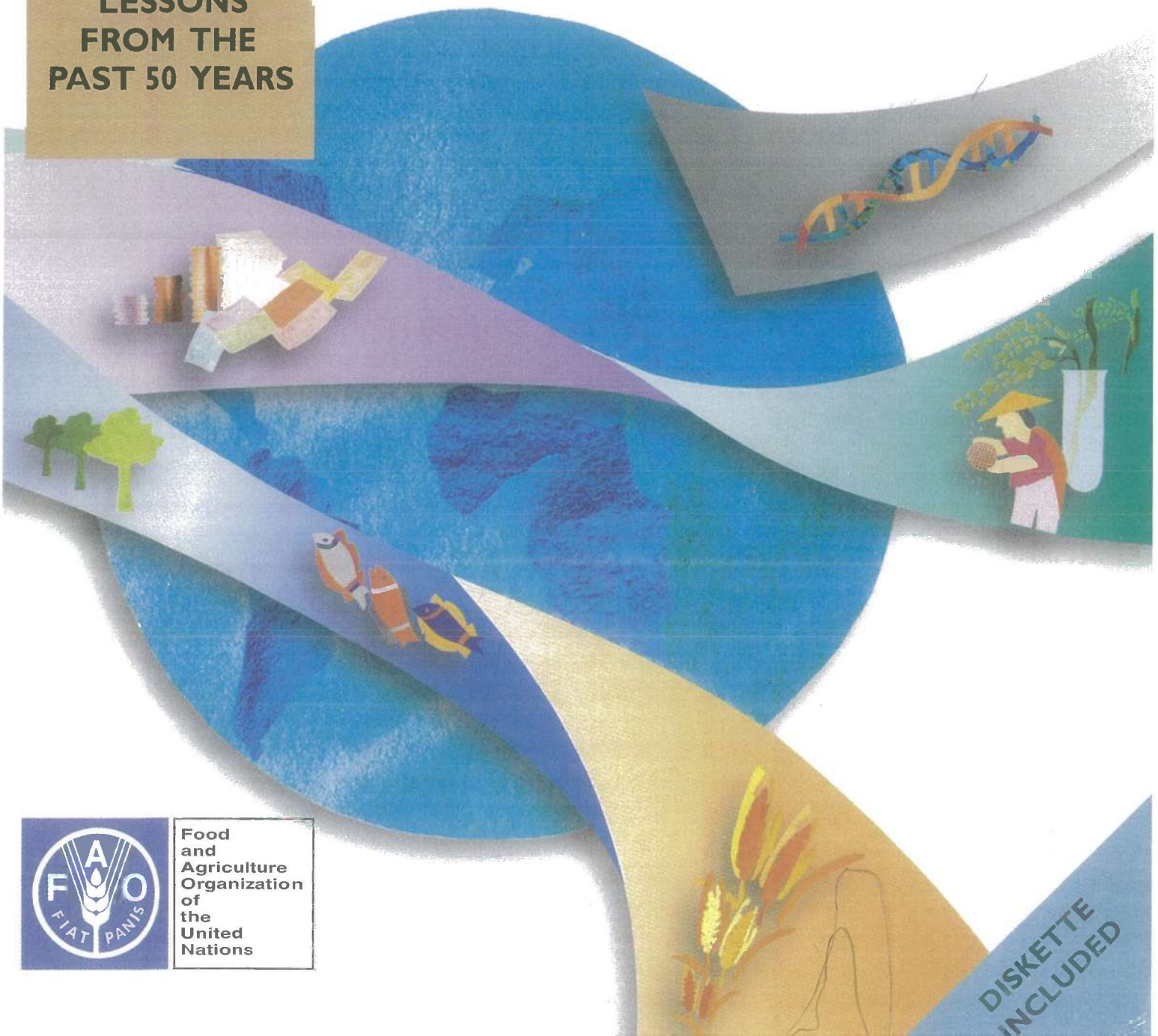
2000

THE STATE OF FOOD AND AGRICULTURE

LESSONS FROM THE PAST 50 YEARS



Food and Agriculture Organization of the United Nations

DISKETTE INCLUDED

The socio-economic impact of agricultural modernization

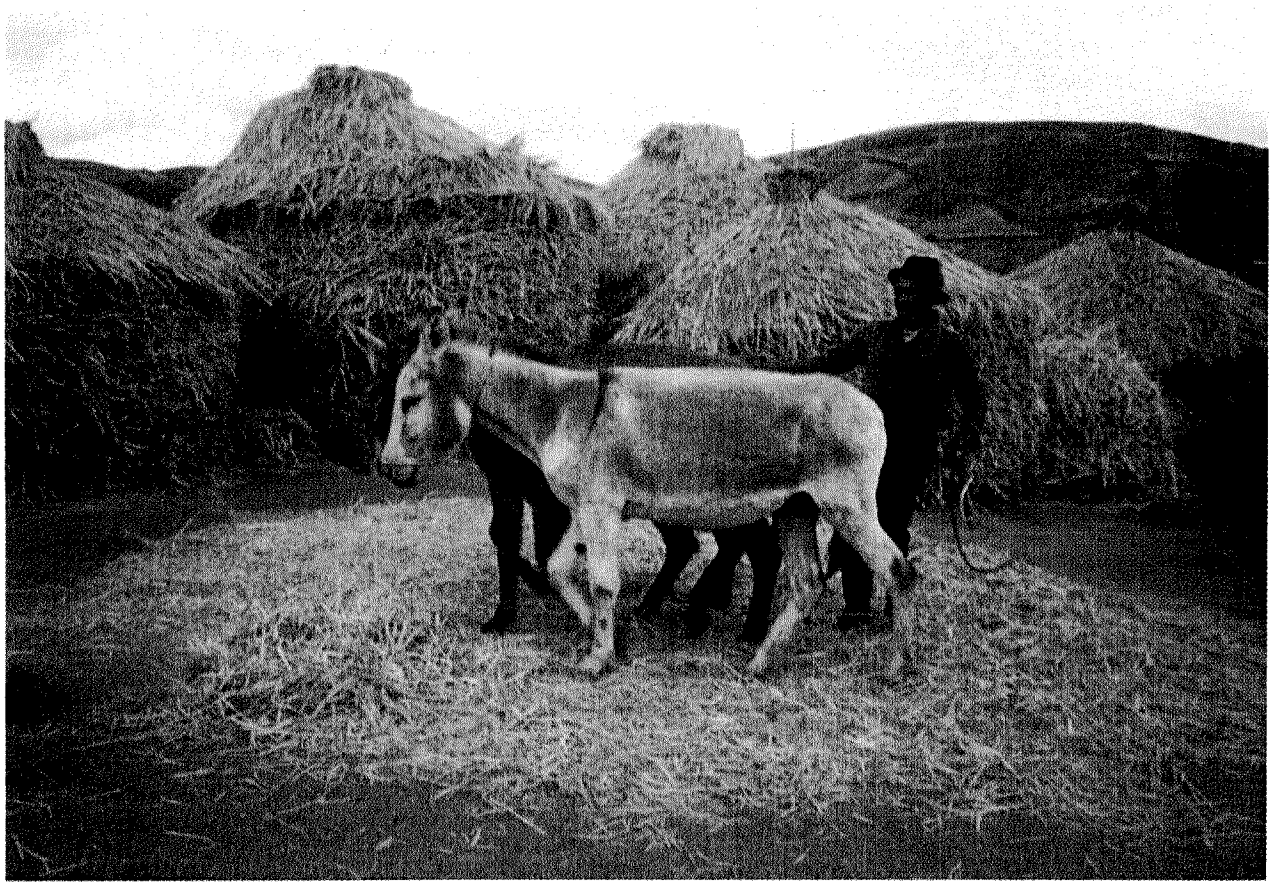
INTRODUCTION

The world's population now exceeds 6 billion people, consuming a daily average of about 2 700 kcal per caput, compared with a population of 2.5 billion in 1950 and an average daily intake of fewer than 2 450 kcal per caput.[1] This means that, over the last 50 years, the increase in global agricultural production has been 1.6 times greater than the total production level obtained in 1950, after 10 000 years of agricultural history.[2]

This enormous increase in food production is attributable to:

- the spread in the developed countries of the modern agricultural revolution (involving motorization, large-scale mechanization, biological selection, use of chemicals, specialization) and its expansion into some sectors of the developing countries;
- the more noteworthy occurrence in the developing countries of the green revolution – a modern agricultural revolution that is not dependent on heavy motorized mechanization but instead involves the use of chemicals and the selection of high-yielding cereal and other domestic plant varieties suited to warm regions;
- the expansion of irrigated surfaces, from about 80 million ha in 1950 to about 270 million ha today;
- the expansion of arable land and land under permanent crops, from some 1 330 million ha to 1 500 million ha since 1950;[3]
- the development of mixed farming systems using high levels of available biomass (combining crops, arboriculture, livestock and, sometimes, fish farming) in the most densely populated areas that lack new land for clearing or irrigation.

