# Population and Technological Change

## *A Study of Long-Term Trends*

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# 1 POPULATION SIZE AND TECHNOLOGICAL DEVELOPMENT

Human history can be viewed as a long series of technological changes. Just a few of the crucial ones are the discovery of the usefulness of fire at least 350 millennia ago, the appearance of food production more than 10 millennia ago, the construction of urban centers more than 5 millennia ago, the invention of mechanized large-scale industry a few centuries ago, and the invention of nuclear power a few decades ago.

Some inventions were made by chance, others after centuries of speculation and experiments aimed at solving particular problems. Except for the inventions of recent centuries, the circumstances in which they were made are seldom known; nor, often, do we know even the approximate time of the invention or the region in which it occurred.

Many of the inventions had important effects on the size and distribution of world population. The use of fire reduced mortality by providing better protection against wild animals and permitted settlement in areas with temperate and cold climates. Many later inventions also helped reduce mortality rates and promoted either decentralization or centralization of population. World population grew from very small numbers at the time when human beings began to use fire to more than four billion today; and the rate of growth accelerated as well, especially in recent centuries. This multiplication of world population would not have been possible without successive technological changes.

It is generally agreed that successive changes in technology had an important influence on population size, but opinions are divided concerning the type of technological change which had the greatest influence in different periods and in different regions. The opposite side of the interrelationship, the influence of population size on technology, has attracted less attention. The focus in historical research has been on original inventions rather than on transmission of techniques from region to region, and the influence of demographic factors on the invention of techniques is less obvious than is the influence of such factors on the transmission of techniques.

Yet societies have most often advanced technologically by introducing technologies already in use in other societies. If we want to study the causes of changing technology in various periods and parts of the world, it is more important to focus on the conditions for transmission of techniques than on the conditions for the appearance of inventions. It is, of course, a matter of choice where the line is drawn between a new invention and a technological adaptation of an existing technique to a new environment. The distinction between invention and transmission of technology becomes blurred if we use a definition of inventions broad enough to include minor adaptations of known technologies.

The speed with which major inventions have been transmitted from place to place varies enormously. During early stages of human history, some inventions seem to have been transmitted relatively quickly over huge distances. By contrast, other major inventions never moved from one people to its nearest neighbors, although contacts were frequent during many millennia. There are still some groups of people who have never introduced food production, and many more who have never constructed urban centers of their own. Much of the world population lives in areas still at early stages of the industrial revolution. It is more important to study the obstacles which prevent the transmission of technologies than to compare the number of inventions which have been made in different societies.

Demographic factors help to explain why some technologies fail to be transmitted in the wake of human contacts. Certain technologies are uneconomic or inapplicable in areas with a small and sparse population, others in areas where population density exceeds a certain level. A technology could be inapplicable for a small population because its use requires a large collective effort. Other technologies require the use of more space than is available in areas with a high population density. Large differences in population density between various areas have existed for many millennia, and the links between population size and the use of particular technologies must have significantly limited the possibilities for transmission. Thus, a technological invention might spread to distant areas with similar population size or density, but not to those areas in between with a different size or density.

Although demographic factors seem to have played a larger role in transmission than in invention of technology, they no doubt also provided some motivation for invention. In the twentieth century, nearly all invention is the result of demand-induced or cost-induced organized research, and there is usually correlation between the resources devoted to research within a given field and the speed of technological progress within that field. Thus, there is a link between the motivation for innovation and the amount of invention.

Such a link existed even before the time of organized scientific research. Most of the inventions in the early stages of the industrial revolution were not made by scientists, but by people with little or no education, who experimented to find new and better solutions to urgent problems.[1] Sometimes they succeeded after many years of vain efforts,



which they would not have made had the problem confronting them been less urgent. Experiments to find new solutions to urgent problems no doubt have been made at all periods of human history, since the time of primitive hunters, but in early periods the chance of success was much smaller, and the period of trial before positive results were obtained much longer, than today. Even today, when large resources are invested in scientific research, the attempts at innovation within some fields continue to be unsuccessful. In other fields the time lag between discovery and practical application is often many decades. In past ages, when inventions were made by trial and error, few experiments were likely to succeed, and in case of success, this time lag may have been centuries rather than decades. Even so, it would seem that motivation had a strong influence on invention.

If it is agreed that many inventions—today as well as in the past—have been demand-induced, it becomes pertinent to ask to what extent this demand pull was in turn determined by demographic changes. Radical changes in the relation between human and natural resources occur in areas in which population multiplies. Shrinking supplies of land and other natural resources would provide motivation to invent better means of utilizing scarce resources or to discover substitutes for them. Moreover, population increase would make it possible to use methods that are inapplicable when population is smaller. Once these motivations led to invention or importation of technologies, the technological changes would then result in further population change, which in turn would induce still further technological change. In this way, an interlinked process of demographic and technological change would occur. Other areas would have little or no technological change because of stagnant populations, and would continue to have stagnant populations because of no technological change.

The interrelationship between population and technological change is a complicated one. Increasing population size may make life easier because there will be more people to share the burden of collective investments, but it may also make life more difficult because the ratio of natural resources to population decreases. At different periods and places, one or the other tendency may prevail. In some periods, a society with a growing population may be motivated to import new technologies by the desire to draw benefit from large collective investments. In other periods, the transmission of important new technologies may be a means to reduce or eliminate the disadvantages of a declining ratio of natural resources to population.

A growing population gradually exhausts certain types of natural resources, such as timber, virgin land, game, and fresh-water supplies, and is forced to reduce its numbers by emigration or change its traditional use of resources and way of life. **Increasing populations must substitute resources such as labor for the natural resources which have become scarce.** They must invest labor in creation of amenities or equipment for which there was no need so long as the population was smaller. Thus, the increase of population within an area provides an incentive to replace natural resources by labor and capital.

Major migrations change the population-resource ratio and also the ability to make collective investments. The area of immigration improves its ability to make collective investments, but pays for it with a higher population-resource ratio, while the area of emigration pays for a reduced pressure of population on resources with a reduced ability to create—and maintain—collective investments. Therefore, major migrations of population are likely to be accompanied by important technological changes in all the areas affected by the migrations.

If it is agreed that, although many technologies are unrelated to population size, others are inapplicable or uneconomic in areas with either a small or a large population, the next step is to ask whether it is feasible to draw up the approximate limits for the population size which permits or prevents the use of "population-linked" technologies. In the first part of this study, an attempt is made to draw up such limits for different techniques of food supply. The method used is cross-country comparison of recent data; the main purpose of the exercise is to throw light on historical interrelations between population size and technology.

Part 2 discusses population size and technological levels in the ancient world. Focus is on two major technological changes: the beginnings of food production and the appearance of urbanization.[2] The early urbanized societies could function only by means of infrastructure investment in construction and transport facilities. These investments could be undertaken only with a large labor force, since they employed human muscle power mainly or exclusively. Therefore, in ancient times, high population size and high technological levels went together.

