An Introduction to Agricultural Geography

Second edition

David Grigg

ROUTLEDGE

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Employing nearly on half of the world's workforce, agriculture is clearly of great economic and social importance. An incredible variety of methods is used globally; the Western world has the latest scientific and industrial advancements at its disposal, yet in some parts of the Third World a living is made using tools that have hardly changed in two thousand years.

David Grigg provides a comprehensive introduction to agriculture in both the First and Third Worlds, describing both human and environmental issues. Covering the physical environment, economic behaviour and demands, institutional, social and cultural influences, and the impact of farming upon the environment, the book explores the wide range of factors which influence how agriculture and agricultural practice differ from place to place.

For this new edition, the text, statistics, artwork and bibliography have been entirely updated and revised. In addition, two new chapters have been incorporated, on modernization and on the environment.

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For Jill, Susan, Catherine and Stephen, with much love

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Michaelmas,
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Chapter 1
Introduction

Agriculture is by far the most important of the world's economic activities; it uses one-third of the total land surface and employs 45 per cent of the working population. Yet the study of agriculture receives relatively little attention from geographers. In Britain and the USA far more notice is given to manufacturing industry and the problems of urban areas. This neglect perhaps reflects the relative unimportance of agriculture in the economies of developed countries, in contrast to its predominance in the developing countries and the world as a whole. In Britain and the USA only 2 per cent of the employed population are engaged in agriculture, and it contributes a similarly small proportion to the national income. In many developing countries, however, over half the population depends upon farming for a living and it is the most important contributor to the national income. But even in developed countries agriculture is more important than these statistics suggest, for between 12 per cent and 30 per cent of disposable income is spent on food, while agriculture is the major user of land. In England, for example, four-fifths of the land surface is used for agriculture purposes.

Thus the study of agriculture geography is clearly important. The subject may be simply defined. Agricultural geography seeks to describe and explain spatial variations in agricultural activity over the earth's surface. The heart of this task is to explain the great diversity of agriculture. It has been estimated that there are over 250 million farmers in the world. Between them they grow many different crops—at least 1000 species are in use—and they raise these crops in a variety of ways. Thus on some British farms aircraft spray the land with pesticides and computers control the day-to-day running of the farm; yet in parts of the Middle East *fellahin* still raise wheat with implements little changed since biblical times. Equally great are the differences in organization and social conditions. Many farmers in Britain or the USA are rich and successful, owning their land; in parts of Latin America *peons* toil on land they do not own under conditions not far removed from slavery. Even more striking are the differences in productivity. One American farm worker can produce enough food to feed nearly fifty other people, yet throughout Africa and Asia many farmers are hard-pressed to feed themselves and their families.

A DEFINITION OF AGRICULTURE

Agriculture has been described as the purposive raising of livestock and crops for human needs. The word 'purposive' thus excludes hunters and gatherers who have not domesticated the plants and animals they use for food. Although forestry and fishing are often placed with agriculture in economic classifications, they are not considered here. It should be noted, however, that many Scandinavian farmers combine agriculture and forestry, while in parts of Asia coastal villages often practise both fishing and farming. Attempts to raise wild game for meat in parts of Africa form an interesting stage between hunting and pastoralism. It has been argued that some modern forms of agriculture, such as the broiler industry, are more akin to industrial operations than agriculture. But the fact that little land is used and that the technology and organization are modern and efficient cannot be allowed to exclude such activities; a rapid growth in the scale of organization and technical expertise is a distinctive feature of modern agriculture.

Some have argued that geographers have confined themselves solely to production on the farm; instead they should deal with the geography of the food system, and cover not only the production of food on farms but also the geography of input production—such as the manufacture of fertilizers and machinery—and the processing of the raw materials raised on farms, in flour mills, sugar refineries and breweries for example. Some would go further and include the distribution and consumption of foods as part of the system. This is a laudable aim, but as yet there is little written upon the subject, and the execution of this task lies in the future.

If agriculture is diverse, it is also remarkably complex, and there is a need to be clear what features of agricultural production the geographer is trying to describe and explain. Yet there is a long list of variables that give rise to diversity. Thus the differences between farming in Britain and the former Soviet Union are legion, but that of land tenure might spring first to mind, for in Britain farmers either own their farms or rent them from private landlords whilst in the Soviet Union all land was the property of the state, and indeed most still is. A study of Louisiana and southern Vietnam would show that rice is grown in both areas but the methods used and the efficiency with which the crop is raised differ greatly. Some comparisons would emphasize differences in the crops grown and the livestock raised. Thus a few miles to the west of Sheffield in northern England there are parishes where few if any crops are grown and no stock kept but sheep, which feed upon rough grazing and permanent grass. A few miles to the east sheep are unknown, rough grazing rare and grass is a small part of a land use pattern dominated by wheat, barley, sugar-beet and potatoes. There is thus a great variety of variables that must be discussed in order to describe spatial variations in agriculture. A Commission of the International Geographical Union has compiled a list (Table 1.1) of the principal variables which includes land tenure and size of farms, the use of labour and capital inputs, the degree of commercialization, the efficiency with which the inputs are used, the types of crops grown and the livestock raised.

Table 1.1 Characteristics of agricultural types

A	**Social attributes**
1	Percentage of land held in common
2	Percentage of land in labour or share tenancy
3	Percentage of land in private ownership
4	Percentage of land in state or collective ownership
5	Size of holding according to numbers employed
6	Size of holding according to area of agricultural land
7	Size of holding according to value of output
B	**Operational attributes**
8	Labour intensity: numbers of employees per hectare of agricultural land
9	Inputs of animal power in draught units per hectare of agricultural land
10	Inputs of mechanical power: tractors, harvesters, etc. per hectare of agricultural land
11	Chemical fertilizers: NPK per hectare of cultivated land
12	Irrigation: irrigated land as a percentage of all cultivated land
13	Intensity of crop land use: ration of harvested to total arable
14	Intensity of livestock breeding: animal units per hectare of agricultural land
C	**Production attributes**
15	Land productivity: gross agricultural output per hectare of agricultural land
16	Labour productivity: gross agricultural output per employee in agriculture
17	Degree of commercialization: proportion of output sold off farm
18	Commercial production: commercial output per hectare of agricultural land
D	**Structural characteristics**
19	Percentage of land in perennial and semi-perennial crops
20	Percentage of total agricultural land in permanent grass
21	Percentage of total agricultural land in food crops
22	Percentage of total agricultural output of animal origin
23	Animal production as percentage of total commercial output
24	Industrial crops (sugar, fibre, rubber, beverages) as percentage of total agricultural land

Source: J.Kostrowicki, *World* Types *of Agriculture* Warsaw, 1976, pp. 10–21

APPROACHES TO DESCRIPTION

There are two contrasting approaches to the description of agricultural adversity.

First is the systematic analysis of the distribution of one variable. Thus it is useful to study the spatial variations in the growth of wheat. This can be done at any scale—the world or a British parish. Such a study tells us where wheat is grown, where it is absent, in what places it is a major crop, in what places it is of minor importance. It also suggests explanations of the pattern. The distribution of wheat growing may be related to rainfall or the presence of large urban markets. Valuable as such an approach is, it has its limitations. Wheat is not grown—or is rarely grown—as the only crop on a farm. Further, analysis of crop statistics may suggest that wheat is generally grown in characteristic crop combinations. In one region it may be commonly grown with sugar-beet and potatoes, in another area with barley and oilseed rape.

Second is the approach to description by means of the idea of type of farming map, or agricultural region. This can be best illustrated by amplifying the remarks made upon the distribution of wheat. The analysis of the distribution of crops requires statistics on the use of agricultural land, usually available only for administrative districts such as the British parish, the French commune, or in the USA, the county. But these figures are aggregates of the land use of a number of farms. If figures were available by farms, then it might be seen that not only are there spatial variations in the importance of wheat or in distinctive crop combinations containing wheat, but that these variations correspond to variations in other variables such as the size of farms or the presence or absence of dairy cows. An imaginary example may make this clearer. In the east of a country little wheat is grown, the farms are small, most of the farmers own their land and rely upon their family for labour. No sheep are kept and few beef cattle; most of the livestock are cows, and the main source of income is from the sale of milk. Moving westwards there are changes; more wheat is grown, sheep and beef cattle replace cows, farms are large and rented, and farmers hire labour. Maps of the distribution of wheat or dairy cows fail to capture the way in which a number of variables change spatially. It is clearly possible to classify farms into types on the basis of not one but several variables. Similarly, it is possible to see that some areas are characterized by a predominance of one type of farming.

Both the systematic study of spatial variations of a single variable, or the definition of type of farming area or agricultural region, are useful approaches to the study of agricultural geography. But they are only a beginning.

APPROACHES TO EXPLANATION

Description is essential to the understanding of the agricultural geography of an area, and it often suggests various ways of explaining spatial variations. There have been several approaches to explanation in agricultural geography.

Environment and agriculture

Agriculture deals with living plants and animals which thrive in some physical environments, but flourish less successfully or not at all in other environments. Not surprisingly students of agricultural geography have for a long time assumed that differences in the physical environment determine spatial variations in agricultural activity, and that regional differences in climate and soil give rise to distinctive agricultural regions or types of farming area. Thus the earliest regional descriptions of British farming, the Reports made to the Board of Agriculture in the 1790s, for the most part assumed that farming varied spatially largely as a response to differences between upland and lowland and between different soil types. Similar assumptions were made in many of the essays on the agriculture of the English counties published in the *Journal of the Royal Agricultural Society of England* in the mid-nineteenth century. It is a view which was still prevalent in the County Monographs of the Land Utilization Survey of Britain published in the 1930s and 1940s. In the USA a series of articles on the agricultural regions of the world, published in the 1920s and 1930s, all bore the assumption that climate was the principal determinant of world patterns of farming.

Such geographical determinism, or environmentalism—the belief that environment inflexibly determines human activities—was not confined to agricultural geography; it was a view attacked by Paul Vidal de la Blache in the early twentieth century. His studies of French *pays,* or regions, emphasized the mutual interaction of man and environment. But by the 1930s American geographers, reacting against environmentalism, were seeking explanations for agricultural differences everywhere but in the environment. After the Second World War this flight from determinism became apparent in Britain and Europe. This did not mean that there was no study of the relationships between crops and the physical environment; rather it was now left to agronomists, soil scientists, climatologists and botanists. Agricultural geographers had cut themselves off from their roots.

J.H.von Thünen, models and explanation

In 1826 J.H.von Thünen, a German economist, published *The Isolated State*. In this he argued that distance from the market was the prime determinant of what crops and livestock were grown and with what intensity.

He devised an imaginary world where all the other factors that could influence farming practice—such as soil type, or imports—were held constant. He thus devised the first economic model. When *The Isolated State* was translated into English in 1966, it had a profound impact on agricultural geographers and prompted many studies of the influence of distance on the farm, at the national level and the world scale. It emphasized one factor, assumed that economic forces were paramount, and largely discounted the significance of environment. It also led agricultural geographers to try and frame hypotheses and test them with rather more rigour than had hitherto been the case.

Behavioural approaches

In the study of agricultural geography the fundamental unit is the farm and the farmer. But most published agricultural statistics are available only at an administrative level that conceals farms by aggregation. Hence it has been difficult to explain agricultural variations in terms of individual behaviour. Yet clearly spatial variations in agriculture are a result of many decisions made by many individual farmers. Torsten Hägerstrand's studies of how Swedish farmers' adopted new farming methods have led to many studies of how farmers attitudes and assumptions affect decision-making on the farm. Such—and allied—studies led to a swing away from the economic determinism of which von Thünen was perhaps an unwitting forerunner. In recent years more emphasis has been put by geographers upon nonenvironmental and non-economic factors in explaining spatial variations in agriculture.

Internationalization, modernization and the political economy approach

In the 1980s the approaches outlined above became less common in agricultural geography, and there was a search for other modes of explanation. This was partly prompted by the growing importance of state intervention in the behaviour of farmers, and the inability to solve the problems of overproduction; and partly by the growing importance of food processers in the food production system. Some believed that the globalization of world food production was of paramount importance in understanding world patterns of production, and linked this to the rise of transnational food producers and processers. Others, concerned with much the same array of topics saw the growth of agribusiness—rarely precisely defined—as the key to understanding. Such theories are often described as the political economy approach. One advocate in the 1980s described these methodologies as being in their infancy, and it is perhaps not unfair to argue that they remain still more polemical than empirical; there are more calls to farther research than reliable evidence. Such work as yet remains on the research frontiers of the subject rather than in an introductory text such as this.

PURPOSE AND PATTERN

The aim of this book is *not* to describe the agricultural geography of any one country, region or the world. This is a laudable aim and has been attempted by many. Nor is the purpose to take one explanatory factor and illustrate its significance. This is an introductory textbook, and it makes the assumption that it is highly improbable that one factor such as climate or distance from the market will explain spatial variations in all parts of the world. Instead those factors that have been suggested by geographers as important are reviewed. It should be emphasized that the aim is to show how a variety of variables can affect spatial variations in farming, not to discuss those variables *per se*. Thus differences in land tenure are a fundamental feature of the world's agricultural geography. But the concern here is only how differences in tenure influence variations in land use, productivity and farming structure.

The first part of the book deals with the biological characteristics of crops and livestock and the way in which the physical environment influences the farmers' choice of crops and animals. The second part deals with the economic behaviour of farmers and the behaviour of the consumers of food and fibre. The role of the state is considered, and also the consequences of the modernization of agriculture. This is followed by a consideration of the influence of the location of urban markets upon farming. Population density and labour availability are then discussed. The third part deals widi institutional and social influences on agricultural geography. The role of land tenure, farm size, innovation diffusion and religion are discussed. A final chapter deals with the impact of farming upon the environment. It is not suggested that this approach is comprehensive or exhaustive; even less that this is the only way to approach the study of agricultural geography. The aim of this book is to emphasize that the remarkable diversity of the world's major industry requires an equal breadth of mind if its spatial variety is to be understood.

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Chapter 2
The biology of agriculture

The farmer—unlike the manufacturer—deals with living things. Plants and animals have inherent biological characteristics that determine their productivity; and they only function efficiently in environments to which they are adapted. Both these factors profoundly influence the nature and location of agricultural production.

FOOD CHAINS

All the energy on earth comes from the sun. The solar radiation received at the earth's surface is used by those plants that contain chlorophyll to produce, by photosynthesis, carbohydrates and protein. In addition the plant needs mineral nutrients that come from the decomposition of rocks and are taken into the plant in solution via its roots. Carbon dioxide, hydrogen and nitrogen are derived from the atmosphere, although the latter has to be fixed in the soil as a soluble nitrate before it can be taken up by the plant. But plants only use a minute fraction of the energy available in solar radiation. The energy contained in plants represents, at the very most between 1 and 5 per cent of the energy in the solar radiation incident at the earth's surface.

The amount of energy formed by plants is known as the Net Primary Product, and all other parts of the natural kingdom are dependent upon this source of food and energy. The natural vegetation provides food for herbivores, animals that graze on plants; they form the second level in the food chain. However, just as the plants contain a small fraction of the energy present in solar radiation, so there is a great loss of energy between the plants and the animals that graze upon them. A further level in the food chain is represented by the carnivores that prey upon the herbivores as does, for example, the lion upon the wildebeest. Again, there is a remarkable loss of energy between the herbivores and the carnivores.

These food chains also exist in agriculture. Solar radiation provides the energy for crop plants; these may be eaten directly by humans in his guise as herbivores, or by cattle and sheep as herbivores. They in their turn are eaten by humans as carnivores. The loss of energy through the chain is considerable. For example, on the open range of the south-western USA 800,000 kilocalories of solar radiation reach each square metre in a year. Of this, after respiration, transpiration and other leakages, only 800 kilocalories are available in the vegetation. Cattle graze this sparse scrub and grassland, but the meat produced by the herds is equivalent, in energy terms, to just 20 kilocalories per square metre; only 2.5 per cent of the energy available in the natural vegetation, and 0.0002 per cent of the energy in the solar radiation incident at the earth's surface.

The loss of energy between vegetation and animal is fundamental to the economics and geography of agriculture. The amount of food produced per hectare by plants is always far greater than that produced by animals. To put it another way, to produce a given number of calories for human food nearly always requires more land for animal food than for plant food. In the United Kingdom milk is the most biologically efficient of the animal products (Table 2.1) but its yield is only one-ninth of that obtainable from potatoes, and one-sixth of that derived from wheat. At the other extreme, beef cattle and sheep produce only 2–3 per cent of the energy per hectare obtained from potatoes. It is not surprising, then, that livestock products are more expensive than plant foodstuffs, or that in densely populated regions in poor countries food crops are dominant and livestock products rare. Perhaps more surprising is that, although the protein content of most plants per unit weight is below that of most animal foods (the protein content of wheaten flour is half that of an egg, that of manioc only a fifth), the protein output per hectare of land under most plants exceeds that of land used by animals (Table 2.1).