However, even these considerable advances in agriculture cannot hide the fact that most of the world's farmers use inefficient manual tools and their plants and domestic animals have benefited very little from selection. Moreover, these underequipped farmers, with their inefficient production methods, are exposed to increasingly fierce competition from better equipped and more productive farmers as well as to the



FAO/15636/J. BRAVO

Traditional farming practices
Barley threshing using donkeys

strong decline in real agricultural prices. This continually condemns resource-poor farmers with low productivity to extreme poverty, making them vulnerable to hunger and prompting their migration to towns and cities that are themselves underequipped and underindustrialized.

The outcome is a contrasting situation between, on the one hand, the modern agricultural revolution, the green revolution, the expansion of irrigation, the clearing of land and the development of mixed farming systems using high levels of available biomass, and on the other hand, stagnation and impoverishment. This is the contradictory result of agricultural modernization in the second half of the twentieth century, and it raises a number of questions:

- How productive and well equipped were the world's farmers in 1950, and to what extent has the explosion of disparities in productivity been caused by the last 50 years of agricultural modernization?
- What means and economic development mechanisms of the modern agricultural revolution were used in the developed countries, and what have been the environmental, demographic, economic and social consequences?
- What are the limits of the modern agricultural revolution

FAO/10980/B. POLIMENI

Highly mechanized farming practices
A combine harvester at work on an extensive grain crop

and the green revolution in the developing countries? What are the mechanisms that lead to the impoverishment and marginalization of the underequipped peasant farmer sector in these countries? What other forms of agricultural modernization are under way in both developing and developed countries?

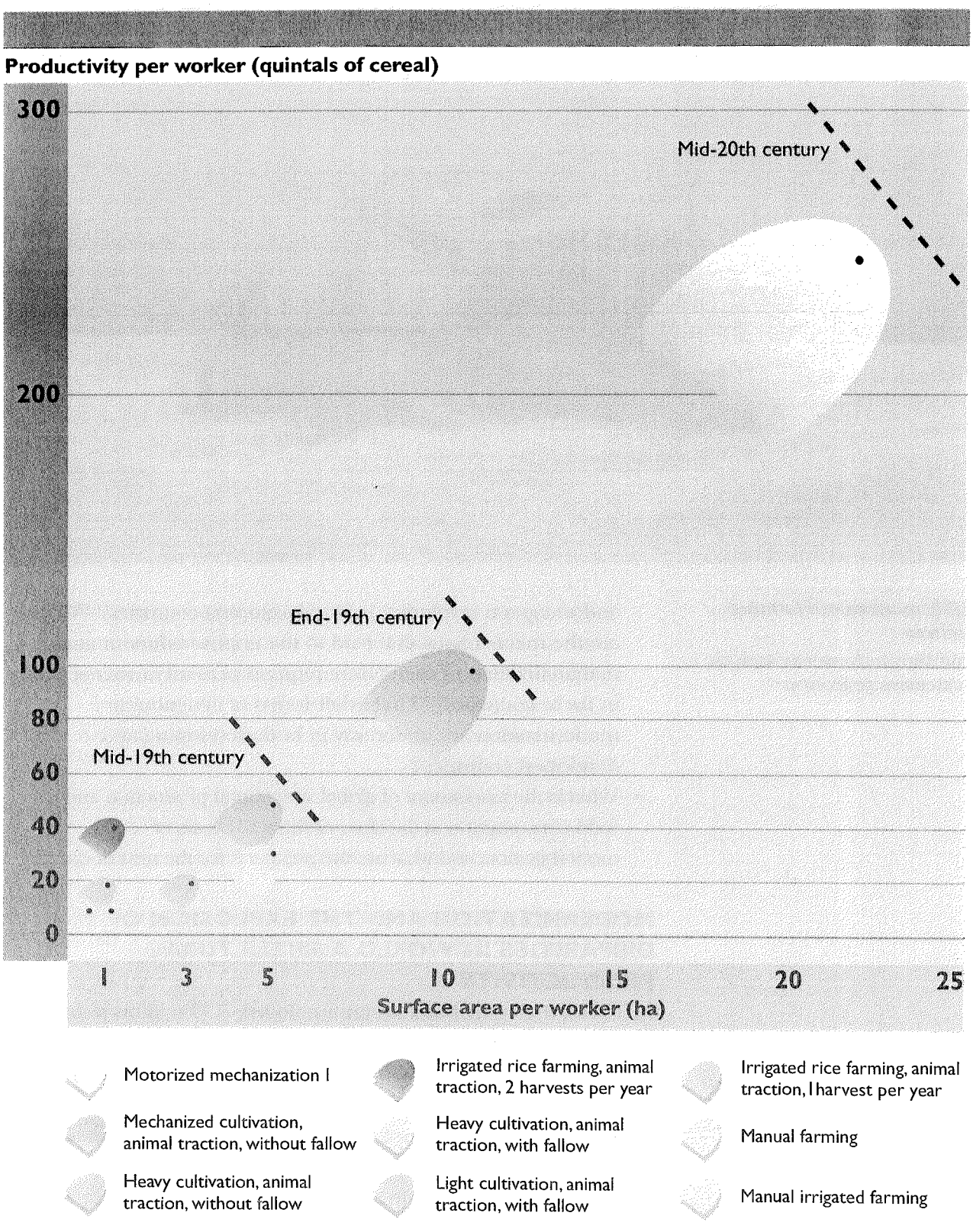
- What is the assessment of global agricultural production and food consumption at the close of these 50 years of modernization, and what are the prospects for the next decades?

MODERNIZATION AND THE EXPLOSION OF DISPARITIES IN WORLD AGRICULTURAL PRODUCTIVITY

In 1950, the agricultural sector employed 700 million people worldwide and used fewer than 7 million tractors (4 million in the United States, 180 000 in West Germany and 150 000 in France) and fewer than 1.5 million combine harvesters. Currently, 1.3 billion people are engaged in agriculture, and there are 28 million tractors and 4.5 million combine harvesters in use, mainly in the developed countries.[4] Only 17 million tonnes of mineral fertilizer were applied in 1950, four times more than in 1900 but eight times less than today. In

Figure 18

COMPARATIVE PRODUCTIVITY OF THE WORLD'S MAJOR AGRICULTURAL SYSTEMS IN THE MIDDLE OF THE TWENTIETH CENTURY



Source: FAO, based on author's elaboration

1950, 30 million tonnes of oilcake equivalent were used as animal feed, six times less than today.

Although the methodical selection of plant varieties and domestic animal species with high-yield potential had started decades earlier, it had not progressed far and only involved a limited number of species. A majority of the world's farmers still used local varieties and breeds. While there was already a wide range of phytosanitary products in 1950, it was minimal compared with the situation today where about 80 active ingredients are used for insecticides, 100 for fungicides and 150 for herbicides.[5] All of these products have been the subject of major toxicological studies. In 1950, average crop yields were 1 000 kg/ha for wheat, 1 500 kg/ha for maize, 1 600 kg/ha for paddy rice and 1 100 kg/ha for barley – much the same as at the beginning of the century. Since then, yields have doubled or tripled. Similarly, the average yield of a milking cow in France, for example, came to less than 2 000 litres per year compared with about 5 600 litres today.[6]

Progress in agricultural production hides a growing disparity among agricultural systems and populations.

These figures give an indication of the progress made in 50 years, but they fail to reveal the growing disparity in productivity among the different agricultural systems, based on quality of machinery and use of inputs. This calls for a comparative economic analysis of the major production systems in each period.

