ISAAA (2001)

and China with 1.5 million ha. The number and type of crops and applications involved is also limited: two-thirds of the GM area is planted to herbicide-tolerant crops. All commercially

## Biotechnology: potential benefits, risks and concerns

*Potential benefits*

- Increased productivity, leading to higher incomes for producers and lower prices for consumers.
- Less need for environmentally harmful inputs, particularly insecticides. Scientists have developed maize and cotton varieties incorporating genes from the bacterium *Bacillus thuringensis* (Bt) which produce insecticidal toxins. Virus- and fungus-resistant varieties are in the pipeline for fruits and vegetables, potato and wheat.
- New crop varieties for marginal areas, increasing the sustainability of agriculture in poor farming communities. These varieties will be resistant to drought, waterlogging, soil acidity, salinity or extreme temperatures.
- Reduced dependence on management skills through built-in resistance to pests and diseases.
- Enhanced food security through reduced fluctuations in yields caused by insect invasions, droughts or floods.
- Higher nutritional values through higher protein quality and content as well as increased levels of vitamins and micro-nutrients (e.g. iodine or beta-carotene enriched rice).
- Better health value and digestibility. Scientists are developing varieties of soybean that contain less saturated fat and more sucrose.
- Production of valuable chemicals and pharmaceuticals at lower cost than is possible at present. Products envisaged range from speciality oils and biodegradable plastics to hormones and human antibodies.

*Risks and concerns*

- Products are tailored largely to the needs of large-scale farmers and industrial processing in the developed world, with the result that resource-poor farmers in developing countries will fail to benefit.
- Market concentration and monopoly power in the seed industry, reducing choice and control for farmers, who will pay ever higher prices for seed. One company alone controls over 80 percent of the market for GM cotton and 33 percent for GM soybean.
- Patenting of genes and other materials originating in the developing countries. Private-sector companies are able to appropriate without compensation the products resulting from the breeding efforts of generations of farmers and from research conducted in the public sector.
- Technologies that prevent farmers re-using seed. These require farmers to purchase seed afresh every season and could inhibit adoption by poor farmers. In the worst case, ignorance of this characteristic could result in complete crop failure.
- Food safety. This has received added attention after a potentially allergenic maize variety that was not registered for food use entered the food chain in the United States.
- The environmental impact of GM crops. There is a risk that inserted genes may spread to wild populations, with potentially serious consequences for biodiversity, or contaminate the crops of organic farmers. Genes for herbicide resistance could encourage the overuse of herbicides, while those for insect resistance could generate resistance in insects, forcing the use of more toxic products to kill them.

grown GM crops are currently either non-food crops (cotton) or are heavily used in animal feeds (soybean and maize).

### Why do we need modern biotechnology?

Globally, agricultural production could probably meet expected demand over the period to 2030 even without major advances in biotechnology. However, biotechnology could be a major tool in the fight against hunger and poverty, especially in developing countries. Because it may deliver solutions where conventional breeding approaches have failed, it could greatly assist the development of crop varieties able to thrive in the difficult environments where many of the world's poor live and farm. Some promising results have already been achieved in the development of varieties with complex traits such as resistance or tolerance to drought, soil salinity, insect pests and diseases, helping to reduce crop failures. Several applications allow resource-poor farmers to reduce their use of purchased inputs such as pesticides or fertilizers, with benefits to the environment and human health as well as farmers' incomes.

Most biotechnology is generated and controlled by large private-sector companies, which have so far mainly targeted the commercial farmers who can afford their products. Nevertheless, there is some public-sector work directed towards the needs of resource-poor farmers. In addition, most of the technologies and intermediate products developed through private-sector research could be adapted to solve priority problems in the developing countries. If the poor of these countries are to reap this potential, national and international action is needed to foster private-public partnerships that will promote access to these technologies at affordable prices. This is the main policy challenge for the future.

### What policies are needed to harness the potential of biotechnology for the poor?

In the case of GM crops, most of the commercial applications developed so far are directed towards reducing production costs, not towards meeting the needs expressed by consumers. The perception of the expected benefits and potential risks of such crops, and of biotechnology as a whole, differ among regions, countries, interest groups and individuals. The urban and landless poor in developing countries need

#### Bt cotton in China: a success story

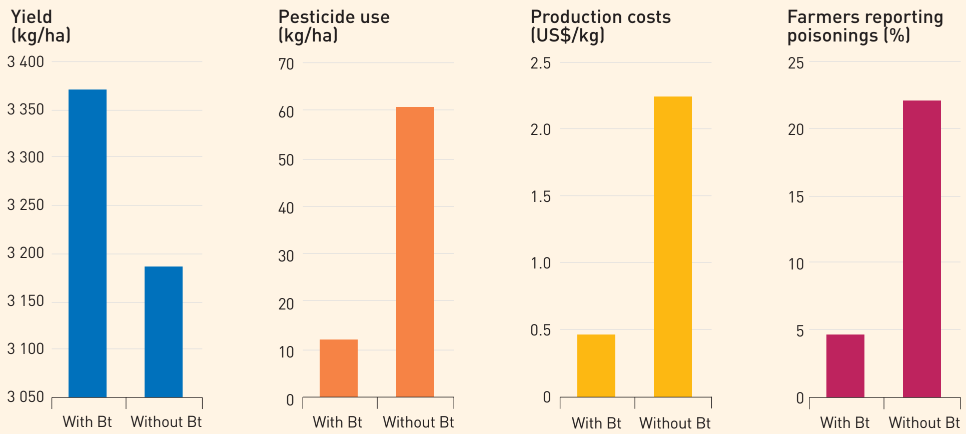
One of the most impressive successes in agricultural biotechnology is China's experience with Bt cotton.

Following research by various public- and private-sector partners, Bt cotton was released to the country's farmers in 1997. It quickly became very popular, with the area devoted to it expanding from 2000 ha in the first year to 70 000 ha in 2000. The reasons for this popularity were mainly economic, but there were important environmental and human health benefits too.

In general, cotton is very susceptible to pests and normally requires many applications of insecticide, which are expensive, require a great deal of extra labour, and often cause health problems in farm workers. Farmers using the new Bt variety needed over 80 percent less insecticide than those using non-Bt varieties and only a third as many applications. They were able to cut both their labour and other input costs. Their yields were also higher: 3.37 tonnes per ha as opposed to 3.18 tonnes with non-Bt cotton. The overall cost of producing a kilogramme of cotton was 28 percent lower.

There were positive effects on biodiversity, with farmers and government extension agents reporting a greater variety of insects and more beneficial species in fields with Bt cotton. In addition there were considerable health benefits for the farmers: only 5 percent of Bt cotton growers reported poisonings, against 22 per cent of growers of non-Bt cotton. The overall economic benefits of Bt cotton were assessed at US$334 million per year in 1999.

### Effects of Bt cotton in China




Source: Huang *et al.* (2002)

cheaper food. In contrast, for consumers in developed countries, where food is plentiful, the health and environmental concerns associated with biotechnology outweigh the possible cost savings. These consumers will be more inclined to accept the new products if they can be assured of their safety through appropriate regulatory frameworks.

Greater and better targeted investments in GM research for developing countries will be needed to ensure that the farmers of these countries have access to the resulting new crop varieties. The focus should shift from pesticide-tolerant crops towards the characteristics that matter to resource-poor farmers: improved resistance or tolerance to drought, waterlogging, salinity and extreme temperatures; improved resistance to pests and diseases; better nutritional values; and higher yields. Such a shift could be based on new private-public partnerships, exploiting the greater efficiency of private-sector research but under the guidance of public-sector donors. Research funds could be made available on the basis of public tenders.

## Further change is on the horizon

The rapid progress made in both generating and extending new biotechnology applications, together with the uncertain public response to these applications, make it difficult to predict the long-term prospects for these technologies, including their impact on future production. However, developments in the short term — the next 3 years or so — are somewhat easier to foresee.

