CHAPTER 4

The Industrial Revolution and Land Transformation

DAVID GRIGG

4.1 INTRODUCTION

For most of human history man has been a hunter and gatherer; although his use of fire, and local over-population, may have altered the environment, the consequences of his actions were small compared with those of farmers. Plants and animals were first domesticated some 12–10 000 years ago, and sedentary agriculture slowly became established in most parts of the world.

Agriculture inevitably transforms the land. Crop production requires the removal of the natural vegetation, or its drastic modification. Thus even shifting cultivation at low population densities, with periods of fallow in which forest is allowed to regenerate, causes changes in the species composition and structure of the secondary vegetation. Most other forms of crop production require the almost complete removal of the natural vegetation; in areas of cereal production in eastern England, not only has the original natural vegetation long been removed, but even the hedges and isolated trees that were planted around arable fields after enclosure are now being destroyed. The slow expansion of cultivation has greatly reduced the forests which covered so much of medieval Europe (Figures 4.1 and 4.2), and the woodland of all the great agricultural civilizations has been much reduced. In this century alone the forest area of Afro-Asia and North America has been halved (World Bank, 1982, p. 60).

Arable farming, particularly where the plough is the main means of cultivating, has profoundly altered the soil by both adding and removing plant nutrients, reducing acidity with lime, draining excess soil moisture with underground pipes, removing stones, and changing the soil structure. More fundamental changes have been brought about by the removal of surface water. Long and painstaking drainage schemes, notably in the English fenlands, the Dutch polders and inland lakes, and in the Po valley of northern
Italy, have converted waterlogged lowlands into first-class farmland. Equally profound have been the changes brought about by bringing water to arid and semi-arid regions; irrigation schemes in Iraq, Egypt, Pakistan and elsewhere have all transformed the land and landscape. Steep slopes and high altitudes present great obstacles to the farmer, but terracing has made arable farming possible in many parts of upland Asia and North America.

Agriculture, in short, transforms the environment; other chapters in this book deal in detail with these matters. The purpose of this chapter is not to describe how agriculture changes the environment, but to explain why changes in agriculture have come about.

4.2 MAJOR CAUSES OF AGRICULTURAL CHANGES

At present agriculture exists in a bewildering variety of forms, ranging from the simple shifting cultivation of parts of the Amazon basin to the technologically complex systems of the United States and Western Europe based upon advances in biological science and the rise of modern manufacturing indus-
The origins of such farming systems can hardly be reduced to one or two major causes. Most of this chapter will be devoted to a few forces that have been important in causing change over time, particularly in Europe: population growth, urbanization, industrialization, transport changes and the role of science and the state. A smaller section deals with some of the major types of farming and their evolution.

4.2.1 Population Growth

Agriculture must provide food supplies if population growth is to be sustained; conversely population growth requires changes in the way agriculture is carried on, prompting the expansion of the area under cultivation and the more intensive use of land already in cultivation (Boserup, 1965, 1981). Both cause land transformation.

Human beings have occupied the earth for some 250,000 years, and until the last 12,000 years they were few in number and population densities were everywhere very low. The domestication of crops and livestock some 12,000
Figure 4.3 World population growths
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years ago made higher densities possible and numbers began to increase, albeit very slowly (Figure 4.3). Accurate information on population numbers is not available until the eighteenth century, when the first regular population censuses began to be taken; many countries had no reliable censuses until this century. Nonetheless, most population historians would agree that the rate of world population increase was very low until the eighteenth century. Since then the rate of increase has progressively risen until the last decade (Table 4.1). Until the nineteenth century, increase was not continuous. Periods of sustained increase were separated by periods of stagnation or even decline. Such periods have been identified in Europe. There was a decline in numbers after the fifth century, increase from ca 950 to 1300, decline from the mid-fourteenth century to the mid-fifteenth century, increase from then until the early seventeenth century, followed by slow increase or stagnation until the continuous and rapid increase that began in the early eighteenth century and only faded in the 1920s (Helleiner, 1967). China also has a history of growth alternating with decline (Ho, 1959). Little is known of Africa’s population history before the nineteenth century, but in Latin America there was a period of sharp decline after the arrival of Europeans in the sixteenth century, and growth may not have commenced again until the eighteenth century (Durand, 1977).

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (millions)</th>
<th>Average rate of increase since preceding date (% per annum)</th>
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<tbody>
<tr>
<td>8000 BC</td>
<td>5–10</td>
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<tr>
<td>AD 14</td>
<td>256</td>
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<td>600</td>
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<td>1000</td>
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<tr>
<td>1340</td>
<td>378</td>
<td>0.1</td>
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<tr>
<td>1600</td>
<td>498</td>
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<tr>
<td>1650</td>
<td>516</td>
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<tr>
<td>1700</td>
<td>641</td>
<td>0.4</td>
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<tr>
<td>1750</td>
<td>731</td>
<td>0.3</td>
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<tr>
<td>1800</td>
<td>890</td>
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</tr>
<tr>
<td>1850</td>
<td>1171</td>
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</tr>
<tr>
<td>1900</td>
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<tr>
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<tr>
<td>1960</td>
<td>2982</td>
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<tr>
<td>1970</td>
<td>3632</td>
<td>2.0</td>
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<tr>
<td>1980</td>
<td>4414</td>
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It was formerly argued that the great modern upsurge in numbers began first in North West Europe in the eighteenth century and was due to a decline in mortality, without initially any fall in the high crude birth rates. The fall in mortality was thought to be due to improvements in the food supply, the control of contagious diseases, and rising standards of living associated with the industrial revolution. This view has been sharply criticized in recent years. It has been shown that advances in medical treatment had little effect on mortality until the twentieth century (McKeown, 1970). It has also been shown that in England a rise in the birth rate was as important as the fall in mortality between 1750 and 1838 (Wrigley and Schofield, 1981); nor was the increase in European areas confined to those states which underwent industrialization, for Ireland, Sweden and Norway had rapid increases in their populations in the late eighteenth century and the first two-thirds of the nineteenth century without experiencing industrialization (Connell, 1950; Drake, 1969; Thomas, 1941). Nor was the increase confined to Europe. J. L. Durand's estimates of world population numbers suggest that the eighteenth century saw a comparable increase in Russia, Asia and Latin America, although not in Africa until the late nineteenth century (Table 4.2, Figure 4.4). Europe, Russia and the areas of European settlement in North America and Australia did increase more rapidly than Afro-Asia in the nineteenth century, so that they made up only a quarter of the world's population in 1750, but a third by the end of the nineteenth century. In this century non-European areas have increased more rapidly than European, particularly since 1950, so that Afro-Asia and Latin America again constitute three-quarters of the world's population as they did in 1750.