Dependence upon a large labor force made the ancient urbanized societies vulnerable to major demographic changes. Often technologically advanced societies reverted to a lower technological stage after epidemics or wars reduced population. Meanwhile, low population densities provided a handicap to urbanization in Western and Central Europe. After the end of the first millennium A.D., however, population densities in that region seem to have reached levels which permitted widespread urbanization. Part 3 discusses the interrelations between demographic trends and technological change in the period of preindustrial urbanization in Europe. It focuses on the increasing shortage of forest areas for cutting timber and fuel wood and for producing the charcoal necessary to smelt iron ore. This shortage of forest areas provided motivation for some of the important technological changes during the industrial revolution.



Part 4 considers the centuries after 1750 when industrial technologies were transmitted from Western Europe to other parts of the world. Until then, areas with low population density were apparently unable to reach technological levels as high as areas with higher densities. The correlation between population density and technological level now became much less close, partly because improved transport enabled areas with sparse population to import labor, capital, and skills from Europe, and partly because some of the most densely populated parts of the world suffered from increasing strains due to a decreasing resource-population ratio.

After 1950, rates of population growth accelerated in most of the world because mortality but not fertility declined rapidly. The reasons are discussed in part 5. **Rapid increases in world population were accompanied by rapid technological change. The process of interrelated demographic and technological change resulted in radical changes in the pattern of international trade and factor proportions.**

# 2 REGIONAL DIFFERENCES IN POPULATION AND TECHNOLOGY

Differences in technological levels between countries pose a major problem to the international community today. There are also significant technological differences between ethnic groups within some countries where smaller or larger groups continue to apply primitive technologies abandoned by other inhabitants millennia ago.

If we compare the primitive technologies still used by some groups with the technologies applied in the large industrial centers, we find that the gap between the most advanced and the least advanced has been widening. But if we use a historical perspective to look at the differences between major regions, we find not only widening but also narrowing gaps, as well as shifts of technological leadership from one region to another.

East Africa[1] and Southeast Asia,[2] which have low technological levels today, seem to have been among the leaders at early stages of human history. At a later stage, North Africa and western Asia may have been ahead of others, and still later the leadership seems to have moved from west to east in Asia. Before Europe took over after the middle of this millennium, China seems to have been the most advanced society.[3] In recent centuries, technological leadership has shifted frequently. It took only a few centuries for the United States to replace Europe, and less than a century for the Soviet Union and Japan to challenge the U.S. in certain fields. The history of technological development is a tale of both widening and narrowing technological gaps, and belies the idea that some peoples are or have been technological leaders because they were more "inventive" than others.

### Long-Term Trends in World Population

It was suggested in chapter 1 that differences in demographic trends may have contributed to the widening or narrowing of technological gaps between different peoples. During many millennia, regional differences in population size and density seem to have been very large, and before the industrial revolution there seems to have been a positive correlation between size and density of population and technological levels.

All such statements must, however, remain tentative because the evidence we have of population size in the past is limited. Most, but not all, countries have reliable population statistics today, but many took their first census after 1950, and only a few before the nineteenth cen-





tury. Thus our information is based on estimates, many of which have a very large margin of error. It is true that China, Japan, and a few other countries began to make records of population size centuries ago, but nearly all this evidence is lost, and the surviving data are difficult to interpret. The same is true of earlier counts of households or fireplaces made in European countries.

Estimates are therefore based on indirect written evidence, such as tax records, registration of agricultural land, or information about the size of armies. Archeological research provides additional evidence; for instance, the number of burials and house sites, the amount of surface covered by buildings, and the distances between towns and villages. Archeological evidence of dietary habits combined with estimates of the numbers who could be nourished on that diet are also useful. Such calculations based on estimates of "carrying capacity" suffer, however, because they are estimates of maximum rather than actual population. It is unrealistic to assume that all populations were large enough to utilize the full capacity for food supply in the area in which they lived.

Before the Christian era, all we have are either "informed guesses" on the size of world population or more reliable estimates for small areas. However, for the beginning of the first century A.D. and for selected later periods, attempts have been made to compare, revise, and supplement existing estimates from many sources and to produce consolidated estimates of world population, broken down by regions. Recently, Durand[4] has produced such a comprehensive estimate of long-term trends in world population, based upon earlier estimates by Colin Clark[5] and predecessors. Durand's estimates are reproduced in table 2.1.

In the period covered by the table, i.e., between A.D. 1 and 1975, world population increased from some 300 million to around [illegible] billion. In this book, the figures for population in millions have been transformed into persons per square kilometer and expressed in density groups, as shown below. Each group has twice the density of the previous one.

| Density | Density group | Persons per km² |
|---|---|---|
| Very sparse | 1 | 0– 1 |
| " | 2 | 1– 2 |
| " | 3 | 2– 4 |
| Sparse | 4 | 4– 8 |
| " | 5 | 8– 16 |
| Medium | 6 | 16– 32 |
| " | 7 | 32– 64 |
| Dense | 8 | 64–128 |
| " | 9 | 128–256 |
| Very dense | 10 | 256–512 |

**TABLE 2.1** POPULATION ESTIMATES FOR WORLD REGIONS (in millions)

| Region | A.D. 1 | 1000 | 1500 | 1750 | 1900 | 1975 |
|---|---|---|---|---|---|---|
| China | 70–90 | 50–80 | 100–150 | 190–225 | 400–450 | 800–900 |
| India, Pakistan, Bangladesh | 50–100 | 50–100 | 75–150 | 160–200 | 285–295 | 740–765 |
| Southwestern Asia | 25–45 | 20–30 | 20–30 | 25–35 | 40–45 | 115–125 |
| Japan | 1–2 | 3–8 | 15–20 | 29–30 | 44–45 | 111 |
| Remainder of Asia, exc USSR | 8–20 | 10–25 | 15–30 | 35–55 | 110–125 | 435–460 |
| Europe, exc USSR | 30–40 | 30–40 | 60–70 | 120–135 | 295–300 | 470–475 |
| USSR | 5–10 | 6–15 | 10–18 | 30–40 | 130–135 | 255 |
| Northern Africa | 10–15 | 5–10 | 6–12 | 10–15 | 53–55 | 80–82 |
| Remainder of Africa | 15–30 | 20–40 | 30–60 | 50–80 | 90–120 | 315–335 |
| North America | 1–2 | 2–3 | 2–3 | 2–3 | 82–83 | 237 |
| Central and South America | 6–15 | 20–50 | 30–60 | 13–18 | 71–78 | 320–335 |
| Oceania | 1–2 | 1–2 | 1–2 | 2 | 6 | 21 |
| Total | 270–330 | 275–345 | 440–540 | 735–805 | 1650–1710 | 3950–4050 |

SOURCE: John Durand, "Historical Estimates of World Population: An Evaluation," *Population and Development Review* 3, no. 3 (New York, 1977).
NOTE: Because of the large margin of error, Durand gives "indifference ranges," i.e., limits within which he sees little ground for preference between the lower and the higher figure.