The success of Bt cotton in China has paved the way for further expansion of GM crops in this country, which has considerable potential for GM products. China is a major producer of soybean, maize and tobacco — all crops for which GM traits have been developed elsewhere. Wide-scale adoption of GM technology in China could well provide the impetus for other developing countries to follow suit.

While the adoption rates for GM technologies in developing countries are likely to rise, they are expected to slow in the developed world. This mainly reflects the impressive growth of the past, which limits the remaining potential. GM soybean, for instance, already accounts for two-thirds of the soybean area worldwide and for an even larger share of the area in developed countries. As the global area of such crops expands, other, more sophisticated biotechnology applications may gain importance. Examples include GM-based nutraceuticals or cosmetic applications. As these new applications are likely to produce a broader range of benefits than "merely" cheaper foods and feeds, consumers in the developed countries may become more inclined to accept them.

## *Towards sustainable agriculture*

Given a conducive policy environment, the next three decades should see the spread of farming methods that reduce environmental damage while maintaining or even increasing production. In some cases these technologies will also reduce the costs of production.

### No-till/conservation agriculture

The negative impact that soil tillage can have on soil biological processes and hence on productivity has been increasingly recognized. In response, no-till or conservation agriculture (NT/CA) has been developed. This form of agriculture can maintain and improve crop yields, providing greater resilience against drought and other stresses.

Like organic farming, NT/CA sustains biodiversity and saves on the use of resources. However, unlike organic farming, it can be combined with synthetic inputs and GM crops. It involves three principal elements:

- Minimal disturbance of the soil. No tillage occurs and crops are planted directly through the soil cover. Besides reducing the loss of nutrients to the atmosphere, this sustains soil structure and ecology.
- Maintenance of a permanent cover of live or dead plant material. This protects the soil against erosion and compaction by rain and inhibits the growth of weeds.
- Crop rotation. Different crops are planted over several seasons so as to avoid the buildup of pests and diseases and to optimize the use of nutrients.

NT/CA can raise crop yields by 20 to 50 percent. Yields are less variable from year to year, while labour and fuel costs are lower. Once demonstrated to farmers at a given location, NT/CA tends to spread spontaneously over a larger area. The main obstacles to its spread are the complexity of managing crop rotation, the transitional costs of switching to new practices and, to a certain extent, the conservatism of agricultural extension services. Retraining, sometimes combined with increased financial incentives, may be needed to speed the pace of adoption.

### Integrated pest management

Pesticides involve a range of hazards in their production, distribution and application. When used conventionally, they can eliminate natural predators as well as target pests, and generate resistance in pests. They may also pollute water and soil resources and cause a range of health problems to operators and their families.

Integrated pest management (IPM) aims to minimize the amount of pesticides applied by using other control methods more effectively. Pest incidence is monitored, and action is taken only when damage exceeds tolerable limits. The other technologies and methods used include pest-resistant varieties, bio-insecticides and traps, and the management of crop rotations, fertilizer use and irrigation in such a way as to minimize pests. Chemical pesticides, if they are used at all, are chosen for minimum toxicity and applied in carefully calculated ways.

Many countries have successfully introduced IPM and have experienced increased production accompanied by lower financial, environmental and human health costs as a result. Again, extension systems and policy frameworks in many countries have tended to favour the use of pesticides. These must be reformed if IPM is to spread faster in future.

### Integrated plant nutrient systems

All crop production uses up plant nutrients in the soil. Conventional fertilizers usually replace only a few key nutrients, while others continue

No-till/conservation agriculture can raise crop yields by 20 to 50 percent. Yields are more stable, resilience against drought improves and labour and fuel costs are lower, but management is more complex.

to be depleted. Many resource-poor farmers cannot afford these fertilizers, resulting in soil mining. In other cases there is overuse, leading to the pollution of soils and water resources.

An integrated plant nutrient system is one in which practitioners aim to optimize the use of nutrients through a range of practices that include the recycling of vegetable and animal wastes and the use of legumes to fix atmospheric nitrogen. External nutrients are used judiciously, in ways that minimize costs and reduce pollution. Managing the use of fertilizers precisely can increase their efficiency by 10 to 30 percent.

### The promise of organic agriculture

Organic agriculture is a set of practices in which the use of external inputs is minimized. Synthetic pesticides, chemical fertilizers, synthetic preservatives, pharmaceuticals, GM organisms, sewage sludge and irradiation are all excluded.

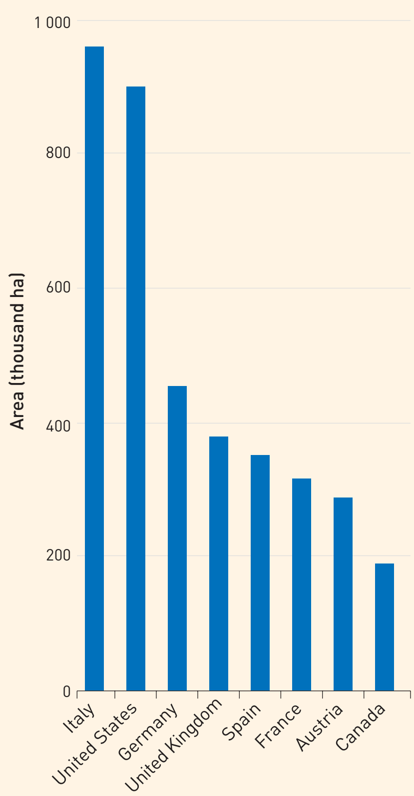
Interest in organic agriculture has been boosted by public concerns over pollution, food safety and human and animal health, as well as by the value set on nature and the countryside. Consumers in developed countries have shown themselves willing to pay price premiums of 10 to 40 percent for organic produce, while government subsidies have helped to make organic agriculture economically viable.

As a result, organic agriculture has expanded rapidly in Western countries. Between 1995 and 2000, the total area of organic land in Europe and the United States tripled, albeit from a very low base.

In 2001, some 15.8 million ha were under certified organic agriculture globally. Almost half of this was in Oceania, just under a quarter in Europe and a fifth in Latin America. About two-thirds of the area is organic grassland. As a percentage of total agricultural land, organic agriculture is still modest — an average of 2 percent in Europe. However, many European countries have ambitious targets for expansion, with the result that Western Europe may have around a quarter of its total agricultural land under organic management by 2030.

With a number of large supermarket chains now involved, the market for organic foods is booming and potential demand far outstrips supply. In many industrial countries, sales are growing at 15 to 30 percent a year. The total market in 2000 was estimated at almost US$20 billion — still less than 2 percent of total retail food sales in industrial countries but a sizeable increase over the value a decade ago.

**Land area under organic management**




Source: Willer and Yussefi (2002)

Demand is expected to continue to grow, perhaps even faster than the 20 percent or so achieved in recent years. The supply shortfall offers opportunities for developing countries to fill the gap, especially with out-of-season produce.

In industrial countries, organic agriculture is based on clearly defined methods enforced by inspection and certification bodies. Most developing countries, in contrast, do not yet have their own organic standards and certification systems. In these countries, organic agriculture may in fact be more widespread than in the developed world but is practised of necessity, since the majority of farmers are unable to afford or cannot obtain modern inputs. Most organic crops for local consumption are sold at the same price as other produce. However, many developing countries are now producing organic commodities in commercial quantities for export to developed country markets. These exports can be expected to increase in the coming years.

Organic agriculture offers many environmental benefits. Agrochemicals can pollute groundwater, disrupt key ecological processes such as pollination, harm beneficial micro-organisms and cause health hazards to farm workers. Modern monoculture using synthetic inputs often harms biodiversity at the genetic, species and ecosystem levels. The external costs of conventional agriculture can be substantial.

In contrast, organic agriculture sets out to enhance biodiversity and restore the natural ecological balance. It encourages both spatial and temporal biodiversity through intercropping and crop rotations, conserves soil and water resources and builds soil organic matter and biological processes. Pests and diseases are kept at bay by crop associations, symbiotic combinations and other non-chemical methods. Water pollution is reduced or eliminated.