Table 2.1 Edible yields from animals and crops

	Energy (Mcal/hectare)	*Protein (Kg/hectare)*
Potatoes	24,000	420
Wheat	14,000	350
Cabbage	8000	1100
Peas	3000	280
Dairy	2500	115
Dairy and beef	2400	102
Pigs	1900	50
Eggs	1150	80
Broilers	1100	92
Beef	750	27
Sheep	500	23

Source: W. Holmes, 'Efficiency of food production by the animal industries', in P.F. Wareing and J.P. Cooper (eds), *Potential Crop Production*, London, 1971, p. 224

CROP PRODUCTIVITY

Botanists measure the productivity of natural vegetation by estimating the total weight of the biomass per hectare, which includes roots, stalks, stems, fruit, seeds and leaves. But the yield of agricultural plants is only the edible part of the crop, or in the case of fibres, the usable part. The yield of crops varies a great deal because of differences in climate, soil type and the amount of inputs such as fertilizer that are used, the amount of weeding, and the efficiency of protection against pests and diseases. But there are also inherent variations in the yield of different crops when measured by the weight harvested per hectare; the world average yield of potatoes (Figure 2.1) is twenty times that of millet, while maize yields are more than double those of sorghum. The yields of the tropical root crops — manioc, yams and sweet potatoes—are well above the tropical grain crops, and the main temperate root—potatoes—yields far more than the leading temperate grain, wheat. But these yields are not an adequate measure of the output of food per hectare, for crops vary in the number of calories they supply per unit weight. For example, 100 g of millet provides 345 calories, but the same weight of manioc only 109 calories. Thus the calorific output of crops is not necessarily the same as the harvested weight, although even with lower calorific values the roots normally produce more calories per hectare than the grains. In Figure 2.1 the yield per hectare and the calorific output per hectare of the principal food crops of West Africa are compared. In both cases the crops are expressed, not in kilograms per hectare, or calories per hectare, but as a percentage of manioc. Although the root crop cocoyams gives a far greater *yield* per hectare than the cereals, its food output per hectare (and that of sweet potatoes) is litde more than that of the grains. Thus, whereas manioc has a marked advantage as a food crop in West Africa, cocoyams has little advantage in food value over the grains, in spite of its greater harvested yield.

PERENNIALS AND ANNUALS

Crops can be classified in a variety of ways, but of particular importance is the distinction between annuals and perennials. Annual crops are sown and harvested within one year, and are resown the following year with seeds retained from the harvest or bought from a merchant. If the growing season is long, then double cropping and even triple cropping is possible in the tropics and sub-tropics, although generally irrigation is necessary. Perennials, in contrast, once planted yield annually for some years. A distinction can be made between the herbaceous perennials and the woody stemmed perennials. In the former the roots are permanent, but the herbaceous growth is cut at the harvest and later regrows; bananas and sugar-cane are the two important agricultural plants in this category. However, because sugar content declines with each succeeding cut, sugar-cane may be replanted at frequent intervals. In the woody perennials, both the roots and the stems above ground are permanent, and it is the fruit or leaves that are harvested. This group includes the temperate orchard trees such as apples and pears, grapes, olives, and tropical crops such as tea, cocoa and coffee. Rubber trees are cut to drain off latex.

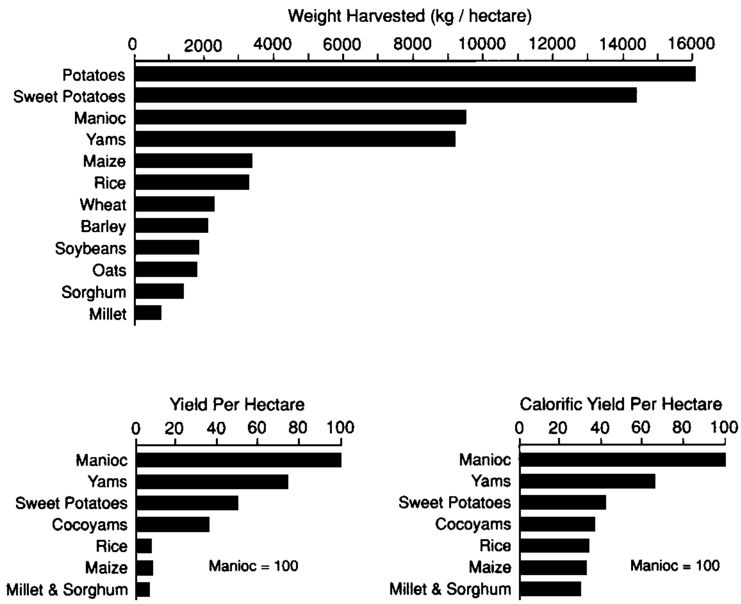

Figure 2.1 **(a) Harvested yields of selected crops, world average, 1987–9**
(b) Harvested yields and calorific yields of food crops in West Africa

The nature of these crops presents a number of difficulties to farmers. First, they do not bear fruit until some years after planting (Table 2.2), and take even longer to bear fruit suitable for sale. Thus many of these crops are grown on plantations where financial resources are great enough for this period without return to be borne. Alternatively, they are grown on smallholdings where, however, most of the land will be devoted to food crops. Second, once planted the crop yields each year regardless of the level of demand, and so problems of overproduction are very marked. Tea and rubber are exceptions to this generalization; latex is only yielded by the rubber tree if the bark is cut, while tea production requires the leaves to be picked; some control of output is thus possible. None the less, the perennial crops have presented persistent problems of overproduction. Part of the reason for this is the expansion of planting when prices are high; there is of course no guarantee that prices will still be high five to ten years later, when the bushes or trees begin to bear commercial fruit. Coffee has proved particularly susceptible to these problems.

THE BIOLOGY OF LIVESTOCK

The differences between crops and livestock in terms of food output per hectare have already been noted. There are also important differences between the various animals used by people to produce meat, milk, wool and hides.

Table 2.2 Perennial crops: their length of life (years)

	Age when bearing begins	*Commercial bearing*	*Maximum yield*	*Duration of yield*
Apple	4–7	6–12	16–25	20–35
Orange	3–4	5–8	15–20	20–35
Grapes	3	4	5	30–40
Coffee	3–4	5–6	–	20
Coconut	7–10	10	–	60
Cocoa	5	10–12	–	–

Source: W.N.Peach and J.A. Constantin (eds), *Zimmerman's World Resources and Industries,* New York, 1972, p. 299

Note should be taken of the difference between the ruminants and the non-ruminants. Ruminants have micro-organisms in the gut that allow them to digest the cellulose in fibrous plants, particularly grass. In this way cattle, buffalo, sheep, goats and deer can feed upon grass and the leaves of trees. People, of course, cannot do this, nor can pigs and poultry which have simple stomachs and eat the same type of plant products as human beings. They are thus in competition with humans for limited food resources. However, as they can eat the residues of human food, they can be kept as scavengers and are particularly useful in densely populated regions; China for example, has 40 per cent of the world's pigs and 20 per cent of the chickens.

Cattle and sheep can feed on grass, which is very widely grown. This has two advantages. First, grass under temperate climatic conditions and good farming methods gives a higher dry matter, energy or protein yield than most crops, but it can only be converted into human food if grazed by ruminants. Second, grass and other plants containing cellulose can colonize large areas of the earth's surface which are too dry or too cold for crops grown directly for human consumption. This land could not be utilized if it were not grazed by ruminants. In the semi-arid areas sheep and goats are more tolerant of aridity than cattle, because cattle need 50 per cent more drinking water per unit of body weight than sheep. Sheep and goats, then, make up the greater part of the livestock of nomadic pastoralists who have for the most part been driven into the remoter arid regions by sedentary cultivators.

Some types of cattle can survive in dry regions, for they can range long distances in search of grass or bushes, but under such circumstances they put on litde weight, and have to be shipped to areas of better grass, or grain must be purchased, to fatten them for market. There is often a distinction between areas (generally environmentally inferior) where catde are reared, and where they are fattened. In Britain sheep are reared in upland areas, but fattened in lowland regions. In the USA, the pattern used to be for young cattle to be reared in the drier parts of the Great Plains and in parts of the Rockies, and then driven east to the lusher grasslands and grain-growing regions of the Midwest, where they were fattened for market. Now, however, cattle are often reared in the drier areas and then fattened on grain imported from further east. Dairy cattle have different requirements from beef cattle; they cannot move any considerable distance in search of food, and the quantity of milk they produce is controlled by the amount and quality of their fodder intake.

The way in which livestock are fed varies a great deal. In many parts of the world cattle and sheep can be kept on natural vegetation, although at very low densities; the interior of Brazil and Australia are examples. Grass plays a part in this vegetation, but is not sown by the rancher or treated in any way. In contrast, sown grass plays a significant role in the feeding of cattle in the Netherlands, New Zealand, Ireland and Britain, but here improved varieties of grass are sown and often irrigated and fertilized. Livestock may also be fed upon crops grown on arable land; a wide range of fodder crops are grown, including potatoes, cabbages, turnips and other fodder roots and various oilseed crops. In addition, grain is now widely grown as a feed for cattle; Europe still imports grain for this purpose.

Livestock densities vary a great deal owing to differences in the environment, but also to the differing feed requirements of the various species. Thus, in the United Kingdom, dairy cows have the highest feed requirement, sheep require only one-tenth of that, pigs one-half and poultry one-fiftieth. This reflects primarily differences in body weight, but livestock also differ in their biological capacity to convert feed into energy (Table 2.3). Pigs are the most efficient converters of feed into energy, beef cattle the least efficient; on the other hand, dairy cattle are the most efficient converters of feed into protein (Table 2.3, note 6). Other factors help to decide what livestock or combination of livestock will be kept. Differences in body weight mean that animals of different species will give very different amounts of edible meat. Catde produce five times as much meat as pigs, but the latter twice as much as sheep. However, these differences are partly compensated for by the differences in gestation periods between cattle and sheep, and poultry and pigs, the former taking longer to produce marketable meat. Pigs and poultry produce far more protein per hectare than sheep or goats, and pigs produce more calories than other livestock (Table 2.3).

PESTS AND DISEASES

Biologists have shown how elaborate are the interrelationships between the flora and fauna of the natural world. Most plants and animals are food for some other plant or animal. Nor are the animals kept by humans, or the plants grown by them, any exception. Catde may be savaged by tigers, sheep by dogs; less dramatically they provide a host for ticks, insects and parasites. Crops, too, provide food for birds, animals and insects. To the farmer these creatures are pests and diseases which must be eliminated, however natural their role. Despite advances in pesticides, pests and diseases still destroy a large proportion of the world's standing crop each year. The spread of disease has also had an important effect on the location of some crops. The banana provides a good example of this.

The banana in the Americas

The banana is widely grown as a food crop throughout the tropics, but in the last century it has been grown both on plantations and smallholdings in the Americas for export to the USA and Western Europe. It was first grown for this purpose in the late nineteenth century in Jamaica and the Caribbean coastal areas of Central America, at that time sparsely populated. The United Fruit Company developed railways and plantations in Honduras, Guatemala, Costa Rica and Panama. Some bananas were grown on the Pacific coast of Central America as early as 1906, but there the dry season meant that irrigation was needed, and production was thus more expensive than on the humid Caribbean coast. The latter region was closer to the north-east of the USA and to Europe, an important factor, for there should be no more than three weeks between cutting and consumption. However, in the 1920s the plantations of the Caribbean coast were invaded by Panama disease, a fungus that attacks the roots of the banana and destroys the plant. Fungicides were developed that would destroy the disease, but they were too expensive. In the 1930s a second disease, *sigatoka,* spread through the region; this attacked the leaves and reduced the quality of the fruit, but it could be controlled by copper sulphate sprays. In the 1930s the United Fruit Company abandoned its disease-ridden holdings on the Caribbean coast, and concentrated banana production on the Pacific coast. However, since the 1950s, the Caribbean areas have been revitalized by replacing the variety *Gros Michel* widi

Cavendish, which is immune to Panama disease; but the Pacific regions remain the dominant producers.

Table 2.3 Efficiency of livestock production

	Output[1] and feed ratio %	*Output[2] energy and feed energy*	*Gross[3] feed energy to edible protein %*	*Crude[4] Protein (kg per hectare per yr)*	*Gross[4] energy (MJ per ha per yr)*
Pigs	–	–	12	–	–
Pork	47.9	35	–	–	–
Bacon	38.5	35	–	105	14,438
Broilers	36.0	16	20	135	7071
Sheep	17.6–13.2	11–14.6	3	65	7486
Cattle	8.6	5.2–7.8[5]	6[6]	53–65	3924–4796[5]

$\frac{\text{Carcase Kg}}{\text{Feed intake kg}} \times 100$ rcase in relation to feed dry matter intake

2 Output of energy in carcase in relation to input of feed energy. Total energy in carcase divided by energy in total feed multiplied by 100.

3 Conversion of gross feed energy to edible protein in lifetime performance.

4 Under UK conditions.

5 Beef herd.

6 Beef herd; for dairy cows it is 23 per cent.

Source: C.R.W. Spedding, S.M. Walsingham, and A.M. Hoxey, *Biological Efficiency in Agriculture,* London, Academic Press, 1981, pp. 253–5, 303

The tsetse fly in Africa

Africa has one-fifth of the world's agricultural land, but only one-seventh of its cattle. There are many reasons for this, including the poor quality of the natural grazing, the lack of suitable fodder crops and the limited local demand for meat, but of particular importance is the prevalence of a disease, sleeping sickness, which afflicts both man and cattle. In cattle the disease is called *Nagana*, and it is carried by a parasite endemic in the game animals of the continent. The tsetse fly bites both game and cattle to obtain blood, and so transfers the disease from game to cattle. The tsetse fly thrives only in areas with thick bush; it is thus not found either in densely populated areas where the bush has been removed for cultivation, or in drier regions where moisture is insufficient to maintain bush. But it does occupy a large proportion of Africa, and cattle are few in these regions (Figure 2.2). Various attempts have been made to eliminate the disease: in northern Nigeria pesticides have been used, but this has proved very expensive, as are curative drugs. As yet there is no means of immunization. The reduction of the tsetse fly, by whatever means, would gready improve the productivity of the African savannas.

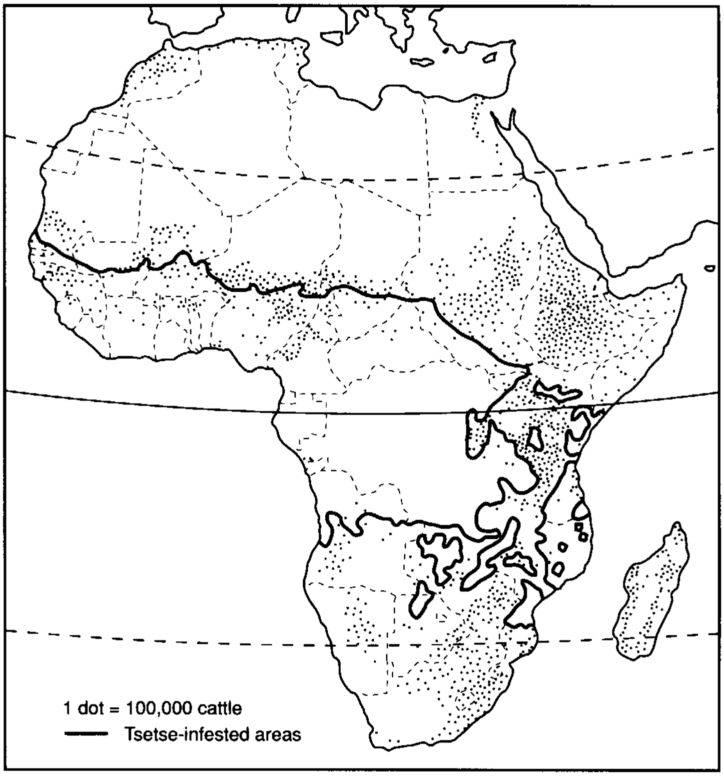

Figure 2.2 The tsetse fly in Africa and the distribution of cattle After A.T.Grove, *Africa,* Oxford, Oxford University Press, 1978

CONCLUSIONS

The biological aspects of agriculture have considerable significance for the agricultural geography of the world, yet they have been relatively neglected by agricultural geographers. Most of the work has been done by agronomists and, more recently, by biogeographers; it is to be hoped that agricultural geographers will build upon their example.