In 1975, the last year shown in table 2.1, the average population density in the world was around thirty persons per square kilometer. (Total territory is defined as total land area, except for areas permanently covered by ice.) This is close to the limit between our density groups 6 and 7 (thirty-two persons per square kilometer). Medium population density has therefore been defined as group 6–7 level in this book, with densities below 6 considered low, and densities above 7, high. (See appendix for a list of the countries in each density group.)

At the beginning of the period covered by table 2.1, average population density in the world is assumed to have been at group 3 level, i.e., less than four persons per square kilometer (see table 2.2). However, regional differences were very large: many regions had group 1 densities, i.e., less than one person per square kilometer, while India may already have had medium population density. Estimates of Indian population size, however, are even more uncertain than those for other regions.[6]

China and India, which seem to have had higher population densities than other regions, had large variations in density within their territories, and variations seem to have been the case also with Mesopotamia and Egypt.[7] Even within the extremely sparsely populated American continents, there seem to have been pockets of dense population around A.D. 1.[8] Those areas were seats of ancient urbanized societies, which were at high technological levels by the standard of the time.



**TABLE 2.2** DENSITY OF POPULATION FOR WORLD REGIONS

| Region | A.D. 1 | 1000 | 1500 | 1750 | 1900 | 1975 |
|---|---|---|---|---|---|---|
| China | 4–5 | 4 | 5 | 6 | 7 | 8 |
| India, Pakistan, Bangladesh | 5–6 | 5–6 | 6–7 | 7 | 8 | 9 |
| Southwestern Asia | 3–4 | 3–4 | 3–4 | 3–4 | 4–5 | 6 |
| Japan | 3–4 | 5–6 | 7 | 8 | 8 | 10 |
| Remainder of Asia, exc USSR | 2–3 | 2–3 | 3–4 | 4–5 | 6 | 8 |
| Europe, exc USSR | 4 | 4 | 5 | 6 | 7 | 8 |
| USSR | 1 | 1 | 1 | 2 | 4 | 5 |
| Northern Africa | 2–3 | 1–2 | 2 | 2–3 | 5 | 5 |
| Remainder of Africa | 1–2 | 1–2 | 2–3 | 3 | 3–4 | 5 |
| North America | 1 | 1 | 1 | 1 | 4 | 5 |
| Central and South America | 1 | 1–3 | 2–3 | 1 | 3 | 5–6 |
| Oceania | 1 | 1 | 1 | 1 | 1 | 3 |
| Total | 3 | 3 | 3–4 | 4 | 5 | 6 |

DATA SOURCE: Same as table 2.1 and UN statistics.

Within Europe also, variations in population density were large. Greece and Italy had medium population densities, while other parts of Europe were very sparsely populated. As late as the mid-eighteenth century, at the beginning of the industrial revolution, Europe, including European Russia, was still sparsely populated (see table 5.2). Even if Russia is excluded, Europe had only medium density at that time. High population densities for major regions are a recent phenomenon. At the time of the industrial revolution, all the regions listed in tables 2.1 and 2.2 except the small territory of Japan still had low or medium densities.

Large parts of the world continue to be sparsely populated today. Average population density in Oceania is at group 3 level. The Soviet Union, Africa, and North America are at group 5 level, and Latin America is just approaching group 6 level. Only east and south Asia and Europe are densely populated.

### Regional Differences in Technological Levels

Using counts of artifacts and selected traits, Carneiro has made interesting quantitative comparisons of technological and cultural levels in ancient societies and in certain contemporary communities.[9] Worldwide quantitative comparisons and long time series for many countries, however, must await the collection and analysis of further data. Attempts at measuring technological levels in quantitative terms are limited in this study to those for the present. Even these involve difficulties, and the results must be interpreted with caution.

Higher technological levels are reflected in higher production per head of population, and nearly all countries publish information about per capita production. These figures, however, are not suited for inter-country comparison of technological levels for a number of reasons. It is difficult to compare money incomes of countries with different price structures and degrees of monetization. Moreover, a country with a small population but a highly profitable industry, for instance, an oil industry, would appear to have a high technological level even though the majority of the population might use primitive technologies. Finally, use of per capita production figures would exclude all communist countries, which define national production in a way that makes comparison with other countries impossible.

To obtain a broad view of contemporary technological levels it is, therefore, necessary to combine a number of statistical series. These should include indicators of different types of technology, not only production, construction and transport, but also health technologies and availabilities of human skills. These indicators must be available for a large number of countries. These principles led to selection here of four indicators, out of seven for which figures are available, from a U.N. study for a period close to 1970.[10] These indicators are:

1. Energy consumption per capita in kilograms of coal equivalent, representing technological levels in production, construction, and transport.

2. Number of telephones per thousand inhabitants, representing levels of communication within the country.

3. Average life expectancy at birth, representing health technology and levels and quality of food supply per capita.

4. Literacy among persons aged fifteen years and over, representing levels of skills and know-how.

The indicators were ranked and given equal weight in a combined index, which was divided into five groups with twenty-six countries in each group. The average value of each indicator for each group is shown in table 2.3.[11] (The grouping of each country according to technological level around 1970 is shown in the appendix.)

Table 2.3 depicts the huge gap between the least developed countries in group I and the highly industrialized countries in group V. Average energy consumption in the first group is 50 kilos per capita, as against 5,000 kilos in group V; number of telephones is 2 per thousand persons in group I, and 280 in group V; adult literacy is 12 per cent as against 98 per cent; and life expectancy at birth is 41 years as against 72 years. However, the figures in table 2.3 do not support the widespread belief in a sharp contrast between a small number of countries with high technological levels and a very large group at very low technological levels. The wide gap between the first and the last group is filled in with



**TABLE 2.3** TECHNOLOGICAL LEVELS AROUND 1970

| | Technology Groups | | | | |
|---|---|---|---|---|---|
| Indicators | I | II | III | IV | V |
| Per capita energy consumption in kilos of coal equivalent | 50 | 205 | 445 | 1785 | 4910 |
| Number of telephones per thousand persons | 2 | 6 | 10 | 70 | 280 |
| Life expectancy at birth | 41 | 47 | 55 | 66 | 72 |
| Percentage of literates 15 years old and over | 12 | 29 | 46 | 80 | 98 |

DATA SOURCE: United Nations, *Developing Countries and Level of Development*, E/AC 54/L 81 Annex II (New York, 1976).

a large number of countries at intermediary stages of technological development. Countries in group IV are on average not much below those of group V, and those of group III are so high that the term medium-technology countries will be applied to groups III and IV taken together. The term low-technology countries will be used for groups I and II. (For the sake of brevity, groups I–IV will be called countries at lower technological levels, i.e., lower than the high-technology countries in group V.)