Although yields are often 10 to 30 percent lower than in conventional farming, organic agriculture can give excellent profits. In industrial countries, consumer premiums, government subsidies and agritourism boost incomes from organic farms. In developing countries, well-designed organic systems can give better yields, profits and returns on labour than traditional systems. In Madagascar, hundreds of farmers have found they can increase their rice yields fourfold, to as much as 8 tonnes per ha, by using improved organic management practices. In the Philippines, organic rice yields of over 6 tonnes per ha have been recorded. Experiences of organic production in low-potential areas such as Northern Potosí (Bolivia), Wardha (India) and Kitale (Kenya) have shown that yields can be doubled or tripled over those obtained using traditional practices.

Organic agriculture also has social benefits. It uses cheap, locally available materials and usually requires more labour, thereby increasing employment opportunities. This is a considerable advantage in areas where, or at times when, there is a labour surplus. By rehabilitating traditional practices and foods, organic agriculture can promote social cohesion.

Certain policy measures are essential if the progress of organic agriculture is to continue. Support for agriculture is increasingly shifting from production goals to environmental and social goals, a trend that could favour organic agriculture. Agreed international standards and accreditation are needed to remove obstacles to trade. Extensionists often promote the idea that synthetic inputs are best and may need training in organic methods. Research to solve technical problems needs to be stepped up. Secure land tenure is essential if farmers are to undertake the long process of conversion to organic standards. If these measures are put in place, organic agriculture could become a realistic alternative to traditional agriculture over the next 30 years, at least at the local level.

Locally, organic agriculture could become a realistic alternative to traditional agriculture over the next 30 years.

# Directions for research

## Strengths and weaknesses of past research

The green revolution has played a key role in the major improvements in food supply over the past 40 years. The yields of rice, wheat and maize in developing countries have risen by 100 to 200 percent since the late 1960s.

Yield gains were the primary focus of the green revolution. Breeding and selection led to the development of improved crop varieties, but greatly increased use of inputs, such as fertilizer, pesticides and irrigation water, were needed to get the best out of these varieties. The green revolution achieved its aims not just through research but through a package of methods and inputs pushed by national and international agencies, extension services and private-sector companies.

But this first green revolution had its shortcomings:

- It was heavily geared to the world's three leading cereal crops, which were suited to its emphasis on maximizing yields. Other crops, including many that are important in sub-Saharan African, such as cassava, millet, sorghum, banana, groundnut and sweet potato, needed a different approach.
- It was suited only to areas with good soils and water supplies, and largely neglected the more marginal rainfed areas with problem soils and uncertain rainfall.
- It relied on farmers being able to afford inputs, and did little for poor smallholders with insufficient funds or access to credit.
- Finally, it largely ignored the possible environmental consequences of high input use, such as the pollution of water and soils with nitrates and pesticides.

## Needed: a doubly green revolution

A second, doubly green revolution is now needed. Its goals, as with the first, must include increased productivity. But it must also aim for sustainability — minimizing or reducing the environmental impacts of agriculture — and for equity — making sure that the benefits of research spread to the poor and to marginal areas.

Productivity must increase on all the lands where farmers seek a living, not just in the well-endowed areas. More varieties and packages for crops other than the three key cereals need to be developed. And the potential of resource-conserving approaches such as IPM needs to be fully realized.

Research for the new green revolution needs to be genuinely multidisciplinary. It must cover not only the biological sciences, including genetic engineering alongside conventional breeding and agronomy, but also the socio-economic context in which farming occurs. And it must focus not only on crops and animals but on the ecology of all life forms within the farming system. Areas of special importance in ecology include the interactions of plants, pests and predators, and competition between crops and weeds. Plant rooting systems and the availability of nutrients and soil organic matter also deserve more emphasis.

Above all, priority must be given to the needs of the poor in the marginal, rainfed areas bypassed by the first green revolution. Scientists must engage in an interactive dialogue with all the stakeholders in the research process, especially farmers but also policy makers, civic society and the general public.

Research towards this second green revolution is already under way in some locations. Its first fruits have shown that it can be successful,

### Key questions for researchers:

- Will the technology lead to higher productivity across all farms, soil types and regions, not just well-endowed ones?
- How will the technology affect the seasonal and annual stability of production?
- How will the technology affect the ecosystem and the sustainability of farming?
- Who will be the winners and losers from the technology — and how will it affect the poor?

especially when farmers participate actively in the design and testing of new technology. However, the research effort needs to be greatly strengthened and the challenge of scaling up the results of research has yet to be adequately addressed.

# Livestock: intensification and its risks

Meat and dairy products will provide an increasing share of the human diet, with poultry expanding fastest. Future demand can be met, but the negative environmental consequences of increased production must be addressed.

Livestock production currently accounts for some 40 percent of the gross value of world agricultural production, and its share is rising. It is the world's largest user of agricultural land, directly as pasture and indirectly through the production of fodder crops and other feedstuffs. In 1999 some 3 460 million ha were under permanent pasture — more than twice the area under arable and permanent crops.

Livestock provide not only meat, but dairy products, eggs, wool, hides and other goods. They can be closely integrated into mixed farming systems as consumers of crop by-products and sources of organic fertilizer, while larger animals also provide power for ploughing and transport.

Livestock have a considerable impact on the environment. Growth of the livestock sector has been a major factor contributing to deforestation in some countries, particularly in Latin America. Overstocking land with grazing animals can cause soil erosion, desertification and the loss of plant biodiversity. Public health hazards are increasing with the intensification of urban and peri-urban livestock production. Wastes from industrial livestock facilities can pollute water supplies and livestock are major sources of greenhouse gases.

### Diets shift from staples to meat

The past three decades have seen major shifts in human diets. The share of animal products has risen, while that of cereals and other staples has fallen. And within the meat sector there has been a dramatic rise in the share of poultry and, to a smaller extent, pig meat. These trends are likely to continue over the next 30 years, though in less dramatic form.

As incomes rise, people generally prefer to spend a higher share of their food budget on animal protein, so meat and dairy consumption tends to grow faster than that of food crops. As a result, the past three decades have seen buoyant growth in the consumption of livestock products, especially in newly industrializing countries.

Annual meat consumption per person in developing countries as a whole more than doubled between 1964-66 and 1997-99, from only 10.2 kg per year to 25.5 kg — a rise of 2.8 percent a year. The growth was much less (from 10 kg to 15.5 kg) if China and Brazil are excluded. The rise was particularly rapid for

Livestock are the world's largest user of agricultural land: in 1999 some 3 460 million ha were under permanent pasture — more than twice the area under arable and permanent crops.

poultry, where consumption per person grew more than fivefold. Pig meat consumption also rose strongly, though most of this rise was concentrated in China.

The overall rise was unevenly spread: in China meat consumption has quadrupled over the past two decades, whereas in sub-Saharan Africa it has remained stagnant, at under 10 kg per person. Differences in meat consumption between countries can be substantial because of differences in meat availability or in dietary habits, including the role of fish in the provision of total animal protein. For example, meat consumption in Mongolia is as high as 79 kg per person, but overall diets are grossly insufficient and undernourishment is widespread. Meat consumption in the United States and Japan, two countries of comparable living standards, is 120 kg and 42 kg per person respectively, but their per capita consumption of fish and seafood is 20 kg and 66 kg.

### Future growth may slow

Looking towards 2030, the trend towards increased consumption of livestock products will continue in the developing countries. However, future growth in consumption of both meat and milk may not be as rapid as in the recent past, given the reduced scope for further increases in major consuming countries.

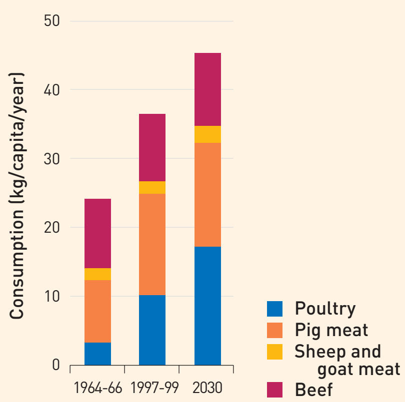
In developed countries the scope for increased demand is limited. Population growth is slow and the consumption of livestock products is already very high. At the same time health and food safety concerns, focused on animal fats and the emergence of new diseases such as bovine spongiform encephalopathy (BSE) and variant Creutzfeldt-Jakob disease (vCJD), are holding back demand for meat. Total meat consumption in the industrial countries has risen by only 1.3 percent a year over the past ten years.