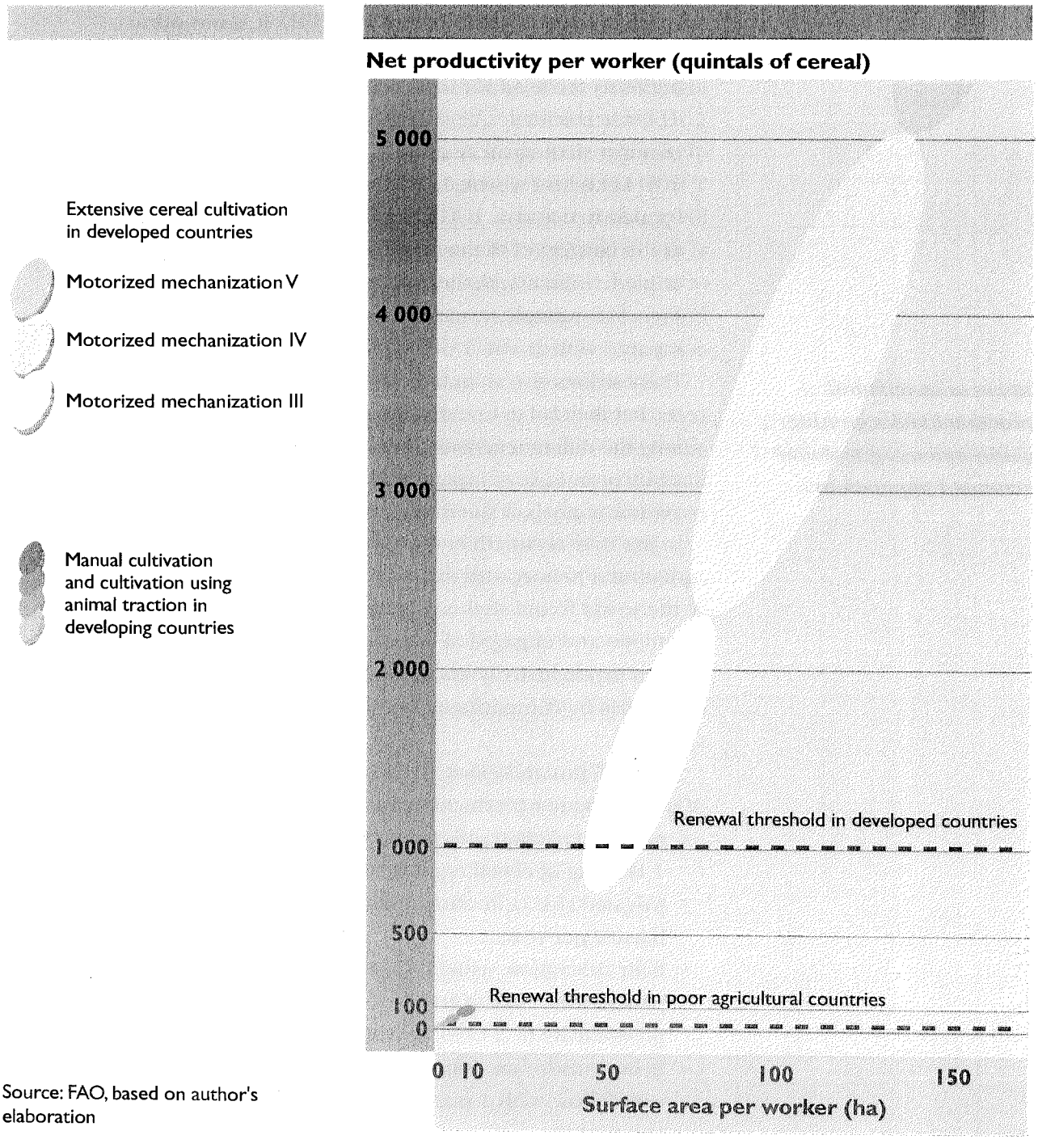
In the mid-twentieth century, after thousands of years of agricultural history with extensive regional variation, the peoples of the world found themselves in widely differing agricultural situations and engaged in production systems that had very uneven productivity levels.[7] Figure 18 illustrates these disparities by comparing potential net productivity for each system.[8]

As the Figure indicates, these systems can be ranked in order of increasing net productivity as follows:

- manual farming, with maximum net productivity of around 1 000 kg of cereal equivalent per worker;
- irrigated rice cultivation, using animal traction, with one harvest per year;
- light cultivation, using animal traction (swing plough, packsaddle, etc.), with fallow, with a maximum net productivity of 2 000 kg per worker;
- heavy cultivation, using animal traction (plough, cart, etc.), with fallow, with a maximum net productivity of 3 500 kg per worker;
- irrigated rice cultivation, using animal traction, with two harvests per year, with a similar net productivity to that of the previous system;

Figure 19

PRODUCTIVITY DIFFERENCES BETWEEN CEREAL SYSTEMS USING MOTORIZED MECHANIZATION AND CHEMICALS, AND MANUAL OR ANIMAL TRACTION CULTIVATION IN DEVELOPING COUNTRIES



Source: FAO, based on author's elaboration

- heavy cultivation, using animal traction, without fallow, with a net productivity of 5 000 kg per worker;
- mechanized cultivation, using animal traction, without fallow, with a net productivity of 10 000 kg per worker;
- first systems of cultivation using motorized mechanization (motorized mechanization I), with a maximum net productivity already exceeding 30 000 kg per worker.

Thus, the ratio in 1950 between the least efficient system (manual farming) and the most productive system (motorized mechanization) was 1:30.[9]

The gap between the most productive and least productive farming systems has increased twentyfold in the last 50 years.

At the end of the twentieth century, after another 50 years of agricultural history, the productivity of manual farming, which is the least efficient but most widespread type of farming worldwide, is still about 1 000 kg of cereal equivalent per worker, while the net productivity of the most motorized and input-intensive farming system exceeds 500 000 kg. The ratio between these two systems is therefore about 1:500 (Figure 19): almost a twentyfold increase in the ratio over 50 years.

THE MODERN AGRICULTURAL REVOLUTION IN DEVELOPED COUNTRIES

The modern *agricultural revolution* that triumphed in the developed countries from the late 1950s onwards was based on the development of new means of production and trade which, in turn, resulted from revolutions in industry, biotechnology, transport and communications.