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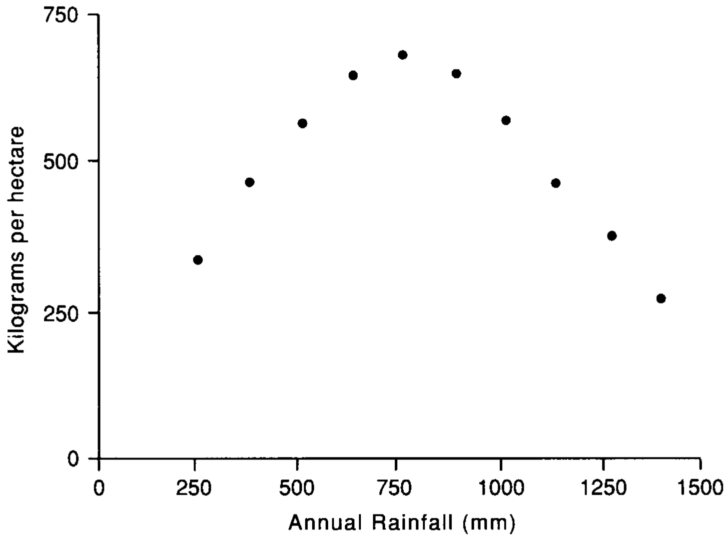
Chapter 3
Climate and crops

All crops differ in their biological characteristics and their environmental requirements, while the physical character of the earth's surface varies greatly from place to place. A great many variables influence plant growth and development, including day-length, the amount of solar energy received, the amount of precipitation available for transpiration, temperature during the growing season and the level of mineral plant nutrients in the soil. Many of these variables, all critical for successful plant growth, can be modified by the farmer; in dry regions irrigation can supplement precipitation, fertilizers can add plant nutrients and temperature and day-length can be modified by growing crops indoors with heating and controlled lighting. But all these modifications of the natural environment are costly. There are, however, some parts of the earth's surface where a particular crop will grow best without these modifications, and a knowledge of such places helps to explain the distribution of crops.

OPTIMUM GROWTH

Plant requirements in terms of temperature, moisture and plant nutrients are rarely linear. For any plant there are (i) minimum requirements of temperature or moisture without which no growth will take place; (ii) maximum limits, beyond which growth ceases. Between these limits are (iii) environmental characteristics which give optimum growth and development; here are found the highest *yields,* the weight of the edible part of the crop per hectare. For example, in the USA in 1908, when little fertilizer was used, wheat did not grow at all with small amounts of rainfall; then, as annual rainfall increased so did yields, until the highest yields were found in places with an amount of rainfall between 625 and 875 mm. Further increases in rainfall led, however, to a decline in yields (Figure 3.1). It follows that one might expect there to be for any one crop areas of the earth's surface where yields are highest and variability is lowest. This is the *ecological optimum.* Away from the optimum area, environmental conditions deteriorate so that yields fall and variability

Figure 3.1 Mean annual rainfall and the yield of wheat, USA, 1908 Little fertilizer was used on wheat crops at this time



Source: O.E.Baker, 'The potential supply of wheat', *Economic Geography,* 1925, vol. 1, pp. 15–52

increases, until the point of minimum requirements is reached and the crop does not grow at all; this is the *absolute* limit to growth.

In an imaginary continent, the optimum conditions for a given crop are in the centre (Figure 3.2). Yields are 5 tonnes per hectare, but they decline away from this zone, and eventually climate conditions are so adverse that no growth occurs and the yield is zero. This is the absolute limit of cultivation. However, farmers are not likely to cultivate the crop near the absolute limit, for economic as well as ecological factors determine where a crop is grown. Suppose the price received for the crop is £100 per tonne, and the cost of production (the same everywhere) is £150 per hectare. Under these conditions production cost per tonne will increase with increasingly adverse climatic conditions (Figure 3.2), and profit per hectare will also decline away from the optimum zone. Indeed, when yields fall to 1.5 tonnes per hectare, the price received will equal production cost and income will be zero. Farmers will clearly cultivate the crop only within this economic limit. The economic limit, unlike the absolute limit, is not fixed. A fall in production cost or an increase in price would extend the economic limit out towards the absolute limit, while an increase in production cost or a fall in price would cause a contraction of the margin of cultivation towards the optimum area.

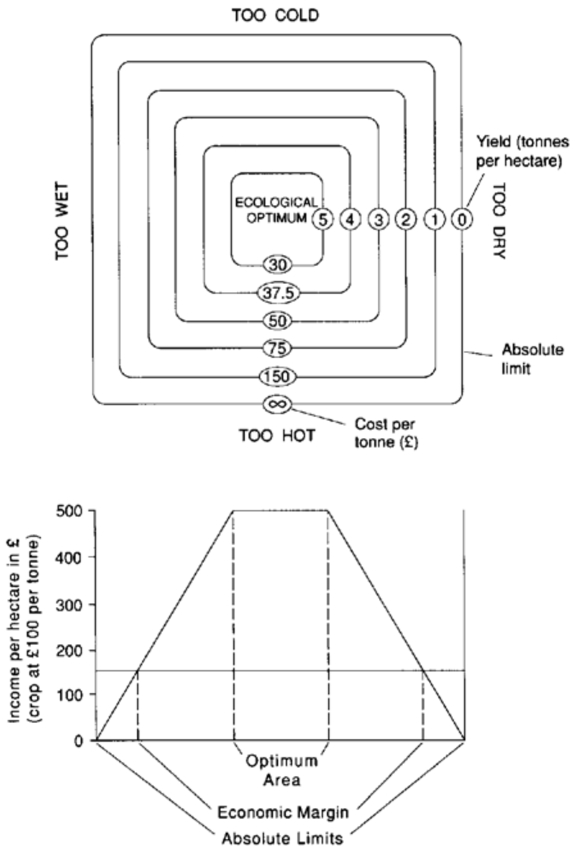


Figure 3.2 The economic and ecological optima and limits (Cost of production £150 per hectare, price per tonne £100)

OPTIMUM AREAS AND COMPETING CROPS

So far it has been assumed that only one crop is grown by farmers, but obviously this is not always so. Now, not only does the earth's surface vary gready in the opportunities it affords for plant growth, but the environmental requirements of crops differ a great deal, so that the optimum areas and the absolute limits will vary as well. In some cases the optimum areas of two crops—or two groups of crops—are mutually exclusive. Thus, tea and rubber are confined to the tropics because they require high temperatures and large amounts of rainfall throughout the year; they cannot be grown in the temperate regions (Table 3.1 and Figure 3.3). Conversely some cereal crops, temperate grasses and potatoes can be grown at the poleward limits, but their successful development needs a period of low temperature—vernalization—that never occurs in the tropics. Sugar-cane and sugar-beet well illustrate this mutual exclusiveness. Both require periods of high temperatures for sucrose to form in the plant, and both ideally require rainfall during the growing season, but a dry period at harvest. However, the risk of frost limits the northward expansion of sugar-cane, and the absence of a cold period prevents the growth of sugar-beet in the tropics. Only in a few regions—such as southern Spain—are sugar-cane and sugar-beet grown together, and then both are irrigated.

Table 3.1 Polar boundaries of selected crops (degrees of latitude, northern hemisphere)

Coconut palm	15°	Soybeans	45°
Oil palm	16°	Millet, sorghum	45°
Sisal	19°	Olive tree	45°
Cocoa, arabica coffee	22°	Grape vines	51°
Bananas, manioc	23°	Beets, corn	51°
Rubber	25°	Rubber tree	52°
Sweet potatoes	35°	Tobacco	53°
Cotton	38°	Maize	54°
Sugar-cane	39°	Wheat	63°
Peanuts, tea	41°	Barley, potatoes	70°
Citrus fruit	42°		

Source: B.Andreae, *Farming, Development and Space. A World Agricultural Geography,* Berlin, Walter de Gruyter, 1981

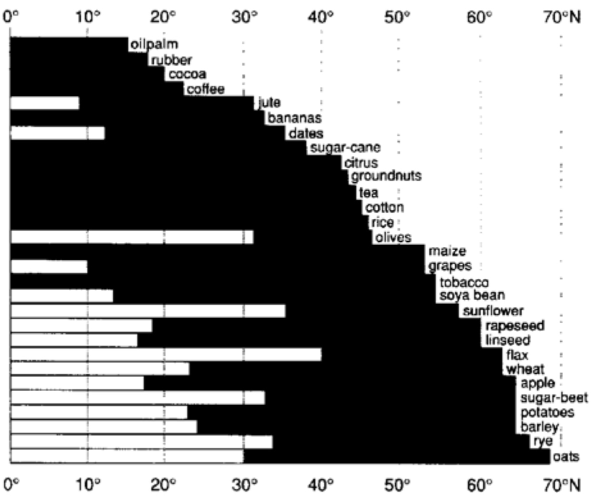


Figure 3.3 The latitudinal limits of the principal crops (northern hemisphere only)

A more common situation occurs where two or more crops have a similar optimum area and compete for the zone where both crops give their highest yields, which diminish with increasing distance from the optimum area (Figure 3.4). This is a situation commonly found on the arid peripheries of humid regions in North and South America, Russia and south-east Australia. The position may be illustrated with reference to Argentina. Both maize and wheat give their highest yields in an area to the west of Buenos Aires, but maize is the predominant crop in this zone, because, with equal inputs, it gives higher yields than wheat (Fig. 3.4). Southwards rainfall declines, and so does the proportion of the cropland in maize, until wheat becomes the dominant crop. This is because maize yields fall off more rapidly than wheat yields as rainfall diminishes, for wheat is more drought-resistant than maize.

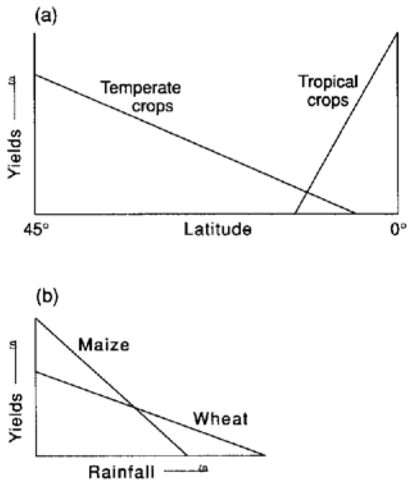


Figure 3.4 Optimum areas and competing crops

NET PHOTOSYNTHESIS

A variety of factors influence the location of crops, but the most important are photosynthesis, temperature and moisture. Photosynthesis is the process by which organic matter is formed in plants and is a chemical process triggered by sunlight. Potential net synthesis can be calculated from meteorological data on solar radiation and temperature, and is a reasonable guide to the potential rate of crop growth in different parts of the earth's surface. The amount of solar radiation received at different times of the year is influenced by day length and cloud cover. Figure 3.5 shows the net photosynthesis in grams per square metre per day for five of

Koppen's climatic regions and for three different growing periods. Of these the eight-month season, which includes all the food grains, is the most important.

Net photosynthesis is highest in the mid-latitudes, (Fig. 3.6) including southern Europe, the Near East, much of Australia, the USA, southern Africa and southern South America. It is lower towards the equator, including the humid tropics, and poleward. Net photosynthesis is highest in the summer four months in northernly locations with long days, but there are few crops that can develop rapidly enough to benefit from this (Fig. 3.5). The tropics have lower potential growth than the mid-latitudes in all three growing seasons, but their disadvantage is least in the year long season, so that perennial crops are an efficient use of their growth potential. The calculation of net photosynthesis assumes that an adequate supply of water and plant nutrients is available, and so is not reliable as a safe guide to where crops grow best. Similarly many of the areas of highest net photosynthesis are in arid regions, and crop production can only take place with irrigation.

TEMPERATURE

Temperature is a principal determinant of the geography of crops. Most temperate crops will not grow until temperatures are above 6°C, and for tropical crops this threshold is higher. Low temperatures are a hazard; in spring they can retard germination, and severe frosts may destroy a growing crop, whilst early frosts in late summer may damage the mature crop. Some autumn sown crops need low temperatures in winter in order to germinate in spring, a process called vernalization. Crops vary greatly in their thermal needs, as can be seen in Table 3.1. A number of crops such as the palm and cacao need high temperatures throughout the year, and this limits their cultivation to the tropics. However, barley, potatoes and some grasses can be grown in cool short summers as far north as the subarctic.

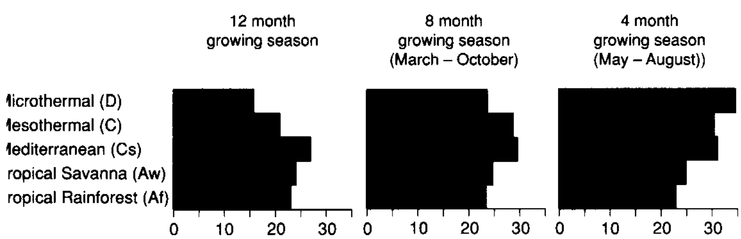


Figure 3.5 Net photosynthesis in grams per square metre per day for five climatic regions
Source: Jen-hu Chang, 'The agricultural potential of the humid tropics', *Geographical Review,* 1986, vol. 58, pp. 333-6

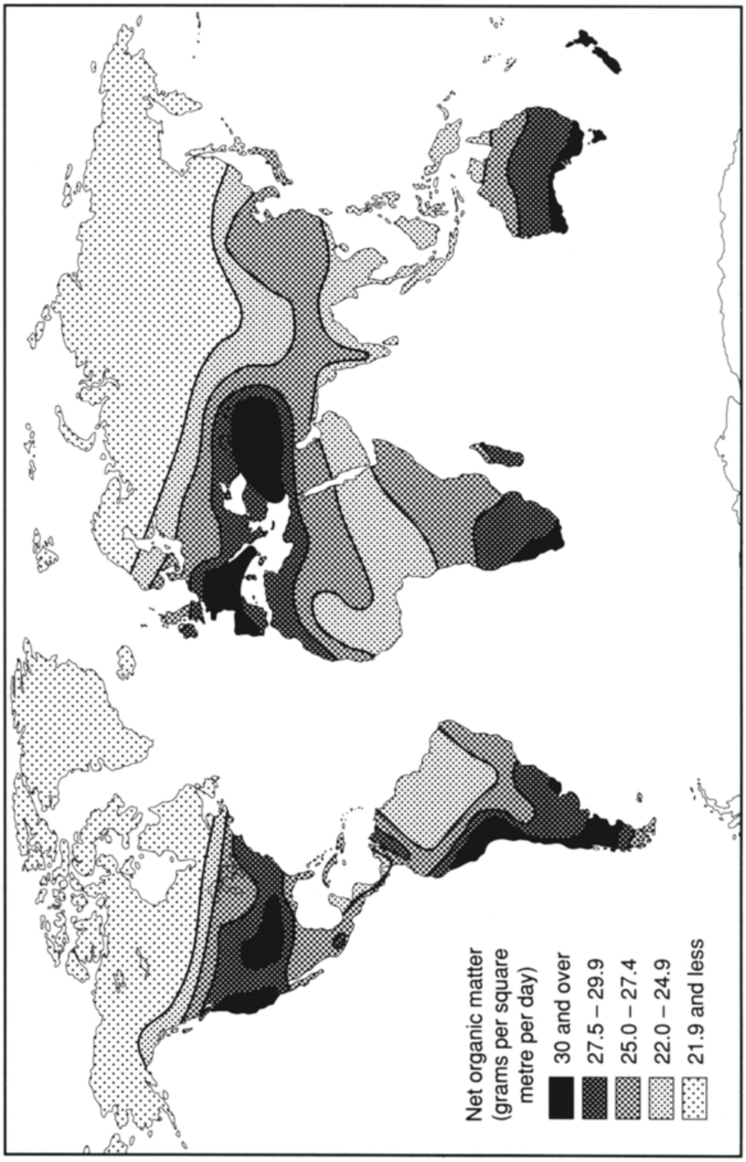


Figure 3.6 World variations in net photosynthesis (net organic matter in grams per square metre per day)

Source: Jen-hu Chang, 'Potential photosynthesis and crop production', Annals of the Association of American Geographers, 1970, vol. 60, pp. 92–101

The distribution of crops has another aspect; just as tropical crops have a limited poleward extension, so many temperate and subtropical crops not only have a northern limit, but also do not extend to the tropics, partly because of high temperatures but also because of disease and excessive rainfall (Fig 3.3). Some crops have a remarkable latitudinal range; of the cereals rice and maize can be grown in lowland areas on the equator, but also north of 50° in the northern hemisphere. Rye, oats, sugar-beet and potatoes are grown north of 50° latitude- in the northern hemisphere, but rarely south of 30°. However, these and other temperate crops can be grown in equatorial regions at high altitudes, where temperatures are lower than at sea level (see Chapter 5).