In developing countries the demand for meat has grown rapidly over the past 20 years, at 5.6 percent a year. Over the next two decades this rate is projected to slow by half. Part of this slowdown will be due to slower population growth and part to the same factor that is at work in developed countries: the countries that have dominated past increases, such as China and Brazil, have now reached fairly high levels of consumption and so have less scope for further rises. In India, which will rival China as the most populous country in the world in the 2040s, the growth of meat consumption may be limited by cultural factors in addition to the continued prevalence of low incomes, since many of India's people are likely to remain vegetarians. However, India's consumption of dairy products is projected to continue to rise rapidly, building on the successes achieved over the past 30 years. In sub-Saharan Africa, slow economic growth will limit increases in both meat and dairy consumption.

The rise in poultry consumption looks set to continue, though a little more slowly than in the

Annual meat consumption per person in developing countries more than doubled between 1964-66 and 1997-99, but there were substantial differences between countries.

**World average meat consumption per person, 1964-66 to 2030**




Source: FAO data and projections

past, from a global average of 10.2 kg per person in 1997-99 to 17.2 kg by 2030. Much smaller increases in world per capita consumption are foreseen for both pig meat and beef.

## Bigger herds, fatter animals

Given the slower growth of demand, livestock production will also grow more slowly than in the past. Moreover, increased efficiency in the sector could mean that extra demand can be met by a smaller growth in the number of animals. In absolute terms, however, the number of animals will still need to rise considerably. The projections show an extra 360 million cattle and buffaloes, 560 million extra sheep and goats, and 190 million extra pigs by 2030 — rises of 24, 32 and 22 percent respectively.

However, it should prove possible to meet much of the extra demand by increasing productivity rather than animal numbers. There is ample scope for this in developing countries, particularly with regard to cattle productivity. In 1997-99 the yield of beef per animal in developing countries was 163 kg compared with 284 kg in industrialized countries, while average milk yields were 1.1 and 5.9 tonnes per year per cow respectively.

Selection and breeding, together with improved feeding regimes, could lead to faster fattening and larger animals. The average carcass weight for cattle, for example, has already risen from 174 kg in 1967-69 to 198 kg 30 years later; by 2030 it could reach 211 kg. The offtake rate should also rise, as animals will be ready for market earlier.

## The shift to more intensive production will continue

A continued shift in production methods can be expected, away from extensive grazing systems and towards more intensive and industrial methods.

Grazing on pasture still provides 30 percent of total beef production, but its market share is declining. In South and Central America, grazing is often pursued on land cleared from rainforests, where it fuels soil degradation and further deforestation. In semi-arid environments, overstocking during dry periods frequently brings risks of desertification, although it has been shown that pastures do recover quickly if stock are taken off and good rains return.

Mixed farming, in which livestock provide manure and draught power in addition to milk and meat, still predominates for cattle. As populations and economies grow, these multipurpose types of farming will tend to give way to more specialized enterprises.

> In recent years, livestock production from industrial enterprises has grown twice as fast as that from more traditional mixed farming systems and more than six times faster than from grazing systems.

Where land is scarce, more intensive systems of stall-feeding emerge. In these systems, fodder is cut and brought to the stabled animals, leading to less soil damage and faster fattening. This trend too can be expected to continue and accelerate.

More industrial and commercial forms of production will gradually increase in both number and scale. These intensive enterprises will make use of improved genetic material, sophisticated feeding systems, animal health prophylactics and highly skilled management. In recent years, industrial livestock production has grown at twice the rate of more traditional mixed farming systems and at more than six times the rate of production based on grazing. At the turn of the century industrial enterprises accounted for 74 percent of the world's total poultry production, 68 percent of its eggs and 40 percent of its pig meat.

Current trends towards industrial and commercial production could pose a threat to the estimated 675 million rural poor whose livelihoods depend on livestock. Without special measures, the poor will find it harder to compete and may become marginalized, descending into still deeper poverty. Yet, if the policy environment is right, the future growth in demand for livestock products could provide an opportunity for poor families to generate additional income and employment. Because of its low capital costs, and its ability to make use of wastes and communally owned resources, livestock production allows poor families to accumulate assets and diversify risks, besides serving as a valuable source of products that improve both cash income and family nutrition. Policy measures that will help the poor enter and stay in the expanding market for livestock products include the provision of low-cost credit, technical support — especially in animal health and quality matters — and better access to markets through improved infrastructure and institutions.

The growing demand for livestock products offers an opportunity for the 675 million rural poor who depend on livestock to improve their livelihoods.

## Environment and health problems

Commercial and industrial systems bring their own environmental problems, which differ from those of extensive systems. The concentration of animals, particularly in urban areas, leads to problems of waste disposal and pollution. Higher animal densities and transport to more distant markets often involve the frustration of natural animal behaviour, bringing distress. Increased trade in livestock products and feedstuffs brings greater risk of disease transmission, both within and across national boundaries. This applies both to diseases limited to livestock, such as foot-and-mouth, and to those that may affect both livestock and humans, such as avian flu.

Infectious animal diseases such as rinderpest or foot-and-mouth are still major threats in developing countries. Increased trade can spread them more widely, even to developed countries. Eradication programmes are shifting away from countrywide control strategies towards more focused and flexible approaches, with the aim of improving the cost-effectiveness of control.

In humid and subhumid Africa, trypanosomiasis (sleeping sickness) poses an enormous obstacle to human health and cattle production. Trypanocidal drugs, aerial spraying, adhesive insecticides, impregnated screens and traps and the use of sterile insects offer the promise of recovering infested areas for mixed farming. This will improve human health and nutrition, as well as livestock and crop production.

Industrial livestock enterprises use antibiotics on a large scale. This practice has contributed to antibiotic resistance among bacteria, including those that cause human diseases. Resistance to antihelminthics is emerging among livestock parasites. Industrial enterprises also use growth hormones to speed fattening and increase the efficiency of conversion of feed into meat. Public concern has led to restrictions on use in the EU, although negative impacts on human health have not been proved.

Increased trade in livestock products and feedstuffs brings greater risk of disease transmission, both within and across national boundaries.

## Promises and risks of biotechnology

Biotechnology will have a profound effect on the future of livestock production. Some biotechnology applications are already in use, while others are still under research.

Artificial insemination, already routine in developed countries, will spread in developing countries. It can greatly increase the efficiency of animal breeding.

The cloning of mammalian cells could also boost productivity and output, particularly for dairy cattle in developed countries. However, the problems with this technology must be solved: currently only 2 to 5 percent of attempts to clone animals actually succeed, and cloned animals often develop serious health problems.

Rapid advances in understanding the genetic make-up of animals will provide additional potential for productivity growth. Genes that are important for economic performance, such as those for disease resistance or for adaptation to adverse environmental conditions, can be identified and transferred into more productive backgrounds, either through marker-assisted selection or through GM. These applications could prove especially useful in developing countries.

GM animals have so far been used mainly for biomedical research or the production of human proteins. GM cattle, sheep, pigs and chickens are now being produced experimentally, with the intention of eventual use for human consumption. Despite signs of consumer resistance to GM foods for direct human consumption, products from livestock fed with GM maize, soybean and cottonseed cake are already on the market.

The main risks of genetic modification arise from potential side-effects on the environment or on human health. These risks are particularly pronounced if there is insufficient testing before widespread release. There is also the risk of narrowing the genetic base and concentrating its control in the hands of large multinational corporations. Almost 5 000 breeds and strains of farm animals have been identified. Some 600 of these face extinction and many more may be at risk if the genetic resource base is not conserved.

### Cereals used as feed: threat or safety valve?

Globally, some 660 million tonnes of cereals are used as livestock feed each year. This represents just over a third of total world cereal use.