The use of a common term for groups I and II should not tempt us to overlook the large differences in technological levels between the least developed countries in group I and the other low-technology countries in group II. The energy consumption in group II is four times that of group I, number of telephones is three times as large, adult literacy is 30 per cent as against 12 per cent, and length of life 47 years as against 41 years. Although most countries had taken significant steps to introduce modern technologies by 1970, a minority still remained at largely preindustrial levels.

Table 2.4 shows regional differences in technological levels. The high-technology countries were still mainly European ones in 1970, but a minority of European countries were at medium technology levels. Nearly all countries in America and in the Arab region (i.e., all the countries of North Africa and west Asia, from Morocco in the west to Afghanistan in the east) were also at medium levels, with group IV countries predominating in Latin America and group III in the Arab region. But it should be noted that the figures refer to a period before the rise of oil prices started a process of radical change in technological levels in the Arab region. Technological levels in east and south Asia vary much more than those in other regions, but the majority of Asian countries, including the large countries in the Indian subcontinent, In-

**TABLE 2.4** DISTRIBUTION OF COUNTRIES BY TECHNOLOGY GROUP

| | Technology Group | | | | |
|---|---|---|---|---|---|
| Region | I | II | III | IV | V |
| Europe | 0 | 0 | 0 | 5 | 21 |
| Oceania | 0 | 0 | 1 | 1 | 2 |
| America | 1 | 1 | 8 | 13 | 2 |
| Arab region[a] | 1 | 2 | 11 | 3 | 0 |
| East and South Asia | 4 | 6 | 4 | 3 | 1 |
| Africa[b] | 20 | 17 | 2 | 1 | 0 |
| Total number of countries | 26 | 26 | 26 | 26 | 26 |

[a] Western Asia and North Africa. [b] Excluding North Africa.
DATA SOURCE: Table 2.3.

**TABLE 2.5** DISTRIBUTION OF COUNTRIES BY TECHNOLOGICAL LEVEL AND POPULATION DENSITY AROUND 1970

| | Technology Group | | | | |
|---|---|---|---|---|---|
| Density Group | I + II | III + IV | V | Unclassified | Total |
| 1–5 | 26 | 13 | 7 | 15 | 61 |
| 6–7 | 18 | 21 | 3 | 2 | 44 |
| ⩾8 | 8 | 20 | 16 | 3 | 47 |
| Total | 52 | 54 | 26 | 20 | 152 |

DATA SOURCE: Table 2.3, and also UN population statistics.
NOTE: In this and some of the later tables, Taiwan and Puerto Rico are included in technology group IV, since it is evident from their official statistics that they belonged to this group.

donesia, and probably China, were at low technological levels around 1970. Nevertheless, Asia was ahead of Africa. Africa is sparsely populated, and the large, low-technology countries in Asia are densely populated: although there no longer is the close correlation between high population density and high technological levels there seems to have been before the industrial revolution, the number of countries with a pronounced inverse relationship between density and technological level is relatively small, as can be seen from table 2.5. Only eight among the forty-four densely populated countries which could be classified by technology group were at low technological levels, and only seven among the sixty-one sparsely populated countries were high-technology countries.[12] The historical developments which have produced this picture will be discussed in later parts of this study. We shall look first at the relationship between population density and technologies of food supply today.

# 3 POPULATION DENSITY AND FOOD SUPPLY SYSTEMS

In this chapter I will attempt to establish a quantitative relationship between an area's population density and its predominating food supply system. A number of different food supply systems are in use in different parts of the world today. Systems such as hunting, pastoralism, and long-fallow agriculture can support only a sparse population. Unless they rely on imported food, densely populated areas must employ systems of intensive agriculture, such as annual cropping or multicropping. In other words, there is a positive correlation between intensity of food supply system and population density.

Food supply systems are of course dependent to some extent on climatic conditions. Cold climates may be suitable for hunting and pastoralism, but unsuitable for agriculture, and the same may be the case with desert areas. High population densities in such areas would require large imports of food, and are therefore unlikely. The close relationship which exists today between population density and food supply system is a result of two long-existing processes of adaptation. On the one hand, population density has adapted to the natural conditions for food production by migrations and difference in natural rates of population growth; on the other hand, food supply systems have adapted to changes in population density.[1] We shall look at this process of mutual adaptation in later parts of this study; here, by means of contemporary agricultural statistics, we study its results.

All the major systems of food supply, agricultural and nonagricultural, can make use of either primitive or high-technology equipment and other inputs. In some parts of the world, hunters use automatic rifles; in others, bow and arrow. Land preparation for intensive agriculture is done with hoes in some areas, with animal operated plows in others, and with tractors in still others. Fertilization for intensive agriculture is variously provided by chemical fertilizer, animal manure, or gathered vegetable matter. Following the lead of Theodore W. Schultz,[2] many experts focus on such differences in quality of inputs and classify agricultural systems as either "traditional" or "modern," without paying attention to the differences in fallow systems. However, if long-fallow systems, in which one crop is followed by twenty years of fallowing, and systems with short or no fallow are lumped together under the heading "traditional agriculture," the important relationship between demographic conditions and methods of food supply is overlooked. In the analysis of food supply systems in this and later chapters, the basic classification will concern extensive and intensive systems and the different lengths of fallow; we shall distinguish the quality of inputs only when it is relevant.

### Adjustment of Population Densities for Agricultural Analysis

In some countries, a large share of the national territory consists of arctic areas, unirrigable deserts, or mountains too steep for terracing or use as pastures. In such cases, it is misleading to use overall population densities for comparison of food supply systems, and many studies measure number of inhabitants per unit of arable land or agricultural land instead. Such a procedure eliminates the downward bias in the population density for countries with large deserts or arctic areas, but it produces a no less serious upward bias for many other countries by eliminating potentially cultivatable land,[3] including land unused for lack of infrastructure investment and investment in land clearing and other improvement; land which is covered by and classified as forest; land used for long-fallow agriculture, since areas are rarely classified as agricultural land if they have been fallow for more than two years;[4] land which belongs to pastoralists and is classified as "rough grazing"; and even land used for pastures for domestic animals, if arable and not agricultural area is used to calculate proportions.

In other words, it is necessary to eliminate unusable land for calculation of population densities, but not land which could be, but is not, part of the agricultural area. Most areas which should be eliminated according to this criterion are classified as "other areas" in international statistics of land use, but this classification also includes land which could be used for agriculture if population were larger.[5] Therefore, we have eliminated "other" land only if it is likely to be arctic or desert and accounts for such a large share of total territory that eliminating most of it would lift the country into a higher density group.