Crop distributions in Finland

Finland is one of the most northerly areas of cultivation in the world, and well illustrates the complex interrelationship of temperature, price and technology in explaining the distribution of crops. The length of the growing season and accumulated temperatures—a measure of the energy available for plant growth—declines from south to north. This has four consequences. First, the range of crops that can be grown diminishes northwards. In the extreme north only potatoes and timothy grass can be grown in the short summer; conversely in the extreme south-west, which has the warmest summer, the widest range of crops can be grown, including winter wheat. Second, the yield of each crop declines northwards as the energy available for plant growth diminishes. Third, farm income per hectare declines northwards, for production costs do not vary greatly for the same crop between north and south, although yields do. Fourtii, the greater range of crops that is possible in the south reduces the risk of total harvest failure. The northern limit of cultivation of each crop is thus not simply the absolute limit where a crop will yield, but also where an adequate net return is obtained.

Neither environment, technology nor prices have remained unchanged. At the beginning of this century spring wheat was little grown in Finland, even in the south-west, but the introduction of hardier varieties enabled it to be grown on the Arctic Circle by 1946. The limit of other crops was extended northwards in this period by the breeding of cold-resistant varieties. Both this northward extension, and the increase in yields between 1920 and 1940, were presumably assisted by the rise in mean annual temperatures experienced at this time, not only in Finland, but throughout the northern hemisphere. Between 1950 and 1969 the northern limit of barley and spring wheat retreated (Figure 3.7); but this was not due to the slight fall in mean annual temperatures that occurred in the 1950s and 1960s. In 1969 crop yields were still higher in the south than the north, but production costs were the same in each region, so that net return per hectare was greater in the south. In the 1960s, however, the price of several crops fell, while production costs rose. Thus, the cultivation of some crops — notably barley and spring wheat—which had been profitable in the north ceased to be so, and it is this that accounted for the southward retreat.

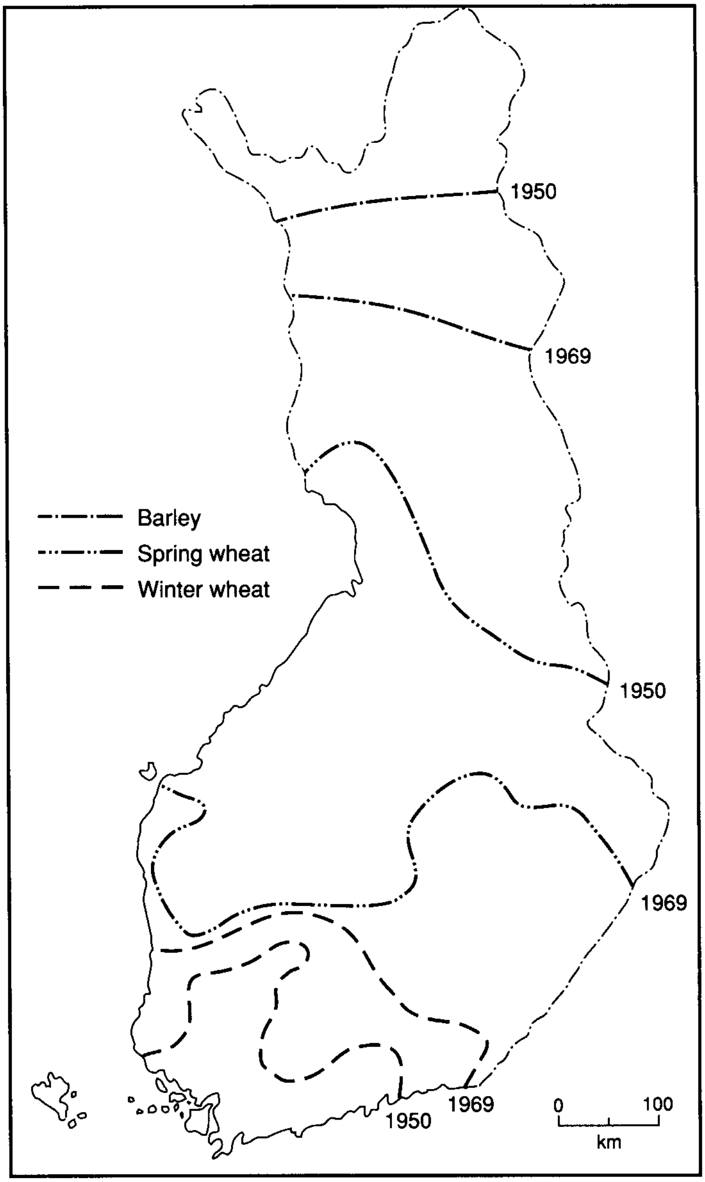


Figure 3.7 The northern limit of widespread cultivation of cereal crops in Finland in 1950 and 1969
After U.Varjo, 'Productivity and fluctuating limits of crop cultivation in Finland', *Geographica Polonica,* 1979, vol. 40, pp. 225–33

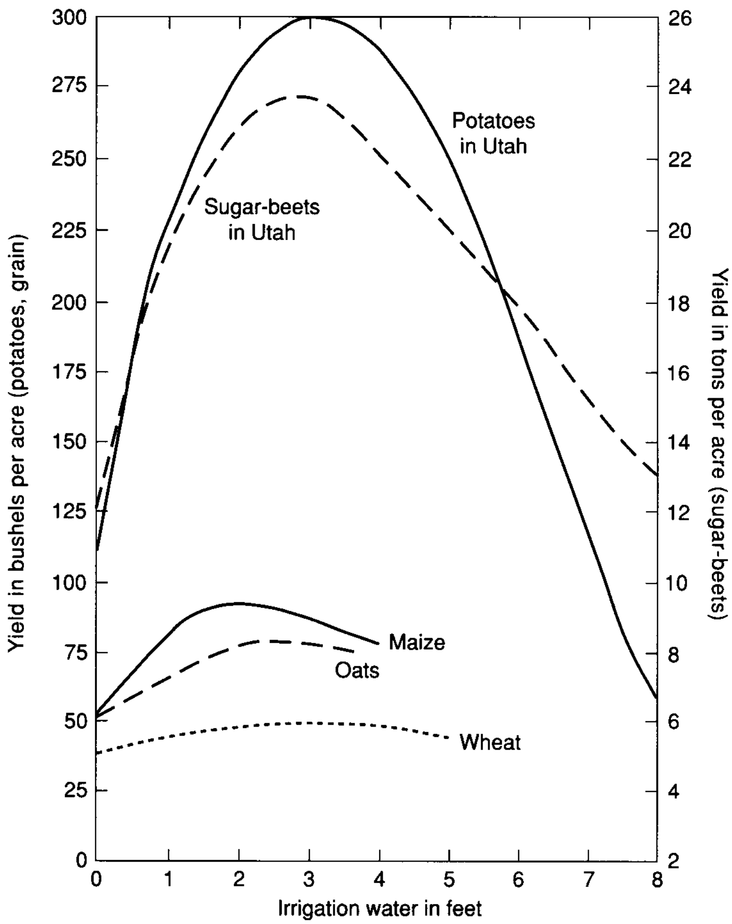


Figure 3.8 Crop yields and the water supply

Source: C.J.Wiesner, *Climate, Irrigation and Agriculture,* Sydney, Angus and Robertson, 1970, p. 90

MOISTURE

Soil moisture is essential to plant growth for without water plants wilt and the, and plant nutrients cannot be taken up by the crop. Moisture affects crop growth in two ways. First, crops differ greatly in the amount of water needed to give optimum yields. Wheat and rye for example, can be grown in areas where annual rainfall is between 25 cm and 100 cm, but rubber needs over 178 cm and tea over 254 cm. As over half the earth's surface receives between 25 and 100 cm of rain in a year, wheat can be widely grown. In contrast only 10 per cent of the earth's surface has over 178 cm and 5 per cent has over 254 cm of annual rainfall, so that tea and rubber have a much more limited distribution. Second, as noted earlier (Figure 3.1) there is a relationship between water supply and crop yield, but it is not linear. The yield of wheat, oats, sugar-beet, maize and potatoes increases as water supply increases, but declines after an optimum yield has been reached (Figure 3.8).

The distribution of mean annual rainfall is not a reliable guide to the possible location of crops, because not all the water is available to the plant; some is evaporated, some transpired. Evaporation rates in the tropics are some four times those in north-west Europe because of temperature differences, and so mean annual rainfalls in West Africa have to be above those in northern Europe to give equivalent soil moisture availability. A map showing the difference between mean annual rainfall and potential evapotranspiration is a guide to the areas where soil moisture is limited (Figure 3.9). In arid areas crop production is impossible without irrigation; in semi-arid areas it is possible but only a limited range of crops can be grown, yields are low and variability is high; subhumid regions have similar but less pronounced problems.

A further problem concerns the seasonal distribution of rainfall; an apparently adequate rainfall may be concentrated in a very short growing season, therefore limiting the range of crops that can be grown, as in the Sahel (see below, pp. 35–7), or rainfall may be in the winter when temperature conditions determine that the effective growing season will be in the spring and summer. But the principal problems of rainfall and crop growth are in the semi-arid areas, where rainfall is low and highly variable from year to year.

Rainfall variability and the margin

Away from the area of optimum rainfall not only do crop yields decline, but variability from year to year increases. This is particularly so in the subhumid and semi-arid zones, where much of the world's commercial wheat is grown; such areas include the Prairie provinces in Canada, the Great Plains in the USA, and southern Russia. Thus in the Southern Great Plains, as rainfall diminishes, so the percentage of harvests that are total failures increases (Table 3.2). In areas of high variability, rain is often concentrated in one season, and brought by depressions whose tracks vary from one year to the next. In the Mediterranean basin for example, the eastward course of depressions in winter determines the amount of rainfall. In Tunisia, if the depression track extends southwards towards the Sahara, then much of the southern half of the country receives the 200 mm thought necessary for a wheat crop; more commonly the depressions run further north and only the coastal regions receive enough rain (Figure 3.10).

Figure 3.9 Aridity zones of the world

Redrawn from a map in N.J. Middleton and D.S.G. Thomas, World Atlas of Desertification, United Nations Environment Programme, Edward Arnold, London, 1992, p. 4

Table 3.2 Annual rainfall and percentage of harvests a total failure, Southern Great Plains, USA

Rainfall (mm)	*Percentage of crop failures*
482 and over	25
457–81	30
431–56	40
406–30	40
381–405	50
330–80	60

Source: K.H.W.Klages, *Ecological Crop Geography,* New York, Macmillan, 1942, p. 190

A very similar situation is found in northern Iraq, at the foot of the Zagros Mountains. Depressions from the west bring winter rainfall to the foothills and to the Asyrian plain, but as the route of the depressions varies from year to year, so the southern limit of the 200 mm isohyet fluctuates; there is a zone of uncertainty between the foothills, where 200 mm is always assured, and further south towards the desert, where 200 mm is rarely (if ever) reached. Farmers have settled only where there is a high probability of 200 mm in a year.

GRASS AND CEREALS IN ENGLAND AND WALES

Two examples of the distribution of crops, in England and Wales and West Africa, illustrate some of the complexities of explaining crop distributions. In 1989, crops occupied 47 per cent of the cultivated land in England and Wales, and grass the remainder. Three-quarters of the total cropland was cereals, and wheat and barley alone made up 70 per cent of the cropland. Although cereals can be grown in every part of the country except the wetter uplands, and there are few places where grass will not grow, there is a marked difference between the distribution of grass and cereals. West of a line drawn north-south through the Isle of Wight, grass occupies at least half the cultivated area. Eastwards it is rarely more than one-quarter, and a large proportion of all wheat and barley is grown in eastern and southern England. Nor is this pattern new. The difference was equally marked in 1870, when reliable agricultural statistics were first available, and was probably as clear in earlier periods.

The predominance of grass in the west, and its lesser importance in the east and south, can partly be related to differences in environment. Grass is the cheapest fodder crop for cattle and provides grazing in spring and

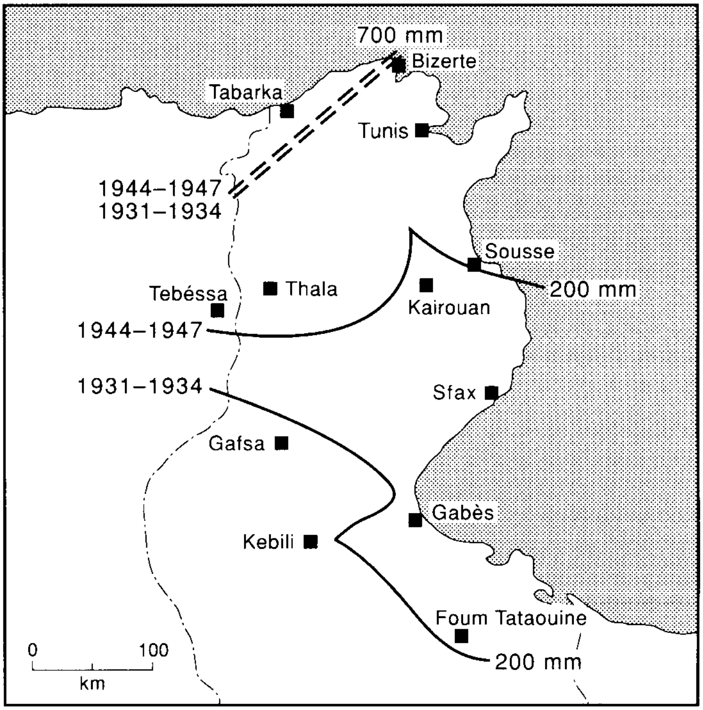


Figure 3.10 The location of the 200 mm and 700 mm isohyets in Tunisia, 1944–7 and 1931–4

After D.B. Grigg, The Harsh Lands, London, Macmillan, 1970

summer, and hay and silage for winter feed. Grass grows in England when mean daily temperatures exceed 5.6°C, so that the growing season is longer in the west and south than in the north and east, and longer in lowland than in upland regions. Rainfall is also necessary for growth, and empirical research suggests that grass will grow as long as the soil moisture deficit — the difference between potential transpiration and rainfall—is less then 50 mm. It is thus possible to calculate the number of days when growth will occur (Figure 3.11) For the period April to September there is a marked difference between east and west. South and east of a line drawn from theHumber to the Exe there are less than 150 grass-growing days, west andnorth there are more than 150 days. As hay yields can be shown to berelated to effective transpiration, Wales and western England have advantages over eastern England in producing grass. However this differenceneeds some qualification. Although the uplands of the north and west lose few days in the growing season due to moisture deficit, high rainfall givespoor quality grass (see below, pp. 51–3) so that the distinction between eastand west refers only to the lowlands.

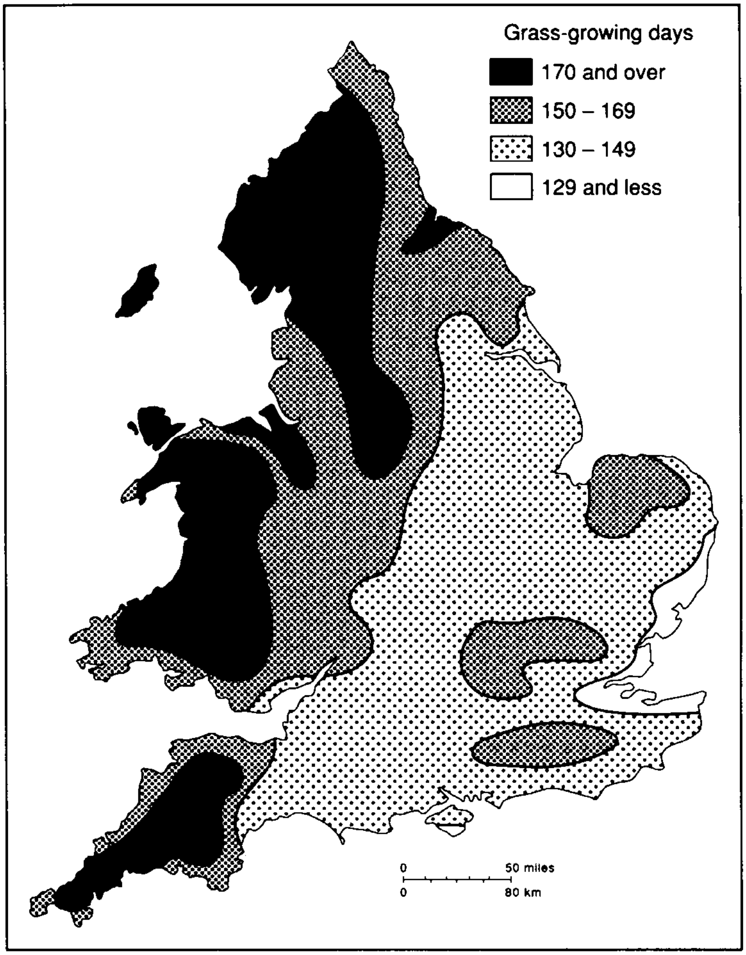


Figure 3.11 The number of grass-growing days in England and Wales. A grassgrowing day is one when mean daily temperature exceeds 5.6° C and the difference between potential transpiration and rainfall is less than 50 mm After G.W.Hirst, 'Grass-growing days' in J.A.Taylor (ed.), *Climatic Factors and Agricultural Productivity,* University College of Wales, Aberystwyth, Memorandum No. 6, 1963, pp. 25–9

It is less easy to show that eastern England has advantages over the west in the cultivation of wheat and barley, for there is no clear regional difference in yield. This may be because the small amounts cultivated in the west are grown only in the most favoured regions, and receive more attention. There are, however, some points to be made.