This use of cereals is often perceived as a threat to food security, since it appears to remove from the market supplies of essential foods that would otherwise be available to poor countries and families, thereby raising food prices. However, it is important to realize that if these cereals were not used as feed, they would probably not be produced at all, so would not be available as food in any case.

The use of cereals as feed may actually help food security. The commercial livestock sector is responsive to the price of cereals: whenever shortages raise prices, livestock producers tend to switch to other feeds, releasing more cereals for food use. As a result, the food use of cereals may contract less than it would have done otherwise. In short, the use of cereals as feed serves as a buffer, protecting food intakes from supply variations.

In recent years the use of cereals as feeds has declined in relative terms. One reason is the growing use of cereal substitutes in livestock feed rations. Another is the collapse of the livestock sector in the transition countries, which led to reduced demand for feed in these countries. A third factor is the shift of meat production to poultry, which are much more efficient converters of feed than other livestock species.

Over the next three decades growth in the use of cereals as feeds is projected to be higher than in the recent past, accounting for half the additional use of cereals. This is partly because the transition countries will resume their agricultural growth and partly because the shift into poultry is expected to be slower.

## India's white revolution

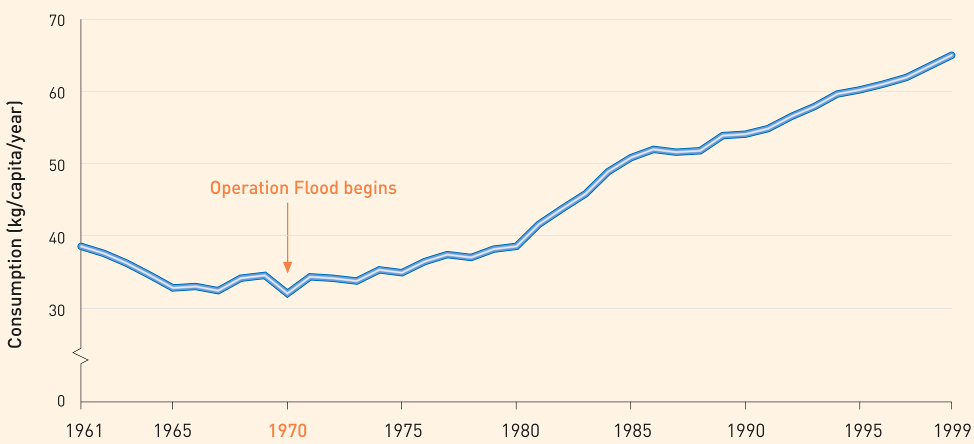
Launched in 1970, India's Operation Flood has had an impact comparable to the green revolution on rural incomes and food prices. It has turned India's dairy sector around.

Milk consumption per person had been falling, from 39 kg in 1961 to only 32 kg in 1970. Since then it has risen rapidly, reaching 65 kg per person by 1999. Prices of milk to consumers have fallen, while the incomes of Indian dairy farmers have quadrupled.

Operation Flood was created and led by national institutions and supported by the World Bank and the EU. It began with the selling of food aid, the profits from which were used to strengthen dairy cooperatives and smallholder management. Local cows were crossed with specialized dairy breeds to produce a robust yet productive animal adapted to local conditions. Artificial insemination, veterinary services and other inputs were provided, leading to improved milk yields, longer lactation periods and shorter calving intervals. Operation Flood also focused on improving smallholders' access to markets, opening new marketing channels for remote rural producers and thereby reducing both the need for middlemen and the seasonal variations in milk prices that had previously discouraged producers. Milk collection and chilling centres were established, minimizing waste due to spoilage.

Operation Flood has greatly helped India's rural poor. Three-fifths of the operation's 9 million producers are marginal or small-scale farmers or landless people. The impact on women has been particularly marked. Six thousand village-level Women's Dairy Cooperative Societies have been formed. As women have shifted into dairy production, they have freed up employment opportunities, especially on construction sites where they traditionally worked as unskilled labourers. Money earned from the dairy industry has been used to keep children in school. Older female siblings, relieved of the need to stay at home to care for younger children, now have the option of continuing their education.

## Milk consumption in India, 1961 to 1999




Source: FAO data

# Towards sustainable forestry

Globally, deforestation is slowing down. At the same time, the productivity of timber processing is improving, helping to meet the rising demand for wood. However, hotspots of deforestation are likely to persist, undermining biodiversity and the provision of other economic and environmental benefits from forests. The major challenge will be to improve the sustainable management of forests and to ensure equitable distribution of the benefits of forest use.

Forests and other wooded areas perform key economic and ecological functions. Not only do they provide goods and livelihoods but they also protect soils, regulate water flow and retain carbon that might otherwise add to greenhouse gases. Forests also shelter much of the world's terrestrial biodiversity.

In 2000 the world had some 3 870 million ha of forests, covering 30 percent of its land area. Tropical and subtropical forests comprised 56 percent of the forest area, while temperate and boreal forests accounted for the rest. Natural forests were estimated to constitute about 95 percent of global forests, while plantation forests constitute around 5 percent.

Altogether, 51 percent of global forests are available for wood supply. Some 12 percent of forests are in legally protected areas, while the remaining 37 percent are physically inaccessible or otherwise uneconomic for wood supply.

More than half the wood biomass consumed globally is burned as fuel. Most fuel consumption occurs in developing countries, where wood is often the primary source of energy. Asia and Africa together consume more than three-quarters of global fuelwood, mostly in domestic cooking, though cottage industries such as food drying and brick-making also consume large volumes in some countries.

Industrial roundwood currently comprises about 45 percent of global wood production. Interestingly, annual per capita wood consumption in developed and developing countries is about equal, at just over 0.5 $m^3$ per person. However, almost 80 percent of wood consumption in developed countries is in the form of industrial wood products, while in developing countries well over 80 percent is burned as fuel.

World trade in wood does not lend itself to easy generalizations. Production and trading patterns are highly diverse, both regionally and among different commodities. In 2000, temperate and boreal zones accounted for 80 percent of world industrial roundwood production and 83 percent of roundwood exports. However, these zones also accounted for 85 percent of wood product consumption. Also in 2000, tropical areas were net exporters of wood products to the tune of around 59 million $m^3$ per year, though this was less than 4 percent of global consumption.

## From deforestation to reforestation

It is often suggested that the world faces a deforestation crisis. Certainly, in some countries the picture is alarming and a rapid decline in forest area continues. During the 1990s, the total forest area shrank by a net 9.4 million ha each year, an area about three times the size of Belgium. Over the decade as a whole, the area lost was bigger than Nigeria.

It is true that if current deforestation rates are projected into the future, then by 2030 natural tropical forests will shrink by a further 24 percent. However, deforestation was slower in the 1990s than in the 1980s and will probably continue to slow during the first decades of the new century.

The picture varies considerably from region to region. Deforestation was most rapid in the tropics, where 1990s losses averaged 12.3 million ha per year. Africa lost 5.3 million ha a year and South America 3.7 million ha. In contrast, annual losses in Asia were only 0.4 million ha, while non-tropical areas actually added 2.9 million ha a year to their forests.

Net deforestation is now slowing in many developing countries. For more than a decade, countries such as China, India, Libyan Arab Jamahiriya, Turkey and Uruguay have planted more forest than they have cut. By 2000, other countries, such as Algeria, Bangladesh, Gambia and Viet Nam, had also begun accumulating net forest area. Some countries, for example Thailand and the Philippines, have imposed complete bans on natural forest harvesting, although these may not last and are difficult to implement. In many developing countries, population growth and dependence on agriculture will lead to continuing loss of forests. However, overall rates of deforestation will slow further in the coming decades. Social, economic and political trends will contribute to the slowdown in deforestation in developing countries. Urbanization will reduce the need to open up new frontier land to create livelihoods. It will also drive a shift from wood to fossil fuels and electricity.

During the 1990s, the area of tropical forests shrank by a net 12.3 million ha each year, but non-tropical areas actually added 2.9 million ha a year to their forests.