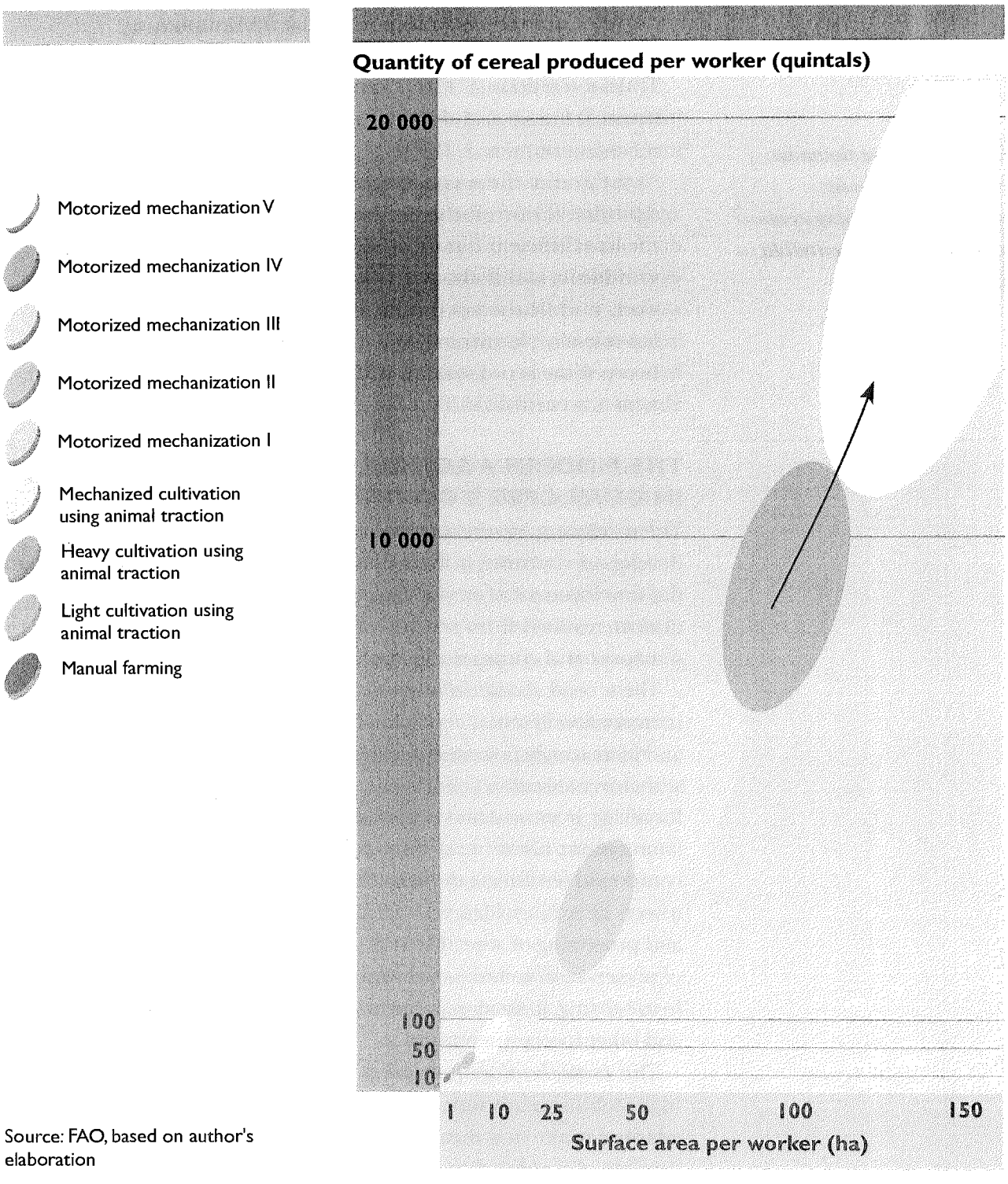
The second *industrial revolution* provided the means for: motorization (internal combustion engines, electric motors, tractors and increasingly powerful machinery, fuels and electricity); large-scale mechanization (increasingly complex and efficient machinery for tillage, treatment and harvesting); heavy mineral fertilization (ammonium, nitrate, nitro-ammoniacal, phosphate, potassium and compound fertilizers); treatment of pests and diseases (herbicides, insecticides, fungicides, veterinary drugs, etc.); and the conservation and processing of vegetable and animal products (industrialization of preservation techniques through cold, heat, drying, smoking, freeze-drying, ionization, fermentation or the addition of salt, sugar and other food preservatives).

The *biotechnology revolution* supplied, through selection, high-yielding plant varieties and animal breeds that were adapted to the new means of industrial production and were capable of making these profitable.

The *transport revolution*, which began in the nineteenth century with the development of railways and steamboats, received a new boost with the motorization of transport by truck,

Figure 20

STAGES OF DEVELOPMENT OF AGRICULTURAL MACHINERY AND MOTORIZED MECHANIZATION IN CEREAL CULTIVATION



Source: FAO, based on author's elaboration

train, boat and aeroplane. This opened up farms and agricultural regions and enabled them to procure their fertilizer, feed and other inputs from further afield and in larger quantities. It also allowed for the sale of their products, including perishable and unmanageable goods, in increased amounts and to wider areas.

Along the same lines, the *communications revolution*, based partly on the transport revolution and partly on telecommunications developments, provided the means for long-distance information supply and commercial transactions. This prompted distant trade and the organization of the large-scale administrative, productive, financial and trade structures that are integral to the modern industrial and agricultural revolution.

Agricultural modernization occurred gradually as a result of progress in industrialization, breeding technology and transport and communications, and in step with the enlargement of farms.

Agricultural holdings of a few hectares per worker, engaged in mixed crop and livestock farming using animal traction and producing much of their forage, manure, seeds, livestock and food, were still very common in the developed countries in the 1950s. How were these farms able to transform themselves within half a century into a small number of specialized production units of tens or hundreds of hectares per worker, operating as major purchasers of equipment and inputs and as sellers of almost all their production?

Rapid though it was, this major metamorphosis did not take place all at once. It occurred through progressive transformations in line with progress in industrialization, breeding technology and means of transport and communications, and in step with the enlargement and capitalization of an ever dwindling number of agricultural units.

Motorized mechanization. The development of motorization and mechanization varied according to the sphere of activity. Cereals and other large-scale grain crops (rapeseed, sunflower, soybean and other leguminous plants and cotton) were the first to benefit, and have always set the pace since. As these crops occupied a large proportion of arable land, they provided ample opportunity for the agricultural machinery industry. Motorized mechanization was then extended to the harvesting of roots and tubers, such as beetroot and potato, which are harder to handle because they are heavy, bulky and high in water content. It eventually spread to dairy cattle, forage harvesting, feeding and excreta disposal, viticulture and vegetable and fruit crops.

In large-scale field cropping, there are five stages in the process of motorized mechanization, each triggered by an increase in tractor power (see Figure 20). Before the 1950s, the

first stage (motorized mechanization I) had relied on the use of low-horsepower tractors (10 to 30 HP) on farms of more than 15 ha. Faster than draught animals and – more important – tireless, these tractors helped increase surface area allocated per worker from some 10 to more than 20 ha.

From the end of the 1950s to the 1980s, the second, third and fourth stages (motorized mechanization II, III and IV) involved the use of increasingly powerful tractors and self-propelled machinery (30 to 50, 50 to 75 and then 75 to 120 HP) with higher tillage, sowing, field maintenance and harvesting capacity, leading to an increase in allocated land area per worker to 50, then 80 and finally 100 ha, respectively.

The fifth stage (motorized mechanization V), which began more than ten years ago, has involved the use of four-wheel drive tractors of more than 120 HP, extending the field crop area handled by one worker to more than 200 ha.

Similarly, for dairy production in 1950, one person could handmilk 12 cows twice a day. This number then doubled with the portable milking machine, rising to 50 cows with the herringbone milking parlour equipped with a milk tank and to 100 cows with the advent of the milking conveyor. With the latest fully automated milking parlour, it now stands at more than 200 cows. In this way, each stage in the motorized mechanization process has resulted in an increase in land area or number of livestock per worker, while concurrent progress in agricultural chemistry and breeding has increased yields per hectare or animal.

Agricultural chemistry and breeding. The considerable increase in major crop yields in developed countries over the last 50 years is mostly attributable to fertilizer use and to the breeding of plant varieties that are able to absorb and use enormous quantities of minerals profitably. Treatment against pests and improved mechanization have also played an important role.

From the late 1940s to the end of the 1990s, average wheat yields increased from 1 100 to more than 2 600 kg/ha in the United States, while mineral fertilizer use rose from 20 to 120 kg/ha of arable land. In France, wheat yields increased from 1 800 to 7 100 kg/ha for 45 and 250 kg of fertilizer, respectively.[10] Nowadays, on the rich loamy soil of northwestern Europe, wheat and maize yields sometimes exceed 10 000 kg/ha, with fertilizer applications of about 200 kg/ha of nitrogen, 50 kg/ha of phosphate and 50 kg/ha of potassium.

Obviously, the jump from landrace cereals producing 2 000

kg/ha to cultivars capable of producing 10 000 kg/ha did not occur overnight. Successive high-yeilding varieties were bred, marking as many stages in the profitable use of increasingly high fertilizer applications. In the case of wheat, for example, pure lines and, more recently, first-generation hybrids were obtained with increasingly shorter stalks, higher grain yields and resistance to cold, lodging, shrinkage, pre-harvest germination, foot rot, rust and powdery mildew. They were also of better quality for milling and baking, and suited the new processing appliances (homogeneity, ease of threshing).

The increased production of all kinds of grain (cereals and oilseeds) and crop by-products was such that a greater proportion could be used as concentrated feed. This, together with the increase in pasture and other forage crop production, helped raise livestock numbers and significantly improve their feed and yields. Therefore, animal breeds also had to be selected for their yield in meat, milk or eggs, and be able to consume increasingly nutritious feed rations in an economically profitable manner. While at the beginning of the century a cow consumed 15 kg of hay daily to produce less than 2 000 litres of milk per year, a highly bred milch cow now produces more than 10 000 litres of milk per year, consuming 5 kg of hay (or equivalent) and more than 15 kg of feed concentrate a day.