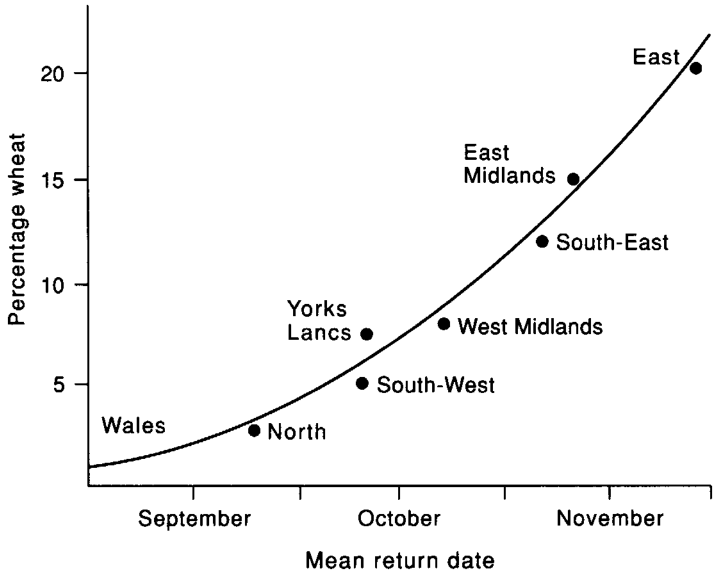


Figure 3.12 The mean date of return to field capacity and the percentage of land in wheat, 1969

After L.P.Smith, 'Assessment of the probable dates of return to soil moisture capacity in the autumn', ADAS *Quarterly Review,* 1971, vol. 2, pp. 71–5

The first relates to the preparation of the seed-bed. Winter wheat is sown in early autumn, and the farmer must prepare the land thoroughly, almost immediately after the previous harvest. During the summer most soils have a moisture deficit, but from early autumn rainfall increases the moisture content and makes them difficult to cultivate, particularly clay soils. The higher the rainfall, the earlier the land returns to field capacity. If this occurs in late summer or early autumn, it may not be possible to sow winter wheat at all, and the land will be fallow until the spring. The average date of return to field capacity is much later in the drier regions of the east, the south-east and the East Midlands (Figure 3.12) than in the north, south-west, the West Midlands and Wales, where the wet conditions make the sowing of autumn crops difficult.

Second, wheat yields in Britain are inversely related to summer rainfall, unlike grass yields which are positively related. The drier south and east thus has an advantage; indeed four-fifths of all the wheat in Britain is grown in areas where summer rainfall is less than 380 mm, and where accumulated temperatures exceed 1500 day degrees C. Third, most British barley, until recently, was sown in spring, ideally by mid-March. The later the crop is sown, the greater the loss in yield. Again the east and south have the advantage of a drier spring than the west, although not of course a warmer spring.

Thus, although wheat, barley and grass can be grown successfully in all but the higher altitudes, the east and south offer better conditions for cereals than for grass, while in the west grass has the advantage. Over the last hundred years the distinction between '.vest and east has persisted. However, the relative area in grass and cereals has changed considerably in this time. In the 1870s a high proportion of the cultivated area was in cereals, but the fall of grain prices in the 1880s led to an increase in the area under grass, and a decline in the area under cereals with a low point reached in the 1930s. Since then, the cereal area has increased again. The greatest change in the relative importance of cereals and grass has taken place not in the driest or wettest areas, but in the climatically intermediate Midlands where both grass and cereals can be grown. It is price changes that determine whether grass or cereals are grown here.

There are other factors that help explain the differences between west and east. In England large farms predominate in the east and south, except in the fens and the London region, while the small farm is the dominant unit in Wales and the west and north-west of England. Modern grain production requires the use of machinery which, however, cannot be economically employed upon small farms. Nor can such machines be easily used in areas with steep slopes; eastern England has larger areas of level land than the west or Wales. Grain production has other drawbacks on the small farm. Returns per hectare are comparatively low; while the occupier of a large farm can make a good living from cereals, the farmer with less than 40 or 50 ha must choose an enterprise with greater returns per hectare. For example, in 1978 the gross margin per hectare for spring barley averaged £246 per hectare, for winter wheat £320, but for dairying £500 per forage hectare. It is this, in addition to the physical advantages of the west for grass, that makes farmers there choose dairying. This demonstrates that physical factors alone can rarely explain the distribution of crops.

CROP DIVERSITY IN WEST AFRICA

In the tropics temperature is a limiting factor for the growth of only a few crops, and it is more commonly the amount and seasonal distribution of rainfall that determines the limits and optimum areas for crop growth. This is well demonstrated in West Africa; a wide range of food and cash crops are grown. There are twenty-one crops that occupy 1 per cent or more of the harvested area of at least one of the seventeen countries. The principal food crops are cereals, millet, sorghum, rice and maize. Root crops such as manioc, cocoyams, sweet potatoes and yams are also important locally. Perennial cash crops include rubber, tea, coffee, oil-palm, coconuts and sugar-cane, while pulses, groundnuts, cotton and soybeans are also grown.

There are, however, variations in the distribution of each crop, and particularly in the diversity of crops grown.

In the southern half of the region a wide variety of crops is grown, each country having at least six crops that occupy 1 per cent or more of the total area of cropland, and, in the case of Cameroon, fourteen (Figure 3.13). Diversity is far less in the north, where from three to six crops only are grown in significant amounts. This reflects differences in the number of days when there was a water surplus in the soil, which, as temperature is not limiting, is a crude measure of the length of the growing season. It was over 200 days in parts of coastal Cameroon, Nigeria, Liberia and Sierra Leone; it was less than twenty days in much of Mauritania, Mali, Niger and Chad, so that crop growth was confined to the southern most part of these states. Of the crops grown in West Africa, millet and sorghum are the food crops most capable of giving a yield in a very short growing season. Hence they dominate the crop combinations of the northern states, occupying over 30 per cent of the cropped area. Further south, farmers have a wider range of possible choices, and rice, yams and maize are all important food crops, but one crop never occupies such a high proportion of the total cropped area as in the north, where the extreme climatic conditions greatly limit both the food crops that can be grown and also the cash crops. Groundnuts is the major cash crop in these regions, although cotton is grown with irrigation. In the south, a wider choice of crops is available to the farmer, and forces other than environment become important.

CONCLUSIONS

Establishing the optimum climatic conditions for the growth of a crop is important for understanding the present distribution of crops, but it is by no means the only factor involved. First, not all the suitable areas are necessarily occupied by a crop. For example, O.Jonasson has estimated that 0.7 per cent of the earth's land surface is suitable for the cultivation of *arabica* coffee, but only one-tenth of that area was in coffee in the early 1960s. This was because of the limited demand for coffee; the area then in cultivation could meet the current demand. Second, many parts of the earth's surface have environmental conditions which are optimum for several crops that are in competition for the land. Factors other than environment then determine its use. Third, some crops are grown in sub-optimal conditions, when the price of a crop is high enough to justify significant modifications of the environment (such as irrigation), or when local price protection allows higher production costs. But, for all these qualifying remarks, climatic differences are the main determinant of differences in crop distribution on a world scale.

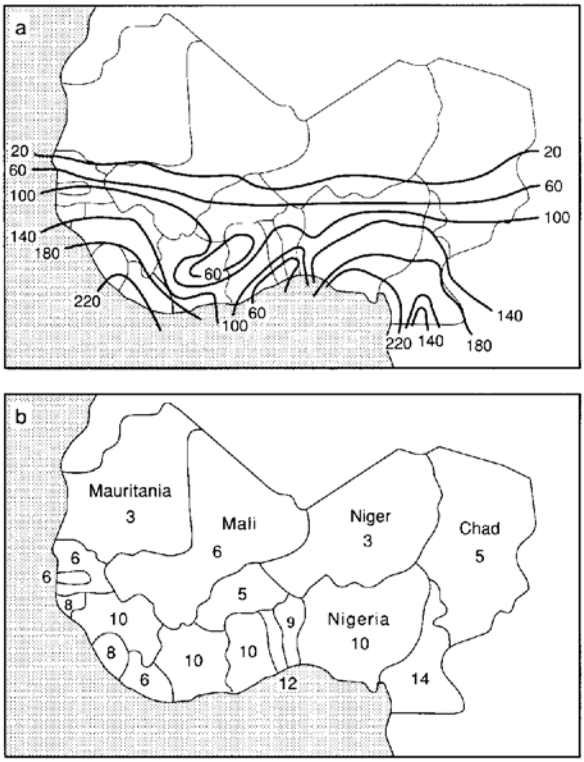


Figure 3.13 Crop diversity and water surplus in West Africa, (a) Number of days in a year when there was a water surplus in the soil (b) Number of crops in each country in excess of 1 per cent of total crop area, 1961–5
After M.D.Dennet, J.Elston and C.B.Speed, 'Climate and cropping systems in West Africa', *Geoforum,* 1981, vol. 12, pp. 193–202

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Chapter 4
Soils and the farmer

Soil has been succinctly described as 'the stuff plants grow in'. It provides not only the material for the plants' roots to grow in, but the water essential for transpiration and most of the sixteen chemical elements necessary for growth and development. Soils vary considerably in their characteristics—in structure, depth, texture, plant nutrient content and acidity—and this affects both the range of crops that can be grown, and the level of crop yields which can be reached. Spatial variations can occur both on the macro-scale (between, for example, the humid tropics and the Arctic) and on the micro-scale, when soil type may vary in one field. It is, however, possible to think of an edaphic—or soil—optimum that is analogous to the climatic optimum discussed earlier.

THE EDAPHIC OPTIMUM

In the optimum soil a wide range of crops can be grown, and high yields are obtained without the need for expensive modifications of the soil. Away from the optimum area, adverse soil characteristics increase, and so fewer crops can be grown and yields are lower. Thus the need to modify the soil by using fertilizers to increase the plant nutrient supply or liming to reduce acidity, increase the cost per unit of output. As with climate (see above, pp. 19–23) an economic margin is reached and later an absolute margin where, for example, excessive acidity, acute waterlogging or a low level of plant nutrients precludes crop growth. Although most crops thrive on deep, well-drained loams with a good supply of plant nutrients, some crops do have optimum soil requirements that differ from the general, and so it is possible to envisage a soil optimum for each crop. Thus rice, unlike virtually all other soils, requires an impermeable subsoil so that the water in the *padi* does not drain away, while cranberries require a very acid soil. As with climate, crops vary in their ability to withstand adverse soil conditions, and this may often explain their distribution. Flour for bread can be obtained from wheat or rye. Over the last hundred years demand for rye has fallen as incomes have risen, and most rye is now fed to livestock. Rye is also an inferior fodder, yet it is still widely grown in northern Europe. This is pardy because of its tolerance of a shorter growing season, but in the Netherlands and northern Germany, where climatically either crop could be grown, rye is still found. This is explained by the presence of sandy, acid soils: rye will tolerate acidity; wheat will not.

Good soils—those which are deep, well drained, neutral and retain sufficient soil moisture for crop growth—are not common. In England and Wales, only 17 per cent of the improved agricultural land is without moderate or severe limitations, and only in eastern England is a high proportion of land in this category. On a world scale, a mere 11 per cent of the total land area is without marked limitations to crop growth, while only 24 per cent of the total area is thought to be capable of growing crops at all.

CRITICISMS OF THE EDAPHIC OPTIMUM CONCEPT

The idea of the edaphic optimum is of less value in interpreting crop distributions than the climatic optimum, partly because of the lack of information on soils. Until recently, soil scientists were concerned primarily with the origin and field properties of soil profiles, regardless of whether these were relevant to crop growth. Few parts of the world have soil maps based upon field survey, as distinct from inference based on geology and climate. It is thus difficult to seek correlation between soil type and crop distribution. It is also difficult to distinguish the effect of soils in *sensu stricto* upon crop growth from other environmental variables.

Texture is thought to be a major determinant of crop yields in England because it influences the amount of moisture available in the soil, yet this is clearly ultimately a function of rainfall and evaporation, not simply texture. The soil is more easily modified than climate or slope. Modern farming methods make it possible to supply plant nutrients to an inherently infertile soil, acid soils can be treated with lime, and waterlogged soils can be improved by underdraining. However, it does not follow from this that good soils are of less importance than in the past. Inputs of fertilizer obtain a better yield response on good soils than upon poor soils. Thus, in the USA corn production has been slowly concentrating in the regions widi optimum soil and climate, and declining elsewhere. This requires not only fertilizers but good conditions that allow such regional specialization.

SOIL CHARACTERISTICS AND AGRICULTURE

An important characteristic of a soil is its *depth*. Many parts of the world suffer from too shallow soils, both in arid regions and in areas such as the Canadian Shield where glaciation has removed the soil, leaving only bare rock. A shallow soil is often unable to carry sufficient moisture for growth, and the supply of plant nutrients may be inadequate. For some crops, shallow soils may be insufficient for root development. In England this is particularly true for potatoes and sugar-beet. Potatoes are rarely grown on the thin limestone soils of the south and south-east, although these soils give excellent crops of the shallower-rooted cereals. It is often argued that potatoes in England are grown either near the major markets (see below p. 117) or, in the case of early potatoes, in the warmer south-west. But in fact the major areas of production are found in areas of deep loams—on the silt of the fenland, on the warp soils of the Humber and on the mosses and sands of Lancashire.

The *texture* of a soil is a measure of the relative importance of particles of different sizes. Soils made up of large particles have many pores, and so water passes through the soil rapidly; these sandy soils may suffer from drought in dry periods and are susceptible to wind erosion. On the other hand, they warm up rapidly in spring, and may be good sites for the cultivation of early vegetables. In contrast to these are the clay soils, which are fine-textured, with a predominance of small particles through which water has difficulty in moving. They may suffer from excess water, which depresses plant growth. In addition, poorly-drained soils are easily damaged by the hooves of animals and compacted by heavy machinery. In spring the sun's energy is used drying-out the wet soil rather than warming it, so that the beginning of the growing season is retarded. In autumn, clay soils are difficult to cultivate in wet years (see above, p. 34). Clay soils have two advantages which, however, are of less significance under modern farming conditions. The large clay fraction slowly releases potassium so that they suffer less than other soils from potash deficiencies, and their water-retaining capacity means that they give above average yields in very dry years. The drainage of clay soils can, of course, be improved by under-drainage with pipes or mole-ploughing, but the texture of a soil cannot be altered. The ideal soil is one which has a predominance of neither clay nor sand. These loam soils suffer neither from excess water nor a low moisture content. Under modern farming conditions in Britain, texture is the main edaphic determinant of yield.

Soils may be classified as either *acid* or *alkaline* on a pH scale running from 0, the most acid, to 14, the most alkaline, with neutral at 7. Acidity is a function of the chemical composition of the parent material and the rate of leaching, which in turn is closely related to the amount of rainfall. In temperate climates soil acidity is greater in areas of heavy rainfall. Thus in the USA acidity increases eastwards of 95°W longitude; to the west soils are predominantly alkaline. In Britain, acid soils are found in the west and the upland areas. As acidity increases the nitrogen-fixing bacteria in the soil are reduced, and so are the soil organisms that improve structure and texture. Crops vary in their optimum pH requirements, but there are few that thrive in highly acid or highly alkaline conditions; most prefer a neutral or slightly acid soil. Of the crops grown in the British Isles, oats, rye and potatoes are the most tolerant of acidity, and lucerne, barley and sugar-beet the least tolerant (Table 4.1). However, acid soils can be limed and the drawback overcome. Highly alkaline soils are rare in temperate regions but common in semi-arid areas and those irrigated areas which have water-logged soils. The date palm, barley and cotton are the more important of the few crops that have a high tolerance of alkalinity.