This slowing is an integral part of the cycle of economic development. In the initial stages of development, rapidly growing populations are still heavily reliant on agriculture and fuelwood and some countries may depend on timber exports to generate foreign currency, with the result that deforestation may be rampant. As countries grow richer and more urbanized, the need to clear forests declines and the value

**Forest area as a percentage of country land area**


Source: FAO (2001)

placed on natural environments rises. More and more forests are protected or managed sustainably.

In developed countries, populations are growing only slowly and forest areas are mostly increasing as marginal farmland is set aside and regenerates as secondary natural forest.

### Wood products: growing demand, growing productivity

Demand for forest products will continue to grow as world population and incomes grow. The most recent FAO projections estimate that by 2030 global consumption of industrial roundwood will rise by 60 percent over current levels, to around 2 400 million $m^3$. Substantial rises are also likely in the consumption of paper and paperboard products.

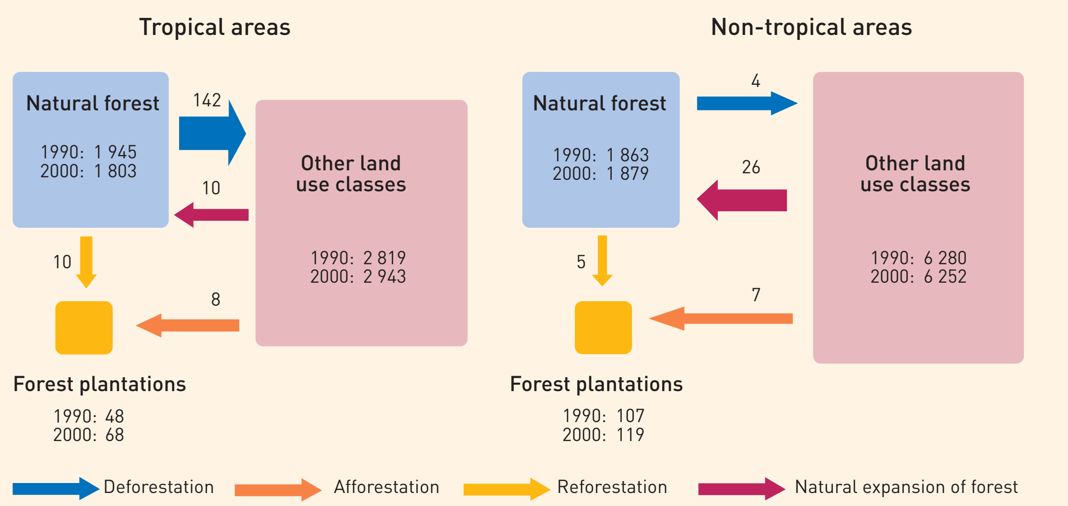
Will the world's forest resources be able to cope? Until the early 1990s, expert assessments were pessimistic, but most experts today no longer foresee a crisis in the supply of wood. Projections of wood consumption are lower now, partly because of lower world population growth. In addition, there have been improvements in forest management and in harvesting and processing technologies, increases in plantation establishment, and an expansion of the role of trees outside forests.

The production of wood-based materials is continually increasing in efficiency, reducing the pressure on forest resources. Not only is there more recycling of paper and wood. The past decade has also seen a shift from industrial roundwood and sawnwood to wood-based panels, which make much fuller use of timber. Global production of sawn timber has remained largely static since 1970, yet that of wood-based panels has more than doubled, while the production of paper and paperboard has almost tripled.

In the future, the key questions will not be whether there will be enough wood but rather where it should come from, who will produce it, and how it should be produced.

There has been a shift in the sources of wood, away from poorly regulated wild forests towards plantations and sustainably managed forests and woodlands. Industrial roundwood production from plantations is expected to double by 2030, from 400 million $m^3$ today to around 800 million $m^3$. Thus increased plantation supplies will meet much of the growth in demand for wood during this period.

**Forest area changes (million ha), 1990 to 2000**




Source: FAO (2001)

Another greatly expanded source of wood will be tree cultivation outside forests.

Changes in the conditions of trade are unlikely to be dramatic, as most significant tariff barriers have already been reduced to moderate levels or completely removed — though eco-labelling and environmental regulations will doubtless increase. However, there will be major shifts in the directions of international trade, as developing countries increase their per capita consumption of industrial wood. In some of the richer countries, per capita consumption is currently at least tenfold that of many developing countries.

### Stressing forestry's environmental services

Increasing realization of the importance of environmental values and services is helping efforts to conserve forest and tree resources. As the wider environmental services of trees are recognized, the planting or conservation of trees and forests is being fostered by development projects and programmes as a means of preventing erosion, regulating water flow and so avoiding downstream flooding, and controlling desertification or salinization. The trend towards tree and forest planting and conservation is likely to continue.

A shift in attitudes has led to a rise in the value attached to environment and nature conservation by non-governmental and development organizations. There is increasing pressure to adhere to acceptable standards of natural resource management in all efforts to stimulate economic growth and promote livelihoods for poor rural people. The emergence of democratic institutions and improved access to information are helping this process.

Shifts in consumer values, especially in the richer developed countries, have led to an increase in environmentally conscious purchasing. The spread of eco-labelling now allows consumers to choose products from sustainably managed forests.

Ecotourism is another outcome of the same shift. This is currently estimated to constitute around 7 percent of global tourism, a share that is expected to increase. Paradoxically, a high volume of ecotourists can place great pressure on sites that offer memorable experiences. Nevertheless, ecotourism can prove a valuable source of income for local communities and hence an economic incentive to conserve remaining forests.

> Measures such as reduced deforestation, forest regeneration and plantation development could reduce carbon dioxide emissions by the equivalent of 12 to 15 percent of all the emissions from fossil fuels between 1995 and 2050.

Growing concern over global warming has focused attention on the potential role of forests in regulating carbon dioxide levels in the atmosphere. Forests store large amounts of carbon in trees, understory vegetation, litter and soil. Globally, they contain some 1 200 billion tonnes of carbon, just over half the total in all terrestrial vegetation and soils.

New forests, or degraded forests that are allowed to regenerate, absorb and store carbon as they grow. Conversely, when they are cleared or degraded, forests can become a substantial source of carbon dioxide emissions. According to the Intergovernmental Panel on Climate Change (IPCC), measures such as reduced deforestation, forest regeneration and plantation development could reduce carbon dioxide emissions by the equivalent of 12 to 15 percent of all emissions from fossil fuels between 1995 and 2050. However, it is not yet clear to what extent this potential will be reflected in formal international agreements on climate change.

### Sustainable forest management

The set of principles and practices known as sustainable forest management (SFM) is increasingly accepted as the core paradigm for forestry development. SFM implies broadening the focus of management from wood production to include more emphasis on equitable and participatory development and on environmental considerations.

If forest development is inequitable, the poor who are excluded from it will continue to depend on land and forest resources, but will exert greater pressure on the remaining areas to which they have access and may encroach illegally on protected areas or those allocated to large-scale enterprises. Hence an important aspect of SFM is its emphasis on providing sustainable livelihoods for the estimated 350 million of the world's poorest and most marginalized people who depend on forest ecosystems.

Non-wood forest products (NWFPs), such as wild foods, plants and medicinal herbs, are crucial to this vulnerable group. The majority are subsistence goods or are traded only in local markets. However, an estimated 150 NWFPs are traded internationally. While dependence on many subsistence products may decline, increasing demand for ethnic foods and medicines may lead to the more systematic cultivation of some NWFPs. Access to knowledge and technology will be critical if local communities are to benefit from this trend.

Under the participatory development associated with SFM, the primary responsibility of forestry departments will shift from management to policy development and regulatory functions. Responsibility for management will pass largely to the private sector, including farmers and local communities.

The environmental goals of SFM will include increasing the area of protected forest and reversing the loss of biomass, soil fertility and biodiversity that occurs when forests are degraded. Unsustainable forestry practices will be discouraged and logging techniques that reduce negative impacts on the forest as a whole will be encouraged. Improved security of land and tree tenure will encourage tree planting, both inside and outside forests.