As a result of this admittedly very crude adjustment, a number of countries were lifted into a higher density group for the purpose of agricultural tables. In many cases, however, the density group remained the same, and only in one case did a country move two steps up in the density classification. This was Egypt, which moved from density group 6–7 to density group 10 and above. Many of the countries with large arctic or dry areas listed in the appendix are excluded from the tables in this chapter for lack of agricultural statistics or indicators for technological level.



### Systems of Supply for Animal Food

Most people consume both animal and vegetable food, and we shall begin with the systems of supply for animal food. The following systems are in use in various parts of the world: hunting, i.e., killing wild animals; pastoralism, i.e., keeping herds and flocks on natural pastures; keeping domestic animals and birds, which gather their food in the fallows, pastures, or forests surrounding the villages or isolated farmsteads; intensive animal husbandry, in which animals and birds consume grains and other fodder, either produced for them in fields and meadows or imported from other areas. Sea, lake, and river fishing, i.e., catching "wild" fish; hatching "domesticated fish" in ponds or flooded paddy fields.

Fishing is often the predominant system of supply of nonvegetable food in densely populated islands and coastal areas. Other densely populated areas have either intensive animal husbandry, or large-scale imports of meat and fodder; alternatively, the population may live on a near vegetarian diet, since they cannot afford to use a large share of the land for natural pastures. The number of animals per head of population and the ratio of pasture land to arable land, both shown in table 3.1, are good indicators of the predominant system of food supply within an area.

**TABLE 3.1 DISTRIBUTION OF COUNTRIES BY LIVESTOCK NUMBERS PER INHABITANT AND RATIO OF PASTURE TO ARABLE LAND, AROUND 1970**

| Density Group | Units of Small Livestock per Inhabitant[a] 0–1 | 1–2 | 2–4 | ≥4 | Total |
|---|---|---|---|---|---|
| 1–3 | 2 | 3 | 0 | 3 | 8 |
| 4–5 | 4 | 8 | 9 | 7 | 28 |
| 6–7 | 9 | 10 | 22 | 4 | 45 |
| 8–9 | 11 | 4 | 2 | 0 | 17 |
| ≥10 | 5 | 0 | 0 | 0 | 5 |
| Total number of countries | 31 | 25 | 33 | 14 | 103 |
| | **Ratio of Pasture to Arable Land[b] 0–0.5** | **0.5–2** | **2–10** | **≥10** | **Total** |
| 1–3 | 1 | 1 | 1 | 7 | 10 |
| 4–5 | 2 | 6 | 15 | 8 | 31 |
| 6–7 | 9 | 18 | 14 | 0 | 41 |
| 8–9 | 15 | 14 | 2 | 0 | 31 |
| ≥10 | 5 | 3 | 0 | 0 | 8 |
| Total number of countries | 32 | 42 | 32 | 15 | 121 |

[a] Includes only countries in technology groups I–IV.
[b] Includes countries at all technological levels.
DATA SOURCE: *UN World Economic Survey* (New York, 1973), vol. 1, table A-40 (livestock units per inhabitant); *FAO Production Yearbook* (Rome, 1972), table 1 (pasture and arable land).

If the ratio of pasture to arable land is very high—say, more than ten—and the number of animals per head is also large, pastoralism predominates. If the ratio is low, less than two, not pastoralism but one of the agricultural systems is predominant within the area. Only in sparsely populated areas do we find ratios which point to pastoralism as the predominant system in the country as a whole, though within a country with higher population density there may be sparsely populated areas in which pastoralism predominates. On the other hand, virtually all the densely populated countries have low ratios of pasture to arable land, and only two have more than two animals per head of population. There are also several countries with low ratios and few animals and which are sparsely populated. These are countries in which the predominant system of supply for nonvegetable food is hunting or fishing.

Most of the calories contained in the fodder consumed by animals are lost by the transformation to meat, milk, and other products for human consumption. Pigs and poultry are more efficient transformers of fodder to animal products than are cattle and other herbivorous animals, but in all cases a large share of the calories is lost. Consequently, populations in densely populated areas can have large numbers of animals and consume large amounts of animal food per capita only if they can afford large-scale imports of meat or fodder from other areas. Many densely populated, highly industrialized countries do import large quantities of animal food and fodder, but table 3.1 does not include highly industrialized countries. Therefore, virtually all densely populated countries in the table have low numbers of animals per head of population, and low per capita consumption of animal food. They use their land mainly for supply of vegetable food.

### Systems of Supply for Vegetable Food

The systems of supply for vegetable food are characterized by differences in the frequency of cropping. The only nonagricultural system, that of food gathering, can be viewed as a system of permanent fallow, in which no crops are planted or sown. Only self-grown wild plants, roots, and fruits are harvested. A population which uses an area only for gathering is using that area very extensively; land use is a little more intensive if the population uses the forest-fallow system and plants one or two successive crops with intervals of 15–25 years fallow or more.

In table 3.2, the major systems of supply of vegetable food are ranked according to intensity of land use, with the most extensive systems at the top, and the most intensive at the bottom. The most intensive agricultural systems are annual cropping, in which a crop is sown or planted each year, leaving only a few months for fallow, and multicropping, in which the same piece of land bears more than one crop each year without ever being left in fallow. Total output of vegetable food in an area is of course many times larger if intensive rather than extensive systems are used.[6]



**TABLE 3.2** SYSTEMS OF SUPPLY FOR VEGETABLE FOOD

| | System | Description | Frequency of Cropping |
|---|---|---|---|
| G | Gathering | Wild plants, roots, fruits and nuts are gathered | 0% |
| FF | Forest-fallow | One or two crops followed by 15–25 years' fallow | 0–10% |
| BF | Bush-fallow | Two or more crops followed by 8–10 years' fallow | 10–40% |
| SF | Short-fallow | One or two crops followed by one or two years' fallow | 40–80% |
| AC | Annual cropping | One crop each year with only a few months' fallow | 80–100% |
| MC | Multicropping | Two or more crops in the same fields each year without any fallow | 200–300% |

NOTE: Frequency of cropping is average cultivated area as percentage of cultivated plus fallow area.

**TABLE 3.3** FREQUENCY OF CROPPING AROUND 1960 IN 56 COUNTRIES

| | Technology Group | | | | |
|---|---|---|---|---|---|
| Density Group | I | II | III | IV | V |
| 1–3 | (35%) | | | | 73% |
| 4–5 | 34 | | 59% | 50% | 92 |
| 6–7 | 39 | 62% | 61 | 66 | 91 |
| 8–9 | | 86 | 82 | 95 | 95 |
| ≥10 | (99) | | | | 99 |
| (N) | 8 | 5 | 16 | 11 | 16 |

DATA SOURCE: Joginder Kumar, *Population and Land in World Agriculture*, Population Monograph Series no. 12 (Berkeley: University of California, 1973), annex table 6.
NOTE: In this and the following tables, parentheses around a figure indicate that information was available for only one country.