Table 4.1 Soil pH below which growth may be restricted on mineral soil

Rye	4.9	Wheat	5.5	Barley	5.9
Potatoes	4.9	Maize	5.5	Beet, Sugar	5.9
Oats	5.3	Rape	5.6	Peas	5.9
Swedes	5.4	Clover, Alsike	5.7	Trefoil	6.1
Turnips	5.4	Mangels	5.8	Lucerne	6.2

Source: Alan Wild (ed.) Russell's Soil Conditions and Plant Growth, 11th edn, Harlow, Longman, Scientific and Technical, 1988, p. 878

PLANT NUTRIENT AND FERTILITY

Plants require some sixteen chemical elements for successful growth and development, of which nitrogen, phosphorus and potassium are the most important. These nutrients are derived from the decomposition of rocks, the decay of organic matter and, in the case of nitrogen, by the fixation of atmospheric nitrogen by bacteria in the soil. Under natural vegetation, nutrients are taken up by the roots of plants and returned to the soil when the plants the and decompose, or through the urine and excreta of herbivores. There is thus a closed cycle of nutrients between soil and vegetation, and little loss from the system. However, once the natural vegetation is cleared and crops planted, there is loss. When crops are grown the removal of the seeds, roots and straw at harvest is a heavy loss of nutrients, while the natural vegetation is no longer present to replenish the soil. If crops are planted continuously, then crop yields will fall to a very low level and the soil will be liable to erosion. Farmers have to devise a system which will allow the removal of nutrients in the harvested crop and also maintain the soil nutrient content. It must also be recalled that crops have different requirements; some remove far more nutrients than others. The essence of successful farming is to find a way to harvest crops, which removes nutrients, while maintaining the soil-plant nutrient status.

FARMING SYSTEMS AND FERTILITY

When natural vegetation occupies an area, there is a cycle of plant nutrients between the soil and the vegetation with little or no loss from the system; soil and vegetation are in equilibrium. Man can collect the fruits and nuts, but this requires no modifications. Once the vegetation is removed then some means of restoring fertility must be found. There are several ways in which this can be achieved.

The natural fallow

In the humid tropics shifting cultivation is still to be found. A small part of the forest is cleared, and the trees and lianes burnt. A variety of crops including cereals, roots and bushes is planted intermixed in the clearing, protecting the soil from high temperatures. After two or three years weeds become difficult to remove and crop yields fall. The tribe move their huts to another area and repeat the process. The original clearing is colonized by bush and, later secondary forest. After twenty years or more the vegetation has restored the soil fertility, and it can be cropped again. Such a system assumes a very low population density. In Africa, shifting cultivation is now rare, and bush fallowing, where fallows are only long enough for grass or bush to be established, is more common. Reduction of the fallow period, without some means of maintaining plant nutrients, makes soil exhaustion likely. Fallowing, although rare now, was once a common method of maintaining soil fertility in both temperate and tropical regions: increasing population density caused other methods to be adopted.

Nitrogen-fixation and legumes

In most farming systems the limiting factor to crop growth is nitrogen. Nitrogen is fixed in the soil by bacteria, which live under two sets of circumstances. First are free-living bacteria, which are not associated with any plant and occur in nearly all soils. They fix very little nitrogen. An estimate made in the USA puts the annual increments as low as 6.7 kg per hectare. However, there is one important exception to this, the blue-green algae which are found in the submerged soils of wet-rice *padi* fields. These free-living bacteria can fix up to 78 kg of nitrogen per hectare. The rivers that provide the irrigation water for wet-rice also deposit plant nutrients brought in solution and suspension from the upper reaches of rivers. This has allowed wet-rice cultivation to produce reasonable rice yields over very long periods, and is still the basis of maintaining soil fertility in much of Asia.

Second, and more important, are the nitrogen-fixing bacteria living symbiotically with the nodules that occur on the roots of all legumes. The temperate legumes include peas, beans and clover. The latter, when grown in southern England, fix between 112 and 224 kg per hectare per year, and lucerne is also as efficient. The growth of clover in rotation with cereals and root crops has been an important traditional method of maintaining the nitrogen level of West European soils and was one of the methods of sustaining crop yields on the mixed farms of Western Europe.

Tropical legumes, such as soybeans, groundnuts and chick peas, are less efficient fixers of nitrogen than the temperate legumes, and have been grown as a protein-rich food rather than for their abilities to maintain the soil's nitrogen content.

Livestock and manure

When human beings or livestock eat plant foods, their bodies absorb some of the plant nutrients, and some of the nutrients are rejected in the urine and faeces. Human excreta has been widely used as a manure, but most notably in southern China. Livestock are everywhere used to provide the manure, but particularly in Europe. In medieval farming systems much of the manure was deposited upon the common grazing land, and only on arable crops when cattle were grazed on the straw left standing after harvest. However, in the nineteenth century and in the first half of the twentieth century, cattle were fed in stalls and their dung mixed with straw. Farmyard manure, which contains nitrogen, potassium and phosphorus, was sufficient to maintain cereal yields at quite a high level. This system requires that much of the farmer's land be in grass or fodder crops, such as turnips; in combination with the growth of legumes it was the basis of mixed farming in Western Europe.

Chemical fertilizers

Inorganic fertilizers have been widely used in traditional farming systems. Thus bones have been crushed to give phosphorus, and clays have been mixed with sands to improve texture and add potassium. The modern fertilizer industry dates back to the 1840s, but it was not until after the Second World War that fertilizer production became cheap enough to allow its intensive use. The consumption of fertilizers has greatly increased in all parts of the world since 1945, but particularly in Europe and European settled areas. This has allowed some farmers to abandon mixed farming—the keeping of livestock and the cultivation of crops on the same farm—and specialize in cereals, for fertilizers can replace farmyard manure entirely.

All farming systems need some means of maintaining the soil's plant nutrients. Without this, the cultivation of crops leads eventually to soil exhaustion, declining yields and soil erosion. Although it was argued that there is an edaphic optimum analogous to the climatic optimum, it is apparent that there are few 'natural' agricultural soils, for their original properties have been greatly changed by ploughing, draining, liming and by using fertilizers.

SOIL TYPE AND THE DISTRIBUTION OF ARABLE LAND

As was noted earlier, soil type can vary both on the world scale and within a field; some illustrations of the significance of soil variations must now be given, beginning with the world scale.

Only a small proportion of the world's land area is used to grow crops—some 11 per cent in 1989. Large proportions are unsuitable for climatic reasons, particularly in the drier and colder regions, but soil type is also a factor in some areas. It should be noted, however, that of the principal soil types only the tundra areas entirely lack arable land. In contrast the chernozem, alluvial and grumusol groups have the highest potentially cultivable proportions. Some of the principal soil types have considerable limitations. In arid regions shallowness of soil is a significant problem, as is salinity, some 7 per cent of the world's land area suffering from this defect. In hot, arid regions, ground water moves to the surface by capillary action, and evaporation causes salts to be deposited in the upper parts of the soil profile and on the surface. This can be a problem in areas of rainfed agriculture—some 40,000 ha were withdrawn from cultivation in western Australia between 1962 and 1970— but is often a greater problem in irrigated areas. In the lower Tigris and Euphrates and in the Indus valley, irrigation over long periods without adequate drainage has led to a permanent rise in the water table, and much land has had to be withdrawn from cultivation.

In the cooler, wetter regions of the world, once covered by coniferous forest, podzols are the dominant soil. Although large areas of podzols are cultivated, particularly in the eastern USA and northern Europe, they require careful cultivation, for they are acid and plant nutrients are easily leached away. In southern podzol areas, such as England, podzolization is only weakly developed, occurring mainly on sands. In the northern podzol regions with long, cold winters, the subsoil is permanently frozen; only the upper layers of the soil melt in summer and so are waterlogged and thus difficult to cultivate. Large areas of northern Russia and Canada are uncultivable for this reason.

The soils of the tropics are less well understood than those of the temperate regions; until recently they were though to be inherently infertile and characterized by the presence of laterite. However, recent research shows that there is a far greater variety of soil types in the tropics, that a high proportion are potentially cultivable, and that the presence of true laterite is unusual. On the recent FAO Soil Map of the World, only 5 per cent of Africa contains laterites. None the less, the soils of the humid tropics, which experience high temperatures and high rainfall throughout the year, do present particular problems. The natural vegetation —of which little is left—is rainforest. This gives some protection to the soil, with the shade reducing soil temperatures. But once this is removed, the very high temperatures and the continuous supply of moisture leaches plant nutrients below the roots of crops. There are farming systems that can overcome this problem; shifting cultivation, for example, only uses the soil for two or three years, and the cleared patches of land are sown with a mixture of cereals, root crops and bushes, which provides protection from the sun and rain. In wet-rice cultivation—which is comparatively rare in the *humid* tropics—the water in the *padi* fields reduces the soil's exposure to the sun. Plantations grow trees or bushes or a mixture of the two, and thus, like shifting cultivation, simulate the rainforest. But in countries where the high cost of fertilizer prevents this method of maintaining soil fertility, a high premium is put upon areas where soil material is continuously being replenished.

Deltas and volcanoes

Areas where soils are constantly being replenished are comparatively rare, but two outstanding cases are the deltas and lower reaches of rivers and regions of recent volcanic activity. In Asia—and particularly in South-East Asia—there is a marked contrast between the population density of the rivers and deltas, and the non-riverine areas. The latter are subject to the problems of leaching and soil erosion touched upon above. The lower rivers, however, gain plant nutrients brought from the catchment basins. These are flat, comparatively easily irrigated, and provide ideal conditions for wet-rice cultivation. The deltas of the Ganges-Brahmaputra, the Mekong, the Irrawady and the Chao Phraya, therefore, all have very high rural population densities. But it does not follow that all deltas have such high densities. Few of the deltas of Africa have been developed agriculturally, and in the Americas farmland is rare in the Amazon basin. Approximately 5 per cent of the Amazon basin is made up of riverine deposits, which are potentially fertile, but four-fifths of these soils are under water for part of the year, and as yet these problems have not been overcome. The upland areas of the Amazon basin present considerable problems to farmers, and the recent attempts to clear and settle the Amazon basin have not been very successful. Probably less than one per cent of the total area has been cleared in the last thirty years, and most farmers have reverted to grazing cattle after failing to grow crops.

The other replenished soils are those near to active, or recently active, volcanoes. Indonesia illustrates their significance. Kalimatan (or Borneo) has a very low population density; so too does most of Sumatra. In contrast, Java, and particularly central and eastern Java, has some of the highest rural population densities in the world. There are several possible explanations for this, but the presence of volcanoes is very important. A chain of active volcanoes, emitting ash and less commonly lava, runs down the west coast of Sumatra and through the centre of Java and Bali; these latter islands have 130 active volcanoes. Kalimatan, however, has no volcanoes. Ash is not confined to the immediate areas of the volcanoes. In Sumatra it is carried by eastward flowing streams and forms the alluvial coastal plain while the northern plains in central Java have a similar origin. There is, however, an important regional difference in the type of volcanic deposits. West of the volcano Gunang Slamet, in central Java, they are acid and give infertile soils in Sumatra and western Java; eastwards they are basic and the soil is more fertile. In addition, central and eastern Java have a dry season, unlike the rest of Indonesia, and leaching is less intensive. So the presence of arable land, and indeed differences in rural population density, can be at least partly attributed to soil type.

Soil type and farming in Britain

In an area the size of Britain, climate is the principal physical factor determining the broad pattern of farming types; soil, however, is the factor of most significance over short distances. Yet there are comparatively few studies which examine the influence of soil type on the distribution of crops and upon their yields. This is not surprising; there are few published maps of British soils, and they for the most part are concerned with soil morphology, not agricultural characteristics. Further, British soils have been farmed for some thousands of years, and their natural characteristics are much changed. Differences in management—in the use of fertilizers, lime, or draining—may be more important in deciding what and how much is grown, than the inherent characteristics of the soil.

None the less, a number of studies have shown the importance of soil type in agricultural geography. C.J.W.Edwards has analysed the relationship between soil type and land use in the area around Glastonbury in Somerset. This is dominated by four upland areas, including the Mendips, and two lowland areas, one on Lias Clay, the other on the organic soils of the Somerset Levels (the latter being very difficult to drain). Edwards identified four principal soil types—the calcareous soils, the Brown Earths, the gley and the organic soils. Three land-use regions were identified. In the upland areas between 30 per cent and 60 per cent of the agricultural land was in crops, in the eastern lowlands less than 20 per cent, while in the badly drained Levels there was no arable land; all was in grass. A series of correlation coefficients was then calculated for relationships between the land use of parishes and the predominant soil type. It was shown that there was a positive correlation between the percentage of a parish in permanent grass and in organic or gley soils; an inverse relationship between the ratio in calcareous soils and in grass; and a positive correlation between barley and calcareous soils. This investigation was repeated using point samples of land use and soil type, and the initial correlations were confirmed, while an analysis of hay and barley yields demonstrated why there was this difference in soil type and land use.

Some of the problems of relating soil type and the type of farming are revealed in D.A. Davidson's study of Lower Deeside in Scotland, an area of predominantly livestock production but with varying emphases upon the rearing, feeding and fattening of beef cattle and sheep raising. He identified morphological units upon a sample of farms, and then for each unit measured slope angle, soil depth, drainage and texture. Each unit was given a score based upon these measures, so that the units could be ranked in order of land capability. Eleven types of farming were identified, and the data were examined to see if there was any correlation between type of terrain and type of farming. This only occurred for the best and the worst land. On the poorer land farmers could only rear beef cattle and sheep, selling them to others for feeding and fattening. On the best land, however, a farmer could rear, feed and fatten cattle. Sheep — an extensive use of land — were not kept on the better land.

CONCLUSIONS

It is rare that the geographical distribution of a crop can be attributed solely to one factor, whether it be physical or economic. This is particularly so with soil type, for soils are the result of interaction between the climate, natural vegetation and parent materials, and so it is difficult to distinguish the importance of soil from that of climate. Moreover, soils have been greatly changed by farmers, and differences in management practices may often explain more of the agricultural geography of an area. However, soil type is not be neglected; it is likely that the growing number of soil surveys adapted to agricultural requirements will reveal more associations between farming and soil type.

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Chapter 5
Slopes, altitude and agriculture

The morphology of the earth's surface has a profound influence upon the type of agriculture which can be carried on. Mountainous areas for the most part offer few opportunities to the farmer; conversely, most of the great farming regions are found in lowland plains. In this chapter some of the reasons for this are explored.

ALTITUDE

Mean annual temperatures decline with height above sea level. The lapse rate averages, in temperate regions, 6°C for every 1000 m above sea level. The consequences of this are dramatic, but differ gready between temperate and tropical regions.

Altitude and agriculture in the temperate regions

In most temperate regions, an increase in altitude has adverse effects upon farming. As mean annual temperatures decrease with increasing altitude, the growing season—the period with mean daily temperatures above 5.6°C —shortens, commencing later in the year and ending earlier, and so the amount of energy received from the sun is less. With increasing height and falling mean annual temperatures, summer temperatures become more variable and the risk of harvest failure greater. Rainfall and cloud increase, reducing the amount of sunshine received, and retarding ripening. Higher windspeeds are found, giving lower sensible temperatures, and in some cases grains may be shaken from the stem of the plant. These conditions require animals specially bred to utilize the poor fodder and cold winters; in Britain some breeds of sheep are adapted to the uplands, others only to the lowlands. Higher rainfall precludes the growth of many crops, and also causes leaching so that soils are often highly acid. In flat, poorly drained areas in the uplands, peat bogs are formed; indeed they occupy 6.5 per cent of the total area of the United Kingdom.

Thus, an increase in altitude in the temperate regions has much the same disadvantages for the farmer as an advance towards the poles. The yield of crops falls, the variability of harvest increases, and the range of crops that can be grown diminishes. Grass growth also declines with increasing altitude as temperatures fall; the growing season begins later and the rate of dry-matter production is less. For example, in Scotland the onset of grass growth in spring is delayed 4.3 days for every rise of 100 m above sea level. On the lower flanks of the British uplands, dairy cattle can be kept if feeds are purchased; with increasing altitude only beef cattle can be reared, for sale to lowland farmers who will fatten them for market upon better pastures. Higher still, only sheep will survive on the poor grazing, and they too are bred for sale to lowland farmers. The range of crops that can be grown diminishes with altitude; in Britain oats, with its tolerance of greater rainfall, is grown higher than other crops.