Livestock and crop protection. Such expensively bred and fed animals represent such an important capital investment with potential returns that the risks of animal or production loss through illness or accident become increasingly difficult to countenance; and the larger and more concentrated the animal population, the higher the risks. Therefore, very strict health precautions are taken and a wide range of expensive preventive and curative treatment is deployed, even veterinary surgery when necessary.

Annual crops undoubtedly represent a lower fixed capital than livestock or perennial plantations. However, as a crop develops, the capital investment (selected seed, fertilizer, fuel) accumulates and may represent as much as half of expected earnings. Moreover, the margin between earnings and expenditure must still cover the depreciation of expensive motorized machinery and wages, among other items. There is therefore no scope whatsoever for harvest losses, which means that phytosanitary products have to be used.

The protection of plant and animal health has become more important to safeguard investments in farm output and has led to greater farm and regional specialization.

We can see how, from the technical and economic perspective, advances in motorized mechanization, breeding, mineral fertilization, livestock feeding and plant and animal

health protection are very closely linked. Moreover, these advances have determined the simplification of production systems and, therefore, the specialization of production units and agricultural regions.

Specialization of crops/livestock. The use of fertilizers has led not only to increased harvests, but also to more straw and other crop residues that can then be ploughed into the soil and thus used to maintain acceptable levels of humus content. As a result, agricultural production units have been freed from the need to produce manure. In addition, with the introduction of tractors, they have been freed from the need to produce forage for draught animals. Consequently, agricultural holdings located in flat regions that are suited to mechanized farming and with good climatic and soil conditions for cereals, oilseeds or roots and tubers have abandoned fodder and livestock production to focus exclusively on growing field crops with motorized mechanization and use of mineral fertilizer.

By specializing in this way, these regions have produced higher marketable surpluses at a low cost, which they then export to regions less suited to large-scale mechanized cultivation. Conversely, farms in hill areas, in low-lying rainy, heavy-soil coastal regions and in arid, almost steppe-like Mediterranean or continental areas have focused largely on pasture and livestock (dairy or beef cattle, sheep, goats). At the same time, the use of agricultural chemicals has released farm holdings from the former crop rotation system used to control weeds, insects and disease. As a result, cropping systems have been simplified and further specialized, culminating in monocropping (or quasi-monocropping).

Trade between agricultural holdings and distant regions has grown and become more economical with the advent of road haulage (which took over from water and rail transport) and better means of communication. Farms can now be efficiently supplied with capital and consumer goods of every kind and no longer have to engage in mixed animal and crop farming for comprehensive localized self-supply. They have therefore been able to focus most of their production resources on the most profitable product (or simplified combination of products) as determined by environmental and trade conditions and local farmer expertise. Virtual monocultures of soybean, maize, wheat, cotton, vineyards, vegetables, fruit and flowers have thus spread over entire regions, giving rise to new specialized regional agricultural systems, each with very different agro-environmental and agro-economic characteristics.

Economic mechanisms for the development of the agricultural revolution

To move forward through all the stages of the contemporary agricultural revolution and establish the best-equipped and most appropriately sized farm, two or three farming generations have constantly had to discontinue less profitable operations and keep the most profitable one (or simplified combination). To do this, they have relied on improved seeds and new inputs, which they have combined so as to maximize profit margin per unit area. They have also continually bought new, more efficient machinery and have expanded operations in order to maximize unit area per worker.

By way of an example, the best located cereal production units in northwestern Europe, equipped with the most up-to-date and efficient machinery, have now attained a fixed capital of $300 000 (value of new material) and a surface area of 200 ha per worker, and have reached net productivity levels (after deduction of depreciation and maintenance costs) of $60 000 per worker. Most of the other specialized systems established during the second agricultural revolution have comparable maximum levels of potential capitalization and productivity per worker.

However, productivity does not equal income: to calculate net income per worker, it is necessary first to deduct interest on borrowed capital, land rent and tax, and add in any subsidies that might exist. Thus, working alone, a highly efficient cereal farmer who has a debt of about $300 000 at 5 percent interest and who leases his or her 200 ha at $150 per hectare, would earn an income (before tax and subsidies) of $15 000 per year.

On a financially viable farm in a developed country, the net income per farm worker is equivalent to the salary of an unskilled worker.

More important, farms with such levels of capitalization, land and productivity are a minority; most have levels of capitalization, land productivity and income per worker of less than half these amounts.

In the developed countries, a net income per worker of $15 000 per year more or less corresponds to the annual salary (including social contributions) of a relatively unskilled worker. If the net income per farm worker is at this level, the farm can renew its equipment and pay for its labour at market prices, but it will have virtually no margin for additional investment.

If income per worker is above this level, the farm has the capacity for net self-investment, and generally also has access to credit which will enable it to capitalize to increase productivity and income; all the more so, the higher the initial levels of capitalization and income.

However, if net income per worker is below this threshold of

renewal and capitalization, the farm cannot renew its means of production and pay its workforce at market rates. Such a holding would in fact be in crisis and could only survive by underpaying its labour or by only partly renewing its means of production, resulting in a gradual decline of its productivity. However, remuneration for work must remain above the survival level, i.e. the minimum wage, otherwise farm workers will no longer be able to meet family needs and will have to abandon the farm. Agricultural holdings situated between the renewal and the survival thresholds generally have average-powered machinery that is obsolete and in bad condition. These farms are without plans for the future and without prospective buyers, but their productive resources could still be taken over, should they cease activity, by one or more neighbouring farms under expansion.

This divergent process has featured during each stage of the agricultural revolution: on the one hand, there has been an unequal and cumulative development of farms that are sufficiently capitalized and productive to be above the renewal threshold and, on the other, an impoverishment and elimination of units below this threshold. The farms that have invested and progressed the least in a given stage have found themselves relegated and then eliminated during the succeeding stage, while the most capitalized and productive units have moved on. Thus, most of the farms that existed in 1950 have disappeared, and only a minority have progressed through every stage and reached today's high capitalization and productivity levels.[11]

While the mechanisms of capitalization and the unequal and cumulative development of farms above the renewal threshold are easy to understand, it is necessary to explain the economic mechanisms whereby a majority of farms that had initially progressed and reached a certain level of capitalization and productivity were successively relegated below the renewal threshold and subsequently eliminated.

Falling commodity prices or higher costs can send a productive farm into an economic crisis.

A production unit that is above the renewal threshold may later fall below the threshold, despite having maintained its technical productivity. This can occur either because the unit's economic productivity has fallen owing to the unfavourable evolution of commodity or input prices or because of a rise in the renewal threshold (itself influenced by the wage levels on the work market), or both.

These two circumstances have actually occurred on a large scale during the past half-century. Real prices of agricultural food commodities have been on a sharp downward trend since 1950 because gains in agricultural productivity in the

developed countries have been superior to those of other sectors during this period. Moreover, up until the 1980s, real salaries of unskilled workers increased in these countries, reflecting the fact that productivity gains in the economy as a whole were directed not only towards capital earnings and accumulation, but also in part towards increasing wages and purchasing power.

Not only is this combination of declining real agricultural prices and a rising in the renewal threshold detrimental to underequipped farms, but it also acts in every region against the least profitable products and product combinations, taking into account local environmental and economic conditions.

In a given region, the levels of attainable productivity from the various possible product combinations are very uneven, and the least cost-effective eventually end up below the renewal threshold and are progressively eliminated. The farms engaged in these combinations are either themselves eliminated or they abandon them in favour of a profitable product combination that generally involves only a few very advantageous and technically compatible production lines.

Thus, each region gradually determines its most efficient specialized product combination and level of equipment (i.e. the production system). As each region abandons the unprofitable activities and focuses on a few profitable ones, the resulting delocalization and then the relocation of all agricultural activities produces a vast interregional division of agricultural work which, taken beyond national borders, gives some countries a very distinctive agricultural profile.

However, there are also regions in which all possible production combinations have eventually sunk below the renewal threshold, leading to the elimination of all farm units, migration from rural to urban areas (when permitted by the overall economy) and the spread of derelict land.

Consequences of the agricultural revolution

Beyond its intrinsic technical and economic aspects, the agricultural revolution has also led to a series of associated large-scale ecological, demographic, economic and cultural changes.