Let us now compare the percentages of cultivation characterizing the agricultural systems listed in table 3.2 with those derived from agricultural statistics. Such information is available in a study by Kumar, which contains ratios of cultivation to fallow around 1960 in fifty-six countries.[7] In table 3.3, this information has been arranged in the same density and technology groups used in the preceding chapter. The table shows that frequency of cropping is positively related to both population density and technological level. The percentages are higher for countries with high population density and high technology. Table 3.2 suggests that if an area had a percentage above eighty, annual cropping or multicropping predominated. This means that annual cropping or multicropping predominates in densely populated countries at all technological levels. (Multicropping is not included in table 3.3. Therefore, the highest feasible percentage is 100.) By contrast, countries with medium and low population densities use different systems if their technological levels are different. In technology group I the percentages for countries with low and medium densities are below forty, implying that bush fallow is the predominant system. In technology groups II to IV, all the percentages are within the ranges typical for short-fallow systems. This is also the case for high-technology countries with very low population densities, but annual cropping predominates in high-technology countries in all other density groups. It is probably because of this predominance of annual cropping in high-technology countries that many experts have paid little attention to differences in frequency of cropping, and to the relationship between population density and food supply systems, when discussing agricultural problems in the Third World.

If we can rely on table 3.3, it is apparent that there is little long-fallow agriculture in countries other than those in the lowest technology group. It should, however, be noted that information about fallow is available for only five of the twenty-six countries belonging to technology group II, and only eight in technology group I. The lack of fallow statistics probably means that countries with fallow periods longer than two years provide no information about fallow because the international classification excludes such areas from the definition of fallow. Thus there is good reason to assume that the distribution shown in table 3.4 is biased, and that it is necessary to supplement the information provided in national statistics with information provided in special studies covering smaller areas.

**TABLE 3.4** DISTRIBUTION OF FORTY COUNTRIES IN TECHNOLOGY GROUPS I–IV BY AGRICULTURAL SYSTEM

| Density Group | FF | BF | SF | AC | (N) |
|---|---|---|---|---|---|
| 1–3 | 0 | 1 | 0 | 0 | 1 |
| 4–5 | 0 | 1 | 8 | 0 | 9 |
| 6–7 | 1 | 2 | 15 | 2 | 20 |
| 8–9 | 0 | 0 | 1 | 8 | 9 |
| ≥10 | 0 | 0 | 0 | 1 | 1 |
| Total number of countries | 1 | 4 | 24 | 11 | 40 |

DATA SOURCE: Same as table 3.3.



A study by Turner, Hanham, and Portararo[8] compares frequency of cropping and population densities in twenty-nine communities of tropical subsistence producers in many parts of the world. None of these communities used plows and plow animals. Table 3.5 is a rearrangement of this material in density groups. These communities have a positive relation between population density and frequency of cropping, and the table provides us with much more information about long-fallow systems than does table 3.3. Among the nine sparsely populated communities, all but one used long-fallow systems. The three communities in density groups 1–3 all used the forest-fallow system, while the bush-fallow system predominated in communities with density 4–5. Bush fallow was also the predominant system in nearly all the communities with medium population density, while most of the densely populated ones had short fallow. It is obvious that fallowing played a much larger role in these communities than is indicated in the countrywide statistics for the countries included in table 3.3, where lack of information about long-fallow systems makes for an upward bias in the percentages for frequency of cropping.

Neither table 3.3 nor table 3.5 accounts for multicropping, but some information about the use of this system is provided in a study by Dalrymple.[9] An inquiry was made in twenty-four countries which were expected to use the system. In table 3.6, the results are arranged in density groups. All but two of the countries studied (Japan and the U.S.) were at medium or low technological levels. It appears from the table that multicropping is the predominant system in countries with group 10 densities and above (5 out of the 7 listed in the appendix were studied). Some countries with 8–9 densities also have high percentages of multicropping. These are Asian countries with large regional differences in population density, and it is in the regions with the highest densities that multicropping is widespread. Eastern China, in which

**TABLE 3.5** DISTRIBUTION OF COUNTRIES BY AGRICULTURAL SYSTEM: 29 TROPICAL COMMUNITIES

| Density Group | FF | BF | SF | AC | Total |
|---|---|---|---|---|---|
| 1–3 | 3 | 0 | 0 | 0 | 3 |
| 4–5 | 1 | 4 | 1 | 0 | 6 |
| 6–7 | 1 | 8 | 0 | 0 | 9 |
| 8–9 | 0 | 2 | 6 | 3 | 11 |
| ≥10 | 0 | 0 | 0 | 0 | 0 |
| Total number of communities | 5 | 14 | 7 | 3 | 29 |

DATA SOURCE: Turner, Hanham, and Portararo, "Population Pressure and Agricultural Intensity," *Annals of the Association of American Geographers* 67, no. 3 (September 1977): 386–87.

**TABLE 3.6** DISTRIBUTION OF COUNTRIES BY USE OF MULTICROPPING AROUND 1970

| Density Group | Area of Multicropping as Percentage of Arable Land | | | | | |
|---|---|---|---|---|---|---|
| | 0–5 | 5–30 | 30–50 | ≥50 | Total | (N) |
| 1–3 | 0 | 0 | 0 | 0 | 0 | 15 |
| 4–5 | 2 | 0 | 0 | 0 | 2 | 31 |
| 6–7 | 5 | 3 | 0 | 0 | 8 | 42 |
| 8–9 | 2 | 3 | 4 | 0 | 9 | 35 |
| ≥10 | 0 | 0 | 1 | 4 | 5 | 7 |
| Total number of countries | 9 | 6 | 5 | 4 | 24 | 130 |

DATA SOURCE: Dana G. Dalrymple, *Survey of Multiple Cropping in Less Developed Nations* (Washington, D.C.: U.S. Department of Agriculture, 1971).

multicropping predominates, has river valleys with extremely dense population; the Indonesian island of Java also is characterized by dense population and predominance of multicropping. By contrast, the percentages were low in those countries with medium and low population density.

Since all systems of food supply, for animal and for vegetable food, are related to population density, the animal and vegetable systems are to some extent linked to each other. In sparsely populated areas with long-fallow systems, the extensive areas of fallow and other unused land provide natural fodder for herds and flocks of pastoralists or for wild animals which can be hunted. In densely populated areas, intensive agriculture leaves little fallow land for gathering of self-grown fodder. Moreover, use of inferior land for cultivation, improved in some cases by large investments of labor and capital, leaves little land for use by domestic animals. Therefore, annual cropping and multicropping are often associated with intensive animal husbandry based upon production or imports of fodder, while short-fallow agriculture in areas with medium population densities makes it possible to avoid fodder production and feed the animals on fallows and natural pasture land.