A study of the Lammermuir Hills, south-east of Edinburgh, illustrates some of the relationships between crops and altitude. Almost the full range of British field crops can be grown at sea level, but the land surface rises from sea level to 533 m in a few miles. M.L.Parry has distinguished an area marginal for oats cultivation (Figure 5.1), and has identified the climatic variables that define these limits: accumulated temperatures over a base of 4.4°C, in day degrees C; a measure of end of summer potential water surplus (PWS); and average windspeed. The absolute upper limit to the cultivation of oats occurs when accumulated temperatures fall below 1050 day degrees, PWS exceeds 60 mm and average windspeed exceeds 6.2 m/s (Figure 5.1). At lower altitudes, where there is greater warmth, lower windspeeds and it is less wet, there is a another limit *below* which yields are high enough for oats to be sold off the farm as a cash crop; between the upper and lower limits oats can be grown, but yields are lower and variable, and the crop can be grown only for consumption on the farm. The decline of oats with increasing altitude is not simply a result of the linear decline of temperatures with height. Although mean annual temperatures fall at a constant rate with height above sea level, the chances of a complete crop failure increase at a quasi-exponential rate. At 215 m above sea level, there is a probability of failure only once in 20 years; at 250 m about once in 10 years, at 300 m once in 5 years and at 330 m once in 3.3 years.

Agriculture and altitude in the tropics

In the tropics temperature is rarely a limiting factor for crop growth, and it is more commonly lack of moisture that prevents cultivation. However, as in temperate regions, increasing altitude leads to a decline in mean annual temperatures. At approximately 3500 m above sea level, temperatures are too low for even the hardiest of temperate crops. Such altitudes are common in the Andes, rare in the Asian tropics, and in Africa are confined to the east. However, areas above 2000 m occupy significant parts of

Central and Southern America, Ethiopia, Tanzania and Kenya. Thus, in the tropics altitude only rarely prevents any crop growth, but the changes in temperature greatly influence the type of crop that can be grown. This is most noticeable in the Americas.

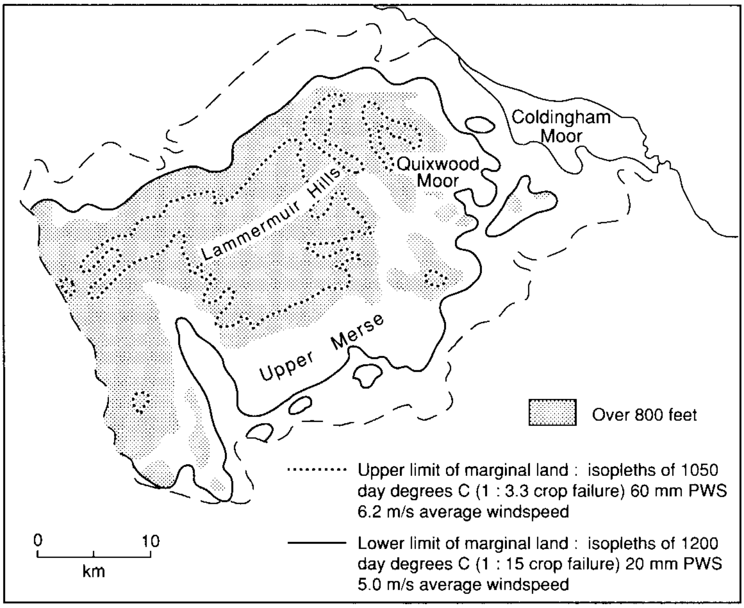

Figure 5.1 The limits of oats cultivation in the Lammermuir Hills, Scotland The upper limit is the absoloute limit for oats cultivation. The lower limit is the line below which the commercial cultivation of oats is possible After M.Parry , 'Secular climatic change and marginal agriculture', *Transactions of the Institute of British Geographers,* 1975, vol. 64, pp. 1–14

In Central America, half the total area lies over 770 m above sea level, with a substantial modification of sea level temperatures, while 10 per cent lies over 1700 m above sea level and has frost frequently between December and February. In South America the Andean plateau areas have agricultural economies substantially different from those found at sea level at the same latitude. Five altitudinal zones are recognized in Latin America. The *tierra caliente* is the lowland area up to about 1000 m. On the Caribbean and Amazonian slopes of the mountains the climate of this zone is humid tropical, the natural vegetation rainforest; on the Pacific coast there is a dry season, and vegetation and crops are different. Between approximately 1000 m and 2000 m, in the *tierra templada,* warm temperate crops such as maize, cotton, sugar-cane and coffee can be grown, but not the crops of the *tierra caliente* such as cocoa. It was the *tierra templada,* which lacks both frost and also the high temperatures and

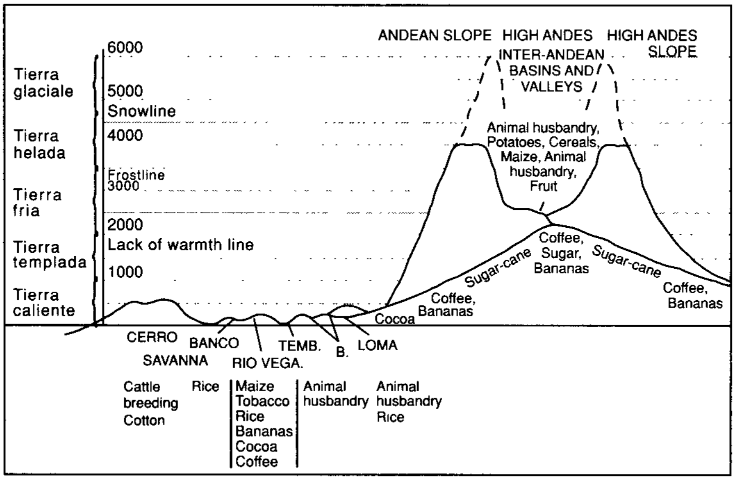

Figure 5.2 A land use transect through Ecuador After W. Manshard, *Tropical Agriculture: A Geographical Introduction and Appraisal,* London, Longman, 1968

humidities of the lowlands, which attracted European settlers in Central and Southern America, as did the 'White' Highlands in Kenya. Above 2000 m lies the *tierra fria,* in which frost occurs from December to February, and the crops of neither the *tierra caliente* nor the *templada* can be grown; instead the staples are potatoes and barley. Above 3500 m is the *tierra helada,* where no cultivation is possible. A transect across Ecuador demonstrates how altitude influences the growth of crops, with the difference between the lowlands and the Andean intermontane zone being most noticeable (Figure 5.2).

SLOPES AND AGRICULTURE

The shape and slope of the earth's surface is a neglected but important determinant of land use. At the micro-scale, the angle and direction—the *aspect*—of slope may influence the type of farming. For example, in the Alps and other mountain areas of the northern hemisphere, valleys that are aligned east-west may have quite different land uses on the valley sides, owing to the different amounts of insolation received on the south-facing —*adret*—slope and the north-facing—*ubac*—side of the valley. In Britain there may be a difference of 20 days in the length of the growing season between a south-facing slope of about 20° inclination, and a level site in the same locality. But slope has wider significance, for it limits the use of machinery and determines the rate of run-off and hence soil erosion.

In developed countries most parts of the farming routine have been mechanized, and much of the machinery is heavy and costly to move. On steep slopes such machines are not only difficult and expensive to operate, but may be hazardous. Thus, areas with a predominance of steep slopes have a limited agricultural value. In addition, areas with very steep slopes may be liable to soil erosion if cultivated. In Britain, slopes above 11 to 13° are rarely sown to crops, although grass and afforestation are possible. Tree crops are indeed a useful way of utilizing slopes too steep for ordinary crops, for the soil is not ploughed each year and the trees or bushes give some protection to the soil from very high temperatures in subtropical and tropical regions. In the Mediterranean regions, tree crops such as olives and grapes often occupy the steeper slopes, while the plains are under cereals. The olive thrives on the plains but can grow on steep slopes; cereals cannot. The occurrence of large areas of flat land is thus a necessary (if not sufficient) condition for the mechanized cultivation of cereals, for it reduces cost and avoids the problem of soil erosion that may occur on steeper slopes. A study of farming in eight states of the American Midwest confirms this. Grain production in the USA is highly mechanized, and can profitably be carried on only if machines can be used, whatever the suitability of other factors. An American geographer calculated the proportion of each county that was in cash-grain farms, and then estimated the proportion of the total area of each county that had slopes of less than 3°. There was a high correlation between the two, but flatness explained only half the distribution. In two areas of predominantly flat land, cash grains were not important. In one soils were too thin for wheat and barley, while in the other, on the good soils of the Mississippi flood-plain, more valuable subtropical crops could be grown.

SLOPES AND WATER

Water will flow very rapidly over even shallow slopes, but in some very flat areas heavy rainfall or the floods of rivers cannot be removed easily, and waterlogging prevents their agricultural use or reduces yields. This was the case in the English fens until the introduction of steam-pumping. Parts of the fenland lie below sea level, and the remainder is very flat; hence the gradient of the rivers that flowed across the plain was very low, and rain falling on the fens was difficult to remove. The construction of dykes and the scouring of the outfalls improved the removal of water, and the building of embankments prevented the rivers overflowing or the sea encroaching. But it was not until power—first steam and later electricity — was available to pump water that this area could be converted to arable land. The English fenland now constitutes the largest area of first-grade land in the country. Similar problems have been met and overcome in other regions, notably the Netherlands.

Conversely, on very steep slopes water moves rapidly, and if there is no natural vegetation cover sheet erosion may remove the top soil and later gullying will destroy the land. Such erosion is particularly likely in the tropics, where the intensity of rainfall (and hence also the impact of rain drops on the soil) is high, while the combination of high temperatures and heavy rainfall accelerates chemical weathering, predisposing the soil to erosion. Many parts of Africa have been subject to soil erosion where the natural vegetation has been removed, particularly where traditional farming practices have been abandoned.

Table 5.1 Slope and soil erosion at Sefa, Senegal (7 year means)

	Slope angle (%)		
	1.25	*1.5*	*2.0*
Annual rainfall (mm)	1235	1235	1186
Run-off (%)	16.5	21.9	30.0
Erosion loss (tonne/ha)	4.75	8.62	11.81

Source: J.M.Kowal and A.H.Kassam, *Agricultural Ecology of Savanna: West Africa,* Oxford, 1978, p. 170

In shifting agriculture and bush fallowing in savanna and forest regions in Africa, land that is not in crops is under a natural fallow: the natural vegetation is allowed to regenerate, and, whether secondary forest or bush, protects the soil. When the land is cleared for cultivation, it is not as thorough as in most European farming, and only the hoe or the digging stick are used. Further, intercropping is practised instead of single stands of one crop; a mixture of crops is grown on the same patch of land. This often includes root crops, cereals and bushes, so that again some protection against high temperatures and heavy rainfall is provided. When such practices are abandoned, then soil erosion becomes more likely, particularly on the steeper slopes. Although slope angle is not the only determinant of erosion, it is a powerful cause of spatial differences in erosion rates. Under natural vegetation in the African savanna, soil erosion occurs but at less than the rate at which new soil is formed. Once the natural vegetation is removed, erosion exceeds soil formation. A study of soil erosion at Sefa, in Senegal (Table 5.1) with a comparatively high annual rainfall, showed that run-off increased with slope, and this greatly increased the rate of erosion. The amount of soil lost on land with 2.0 per cent slopes was more than twice that on 1.25 per cent slopes.

SLOPES, WATER AND WET-RICE

As has been seen, the mechanized production of cereals is closely associated with flat land in the USA, and indeed in the other leading cerealproducing regions in the former Soviet Union, Canada, Australia and Argentina. Wheat and barley form the principal crops in these regions, and oats and rye are also grown. But rice, the leading cereal in the world (together with wheat), is absent from these regions. Like wheat, but for quite different reasons, rice requires flat land.

Two principal varieties of rice can be distinguished: dry-rice is sown and cultivated like any other cereal; wet-rice, however, is grown in slowly moving water which reaches an average of 100–150 mm on the stalk for three-quarters of the growing season, the water being withdrawn for the ripening stage, harvesting, and to allow weeding. This requires an elaborate system of water control to direct water which comes as rainfall, river floods or from reservoirs. To ensure that the water is the same height upon the stalk demands that fields be level and surrounded by small earthen bunds to contain the water. Such fields, generally called *padi* fields, but in Indonesia *sawah,* must be made upon flat land. The production of wet-rice in Asia is thus found overwhelmingly in the deltas and lower reaches of rivers. This location gives not only flat land which can be turned into *padi* with only rudimentary levelling, but it also, of course, provides easy access to water. In some areas, flat land for *padi* fields has been created on steep slopes by terracing, but this requires enormous labour; terracing is by no means common in Asia. It is most noteworthy in southern China, where a quarter of the cultivated land is terraced, Japan, and in some of the islands of South-East Asia, especially Java. It is rare in the Indian subcontinent and mainland South-East Asia.

The unusual circumstances of wet-rice cultivation provide other favourable conditions for growth. The rivers bring plant nutrients, in solution and suspension, removed by erosion from the upper reaches of the rivers, and so each annual deposition of silt helps maintain soil fertility. In the lower reaches of rivers the heavier silt carried by water is finally deposited; and this forms clay soils, often impermeable, which are necessary for the *padi* fields. On sandy, light-textured soils, the water in the *padi* would drain away. Finally, the presence of blue-green algae in the *padi* fixes nitrogen in the soil, and this helps maintain soil fertility.

CONCLUSIONS

The morphology of the earth's surface has been neglected in the study of agricultural geography. Yet a combination of high altitude and steep slopes make much of the earth's surface unsuitable for farming. Conversely, the commercial production of cereal crops requires not only a suitable climate, but flat land. On the micro-scale, slope may be significant; aspect influences the location of frost-susceptible crops, and on many British farms the steeper slopes are left in grass.

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Chapter 6
The demand for agricultural products

Agricultural geographers have concentrated upon supply conditions when studying spatial variations in agricultural activity, yet the pattern of demand is of great importance. Agriculture provides a wide range of products. Crops provide not only foodstuffs but also fibres, perfumes, drugs, oils for lubrication and paint, dyes and alcoholic and non-alcoholic drinks. Livestock provide not only meat and milk, but hides, bristles, wool and fats, and in much of the world they are the main source of draught power on the farm. But although agriculture provides a wide range of goods for industry, foodstuffs are by far the most important products. In the USA 90 per cent of the value of farm produce is consumed as food, and 93 per cent of the farmland is sown with food crops. No comparable figures are available for other parts of the world, but even in countries often thought of as mainly producers of industrial raw materials, food crops are dominant. In Bangladesh, for example, jute occupies only 7 per cent of the arable area.

HUMAN FOOD REQUIREMENTS

The minimum food requirements for a healthy life vary a great deal according to sex, climate, age and occupation. All, however, need an energy intake, measured in kilocalories, to maintain the metabolic rate and to allow the body to work. Energy intake per capita in 1986–88 averaged 3398 kilocalories in the developed countries, but only 2434 in the developing countries. The human body also requires protein, which is necessary for healthy growth and development. Protein is made up of 22 amino-acids, of which some 10 or 11 are essential. These can be derived from two sources. Eggs and most meats provide all the essential amino-acids, but animal products are expensive, and few people in the developing countries can afford them in adequate amounts. Protein is also found in most plant foods, although generally in low quantities. Further, no one crop contains all the essential amino-acids. However if a combination of plant foods is eaten, this drawback can be overcome. This explains why most traditional diets contain both a cereal and a legume. In Western

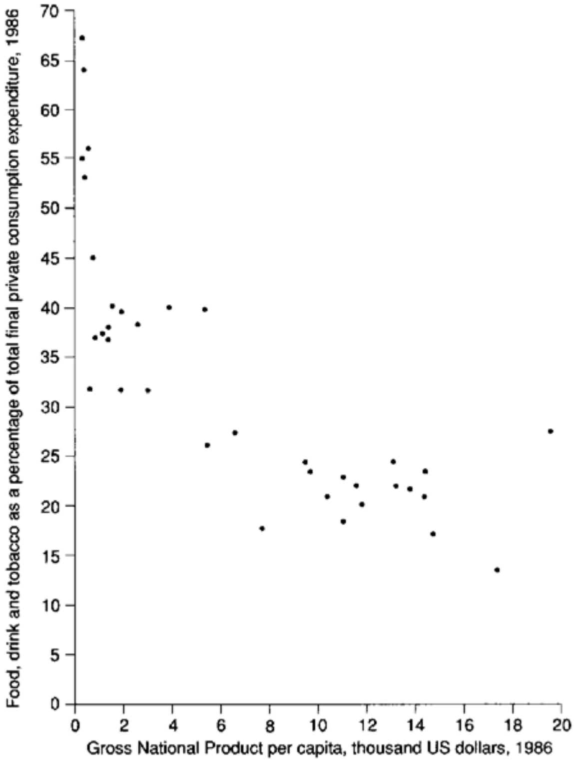

Figure *6.1* The relationship between food, drink, and tobacco as a percentage of consumption expenditure and gross national product per capita, US dollars, 1986

Sources: Food and Agriculture Organization, *Food Balance Sheets 1986–88,* Rome, unpubished; World Bank, *World Development Report, 1988,* Oxford, Oxford University Press, 1988

Europe in the past wheat was grown in combination with peas or beans, in the Americas maize and beans are still grown together on many farms, and in eastern China rice is grown with soybeans or peanuts.