Table 4.2 Rates of population increase by major regions, 1750–1979 (% per annum) (Durand, 1977, pp. 253–296; United Nations, 1982)

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<td>0.3</td>
<td>0.9</td>
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<tr>
<td>New Zealand</td>
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<td>–</td>
<td>1.4</td>
<td>1.8</td>
<td>1.8</td>
<td>2.9</td>
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<tr>
<td>Japan</td>
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<td>0.8</td>
<td>1.3</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Developed</td>
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<td>1.0</td>
<td>0.8</td>
<td>1.0</td>
<td>0.75</td>
</tr>
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</table>
Figure 4.4  Population growths for major regions
4.2.1.1 Population Distribution

Regional variations in mortality and fertility combined with long-distance migration have changed the spatial distribution of the world's population, but not perhaps so dramatically as was once thought. At the time of Christ the major centres of population were already Europe, the Indian subcontinent and China; however, in Europe, the highest densities were to be found south of the Alps and in the nearby parts of the Middle East; population density and numbers were low in northern Europe (United Nations, 1953). In China the great centres of population were in the north and centre; the south was as yet comparatively sparsely populated (Trewartha, 1969). The world's regions have had a variety of experiences since then, but the only major relative change has been the emergence of North America as an important centre of population, a result of European emigration, and in the eighteenth and nineteenth centuries, very high fertility.

It is worth noting that now as in the past a very high proportion of the world's population is concentrated upon a small part of its area. In 1960, nearly two-thirds of the earth's surface had a population density of less than 13 per km²; conversely, the major population concentrations—east and south Asia, eastern North America, European Russia and Europe—had two-thirds of the world's population upon only one-tenth of its land area (Grigg, 1969b). The proportion of the earth's surface that is used for agricultural purposes is also surprisingly small. In 1980 only 11.1% was used for growing crops and rotational grasses; however, 23.8% was used for grazing livestock, including large areas of prairie, savanna and scrub largely unimproved by the pastoralist (FAO, 1982).

4.2.1.2 The Consequences of Population Growth

Until the nineteenth century the greater proportion of the world's population were dependent upon agriculture for their livelihood; indeed as late as 1900, 75% of the world's labour force were employed in agriculture. Furthermore, the great majority of these were subsistence farmers. Their main aim was to provide food for their families, and comparatively little of their output left the farm. Any increase in numbers left the farmer with two possibilities of increasing the food supply. Either he could intensify output by increasing the yields of his crops, or he could bring land hitherto unused into cultivation. Until the nineteenth century the possibilities of increasing yields significantly over a short period were very limited, and the primary response to population growth was an expansion of the area in crops. There are few reliable statistics on land use at the national level before the nineteenth century; but such as do exist, together with contemporary documents, suggest that the expansion of the arable area more or less matched the growth of population except in
periods of particularly rapid growth such as the late thirteenth century in Europe or in eighteenth century China (Grigg, 1980). Over the last 100 years, however, arable expansion has not matched population growth in some regions, and area expansion has been increasingly supplemented with yield increases.

The way in which the extra land has been brought into cultivation has varied from region to region. After the migrating movements of the first millennium after Christ, the main features of European settlement were established, and subsequent increases in cropland came from clearing the woodland between villages when numbers rose, and advancing into areas which were initially thought unsuitable for farming. The high middle ages thus saw much settlement of upland areas in western Europe and the reclamation of poorly drained land. There were few agricultural frontiers in early modern Europe, although the settlement of the plains east of the Danube in Hungary in the eighteenth and nineteenth centuries justify this description. In the first millennium after Christ there were, however, major movements into new land in China and Africa. In AD 2 the most densely populated part of China was the lower Hwang Ho, and 43 million of the 58 million in the Han empire lived north of the Yangtse; south of the Yangtse there were few Han Chinese. Over the next 1000 years the Han Chinese occupied the south and the distinctive wet rice economy emerged. By the fourteenth century the major rice growing areas of China had emerged with double cropping, irrigation and intensive cultivation. Over the same period farming pushed northwards in Japan from its source area around the Inland Sea. In Africa, Ethiopia and the West African savannas were early areas of agricultural development, whilst much of eastern and southern Africa remained occupied by hunters and gatherers. It is believed that the Bantu-speaking peoples, originating in what is now Nigeria, spread slowly east and south, bringing with them cattle, sorghum and other crops and practising shifting cultivation. By the eleventh century they had reached what is now the Transvaal (Grigg, 1974).

These great migrations into sparsely occupied areas, prompted by the slow increase in population, took over 1000 years to achieve. But the upsurge of

<table>
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<tr>
<th></th>
<th>1860</th>
<th>1900</th>
<th>1930</th>
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<tbody>
<tr>
<td>United States</td>
<td>65</td>
<td>128</td>
<td>166</td>
<td>158</td>
</tr>
<tr>
<td>Russia</td>
<td>49</td>
<td>113</td>
<td>109</td>
<td>196</td>
</tr>
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<td>8</td>
<td>23</td>
<td>25</td>
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<tr>
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<td>–</td>
<td>6</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>Australia</td>
<td>0.4</td>
<td>3</td>
<td>10</td>
<td>12</td>
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</table>
population in the eighteenth and nineteenth centuries was accompanied by much more rapid migration and increases in the cultivated area, principally by Europeans. The movement of Europeans to eastern North America, Australasia, Argentina and Uruguay, South Africa, and of Russians from the long occupied forest lands into the grasslands of southern Russia and later east of the Urals, led to remarkable increases in arable area (Table 4.3), and in the early part of this century there was a major Chinese movement north into the grasslands of Manchuria.