Ecological changes. Specialization has brought about massive spatial relocations and regional regroupings of field cropping in some places, pasture and livestock farming in others, and vineyards, market gardening, flower or other cultivation, fallow land and afforestation elsewhere. Thus, today's cultivated

ecosystems differ from past multicrop/livestock ecosystems in which every village, every farm even, comprised a mosaic of land areas used for different purposes (cereals and other field crops, pasture, meadow, woodland, vegetable gardens, vineyards, orchards, etc.), each with a different crop and animal population.

Today's cultivated ecosystems are simpler and more uniform; wheat or maize fields, vineyards, or pasture and grazing herds sometimes succeed each other for hundreds of kilometres, and even the crop varieties and breeds vary little. What is more, being better nourished and protected, both crops and livestock are more vigorous and generally more densely stocked than in the past.

On the other hand, wild plants and animals have been seriously impoverished (there are more thistles, wallflowers, poppies and cornflowers and fewer insects, birds and rodents). The use of high concentrations of fertilizer and chemicals and the massive application of excreta from the large numbers of animals housed under the same roof can cause mineral and organic pollution, particularly of surface water and groundwater, and at times also adulteration of foods themselves (an excessive amount of nitrates in vegetables, pesticides on fruit and hormones and antibiotics in meat).

Tight economic conditions on a farm can make it difficult to maintain the productivity of natural resources.

The intensity of production and the cost-effective application of inputs, under the present system of comparative prices, frequently exceed ecological tolerance limits and a socially acceptable level of risk. However, clean-up operations are generally very expensive to the community, while the regulatory limitation of practices that may be optimal from a microeconomic point of view but pollute the environment inevitably reduces agricultural productivity. The cost of producing foodstuffs and maintaining an environment that both meet society's new quality expectations will have to be paid in one way or another.

Demographic changes. The replacement of most of the agricultural workforce by machines, together with the increase in land area per worker and the concomitant reduction in the number of farms, has generally led to very high agricultural outmigration, a process also fuelled by the reduction of allied activities (e.g. upstream and downstream trade and craftwork and public services). Thus, with 100 to 200 ha of field crops per worker, and 200 to 1 000 ha under extensive livestock production, without even considering the regions that have abandoned farming altogether, population density has fallen to below five and sometimes even one inhabitant per km^2□.

This makes it very difficult to maintain services, such as post offices, schools, shops and health care, and to preserve local social life.

On the other hand, in some regions, specialization has led to agricultural and rural population densities equal to or even greater than in the past. With fewer than 5 ha per worker in quality viticulture, and less than 1 ha per worker in greenhouse market gardening or flower cultivation, population densities may amount to tens or hundreds of inhabitants per km^2.

Economic changes. The productivity gains from the agricultural revolution have been so vast that they have freed most of the workforce previously engaged in agriculture. During the first three postwar decades, this helped provide the large number of workers needed for industry and services in full development. Since the mid-1970s, however, economic growth has slowed and the continuation of agricultural migration has only fuelled unemployment. On the positive side, productivity gains in agriculture and other sectors have led to a shorter working week, a lowering of the retirement age and longer schooling. Finally, in the developed countries an active agricultural population, reduced to less than 5 percent of the total active population, has been able to feed the whole population – and better than before.

Cultural changes. As the new means of production are largely designed and manufactured in research and development centres and in concentrated industrial and service enterprises located far from the farm holdings and their immediate vicinity, the training of farmers and agricultural workers no longer takes place through apprenticeship on the farm, but increasingly in public and private institutes and using technical and economic information services. The former rural cultural heritage, produced and handed down locally, has given way to a relatively uniform culture, disseminated by education and the media.[12]

These immense ecological, demographic, economic and cultural changes indicate the extent to which the agricultural revolution has triumphed in the developed countries. Yet, looking a little further afield, this has clearly not been the case in the developing countries. Although motorized mechanization, high-yielding varieties and breeds, fertilizers, concentrated feeds, phytosanitary products and specialization have also reached these countries, more often than not they have been spread in an incomplete form and to a limited extent.

LIMITS TO THE AGRICULTURAL REVOLUTION

In the developing countries

The agricultural revolution has reached few areas of the developing countries.

The current agricultural revolution with all its attributes, in particular its heavy, complex and very expensive motorized mechanization, has not extended far beyond the developed countries, with the exception of small portions of Latin America, North Africa and South Africa and Asia[13] where it has only been adopted by large national or foreign farms that have the necessary capital. Alongside this, numerous small farmers continue to farm manually or using animal traction. Heavy motorized mechanization is also virtually non-existent in most parts of sub-Saharan Africa, in the Andes and in the centre of the Asian continent.

As a result of the green revolution, other regions and more farms have benefited from some of the components of the agricultural revolution: high-yielding varieties of maize, rice, wheat, cassava, broad bean, sweet sorghum and pigeon pea[14] selected in the course of the last decades in international research centres (e.g. the International Rice Research Institute and CIMMYT), fertilizer and phytosanitary products. There have been significant increases in yield in several countries, particularly with large-scale irrigated agriculture and proper water control. Water control throughout the year and the breeding of non-photoperiodic rice varieties suitable for cultivation in all seasons have permitted more than three harvests per year on the same plot of land.

Thanks to these achievements, the well-located and better-off farmers have been able to obtain animal traction – sometimes even power tillers or small tractors – and to some extent approach the productivity levels of developed countries. Also helped by low local wages, the production and productivity levels attained have enabled certain countries to reduce undernutrition significantly (e.g. India and China) or even to become rice exporters (e.g. Thailand, Viet Nam and Indonesia). Yet, despite these gains, extreme poverty and chronic undernutrition have by no means disappeared in these countries.

Even in green revolution regions, numerous small, poorly equipped and very low-income farms were unable to gain access to the new means of production. Unable to invest and progress, they saw their incomes fall as a result of the drop in real agricultural prices. Many of them sank to levels of extreme poverty and were eliminated. Above all, vast hilly and barely accessible regions of rainfed or scarcely irrigated agriculture were essentially bypassed by the green revolution. The varieties

cultivated in these regions (millet, sorghum, taro, sweet potato, yam, plantain, cassava) benefited marginally, if at all, from selection. The same was true for varieties of major cereals (wheat, maize, rice) that were adapted to difficult local conditions (altitude, drought, salinization, aridity, waterlogging). For example, the average output of millet throughout the world today is barely 800 kg/ha, and that of sorghum is less than 1 500 kg/ha. These so-called "orphan" varieties, having been bypassed by the selection process, make the use of fertilizer and phytosanitary inputs unprofitable, which only adds to the problems of the regions where they are grown.

Integration into global markets can be a two-edged sword for farmers in developing countries.

Admittedly, the less accessible regions that were only marginally affected by the green revolution remained sheltered for a long time from the cheap imports of cereals and other staple foods from the more advantaged regions and countries. In this way, regions that had not been reached by modernization were able to maintain their production systems (diversity, breeds, implements, crop and livestock combinations and practices), their population and their culture longer than others. However, as soon as these regions were penetrated by the advance of motorized transport and commerce, they also found themselves caught up in interregional trade and were thus exposed to low-cost imports of cereals and other food commodities.

Based on the price paid to well-equipped cereal growers in developed countries (i.e. less than $15 per 100 kg of grain), a manual cereal grower producing 1 000 kg of grain net earns less than $150 per year. However, at least 700 kg of production have to be set aside for household consumption, so cash income does not even amount to $50 per year, and this is assuming that farmers do not have to pay land rent, interest on loans or taxes. At this income level, it would take a lifetime for manual cereal growers to purchase a pair of work oxen and basic animal traction equipment, assuming all their cash income could be spent on this purchase; and it would take three centuries to buy a small tractor.

Under these conditions, farmers try to take advantage of the widening access to external trade by diverting part of their resources and workforce to cash crops (cotton, oil-palm, rubber, coffee, cacao, banana, pineapple, tea). But this means that local food production declines and food dependence sets in; and, being underequipped and underproductive, most of these farmers are unable to invest and progress sufficiently to withstand the continuing and generalized decline in real agricultural prices. In such circumstances, hundreds of millions

of underequipped peasant farmers in the more deprived regions sink into a three-pronged economic, environmental and nutritional crisis.