There has been progress towards the wider adoption of SFM, though that progress has been uneven. At one end of the spectrum, forest management is carefully monitored against agreed social and environmental criteria. At the other, substantial tracts of (mainly tropical) forests are still managed poorly or not at all, leaving them vulnerable to careless or unscrupulous degradation.

Advances in remote sensing and in data processing and exchange will make it easier for national and international bodies to monitor forest management practices. But if SFM is to succeed, it will be crucial to strengthen the developing world's forestry institutions, which are still severely under-resourced.

**Some non-wood forest products**

| End use | Typical products |
| --- | --- |
| Food products and additives | Wild meat, edible nuts, fruits, honey, bamboo shoots, birds' nests, oil seeds, mushrooms, palm sugar and starch, spices, culinary herbs, food colorants, gums, caterpillars and insects, fungi |
| Ornamental plants | Wild orchids, bulbs, cycads, palms, tree ferns, succulent plants, carnivorous plants |
| Animals and animal products | Plumes, pelts, cage birds, butterflies, lac, cochineal dye, cocoons, beeswax, snake venom |
| Construction materials | Bamboo, rattan, grass, palm, leaves, bark fibres |
| Organic chemicals | Phytopharmaceuticals, aromatic chemicals and flavours, fragrances, agrochemicals/insecticides, biodiesel, tans, colours, dyes |

Souce: FAO data

### The role of forests in protecting biodiversity

Increasingly, biodiversity is seen not just as a source of genetic material, medicines or other commercial products but as having value in itself. It has been estimated that forests, especially tropical rainforests, harbour as much as half the world's biodiversity.

Globally, more than 30 000 protected areas have been established. The goal of the World Conservation Union (IUCN) is that 10 percent of each country's land area should be under some form of protection. At present, some 80 countries have attained this level, but around 100 countries still have less than 5 percent.

The World Conservation Monitoring Centre estimates that only 6.4 percent of the area of forest biomes is under some form of protection at present — and as little as 3.6 percent in the case of temperate broad-leaf forests. These shortfalls reflect the uneven distribution of forest ecosystems among countries, in addition to an overall failure to meet the IUCN goal.

Almost 9 percent of tropical rainforests are protected, but in many developing countries this protection is only nominal. These forests continue to suffer serious encroachments, including logging, deliberate burning, poaching and other forms of clearing or degradation.

The prospects for future expansion of protected areas are more modest than in the recent past. In many countries where conservation efforts fall below the IUCN goal, there are already intense pressures on these areas and strong conflicts between economic and environmental objectives. During the next 30 years the total land area under strict protection will increase only moderately. Other means must be found to conserve biodiversity, including the on-farm production and conservation of trees and the conservation of germplasm in genebanks. Larger areas could also be placed under SFM, which affords conservation high priority as a management objective.

# World fisheries: a choice of futures

The marine fisheries catch levelled off during the 1990s. Aquaculture grew rapidly, allowing continued growth in total fish production. With many marine stocks now fully exploited or overexploited, future fish supplies are likely to be constrained by resource limits. Achieving effective governance of world fisheries is crucial.

Fisheries play an important role in the world food economy. Worldwide, more than 30 million fishers and fish farmers and their families gain their livelihoods from fisheries. Most of them are poor artisanal fisher families in developing countries.

Globally, fish provide about 16 percent of the animal protein consumed by humans, and are a valuable source of minerals and essential fatty acids. Ocean and freshwater fish are also an increasingly important recreational resource, both for active users such as anglers and for passive users such as tourists, sports divers and nature-lovers.

## As marine capture fisheries level off, aquaculture expands

Over the past three decades world production of fish has more than kept pace with human population growth, with the result that the amount of fish available per person has increased. The recent stagnation of capture fisheries has been balanced by the rapid build-up of aquaculture.

Total annual fish production almost doubled between 1970 and 1999, from 65 million tonnes to 125 million tonnes. This rise was the outcome of two contrasting trends: growth in capture fisheries followed by a levelling off in the 1990s, and dramatic growth in aquaculture during the 1990s.

Since the1950s, increases in marine capture levels have been made possible by advances in fishing technology and efficiency, including synthetic fibres for fishing gear, on-board freezing, electronic fish finding and improved navigation. However, as more and more fishery areas and fish stocks reached full utilization or were overfished, the growth of marine catches began to flatten out. During the 1990s, marine catches fluctuated between 80 and 85 million tonnes per year, despite the discovery of new stocks.

> The continuing rise in overall fish production was made possible by the growth of aquaculture at 10 percent per year during the 1990s. The contribution of aquaculture to world fish production doubled over the decade, reaching 26 percent in 1999.

Catches in inland waters, however, continued to grow moderately, from 6.4 million tonnes per year in 1990 to 8.2 million tonnes in 1999 — though the true inland total may be much higher, as produce is often bartered, sold or consumed locally without being formally recorded.

What made possible the continuing rise in overall fish production was the rapid growth of aquaculture, which expanded by 10 percent per year during the 1990s. The share of aquaculture in world fish production doubled over the decade, reaching 26 percent in 1999.

So far, aquaculture has been heavily concentrated in Asia, which provided 89 percent of world production in 1999. A growing diversity of species is now cultured. Until the mid-twentieth century the range was limited to oysters, mussels, carps, trouts and shrimps. However, since the 1950s scientists have gradually solved the problem of artificial reproduction for different carps, salmonids and other species.

The overall increase in fish production has been paralleled by a steady growth in consumption. Fish now account for an average of 30 percent of the animal protein consumed in Asia, approximately 20 percent in Africa and around 10 percent in Latin America and the Caribbean. By 1999 global average intake of fish, crustaceans and molluscs reached 16.3 kg per person, an increase of more than 70 percent over the 1961-63 level.

Fisheries are also a significant source of livelihoods. In developed countries, employment in fishing has declined due to improvements in productivity and the collapse of some important fisheries. In contrast, in developing countries fisheries employment has continued to expand. Over 90 percent of the people fully employed in the fisheries sector in the early 1990s were in the developing or transition economies.

Nearly 40 percent of all fish production is now internationally traded. As a result, fisheries are increasingly seen as a powerful means of generating hard currency. Developing countries' gross earnings from fish exports have grown rapidly, from US$5.2 billion in 1985 to US$15.6 billion in 1999, a level that far exceeds earnings from commodities such as coffee, cocoa, banana or rubber.

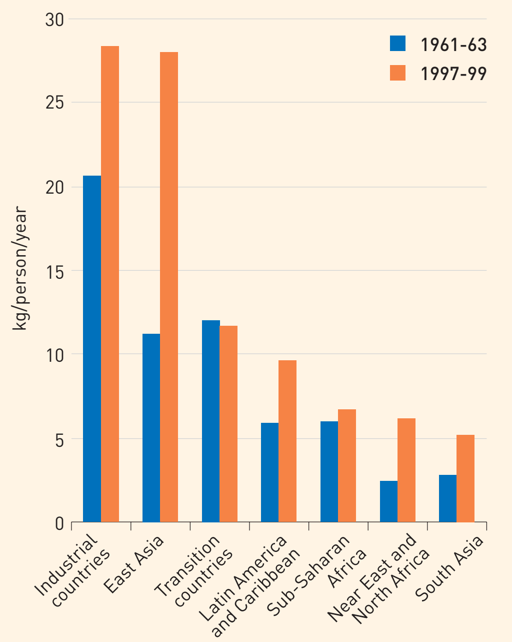
## Fish consumption may be constrained by resource limits

Fish consumption per person is expected to continue to rise. If it were to be determined solely by income growth and dietary changes, average intake could reach as high as 22.5 kg per person by 2030. Combined with population growth, this would imply a total annual demand for fish of 186 million tonnes by 2030 — almost double the present level. However, since supply will probably be limited by environmental factors, a more likely range for demand is 150 to 160 million tonnes, or between 19 and 20 kg per person.

The regional picture will be very diverse. Health and diet quality concerns will boost consumption in North America, Europe and Oceania, but slow population growth will mean slow increase in overall demand.