4.2.1.3 The Intensification of Output

Prior to the nineteenth century yield increases were slow. Between 1300 and 1800 the yields of wheat and rice possibly doubled in England and China, and were much slower elsewhere. Thus arable expansion was the primary response to population increase. There were other ways of increasing output, however, again prompted by population increase. Most traditional farming systems have a period of fallow in the cropping sequence, to help maintain soil fertility, to allow the removal of weeds, and to control plant diseases. The length of fallow is variable; in some shifting agriculture systems it may be as long as 30 years, which allows the regeneration of a forest cover. But increases in population density lead to a reduction in the area in fallow. In medieval Europe between one-half and one-third of the arable land was in fallow. Although eliminated in much of the Low Countries and parts of England by the seventeenth century, fallow persisted in much of Europe until well into the nineteenth century. Slowly legumes, potatoes and sugar-beet replaced the fallow, the root crops allowing the removal of weeds during growth and fodder for livestock, which in turn provided farmyard manure for maintaining crop yields, whilst clover, beans and peas all added nitrogen to the soil (Chorley, 1981; Slicher van Bath, 1963).

In the rice economies of Asia, the occurrence of blue-green algae in the rice paddies helped maintain yields over long periods, and annual cropping without a fallow was common from an early time; indeed, double cropping became possible in some regions where the growing season was long enough and irrigation efficient. Thus the introduction of rice varieties with a shorter growing season allowed double cropping in Southern China in the eighth century (Ho, 1956). In China as in most other parts of the world increases in yields were only possible by using more manure, by the more careful selection of seed, and above all by the use of more labour in weeding and harvesting. Not until the mid-nineteenth century did industrial inputs such as chemical fertilizers become available to the farmer, and the breeding of higher yielding crop varieties has occurred mainly in this century.

Both area expansion and more intensive cultivation have obviously transformed the land, not always for the better. In the nineteenth and twentieth
centuries frontiers of settlement ventured into land too arid for permanent settlement without irrigation, as in the Great Plains of the United States in the 1930s and in Kazakhstan in the USSR in the 1950s. But in the nineteenth and twentieth centuries change in agriculture has been prompted by profit as much as by population increase.

4.2.2 Urbanization and Agricultural Change

Whilst general population growth has been a major cause of both the expansion of the arable area and the intensification of farming, changes in the distribution of population have also been important; and in particular urban growth (the increase in the population of towns) and urbanization (an increase in the percentage of the population living in towns).

Until the modern period yields per hectare and output per man were low in Europe—and elsewhere—and this meant that few societies could support many people who were not occupied in agriculture. Thus towns were comparatively few in number, very large towns were rare (Table 4.4), and only a small proportion of the population were engaged in activities other than agriculture, and the urban population were a small proportion of the total population (Table 4.5). Thus in the late eighteenth century four-fifths of the population of France were engaged in agriculture, and this proportion was only significantly lower in Britain and the Low Countries.

The smallness of Europe’s urban population was a function not only of low productivity in agriculture, but also of the high cost of transporting food; overland costs were particularly high, and grain would rarely be moved more than 35 km; costs of movement by water were appreciably lower. Not surprisingly most of Europe’s towns were on rivers, and the great cities before the nineteenth century were invariably ports, for the cost of shipping food-stuffs by sea was approximately one-eighth that of overland movement (Grigg, 1982b).

The growth of towns—and particularly either clusters of towns, as in the Low Countries, or very large towns such as Paris, London, Naples or

| Table 4.4 Number of towns of particular sizes in Europe, 1500–1800 (J. de Vries, 1981) |
|----------------------------------|-----|-----|-----|-----|
| 1500 1600 1700 1800            |
| Over 100 000                   | 4   | 8   | 11  | 17  |
| 50 000–99 999                  | 7   | 11  | 20  | 32  |
| 20 000–49 999                  | 46  | 73  | 74  | 109 |
| 10 000–19 999                  | 99  | 125 | 116 | 205 |
Rome—had a profound influence upon the agriculture of their hinterland. The demand for food in the towns meant that there was a ready market, and the commercialization of agriculture first occurred in these regions. The high value of land meant that small farms predominated and the fallow was soon extinguished, for soil fertility could be maintained by bringing horse manure and other wastes from the town. Farming was intensive, and the products generally high-value goods. These regions were among the first to adopt innovations, had access to capital from the towns, and were generally the advance guard of agricultural improvement. This was notably so in northern Italy in the fourteenth and fifteenth centuries, in the Low Countries in the fifteenth, sixteenth and seventeenth centuries, and in the hinterlands of London and Paris in the eighteenth and nineteenth centuries. Wilhelm Abel has described these small regions (Abel, 1980). And small their influence was. In Figures 4.5 and 4.6 the circles represent not only the relative population size of towns over 10,000, but also the area of farmland which was necessary to feed the towns. In the year 1500 (Figure 4.5) only a small proportion of Europe was directly influenced by towns; even in 1800, on the eve of the industrial revolution, large areas remained beyond the innovatory influence of the cities (Figure 4.6).

### 4.2.3 Industrialization and Agricultural Change

Since 1800 the developed countries of the world have all gone through the process of industrialization, and this has had dramatic consequences for agriculture.

First industrialization was everywhere accompanied by rapid population growth, which in itself increased the demand for food. But in addition, industrialization led to an increasing proportion of the population living in towns, and thus dependent upon the agricultural population for their food. This encouraged the commercialization of agriculture and the decline of subsistence farming.