Because of falling agricultural prices, the already low cash income of these farmers becomes insufficient to maintain and entirely renew their equipment and inputs and thus further erodes their production capacity. At this stage, an able-bodied member of the family can still be sent out to find temporary or permanent work elsewhere, although this weakens farm production capacity still further. The temporary survival of the farm only becomes possible by means of decapitalization (sale of livestock, non-renewal of equipment), underconsumption, undernutrition and the migration of part of the workforce.

Increasingly poorly equipped and badly fed, these farmers are obliged to concentrate their efforts on short-term returns and to neglect the maintenance of the cultivated ecosystem. This neglect takes the form of poor maintenance of irrigation systems, slash-and-burn of ever younger fallow, insufficient weeding, sale of livestock and reduced transfer of fertility to the soil. The economic non-renewal of the productive system leads to the non-renewal of fertility of the cultivated ecosystem.

The reduction in equipment, the diminished workforce and the degradation of fertility of the cultivated ecosystem also lead farmers to simplify their cropping systems: "poor" crops, which are less demanding on the level of mineral fertility of the soil and require less labour, replace more demanding crops. This, coupled with the near disappearance of animal products, leads to serious protein, mineral and vitamin deficiencies. Thus, malnutrition resulting from the degradation of the cultivated ecosystem is compounded by undernutrition through poor crop quality.

These are the basic economic and environmental mechanisms that explain why the destitute peasant farmer population of poor agricultural regions constitutes the bulk (three quarters)[15] of the more than 800 million people suffering from undernutrition in the world today. Since a significant proportion of these peasant farmers and other rural inhabitants migrate each year to overpopulated urban areas, and since the number of chronically undernourished peasant farmers remains constant year after year, this means that the poor farmer population is constantly being renewed.

Reduced to the limits of survival, this impoverished peasant farmer population is thus at the mercy of the slightest adversity, whether climatic (flooding or drought), biological (plant, animal or human disease), economic (falling agricultural prices) or,

more and more often, political (war) as extreme poverty and hunger are two further elements in the complex causes of local or regional conflicts.[16]

This process of impoverishment and exclusion has not yet affected the whole of the peasant farmer sector engaged in manual cultivation. It has affected the most deprived, who are especially numerous in resource-poor regions or where their condition is further aggravated by circumstances such as natural constraints (insufficient or excessive rainfall, cold, salinization), infrastructural obstacles (lack of irrigation), structural constraints (microholdings, precarious land tenure) and policies unfavourable to agriculture (overvalued currency, subsidies for food imports, taxation on agricultural exports, fluctuating prices, limited or inefficient public investment in agriculture).

The agricultural transformations of the past half-century are not limited to the two extremes of the contemporary agricultural revolution and green revolution, on the one hand, and impoverishment, exclusion and hunger, on the other. A closer analysis reveals that agriculture throughout the world is subject to change that does not originate from these agricultural revolutions but that contributes, in its own way and to its own extent, to the process of modernization.

In fact, agriculture does not stand still. Even the smallest-scale farmers in the African savannahs, the Andes and the high valleys of Asia routinely adopt new plants and new animals originating from other continents and, if they can afford them, new metal tools, either manual or animal-drawn. Above all, in order to adapt to ever changing economic, environmental and demographic conditions, they are continually combining and recombining crops and varieties, animal production systems and breeds and old and new tools to create new production systems, and the less favourable the conditions the greater the ingenuity.

For example, on the highly leached soils of the poor savannahs of the central plateaus of the Congo, during the last few decades the Batéké farmers have perfected systems that combine orchard gardens, annual crops (potato, bean, tobacco) on burn-beaten mounds, biennial cassava cropping on ridges and coffee plantations under the shade of restored woodlots on abandoned village orchard gardens.[17] Another example is the orchard garden with small livestock raising in the hills of Burundi or Haiti, practised under rainfed cultivation on sometimes very sloping terrain, and supporting populations of several hundreds of inhabitants per km^2. While the labour productivity of these systems cannot exceed the limits of their

manual equipment, they are nonetheless modern and very sophisticated.

Most remarkable are the mixed systems with very intensively used biomass combining crops, arboriculture, breeding and sometimes even aquaculture, which are vigorously developed in the most populated regions of the world. For example, in certain plains, valleys and deltas of Southeast Asia (central-south Java, the Mae Klong delta in Thailand, the Mekong delta in Viet Nam), the cropping systems alternate raised beds (with the multicropping of cereals, tubers, roots and vegetables under plantations of banana, papaya, coconut palm and sugar palm) and aquaculture or rice basins with two or three harvests per year, supporting high densities of large and small livestock and providing jobs, subsistence and cash income to populations of 1 000 to 2 000 inhabitants per km^2. In the Nile valley, in Egypt, systems of two or three irrigated crops per year of fodder, cereals and vegetables under or alongside plantations of banana, citrus, palm and other fruit-trees support equally high animal and human densities.[18] These systems, often using little or no motorized mechanization and limited quantities of inputs, have a relatively modest productivity rate, but their production of usable biomass (including all forms of production) by unit of surface area largely exceeds the average production of large-scale specialized cropping in the developed countries. With the world's growing population, there is no doubt that these systems will become increasingly important in many regions.

In the developed countries

Even in the developed countries, the agricultural revolution has its limits and drawbacks. In temperate regions with only one cropping season, it is difficult to exceed annual yields of 12 000 kg of grain per hectare or milk yields of 12 000 litres per cow. Degradation of the environment and the quality of food worsens with overuse of fertilizers and agricultural chemicals, excessive concentrations of animal production and the recycling of possibly unhealthy organic waste in compound feed. At the same time, the huge mechanized capacity, rural outmigration and the abandonment of farmland pose increasingly acute problems of employment and land maintenance.

Alternative forms of agriculture are already developing in pockets of industrialized countries in response to these excesses. Including ecologically sound and organic agriculture, these alternative forms are less specialized, more economical in their use of non-renewable resources, more environmentally and socially friendly, and more geared towards product quality. They

are in tune with the aspirations of the public and many farmers[19] and are destined to expand considerably.

ASSESSMENT AND FUTURE PROSPECTS

The first question is whether the conquest of new cropland, the extension of the agricultural and green revolutions to poor farmers and the development of sustainable forms of agriculture, in both developed and developing countries, will raise world food production to meet the quantitative and qualitative needs of the much larger human population of future decades.

The second question is whether these agricultural developments will take place under economic and social conditions that will finally give the more deprived population groups access to sufficient food.

After 50 years of modernization, world agricultural production today is more than sufficient to feed 6 billion human beings adequately. Cereal production alone, at about 2 billion tonnes or 330 kg of grain per caput/year and representing 3 600 kcal per caput/day, could to a large extent cover the energy needs of the whole population if it were well distributed.[20] However, cereal availability varies greatly from one country to another: more than 600 kg per caput/year in the developed countries, where most is in fact used as animal feed, but less than 200 kg per caput/year in the poorer countries. Moreover, within each country, access to food or the means to produce food is very uneven among households. Consequently, in many countries, large segments of the population do not have enough food. And, as noted earlier, the large majority of the 830 million chronically undernourished are in the poor peasant farming community.

World food security is determined by poor farmers' production methods and poor consumers' purchasing power.

World food security, therefore, is not an essentially technical, environmental or demographic issue in the short term: it is first and foremost a matter of grossly inadequate means of production of the world's poorest peasant farmers who cannot meet their food needs. It is also a matter of insufficient purchasing power of other poor rural and urban consumers, insofar as the poverty of non-farmers is also a product of rural poverty and migration from the land.

The demographic transition (i.e. the fall in fertility and thus population growth), which started a long time ago in the developed countries and which is spreading increasingly to the developing countries, leads many demographers to forecast a world population of about 10 billion in 2050, stabilizing at around 12 billion during the second half of the twenty-first century: twice as many people as in the year 2000. The experts

estimate that present world food production will have to be tripled[21] if hunger and malnutrition are to be eliminated and if a population that has doubled, and consists of higher average build and age, is to be properly fed.

The question is, therefore, whether these estimated needs of humanity are not beyond the capacity of the earth's land and water resources. Indeed, many regions are already fully exploited and sometimes even dangerously overexploited and degraded by erosion, reduced organic fertility and pollution.