In sub-Saharan Africa and the Near East and North Africa, fish consumption per person may stagnate or even decline, despite current low levels. In Africa, local wild stocks are almost fully exploited and, except in Egypt, aquaculture has barely begun. Per capita demand in South Asia, Latin America and China may increase only gradually, while in the rest of East Asia it will almost double, reaching 40 kg by 2030.

**Fish consumption by region, 1961-63 and 1997-99**




Source: FAO data

Asian aquaculturists should be able to increase production, and any remaining shortfall can be met by imports.

There is a growing trend to market fish fresh for human consumption. This is because the costs of delivering fresh fish to markets are falling and consumers are willing to pay a premium for this product. Demand for fish meal and fish oil will continue to grow rapidly. These products are used for livestock and aquaculture feeds, and at present account for about a quarter of world fish production. So far the raw material for fish meal and oil has been supplied by capture fisheries, and in all likelihood this will continue. However, the competition for small surface fish will become more intense, and the fish meal and oil industry will need to exploit other raw materials, such as mesopleagic fish and krill. Rising prices will also drive a switch to substitute feeds. However, a satisfactory replacement for fish oil has not yet been found.

## Aquaculture and marine ranching will continue to expand

Over the next three decades, the world's fisheries will meet demand by continuing the same shift from fish capture to fish cultivation that gained momentum in the 1990s.

The share of capture fisheries in world production will continue to decline. The maximum sustainable marine production has been estimated at around 100 million tonnes a year. However, this is higher than the annual catches of 80 to 85 million tonnes achieved during the 1990s, and assumes that large quantities of hitherto underexploited aquatic resources will be used, including krill, mesopelagic fish and oceanic squids.

As in the 1990s, most of the shortfall will be made up by aquaculture, which will probably continue to grow at rates of 5 to 7 percent a year, at least until 2015.

Aquaculture species will be improved. Traditional breeding, chromosome manipulation and hybridization have already made significant contributions. In future the use of new technologies, such as genetic modification, can be expected. Already, a gene that codes for an antifreeze protein in the Arctic flounder has been transferred to Atlantic salmon to increase its tolerance of cold waters. Currently, however, no commercial aquaculture producer is marketing such transgenic species for human consumption. If this field is to progress, public concerns about GM organisms will need to be addressed through risk assessments and the development of policy guidelines for responsible use.

Additional species will be domesticated for aquaculture. For halibut, cod and tuna, which have been fished in high volumes in capture fisheries, aquaculture production could eventually be high. If commercially viable technology is developed soon, by 2015 the cultured production of cod could reach 1 to 2 million tonnes per year.

Environmental concerns will probably shift the focus of aquaculture away from coastal zones into more intensive inland systems. Marine ranching will also expand, though its long-term future will depend on solutions to the problems of ownership surrounding released animals. At present, only Japan is engaged in sea ranching on a large scale.

Social and political pressure will also drive efforts to reduce the impact of capture fisheries, for example by making use of the unwanted catch of non-target species and by using more selective fishing gear and practices. Increasing use of eco-labels will enable consumers to choose sustainably harvested fish products, a trend which will encourage environmentally sensitive approaches in the industry.

### Towards sustainable fisheries

The single most important influence on the future of wild capture fisheries is their governance. Although in theory renewable, wild fishery resources are in practice finite for production purposes. If they are overexploited, production declines and may even collapse.

Resources must therefore be harvested at sustainable levels. In addition, access must be equitably shared among producers. As fish resources grow increasingly scarce, conflicts over access are becoming more frequent.

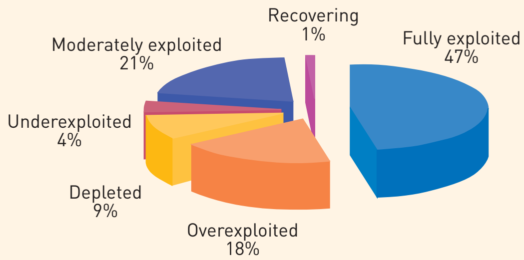
The principal policy challenge is to bring the capacity of the global fishing fleet back to a level at which fish stocks can be harvested sustainably. Past policies have promoted the buildup of excess capacity and incited fishermen to increase the catch beyond sustainable levels. Policy makers must act fast to reverse this situation.

There are numerous measures that could encourage sustainable use and remove the perverse incentives to overfish. Fisheries based on clearly defined rights of access will need to become more common: experience shows that when these rights are not merely in place but are understood and observed by users, conflicts tend to be minimized.

Laws and institutions need to be established or strengthened to limit and control access to marine fish stocks, both by larger ocean-going

The maximum sustainable marine production is estimated at around 100 million tonnes a year, compared to annual catches of 80 to 85 million tonnes in the 1990s. But the estimate assumes that large quantities of hitherto underexploited resources will be used, including krill and oceanic squids.

**State of the world's fishery stocks, 1998**




Source: FAO data

## The changing ecology of the oceans

Biodiversity comprises four main elements: variability within species, among species, among ecosystems and among larger ecological complexes. It is a key ingredient of sustainable fisheries in the future.

Altogether, over 1 100 species of fish, mollusc and crustacean are taken in capture fisheries, while over 300 species are used in aquaculture. Biodiversity in wild populations allows adaptation to the changing environment, while in farmed fish it allows continued breed improvement.

Human fishing activities have had a powerful impact on aquatic biodiversity. The current high level of impact may limit capture fishing in future, unless the governance and management of ocean and freshwater resources are greatly improved.

Damage is done by several unsustainable fishing practices. These include: the use of poison and dynamite near coral reefs; non-selective fishing gears that capture marine mammals, unwanted species or fish that are too small; and bottom trawling, which disturbs the ecology of the ocean floor.

Perhaps the major ecological impact stems from the sheer extent of human fishing. Many fishing areas and stocks are fished up to or beyond the sustainable limit, while fishing pressure appears to have altered the distribution and size of some fish.

The overall impact on ocean ecology is only sketchily known, but appears to be significant. Statistics on fish landings suggest that there has been a reduction in the numbers of larger predatory fish, shifting the balance of catches towards fish that eat lower down the food chain. As high-value species such as bottom-dwellers or large surface fish such as tuna are overfished, they are gradually replaced by shorter-lived and smaller surface-dwelling and schooling fish. Numbers of smaller fish are also boosted in some areas by increased plankton production.

By 1998, some 12 out of the FAO's 16 world fishing regions had production levels at or below their historical maximum. Indeed, the Antarctic, the Southeast and Northwest Atlantic and the Southeast Pacific had fallen below half their maximum past production levels.

In terms of stocks of main species, FAO estimates suggest that, by the end of the 1990s, only a quarter of stocks were moderately exploited or underexploited and 1 percent were recovering. Nearly half of all stocks were exploited up to their maximum sustainable yield and were thus potentially on the brink of being overexploited. More than a quarter of stocks were overfished or depleted.

Such developments have raised concern among environmentalists and other stakeholder groups. In response, fishery administrations are working to minimize or mitigate the negative impacts on genetic and biological diversity. Measures include the development and use of selective fishing gears that reduce the capture of marine mammals, undersized target species and unwanted bycatch, direct controls on the total catch allowed of various species and, in some cases, outright fishing bans and moratoriums.

Unfortunately, inappropriate fishing and aquaculture activities are only one of the threats to aquatic biodiversity. Additional threats include pollution, loss of habitat and habitat degradation. Such threats often combine to aggravate pressure on biodiversity. The whole range of threats must be addressed if aquatic biodiversity is to be protected.

vessels and by local artisanal fishers. Increasingly, the responsibility for managing fisheries will have to be devolved to fishing interests and other stakeholder groups. Traditional arrangements in fishing communities can be incorporated into new management regimes. However, the need to control entry into artisanal fisheries will become more pressing. Indeed, if this issue is not tackled, a large number of fisher households may be forced out of fishery and, unless there are alternative livelihoods, into poverty.

If the world's fisheries are to achieve their full potential, the major policy and management challenges must be met, and the cultural and social concerns of all stakeholder groups must be addressed. These are enormous challenges, yet they are not insurmountable.