Second, industrialization led to slow increases in the incomes of nearly all
classes. As long as the bulk of the population had wages little above the subsistence level, then most of the diet had to come from cheap foodstuffs (mainly cereals and potatoes). Indeed, as late as 1880, 70% of the French calorific intake came from bread and potatoes (Toutain, 1971). But as incomes rose so the demand for more expensive foodstuffs, and in particular livestock products, increased. From the end of the nineteenth century livestock products became an increasing proportion of the diet in North America.
and Western Europe, and as a result farming turned increasingly to the production of livestock products which now make up between 55% and 85% of the value of total farm output in the developed countries. This has not led to any decline in the importance of cereals in the agriculture of these countries. Livestock are fed increasingly upon grain; in the developed countries 70% of all grain is used as livestock feed (Aymard, 1975; Teuteberg, 1975).
Third, the first industrial revolution saw a shift in the raw materials of industry from the organic to the inorganic; even so agricultural products were increasingly needed by manufacturing industry. The development of machinery in the textile industries in Western Europe combined with income increases and population growth led to an almost insatiable demand for cotton and wool, satisfied only by the westward expansion of cotton-growing in the United States, and later more widely in the subtropics, whilst Australia and New Zealand became sheep farms for Bradford. Vegetable oils became of major importance, not only for cooking, but before the exploitation of petroleum, as lubricants, as the basis for paints and for many other industrial purposes. With the development of the electrical engineering industry, and later motor vehicles, rubber moved from a minor curiosity to a major raw material, and in the early twentieth century rubber expanded prodigiously in south-east Asia (Grigg, 1974).

A further consequence of industrialization was that farming ceased to provide all its own inputs. In traditional agriculture farmers got their seed from their own harvest, their manure from their livestock, feed for animals from grass or roots grown on their own farm. Implements were bought locally, generally made by craftsmen, and power came from human and animal muscle. But from the 1830s and 1840s farmers increasingly bought more and more of their inputs from off the farm, much of these from manufacturing industry. In the mid-nineteenth century the theory of Liebig in Germany and the practice of J. B. Lawes in England led to the beginnings of the modern chemical fertilizer industry. At much the same time the availability of cheap iron and the need for more powerful equipment led to the rise of the modern agricultural implements industry which from the 1840s provided iron ploughs, drills, reapers, steam threshing engines, in the 1870s reaper-binders and elevators, in the 1890s the first milking machines, combine harvesters and tractors; much of the initiative now came from the United States, although advances in dairying began in Western Europe (Ojala, 1952; Whetham, 1970; Danhof, 1972).

The dependence of the farmer upon purchased inputs accelerated after the end of the Second World War as pesticides were widely adopted to control disease and herbicides replaced the hoe and harrow; fertilizer consumption has risen dramatically in the developed countries and an extraordinary variety of implements is available to sow and harvest crops. Whereas in the 1930s horses and human muscle provided most of the power on farms in Europe and North America, electricity and the tractor provide nearly all now.

Industrialization has transformed the role of agriculture in the economies of the western world. In the early eighteenth century farmers and farm workers made up three-quarters or more of the labour force in nearly every country. But during the industrialization of the nineteenth century the numbers employed in new manufacturing industries, in transport, and in mining
Figure 4.7  Trends in the labour force employed in agriculture
increased far more rapidly than the numbers in agriculture; in the present century this trend has continued as the number in administration and other services has risen. Consequently the proportion of the workforce employed in agriculture has greatly declined. In Sweden, Switzerland, the United Kingdom and the United States it is now no more than 2% (Dovring, 1959; Grigg, 1975). In pre-industrial Europe agriculture provided most of the wealth: now agriculture produces a small proportion of the gross domestic product in most developed countries. In the European Economic Community farming employs only 8% of the workforce and produces but 4% of the gross domestic product.

Although the proportion of the population engaged in agriculture has been declining in Western Europe and North America since the early nineteenth century, the absolute numbers continued to increase for much of the century, for natural increase in the rural areas exceeded emigration to the urban areas. But in the late nineteenth century the labour force began to decline slowly at first, at a dramatic rate after 1945 (Figure 4.7). This has led to pronounced changes in agriculture. Capital, in the form of machinery, has been substituted for labour. Farms have become bigger in order to exploit fully the capabilities of tractors and combine harvesters. Labour productivity has increased rapidly—indeed for the last three decades more rapidly than in manufacturing industry. Whereas on the eve of the industrial revolution it took four men employed in agriculture to feed one man in non-agricultural activities, one man in American agriculture now feeds fifty or sixty in other jobs (Cochrane, 1979; Rasmussen, 1982; FAO, 1972).

4.2.4 Transport and Agricultural Change

For much of human history the transport of agricultural goods over long distances has been impractical because the means of transport have been slow and many foodstuffs are perishable, and because the cost of moving commodities in bulk has been prohibitively high. This had many consequences for farming and the economy in general. It limited the growth of cities because the area needed to feed urban non-agricultural populations was large with the low productivity of agriculture before the nineteenth century; the cost of movement soon equalled the price of the crop transported. It made regional specialization in one or two products for which an area had physical advantages difficult, for each area had to produce as much of its food supply and fibres as possible. It meant that comparatively little agricultural produce entered into trade unless the product had a high value per unit weight (such as wool) or could be moved in the relatively cheap coastal shipping trade. Early regional specialization was thus associated with low-cost movement.

The prime example of this was the Netherlands which, in the sixteenth and seventeenth centuries, became highly urbanized, specialized in dairying and
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horticulture and imported grain from the Baltic (De Vries, 1974). Maritime freight rates fell almost continuously from the mid-seventeenth century, at between 0.5% and 1% per annum from 1650 to 1770 and at 3.5% per annum from 1814 to 1860. On land the decline in freight rates was slower, although slow improvement of road surfaces, the substitution of the horse for the ox and the use of the four-wheeled waggon showed some reduction in the cost of transport after 1650. It was the spread of the railway after 1820 that accelerated the decline; this was of particular importance in opening up the sparsely populated interiors of Russia, North America and temperate South America. It cost over 100 cents to move a hectolitre of wheat from Chicago to New York in 1873–4, and only 24 cents in 1905. The oceanic freight rate for wheat from New York to Liverpool in 1900 was only a third of what it had been in the 1870s. Combined with advance in the preservation of foodstuffs, and in particular the introduction of refrigeration into steamships in the 1870s, these declines in transport costs allowed the opening up of great new agricultural areas in the Canadian prairies, the American Mid-West, the Argentine pampas, the Russian Steppes and the interior of Australia. In England and the north-eastern United States the railway allowed comparatively remote dairy regions to provide fresh milk to London, Boston and New York. Before the railway few towns obtained fresh milk from more than 35 km. By the 1930s Berlin drew some of its milk from over 700 km (North, 1958, 1968; Morris, 1958; Youngson, 1965; Grigg, 1974, 1982b).