On the other hand, many regions with potential have not been exploited or are underutilized. FAO data suggest that rainfed and irrigated cropland could be significantly expanded in several regions without much difficulty and without harming the environment, particularly through appropriate land use management.[22]

Moreover, the current agricultural revolution can still produce higher yields in many regions, although its excesses need to be corrected. It can be extended to new land in developing countries and can even reclaim abandoned land in the developed countries (hilly, stony terrain) provided that its biological and mechanical resources are diversified and adapted. Similarly, the green revolution in its classic form can still make significant progress in yields and surface area in the regions where it is already developed.

A new green revolution should be extended to resource-poor regions and farmers and to "orphan" species and varieties that were previously bypassed.

Above all, a second green revolution could be extended to all hitherto neglected regions, including the most disadvantaged. However, this must be on condition that an in-depth study is carried out of the agricultural systems, experience, assets, constraints and farmers' needs of these resource-poor regions to serve as the basis for related projects and policies. Furthermore, selection must be resolutely applied to "orphan" species and to varieties and breeds appropriate to these regions. This large-scale renewal and revival of the green revolution to encompass more regions, populations, plants and animals is referred to by some as the "doubly green" or "evergreen" revolution.

Considering these different forms of agricultural progress and the experience of recent decades, many economists – very influential during the last 20 years and pushing optimistic liberalism to its extreme – believe that the productivity gains and falling real agricultural prices that result from trade liberalization and greater international competition will allow an abundant supply of low-cost food to be available to the majority of the world's population. They further believe that the redistribution of income and assistance targeting of the poorest will, in the short and

medium term, lead to a reduction in the number of people suffering extreme poverty and hunger.

Under this long-term perspective, with the unrestricted circulation of capital, the development of industry and the service sector should be sufficient to eliminate unemployment and mass poverty worldwide, while bringing about a degree of convergence of human development in the different parts of the world.

However, liberalization thus envisaged concerns solely the movement of goods, services and capital, and certainly not the free movement of the mass of low-skilled labour excluded from the peasant farmer sector in the developing countries; nor does it imply the unrestricted access of the huge number of peasant farmers, who are excluded from agriculture in the South, to the land, infrastructures, credit and employment of the North.

While optimistic liberalism prevails today, such a perspective is nevertheless considered by many economists to be an unobtainable mirage. Quite apart from the imperfections of the real markets – for example, increased economies of scale, monopolies, monopsonies, asymmetry of information, transaction costs – we cannot fail to ignore the fact that, in just a few decades, the international food markets have been able to absorb vast historical national and regional economic entities, with significant disparities in development and productivity.

Under these conditions, agricultural prices set at the lowest international level have helped make agricultural commodities more accessible to consumers. At the same time, however, they have led to interruptions in development as well as to the impoverishment, and ultimately economic exclusion, of large segments of the most disadvantaged peasant farmer populations of the world.

In addition, over the last 20 years of free movement of goods, services and capital but not of people, the massive outmigration from agriculture has greatly exceeded the capital accumulation and employment-generating capacity of the world economy, notably in the South; and disparities among and within countries have widened, as has the scale of mass poverty.[23]

The experience of the last decades has also shown that, for all their merits and undeniable successes, international assistance, development projects and income redistribution policies have failed to eradicate poverty and hunger. In particular, assistance targeting of "vulnerable social groups" – the type of assistance that goes hand in hand with structural adjustment and stabilization policies – has fallen far short of the mark.

If, at the beginning of the twenty-first century, we continue down the path of liberalization of trade in food, other goods

and services and capital, without the free movement of people and without providing the material and regulatory means for everyone to enjoy basic economic rights, extreme poverty and chronic undernutrition can be expected to persist in rural areas. The migration of agricultural workers, unemployment and low wages can also be expected to persist in the poorer countries that have no or few resources other than agriculture. This will contribute towards keeping the prices of exported goods and services and private and public incomes at very low levels in these countries, thus denying them the resources needed to provide the minimum public services required for development and good governance.

Finally, as the population of these countries accounts for more than half of humanity,[24] the signal weakness of their effective demand and their limited involvement in international trade will continue to hamper trade growth and will seriously compromise development of the global economy.

Definite action is required if enough food is to be produced and made accessible to the world's projected population of 10 billion to 12 billion people, and if their expectations of both environmental and product quality are to be fulfilled. First, approaches to development and food security need to prioritize the problems of the farming poor. Rescuing the most destitute half of the world's peasant farmer population from exclusion and poverty is in itself a fundamental social and humanitarian goal, but it is equally important to enable these farmers to play a tangible role in tripling world food production – the neccesary goal to be achieved in the next few decades.

Action targeting the most destitute farmers must aim at developing their food production capacity both to help them improve their nutritional status and to create employment and income for the poorer groups. The importance of these objectives and the policy measures required to achieve them are discussed in the next section of this review.

NOTES

1 FAO. 1999. *FAOSTAT '98. FAO statistical databases.* CD-ROM; FAO. 1954. *FAO Production Yearbook*, Rome.

2 M. Mazoyer and L. Roudart. 1998. *Histoire des agricultures du monde.* Paris, Éditions du Seuil.

3 The total net increase of 180 million ha is the result of an increase in the developing countries and a weak reduction in the developed countries. See FAO, op. cit., note 1.

4 FAO, op. cit., note 1.

5 *ACTA Phytosanitary Index*, 1999.

6 FAO, op. cit., note 1.

7 Mazoyer and Roudart, op. cit., note 2.

8 Estimated in kilograms of cereal equivalent (the quantity of cereals having the same calorie value as the total foodstuffs under consideration). Productivity is calculated as follows: maximum surface area cultivated by one farmer multiplied by potential yield per hectare of good soil, subtracting seeds, losses and quantity of grain needed to cover the cost of inputs and depreciation of materials. For each major system, the maximum surface area per worker and the maximum yield per hectare vary according to region, which explains why maximum productivity also varies to a certain extent.

9 Mazoyer and Roudart, op. cit., note 2.

10 The use of fertilizer and yields are very unequal in these two countries: they are low in the United States, where farmers dispose of a very large surface area, and higher in France, where the size of production units is much smaller. After the mid-1970s, the use of mineral fertililizer reached a peak and then declined in France, although yields have continued to rise because agriculture is tending to use fertilizer more sparingly (needs are calculated more carefully and split applications are made).

11 Mazoyer and Roudart, op. cit., note 2.

12 M. Mazoyer. 1999. Compte-rendu de l'atelier Agriculture, Ressources naturelles, Environnement. Colloque *L'enseignement agricole, quels apports à la société?* Paris, French Academy of Agriculture.

13 Today, with 1.3 billion people actively involved in farming, only 28 million tractors are used in agriculture worldwide.

14 FAO. 1995. *Dimensions of need. An atlas of food and agriculture.* Rome.

15 FAO. 1996. *Technical background documents. World Food Summit*; IPU. 1998. Inter-Parliamentary Union Conference – Attaining the World Food Summit's Objectives through a Sustainable Development Strategy, 26 November-2 December 1998, FAO, Rome.

16 M. Mazoyer and L. Roudart. 1997. Development of agricultural inequalities in the world and the crisis of the comparatively

disadvantaged peasant farming sector. *Land Reform*, 1: 7-17. Rome, FAO; M. Mazoyer and L. Roudart. 1997. L'asphyxie des économies paysannes du sud. *Le Monde diplomatique* (October).

17 C. Serre-Duhem. 1995. Les transformations d'un système agraire au Congo: le plateau Kukuya. National Institute of Agronomy Paris-Grignon. (thesis)

18 L. Roudart. 1998. Origines et transformations récentes des systèmes hydroagricoles de la vallée du Nil en Egypte – Le rôle de l'État. National Institute of Agronomy Paris-Grignon. (thesis)

19 Mazoyer, op. cit., note 12.

20 FAO. *The State of Food and Agriculture*. (various years) Rome.

21 P. Collomb. 1995. Population mondiale: conférences internationales et paradoxes du discours démographique. *Problèmes économiques*, 2.421: 20-23.

22 FAO. 1995. *World agriculture – towards 2010*. Rome.

23 UNDP. *Human Development Report* (various years). New York.

24 The population of the low-income food-deficit countries amounts to more than 3.6 billion people. See FAO (1999), op. cit., note 1.