A summary of the conclusions reached above is presented in table 3.7. The table refers only to low-technology countries. By pairing domestic animals and intensive animal husbandry with particular vegetable systems, we arrive at a simplified classification of seven major systems found to predominate in low-technology areas within the range of population densities suggested for each system. The very low densities suggested for hunting and gathering seem to be generally agreed upon,[10] although no statistics are available. The densities suggested for pastoralism are derived from table 3.1, those for forest and bush fallow from table 3.5, those for short fallow from tables 3.3 and 3.5, those for annual cropping from table 3.3, and those for multicropping from table

**TABLE 3.7** PAIRING OF POPULATION DENSITIES WITH FOOD SUPPLY SYSTEMS IN LOW-TECHNOLOGY COUNTRIES

| Food Supply System | Density Group |
|---|---|
| Hunting and Gathering (HG) | 1–3 |
| Pastoralism (P) | 1–3 |
| Forest fallow (FF) | 1–3 |
| Bush fallow (BF) | 4–5 and 6–7 |
| Short fallow with domestic animals (SF) | 6–7 |
| Annual cropping with intensive animal husbandry (AC) | 8–9 |
| Multicropping with little animal food (MC) | ≥10 |

**TABLE 3.8** USE OF CHEMICAL FERTILIZER AROUND 1970 (kilos in fertilizer content per hectare of arable land)

| Density Group | Technology Group | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| 1–3 | | | | | 22 |
| 4–5 | (3) | 5 | 16 | 19 | 210 |
| 6–7 | 1 | 6 | 44 | 37 | 206 |
| 8–9 | 1 | 24 | 47 | 89 | 224 |
| ≥10 | | | | 247 | 575 |

DATA SOURCE: UNRISD, *Data Bank of Development Indicators* (Geneva, 1976), 1:56.
NOTE: Includes 81 countries.

3.6. It must be kept in mind that this pairing of densities and food supply systems relates only to "typical" low-technology areas, and that climatic and other factors account for deviations from these values.

### Technological Level and Food Supply Systems

It appears clear from the analysis in the preceding section that countries at high technological levels use much less fallowing than do countries at lower technological levels with similar population densities. The main explanation of the large differences is the much more widespread use of industrial chemicals in countries at higher technological levels. Countries in technology group I use virtually no fertilizer on food crops (small quantities are used for nonfood crops for export), while countries in group V with densities above group 1–3 level use hundreds of kilos per arable hectare, as can be seen from table 3.8. Only the most densely populated countries in technology group IV use quantities of chemical fertilizer which approach those used in technology group V.

Fallowing serves several purposes. Some of the most important ones are to prevent exhaustion of soil fertility, to reduce weed growth, and to limit the spread of plant disease. These purposes can also be served by use of chemical fertilizer, herbicides, and pesticides. In other words, industrial inputs can substitute for fallowing, and they do so in high-technology countries.

Chemical inputs, however, are not the only substitute for fallowing. Proliferation of weeds can be prevented by repeated weeding. Parasites can be removed by hand from individual plants subject to attack, or such plants can be removed. Soil fertility can be preserved by applying manure and night soil as well as vegetable matter found in forests and other uncultivated areas or at the bottom of rivers and lakes. Table 3.8 includes only chemical fertilizer, not composts made of other fertilizing matter. It can be seen from table 3.9 that as late as 1965, other than industrially made fertilizer accounted for the larger share of Chinese fertilizer consumption, and a large part of Japan's as well.

Use of such fertilizing matter, most of which is gathered by peasants and their families and placed in the fields, is the chief means of preserving soil fertility in densely populated areas in which the peasants are unable to use fallowing. Therefore, use of chemical fertilizer, is not a good indicator of fertilizer use; only if differences in population density are taken into account is it an indicator of technological levels in agriculture.

It was mentioned above that one of the purposes for which fallowing is used is to reduce the growth of troublesome weeds. Therefore, producers who use a plow to prepare the land before sowing or planting can better reduce the length of fallow periods than those who use only hand tools. The manure from draft animals may also help to reduce fallowing. The difficulties in reducing fallowing when no plows are used help to explain why the tropical communities with medium population densities in table 3.5 used long-fallow systems. These communities used neither plows nor draft animals.

Use of intensive agricultural systems with frequent cropping not only requires that the problems of fertilization and weed control be tackled

**TABLE 3.9** USE OF FERTILIZER IN CHINA AND JAPAN (kilos in fertilizer content per hectare of arable land)

| | | Chemical Fertilizer | Other Fertilizer | Total Fertilizer |
|---|---|---|---|---|
| China | 1957 | 3 | 112 | 115 |
| | 1965 | 18 | 117 | 135 |
| Japan | 1958 | 224 | 196 | 420 |
| | 1970 | 386 | | |

DATA SOURCE: Shigeru Ishikawa, *Factors Affecting China's Agriculture in the Coming Decade* (Tokyo, 1967); Japan 1970 figures from UNRISD, *Data Bank for Development Indicators* (Geneva, 1976), vol. 1, table II, 18.



by one of the methods mentioned above, but also often necessitates regulating the water supply and leveling or terracing land, especially for the use of multicropping. Because the second and third crops must be grown outside the most favorable season, irrigation may be needed even in areas with a relatively humid climate. The extensive use of water control in areas with group 10 densities in which multicropping predominates can be seen from table 3.10. This table also shows that all countries with more than forty per cent of the arable land under irrigation around 1970 were densely populated countries. In contrast, nearly all sparsely populated countries have low percentages of their arable land under irrigation. This may seem surprising, since many of them have dry climates. The explanation is that the population in a sparsely populated country with dry climate can limit cultivation mainly to land near rivers and lakes, which receives natural humidity. The inhabitants may also be mainly pastoralists, whose herds and flocks may use dry land. Therefore, the populations in these sparsely populated countries have been able to avoid investments in the irrigation facilities needed in densely populated countries with similar climatic conditions.[11]

Like fertilization and weed control, water control can be effected either by industrial inputs or by labor-intensive operations. With primitive or mechanized equipment, ground water can be lifted or surface water gathered from rivers and lakes and transferred to the fields, and land can be terraced to prevent erosion. The relationship between use of mechanized draft power, population density, and technological level is shown in table 3.11. Erosion of hillsides used for cultivation can also be prevented by a forest-fallow system, and fallowing is sometimes used to preserve humidity in land which is too dry to bear a crop each year. In humid areas, draining facilities are likely to be needed for intensive agriculture, and many densely populated European countries have

**TABLE 3.10** DISTRIBUTION OF COUNTRIES BY PERCENTAGE OF IRRIGATED LAND AROUND 1970

| | Percentage of Arable Land Equipped with Irrigation Facilities | | | | |
|---|---|---|---|---|---|
| Density Group | 0–5% | 5–20% | 20–40% | ≥40% | Total |
| 1–3 | 4 | 1 | 0 | 0 | 5 |
| 4–5 | 17 | 5 | 2 | 0 | 24 |
| 6–7 | 24 | 10 | 3 | 0 | 37 |
| 8–9 | 10 | 14 | 6 | 3 | 33 |
| ≥10 | 1 | 3 | 1 | 3 | 8 |
| Total number of countries | 56 | 33 | 12 | 6 | 107 |

DATA SOURCE: FAO, *Production Yearbook* (Rome, 1972), table 1.