Whereas the initial impact of cheaper transport was upon agricultural produce, the growing dependence of farmers upon purchased inputs was made easier by these advances. In early nineteenth century England canals made possible the movement of coal for threshing machines, pipes for under-drainage and lime and superphosphates; it was the extension of the railways which further cheapened the movement of these goods. But the introduction of the petrol-driven motor vehicle has been even more significant, for fertilizers can come direct to the farm and be more easily moved around the farm and bulk tankers can collect milk. Indeed, much of the change in agriculture over the last 200 years would have been impossible without improvements in transport.

4.2.5 Science, the State and Agricultural Change

Until the nineteenth century most of the advances in agriculture were provided by farmers themselves, who modified implements, selected the better-yielding seeds, experimented in breeding better cattle and acquired new crops. But from the nineteenth century much of the new technologies were dependent upon advances in science; this was particularly true of plant breeding. With the rediscovery of Mendel's ideas on genetics in 1900, plant-breeding stations were established in many countries, and since then
The state-supported research has produced most of the new crop varieties which account for so much of the increased crop yields of the last 40 years. This is true not only of the new high-yielding rice and wheat varieties developed at experimental stations in Mexico and the Philippines, but also of most new varieties in North America and Western Europe. The growth in chemical fertilizers in the nineteenth century depended upon new knowledge in chemistry, whilst their modern multiplication depended upon the heavy chemical industries. This is even truer of pesticides and herbicides. These advances have required far more specialized knowledge than farmers would possess, and the cost of research and development has been beyond the resources of even groups of farmers. The state has thus been the prime-mover in agricultural research in the developed countries over the last century (Russell 1966; Petersen, 1980).

Nor have the activities of the state been confined to the promotion and finance of research. Until the mid-nineteenth century most European states attempted to ensure their food supplies by protecting their farmers against imports of grains, by controlling the quality of bread, and by forbidding the export of grain when home supplies of grain ran short. From the middle of the nineteenth century free trade spread from Britain to many parts—but not all—of the world. However, from the 1930s Britain, the main food importer—and the United States, the main exporter—both began to defend their farmers against low prices and imports of cheaper foodstuffs. In the United States attempts to both control surplus output and to maintain farm incomes ultimately benefited farm incomes, whilst the federal government bought and stored output that could not be sold. In Britain the import of food continued unimpeded, but until the early 1970s home farmers were paid guaranteed prices, not the market prices. In Western Europe the Common Agricultural Policy has established guaranteed prices for most farm produce and taxed imports from outside the EEC. Whatever the objections to these interventions by the state, farmers have been relatively prosperous in the last 40 years; without this prosperity, they would not have invested in the many farm improvements that have greatly increased output and productivity since 1945 (Fite, 1981; Tracy, 1982).

In the Socialist countries the intervention of the state has been comprehensive. Beginning in the Soviet Union but later followed in Eastern Europe and China, private ownership of land has been abolished and farms have been grouped into collectives or state farms. Many of the decisions about what is to be grown, and with what methods, have been transferred from the farm to planning commissions at both the regional and national levels (Pallot and Shaw, 1981).

The state has also intervened far more than in the past in the developing countries. With the end of colonial rule in the post-war period many newly independent governments have sought to increase the output of food for
rapidly growing populations by large-scale agricultural development projects, where both the finance and technical direction has been provided to farmers by the state. Thus in countries of very different political complexions the state has become a major cause of change in farming.

4.2.6 The Diffusion of Technology, Crops and Livestock

By the beginning of the Christian era the idea of domestication of plants and livestock had spread to all but the remotest parts of the globe. But initially only indigenous plants were grown, and certain farming methods also remained confined to their regions of origin. Thus the plough probably had its origins in the Near East, and by the beginning of the Christian era was the basis of farming in the great agricultural civilizations of China, India and Europe. In Africa, however, the plough was unknown until brought by Europeans in the late nineteenth century, and still has limited use, except in the Mediterranean north and in South Africa. Nor were the plough or the wheel known in the Americas until after the arrival of Europeans in 1492. Equally marked was the absence of sheep, cattle, pigs, chickens and horses from the New World. However, all were introduced into the Americas by Europeans and were spread rapidly throughout the continent (Isaac, 1970).

Knowledge of the crops indigenous to other regions spread slowly throughout the world before the modern era. Rice is thought to have been domesticated in mainland south-east Asia and spread north into southern China, west into the Indian subcontinent, so that by the time written records are available it was the basis of civilization in most parts of Asia (Chang, 1976). Wheat and barley were first domesticated in the Near East and had been taken or spread into northern Europe long before the Christian era. Other crops remained confined to their hearth lands for very periods. Thus the soy-bean was grown mainly in China until this century; it was taken to the United States in the late nineteenth century and has become a major crop in the last 30 years, whilst its emergence in Brazil has been even more recent (Berlan et al., 1977).

The widespread interchange of crops, livestock and techniques accelerated with the discovery of the Americas and the later migration of Europeans to all parts of the world. Crops indigenous to the Americas have profoundly altered the cropping patterns of the Old World. In Europe the potato was known but little grown before the mid-eighteenth century, but became a major food crop by the mid-nineteenth century (Langer, 1975). Maize spread through the warmer southern parts of Europe in the eighteenth century; in the last 30 years the breeding of varieties capable of yielding in cooler, shorter summers has seen its diffusion into northern France and even into southern Britain. African consumption habits were profoundly changed in the slow spread of maize and manioc in the nineteenth and early twentieth centuries, whilst in parts of Asia sweet potatoes and peanuts, as well as maize, have become
important supplements to rice and wheat (Geertz, 1963; Jones, 1956; Miracle, 1965; Ho, 1955).

In the last century most of the advances in agricultural technology have come in Western Europe and the United States. Chemical fertilizers were first developed in Britain and Germany, milking machines in Scotland, pesticides in France, the tractor and the combine harvester in the United States. Great improvements in the breeding of livestock and crops have taken place. Farmers in the western world were comparatively slow to adopt these innovations for various reasons; for the most part they were adopted if they were seen to increase output and profit. Thus the rate of adoption has greatly accelerated in the last 40–50 years, during the period in which farmers in Western Europe and North America have been protected from competition, and farmers have had an unrivalled period of prosperity.

In Afro-Asia and Latin America the adoption of innovations was equally slow, but the great increase in population since 1945 has meant an increased demand for food. This has to some extent been met by traditional methods, but there have also been attempts by governments and international agencies to accelerate the adoption of innovations that would raise crop yields. The spread of new high-yielding varieties of wheat and rice clearly illustrate the rise of ‘induced innovation’. The research on the breeding of hybrid maize was first undertaken in the United States, on semi-dwarf wheat in the United States and Mexico, and on hybrid rices in the Phillipines by groups of scientists financed by the Ford Foundation of the United States. Since 1965 the new rices have spread rapidly through Asia owing to the intervention of governments who have provided extension workers, who have explained the new farming methods that are necessary, and subsidized the use of fertilizers and irrigation (Dalrymple, 1979; Hayami and Ruttan, 1971).

### 4.3 MAJOR TYPES OF FARMING AND THEIR EVOLUTION

There have been many attempts to establish a typology of world agriculture; few have been successful, indeed the great diversity of farming and the lack of comprehensive statistical information makes it an almost impossible task. (Grigg, 1969a; Duckham and Masefield, 1970; Kostrowicki, 1964, 1974; Whittesey, 1936). Nor is there space here to discuss all the various types of agriculture. Consideration will be given to three traditional farming systems, and emphasis will be put upon the way in which they maintained soil fertility and how they have adjusted to growing numbers.

#### 4.3.1 Western Europe

The most distinctive features of agriculture in Western Europe before the nineteenth century were, first the use of the ox-drawn plough, and second that
most farmers combined the keeping of livestock and the growing of cereal crops. These features had appeared in the Middle ages.

A fallow period of one in two or three years was an essential means of maintaining soil fertility, suppressing weeds and preventing the build-up of plant disease. Sheep and cattle were grazed on grassland held in common, that surronded the arable fields, and were fed on the stubble after harvest. The principal cereal crops varied, but wheat, barley, rye and oats were widely grown, and small amounts of peas and beans added some nitrogen to the soil. This system made the maintenance of yields over long periods possible and, except possibly in the early fourteenth century, there was no sign of soil erosion or falling yields. There was a balance between numbers and the farming system (Duby, 1962; Postan, 1966; Cooter, 1978).

This basic system was modified in different parts of Western Europe between the sixteenth century and the mid-nineteenth century in response both to growing numbers and the extension of commercialized agriculture around the cities. The major change was the greater integration of livestock and arable husbandry. In the medieval system livestock relied upon the grazing of common pasture and woodland for their fodder. However, in the fifteenth century, although mainly from the seventeenth century, part of the arable land began to be allocated to the growth of fodder crops, which included roots, notably the turnip, and clover. Root crops were sown in rows, and weeded during cultivation, which the broadcast cereals could not be; clovers not only provided grazing and hay for livestock, but added significantly to the nitrogen content of the soil. This, combined with the adoption of the potato, an American crop, allowed the considerable increase in food output that sustained the great increase in population between 1700 and 1850, all before industrialization had much effect upon European farming (Slicher van Bath, 1977; Chorley, 1981; Kerridge, 1967; E. Le Roy Ladurie, 1975).

Although the development of West European farms had led to great changes in the physical environment—notably the removal of much of the forest cover and the reclamation of poorly drained areas—it had not led to great damage to the environment. Severe forms of soil erosion, for example, were not found in Western Europe or indeed in those regions to which Europeans had migrated. Farming in eastern North America was still essentially European in origin, as were the types established in south-east Australia, although by the late nineteenth century, intensive agriculture in south-eastern North America was accompanied by severe erosion. But when Europeans moved out of the temperate forest areas where their agriculture had evolved into the drier treeless plains of western North America, Southern Russia and the interior of Australia, in the mid-nineteenth century, they had to discover methods of dealing with low and variable rainfall, and for the first
time there were serious problems of soil erosion (Meinig, 1962, 1968; Fite, 1966; Lyaschenko, 1949).

Traditional European farming reached its zenith in the mid-nineteenth century. The oxen had been replaced by the horse, ploughs were increasingly made of metal rather than wood, a variety of implements were available to farmers which had been unknown to their predecessors. Much of the farmers' activity was devoted to feeding livestock to produce not only meat, milk, wool and hides, but the large amounts of manure needed to sustain and increase crop yields; stall-feeding, folding and muck-spreading were a great part of the farming year. This system reached its apogee in Eastern England and the Lothians of Scotland; more labour-intensive systems of equal elegance were found in the Netherlands and north-west Germany. Man and the horse provided the power, livestock returned nutrients to the soil to provide a balanced, self-sustaining farming system (Dovring, 1965; Ernle, 1968).