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**TABLE 3.11** NUMBER OF MALE AGRICULTURAL WORKERS PER TRACTOR UNIT

| Density Group | Technology Group I | II | III | IV | V |
|---|---|---|---|---|---|
| 1–3 | 11000 | 560 | | (20) | |
| 4–5 | 30000 | 1260 | 100 | 60 | |
| 6–7 | 24000 | 2860 | 240 | 150 | (1) |
| 8–9 | (7000) | 2980 | 2230 | 70 | 7 |
| ≥10 | | | (300) | (51000) | (45) |

DATA SOURCE: *UN Implementation of the International Development Strategy* (New York, 1973), vol. 1, table II,18.
NOTE: Includes 69 countries, only selected countries for technology group V.

draining facilities. However, such facilities are not covered by statistics, which include areas equipped with draining facilities only if these are part of irrigation facilities. This explains why the percentages for water control are low in many densely populated countries.

In other words, there are three different ways to deal with the problems of soil fertility, weeds, water control, and erosion: (1) fallowing, as in sparsely populated countries; (2) industrial inputs, as in high-technology countries; and (3) labor-intensive practices, as in densely populated countries at low technological levels.

## Population Density and Output of Land and Labor

Densely populated countries use a larger share of their territory for food production, as shown in table 3.12, and also use it more intensively than sparsely populated countries. **Gross output per unit of land used for crops and pasture is much higher, as can be seen from table 3.13, which is based on data for output of land and labor computed by Hayami and Ruttan.**[12] Since countries at higher technological levels have better statistics table 3.13 includes mostly countries in technology groups III to V; India is the only low-technology country included. In each technology group, output per hectare can be seen to rise with increasing population density, with the most densely populated countries having more than ten times the output of the most sparsely populated countries within the same technology group. There are also differences in output per hectare between technology groups with similar densities, depending on use of industrial and scientific inputs or imported fodder, but these differences appear to be smaller than those between density groups.

The area per male agricultural worker tends to be larger in high-technology countries, because they use better equipment and purchased



**TABLE 3.12** DISTRIBUTION OF COUNTRIES BY AVAILABILITY OF ARABLE LAND AROUND 1970

| Density group[a] | Arable Land[b] as Percentage of Total Territory: 0–5 | 5–10 | 10–20 | 20–40 | ≥40 | Total |
|---|---|---|---|---|---|---|
| 1–3 | 11 | 3 | 1 | 0 | 0 | 15 |
| 4–5 | 16 | 9 | 3 | 2 | 0 | 30 |
| 6–7 | 3 | 6 | 20 | 11 | 1 | 41 |
| 8–9 | 0 | 1 | 4 | 19 | 11 | 35 |
| ≥10 | 0 | 0 | 3 | 5 | 1 | 9 |
| Total number of countries | 30 | 19 | 31 | 37 | 13 | 130 |
| | **Hectares of Arable Land per Inhabitant: 0–0.1** | **0.2–0.4** | **0.5–0.8** | **0.9–1.6** | **≥1.7** | **Total** |
| 1–3 | 1 | 2 | 2 | 1 | 4 | 10 |
| 4–5 | 2 | 14 | 7 | 6 | 4 | 33 |
| 6–7 | 0 | 17 | 16 | 8 | 0 | 41 |
| 8–9 | 9 | 20 | 7 | 0 | 0 | 36 |
| ≥10 | 10 | 0 | 0 | 0 | 0 | 10 |
| Total number of countries | 22 | 53 | 32 | 15 | 8 | 130 |

[a] Unadjusted densities. [b] Arable land is land under crops plus land classified as fallow.
DATA SOURCE: FAO Production Yearbook (Rome, 1972), table 1.

**TABLE 3.13** ANNUAL OUTPUT OF LAND AND LABOR AROUND 1965

| Density Group | I | II | III | IV | V | I | II | III | IV | V |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Countries[a] | | | | | Average Output per Hectare[b] | | | | |
| 1–3 | 0 | 0 | 0 | 0 | 2 | | | | | 0.5 |
| 4–5 | 0 | 0 | 1–2 | 4 | 2 | | | 0.3 | 0.4 | 1.8 |
| 6–7 | 0 | 0 | 2 | 3 | 4 | | | 0.6 | 0.4 | 2.1 |
| 8–9 | 0 | 1 | 2 | 3–4 | 8 | | (1.2) | 2.2 | 1.8 | 3.0 |
| ≥10 | 0 | 0 | 1 | 1 | 3 | | | (7.8) | (11.9) | 7.6 |
| | Area per Worker[c] | | | | | Average Output per Worker | | | | |
| 1–3 | | | | | 240 | | | | | 120 |
| 4–5 | | | (18) | 48 | 57 | | | (11) | (19) | 102 |
| 6–7 | | | 15 | 23 | 28 | | | 9 | 9 | 58 |
| 8–9 | | (2) | 2 | 11 | 13 | | (2) | 5 | 20 | 39 |
| ≥10 | | | (0.6) | (0.7) | 6 | | | (5) | (8) | 46 |

[a] 39 countries for output per hectare and 37 for output per worker. [b] Gross output converted to wheat units, but excluding fodder and other inputs produced and consumed in agricultural enterprises. Hectares include arable land and pasture. [c] Workers include only male, adult workers.
DATA SOURCE: Yujiro Hayami and Vernon W. Ruttan, *Agricultural Development: An International Perspective* (Baltimore, Johns Hopkins University Press, 1971), p. 732.

inputs instead of labor inputs. But the differences between technology groups seem to be smaller than those between density groups. However, if we compare output per male worker in density groups at similar technological levels, the smaller area of land per male worker in the densely populated countries is compensated for by the higher output per hectare. Therefore, differences in output per worker are relatively small between density groups, and output per worker tends to be lower in densely populated countries than in sparsely populated ones at similar technological levels.

It is important to note that while the figures in the table refer to annual output per adult male worker, work hours are not of equal length, and work days per year are more numerous when intensive systems are used than when extensive can be applied. Moreover, there are large differences in the extent to which women and children participate in agricultural work in different countries.[13] Therefore, differences in output per unit of labor input are likely to deviate considerably from the differences per male worker shown in the table. We shall return to differences in labor input in later chapters.

# II Population and Technology in the Ancient World