From the 1850s there were great changes in the implements and methods available to farmers, although it was not until the 1930s that the widespread adoption of these innovations transformed farming in the western world. The differences between European farming in its homeland and in the sparsely populated regions of North America now became apparent. The shortage of labour in North America required improved implements and machines, and these were forthcoming: the reaper replaced the scythe, the reaper-binder shortened stooking, and the combined harvester replaced the threshing machine which earlier had ended the long history of the flail. At the end of the century the first tractors appeared in the United States and were tried in Britain during the First World War. In Europe, advance in farming methods concentrated on increasing, not output per man, but output per hectare and output per animal, although in dairying many other nineteenth century advances also improved output per man. The development of the chemical fertilizer industry, the first crude pesticides and fungicides, and the breeding of new varieties were all well under way in Western Europe before the First World War.

Since then the series of innovations has continued; artificial insemination of livestock; great advances in the control of animal disease, the scientific planning of animal feeding, the discovery of effective herbicides and fungicides in the 1940s, and further advances in plant breeding have transformed the farming of Western Europe and North America (Cochrane, 1979; Staniforth, 1975; Duckham, 1966). These changes have taken place against a background in which three economic changes have been crucial. First, the labour force in agriculture has declined dramatically, demanding the adoption of labour-saving machinery. Second, governments throughout the western world have subsidized inputs and protected producer prices, so that food output has more than doubled in the last 30 years; but demand has not, so
that a surplus of agricultural produce has become a constant feature of western agriculture, with the attendant political embarrassments. Thirdly, western diets have become dominated by the consumption of animal products, and in most western countries livestock products account for two-thirds of the value of output (Tracy, 1983).

Thus European agriculture has changed profoundly but slowly over the last thousand years, the underlying forces of change being the growth of population, the rise of urban society, the changing structure of demand brought about by higher incomes, and the technological advances that these changes have induced. At all times the capacity of farmers to change their environment has been enormous, but it has rarely been irreversible. In recent years great concern has been expressed at the capacity of modern machinery, and especially modern chemical inputs to damage the environment. It is perhaps too soon to know whether these changes are as dramatic as sometimes is suggested.

4.3.2 The Rice Economies of Asia

Although rice is very widely grown in Asia it is most closely associated with the densely populated deltas and alluvial valleys of the major rivers. Rice, although rarely a mono-culture, occupies a high proportion of the arable land; ploughs are drawn by zebu cattle or water buffalo; livestock, other than chickens or pigs are uncommon, for land cannot be spared to grow fodder crops, and so great is the pressure on land that grazing land is rare. The crop is frequently weeded, and in some regions is sown initially in nursery beds and then transplanted into the fields. Where there is sufficient water, two crops, although not necessarily both rice, are grown during the year. But the most distinctive feature of these economies is the relationship between the crop and water. Rice—or, more precisely, wet-rice—is sown in soil that is soaked to a muddy state; as the seedling grows, water is let into the small fields or padi in which it is sown, and it is grown with the stalk partly submerged until the water is withdrawn before harvesting. These unique growing conditions explain many features of the distribution of the crop and its ability to sustain high yields over long periods (Grist, 1953; Goor, 1966).

First, the padis contain blue-green algae which fix nitrogen, and play the role that legumes have in European agriculture. Second, the need to keep the water at a constant level on the stalk during growth has meant that rice is ideally grown in deltas and the flat plains of the middle and lower parts of rivers. These areas receive plant nutrients in solution and in suspension from the upper reaches. Third, rice is best grown in areas with a heavy clay subsoil that reduces the seepage of water downwards away from the padis; this also reduces the amount of leaching, and hence loss of nutrients in the soil. Finally, the fact that the fields are covered with water during most of the growing
season means that soils are not exposed to high temperatures. This system of farming has proved capable of sustaining high crop yields over very long periods. It is also a system capable of registering small but continuous increases in yields in response to greater labour inputs (Geertz, 1963).

Rice was domesticated somewhere in the south-east Asia between India and South China, but the present distribution and features of the system only emerged in the first millenium after Christ. During this period the Han Chinese slowly moved southwards, and in India, Bengal, which was a frontier region as late as the sixth century AD, was occupied. By the eleventh and twelfth centuries much of the modern pattern was apparent, with high rural densities in southern China, Korea, Japan, much of India, parts of the Phillipines, and Java, but not in the deltas and lower valleys of the Mekong, the Irrawady or the Menam. A variety of means of extending the area under wet rice and increasing yields were practised. Wet rice padis could only be made on flat land, but in areas of great density cultivation was extended up hillsides by terracing, which is common in South China, but rare in the Indian sub-continent. High yields and multiple cropping are only possible if there is water-control and irrigation. The maintenance of water in the padis requires water control, a means of moving water in and out of the fields. This is not the same as irrigation. A majority of Asia’s rice is still grown without irrigation and relies either on rainfall or the floods of rivers. Nonetheless the slow improvement of irrigation and water control has offered possibilities of increasing yields by making the supply of water more reliable, and by allowing the cultivation of two crops, often rice and wheat, in a year. The extension of multiple cropping has also been made possible by the selection of rice varieties with a shorter growing season (Grigg, 1974).

Greater labour inputs have also increased crop yields. Transplanting is only practised in the more densely populated areas; the frequency of weeding requires more work. Unlike the traditional European farming system, livestock manure has played a very small part in increasing or maintaining rice yields, although in southern China night soil has been used and some forms of green-manuring practised. Some extreme forms of labour intensity have been practised; in parts of Java, rice was harvested stalk by stalk with a knife to prevent loss of grain (Krinks, 1978).

Until the middle of the nineteenth century wet-rice cultivation remained little influenced by external forces. Neither urbanization nor industrialization occurred in Asia, and there were few improvements in transport. However, the expansion of European colonialism had two important consequences. First rice became an important export, particularly in French Indochina, Burma, and Thailand, which had remained comparatively sparsely populated. Second, in some parts of Asia the colonial powers introduced modern methods of irrigation, based on the use of massive dams and lined canals; this was most noticeable in British India and in Java (Pelzer, 1945; Randhawa,
1962). However, possibly more important advances were underway in Japan, where the government promoted the improvement of agriculture in the late nineteenth century. Improved varieties of rice were introduced and chemical fertilizers began to be used. This led to the first comparatively rapid increases in rice yields and was the first instance of modernization in the rice economies of Asia. Similar methods were promoted in Korea and Taiwan whilst the latter were Japanese colonies, and between the two world wars rice yields were increasing in these parts of East Asia, but not elsewhere.

The period since 1950 has, of course, seen major attempts to improve farming in Asia, to provide food for a population that has nearly doubled since 1945. The most successful attempt has been the introduction since 1965 of high-yielding varieties of rice and wheat. Both are semi-dwarf varieties with short stems capable of bearing a heavy head of grain without lodging and responding to the application of chemical fertilizers. However, they require for optimum yield adequate moisture throughout the growing season; but only one-third of Asian rice is grown under irrigation. Combined with the use of pesticides the adoption of these varieties has led to substantial increases in crop yields. Although in some parts of Asia the adoption of these yield-increasing techniques has been accompanied by the use of tractors and machinery, Asian agriculture remains firmly linked to its long traditions (Dalrymple, 1979).

4.3.3 Shifting Cultivation and Bush Fallowing

A third way of maintaining soil fertility over long periods is the natural fallow. In most areas, if land is cropped continuously without any means of replacing plant nutrients, crop yields fall steeply and then maintain a low but constant level. One way of restoring the soil fertility without recourse to manure, fertilizers or the special conditions of the wet-rice padi is to crop the land for two or three years, then abandon the land and allow the natural vegetation to colonize the area. The re-establishment of the vegetation cover protects the soil from high temperatures and intense rainfall, and allows humus and plant nutrients to accumulate in the soil. After a period of years, which varies with climate, vegetation and soil type, the plant nutrient level is high enough for the vegetation cover to be partially removed and crops sown again for several years before the land is again abandoned.

Such a method of farming, variously described as shifting cultivation, or bush fallowing, has been widely practised in the past, in nearly all the major climatic and cultural zones. It is still found in parts of Latin America (Watters, 1971) and south-east Asia (Spencer, 1966), but is only the major system in tropical Africa where three-quarters of the arable area is farmed by bush fallowing. Fifty years ago Europeans regarded shifting cultivation as a primitive and wasteful farming system, but it is now realized that it is a successful
means of utilizing tropical environments, and its defects are due to very rapid population growth.

There are innumerable ways of practising bush fallowing (Conklin, 1961; Pelzer, 1945; Watters, 1960). However, there are some general features in common. First of all, land to be cropped is cleared from either primary or secondary woodland or grassland; the plots cleared are small, and the vegetation is cleared with the use of axe, machete and fire. Not all the trees are cleared and stumps are frequently left. Ash from the fire provides some plant nutrients; fire makes the surface soil friable, and the presence of stumps accelerates regeneration when the plot is abandoned. Methods of preparing the soil for sowing vary a great deal. In areas with long fallow the soil is hardly disturbed, so only a digging stick is used. In more densely populated areas of Africa, however, soil is piled on mounds or ridges. The distinctive feature of cropping is that a number of crops are planted in the plot; ideally this will include not only cereals but also roots such as yams or cassava, and small shrubs. Together with the larger trees this provides a layered structure that simulates the forest and protects the soil from higher temperatures, and the impact of tropical rainstorms. Intercropping has recently been shown to have other advantages; the total yield of a combination of crops gives a higher yield than single stands of the individual crops, possibly because crops use complementary plant nutrients and the absence of large stands reduces the incidence of plant disease. It also staggers the chronology of harvesting (Morgan, 1969; Papendik et al., 1976).

No fertilizer is used in bush fallowing, and the amount of weeding done varies, but is usually small. When weed growth becomes too exuberant the plot is abandoned. Indeed some have argued that it is this, as much as falling crop yields, that leads to the abandonment of the plot. In all forms of shifting cultivation the plot is abandoned after three or four years cropping, and is colonized by the natural vegetation. The length of the fallow depends upon the type of natural vegetation, but also important is the density of population. In very sparsely populated areas the fallow may last 25 years or more, and the settlement of the cultivators is moved. In more densely populated areas not only is the settlement permanent, but the fallow length has to be reduced; there is not sufficient land to allow long fallows. As the fallow is reduced so alternative means of maintaining soil fertility are sought; in parts of Africa fallows are planted with rapid growing bushes and grasses, some leguminous, and in the very densely populated areas such as northern Nigeria, pastoralists are encouraged to feed their livestock on fallow plots. But in most bush fallowing systems there is an absence of manuring as there is indeed of livestock, the plough is unknown and the complete clearance of natural vegetation is unusual. The chaotic mixture of crops and natural vegetation led Europeans to believe that such farming systems were primitive. It is now recognized that bush fallowing is a satisfactory means of providing food with
relatively low labour inputs, and maintaining soil fertility and crop yields over long periods.

What is equally clear, however, is that shifting cultivation can only maintain this ecological efficiency if land is abundant. As fallows are reduced by rising population densities, as has occurred in Africa in the last 50 years, the ability of the natural fallow to restore soil fertility diminishes, and the risks of soil erosion increase.

4.4 LAND TRANSFORMATION AND THE HISTORY OF AGRICULTURAL CHANGE

Throughout the history of agriculture men have been constantly modifying the environment to facilitate the production of crops and livestock. The destruction of vegetation, the salinization of poorly drained irrigated areas, the wind erosion that results when dry areas are farmed with modern machinery, are all damaging to the environment, as are many of the consequences of the use of modern pesticides and chemical fertilizers. It is, however, perhaps unwise to insist that all land transformation by farmers is for the worse, for many of the world's most aesthetically pleasing and ecologically satisfactory landscapes are the result of the long, slow interaction of man and the environment. Other chapters in this book describe the adverse effects of human interference with the environment. It is perhaps as well to recall that a pessimistic view of the advance of agriculture could have been adopted at any time in the last 10 000 years. Land transformation is not new, even though the modern forces for change are far more powerful.

4.5 REFERENCES

The Industrial Revolution and Land Transformation