INCOME AND FOOD REQUIREMENTS

The two major determinants of the demand for food are, over time, the growth of the population and changes in income.

Many studies of the relationship between household income and expenditure on food show two constant relationships. First, the poorer the household, the larger the proportion of total income spent on food; as income increases so the proportion of total income spent on food declines. Second, the absolute amount spent on food increases. Thus in India the

1960s, the poorest 20 per cent of a sample survey spent 72 per cent of their monthly income on food, the richest 51 per cent spent 41 per cent. But the richer group none the less spent nearly six times as much upon food as the poor.

Much the same relationships hold if countries rather than families are considered (Figure 6.1). In the poor countries of the developing world, with national incomes per capita of less than US $4000, between 32 per cent and 67 per cent of all consumption expenditure is upon food and drink, but in the richer countries, with national income per capita over US between 27 per cent and 13 per cent of consumption expenditure is on food. But as with family expenditure, the *amount* spent per capita on food is far higher in the developed than the developing countries.

Table 6.1 Proportion of all calories derived from specific foods, 1986–8

	Developed Countries	*Developing Countries*	*All Countries*
All plants[1]	69.7	89.4	81.2
Cereals and roots	33.3	65.7	52.5
Pulses	0.7	3.5	2.8
Oil bearing crops and vegetable oils	11.3	8.0	9.5
Sweeteners	12.7	6.8	9.2
Vegetables and fruit	4.8	3.6	4.3
Alcohol	5.1	1.1	2.5
All plants foods other than cereals and roots	36.4	23.7	28.7
All livestock[2] products	30.7	10.6	18.8
Meat	12.7	4.0	7.1
Milk[3]	8.2	4.5	6.8
Animal fats[4]	6.5	0.9	2.8

Notes: 1 Includes beverages, spices, nuts and miscellaneous not recorded separately in this table.
2 Includes eggs, offal and fish not recorded separately here.
3 Milk and all milk products except butter.
4 Includes butter.
Source: Food and Agriculture Organisation, Food Balance Sheets 1986–8, Rome, FAO, 1989

LOW INCOMES AND THE STARCHY STAPLE RATIO

These two facts have very important consequences for the demand for food and for the geography of its production. Poor families and poor nations have to try and meet their minimum requirements for calories by buying the foods that give the most calories for the least money.

In most countries the cheapest source of calories are cereals and root crops, such as potatoes and yams, because they give a high yield of calories —and protein—per hectare. Thus the major food crop in much of Asia is rice, in parts of Latin America and tropical Africa it is maize and in the drier regions of Africa it is sorghum or millet. In parts of West and Central Africa manioc or yams are the chief source of energy. As a consequence most of the countries with low national incomes per capita get a high proportion of their calorie intake from the starchy staples, cereals and roots. (Table 6.1; Figures 6.2 and 6.3). In the developed countries, with higher incomes, more of the expensive livestock products can be eaten, and the starchy staples are consequendy a much smaller percentage of all calories consumed. Live-stock products are expensive because they give a very low calorie and protein output per hectare, for reasons that have been explained earlier (see Chapter 2). As a result of these variations in consumption, and hence demand, food output in the developing countries is dominated by cereals and roots (Figure 6.3); exceptions occur, where crops are grown for export. Livestock may be numerous, but production is a small part of total output, for few people can afford to purchase more than small amounts of meat or dairy products.

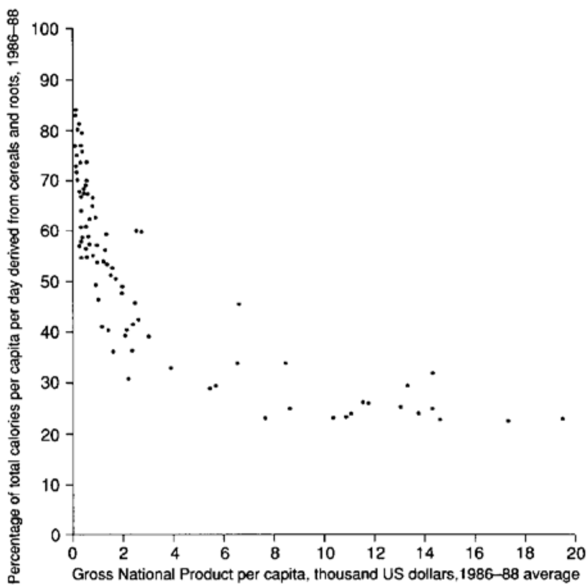

Figure 6.2 The relationship between the percentage of total calories per capita per day derived from cereals and roots and gross national product per capita, US dollars, 1986–8
Source: Food and Agriculture Organization Food *Balance Sheets, 1986–88,* Rome, unpublished; World Bank, *World Development Report, 1988,* Oxford, Oxford University Press, 1988

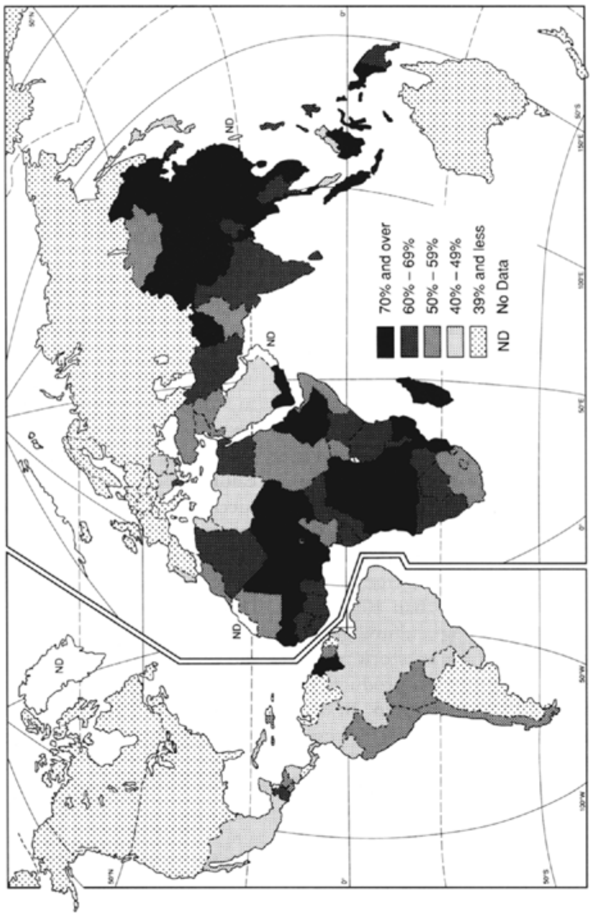

Figure 6.3 Percentage of all calories derived from cereals and roots, 1986–8

Source: Food and Agriculture Organization, Food Balance Sheets 1986–8, Rome, unpublished

HIGHER INCOMES AND CHANGING DEMAND

When very poor people get an increase in their incomes, they spend it upon the cheapest cereals and roots to satisfy their hunger. This once done they begin to buy a preferred staple: in the nineteenth century as Europeans became better off they switched from rye flour to wheaten flour and the area under rye declined. Later, and once Europeans were receiving an adequate intake of energy, they began to buy more expensive foods, including fresh vegetables and fruit, but above all livestock products — meat, milk, cheese and butter. For a variety of reasons (see Chapter 2) livestock products are far more expensive per calorie than cereals or roots. In most developed countries there has been a decline in the consumption of potatoes and bread since the 1920s, and an increase in the consumption of animal foods. In North America, Australasia and Western Europe over a third of all calories are derived from animal foods (Figure 6.4) but in Africa and Asia the figure is less than 10 per cent. This has far-reaching conse — quences for the world's agricultural geography. In the developed countries there is a high demand for livestock products, and they make up two-thirds or more of the value of farm production. These animals are fed partly on grass, but increasingly upon grain. In contrast, in the poor countries little land is devoted to growing crops to feed animals, and livestock production is a small part of total output, which is dominated by staple food crops.

When countries reach the levels of affluence in North America and Western Europe in the last thirty years, there are yet further changes in the demand for food (Table 6.2). An increasing proportion of food is consumed not at home but in restaurants and cafés; bread and potatoes decline in consumption; above all foods are increasingly processed before they are bought. Thus in Britain the consumption of fresh vegetables has declined while that of frozen and processed vegetables has increased. In the last twenty years, the consumption of carcase meat from butchers has declined but more processed and packaged meats have been eaten. The growth of the intensive feeding of pigs and poultry has cheapened their meats relative to those from cattle and sheep with consequent changes in consumption.

There have been two important results of these latter trends. First, at least half the price of food in the shops goes to processors and retailers; the farmer gets less than half. Second, because such an increasing proportion of food is processed after leaving the farm gate, there has been a tendency for food processors to buy land in order to control the supply of their raw materials. This system, of course, always existed in the past on plantations in the tropics. It has now extended to the production of temperate crops, particularly in the USA, where the rise of the agribusiness has been a distinctive feature of the last twenty years.

TASTES AND PREFERENCES

The growth of numbers and incomes are not the only determinants of demand for food or of spatial variations in diets, although they are most important. Religious taboos are a powerful factor in regard to some products. Thus neither Jews nor Muslims eat pork; although the Near East has 5 per cent of the world's population and 6 per cent of the arable land, it has only 0.04 per cent of the world's pigs (see below, pp. 191–2). The Muslim prohibition on alcohol also has an effect upon demand, consumption and thus land use, although perhaps only in a minor way. It accounts for the decline of viticulture on the eastern and southern shores of the Mediterranean between the seventh and nineteenth centuries. The present vineyards to the south of the Mediterranean are French and Spanish introductions of the nineteenth century. Other differences in demand have less obvious explanations. For example, in Europe until recently only the British consumed lamb and mutton in significant amounts, while within Britain there is no obvious reason for the higher consumption of mutton in Wales and the west of England.

Table 6.2 Purchase of selected foods for home consumption (Indices of average quantities per person per week, 1986=100)

	1961	*1971*	*1981*	*1990*
Bread, white	218	181	132	89
Fish	110	100	95	98
Potatoes	146	127	108	91
Fresh vegetables[1]	103	100	99	93
Sugar	225	197	138	75
Other Vegetables and vegetable[2] products	51	65	87	95
Cheese	74	87	94	96
Eggs	155	151	122	73
Beef and veal	138	121	106	80
Mutton and lamb	224	180	141	97
Pork	54	84	105	82
Poultry	33	67	100	109
Milk and cream	125	124	107	92

Notes: 1 Excluding potatoes.
2 Excluding fresh vegetables.
*Source: Central Stat*istical Office, Social Trends 22, London, 1992, p. 128

INDUSTRIAL DEMAND FOR AGRICULTURAL PRODUCTS

Although most of the world's agricultural land is used to produce food, crops for industry may locally be very important, and often dominate the export trade, as does jute in Bangladesh and rubber in Malaysia. The

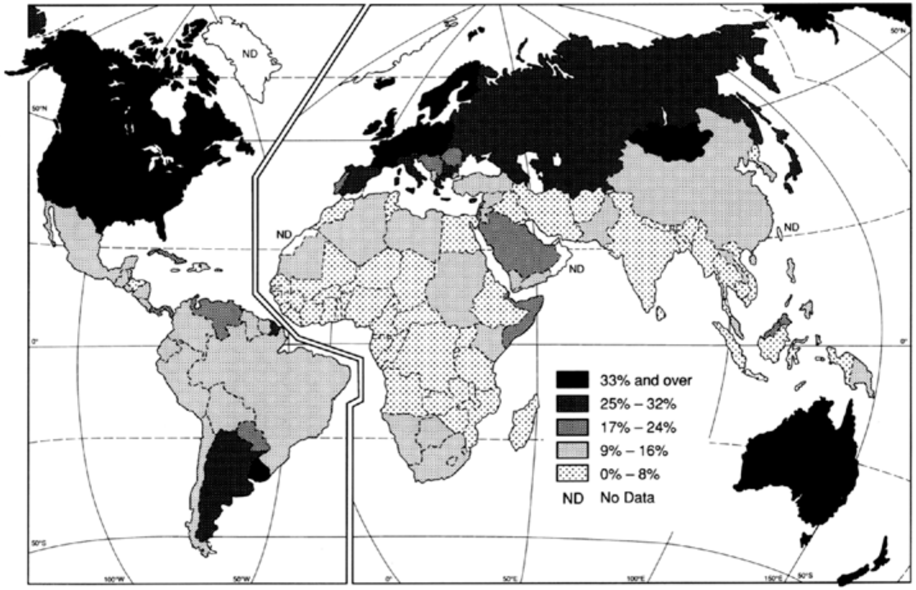

Figure 6.4 Percentage of all calories derived from livestock products, 1986-8

Source: Food and Agriculture Organization, Food Balance Sheets 1986-8, Rome, unpublished expansion and contraction of the areas under non-food crops is influenced by industrial demand and the development of alternative raw materials.

The growing of fibres has been much influenced by the development of synthetic fibres, beginning in the 1930s and widely used since 1950. This has principally influenced the cheaper fibres, and the output of sisal, hemp, wool and flax has declined over the last ten years, while jute output has increased only slowly. Initially the introduction of nylon had a disastrous effect upon the Japanese silk industry, but the growing prosperity of the 1960s and 1970s led to a renewed if limited demand for it. Cotton output has held up better than most fibres, for there is no satisfactory synthetic substitute.

Rubber had little value until the invention of vulcanization; initially used for weatherproofing, demand for rubber grew as the electrical and motor vehicle industries got under way in the early twentieth century, and there was a remarkable spread of rubber-growing in South-East Asia, leading to much overproduction in the 1920s. Synthetic rubber was first made in the 1930s, and its output expanded enormously during the Second World War. It might be thought that this would have had disastrous consequences for the rubber industry, but the boom in motor vehicle production allowed natural rubber and synthetic rubber to share a growing market.

The industrial recession of the 1970s and 1980s has also had an impact upon demand for agricultural products. However, although this had a severe impact on some economies, agricultural products for industry remain a small proportion of total agricultural output.

THE IMPLICATIONS OF VARIATIONS IN DEMAND

The most fundamental differences in demand are between the high incomes of the developed world, and the low incomes of the developing world. In the latter the poverty of the mass of the population means that a very high proportion of the area in crops has to be devoted to cereals and root crops that give a cheap supply of energy. Little land can be spared for horticulture or fodder crops, and the limited demand for livestock products means that such products are rarely a significant part of farm income. Paradoxically, this does not mean that livestock are not numerous in these countries. Livestock are kept as a source of draught power on the farm, and their manure often forms the supply of plant nutrients, although in some countries it is also used as a fuel. In some areas livestock dominate the farm economy, as in parts of Africa and the Middle East where pastoral nomads occupy considerable areas. In the developed countries high incomes mean that livestock products provide a high proportion of farm income; in much of Western Europe two-thirds or more of total farm income is derived from livestock products. Yet this does not mean that cereals are unimportant in Europe and North America; a high proportion of cropland is in cereals but much of this is fed to livestock, while in addition Europe imports grain and other fodder crops for this purpose. Horticultural products are also of importance locally in the developed countries.

Although lack of demand greatly influences the agriculture of the developing world, it does not follow that livestock production or horticulture are entirely absent. Even in the poorest countries there are some people with high incomes, while some high value products, although too expensive for the local population, are grown for export.

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Chapter 7
The economic behaviour of farmers

Demand determines why farmers produce food and fibres; the supply of these goods and why there are spatial variations in the production of different crops and livestock is the concern of the rest of this book. It is, however, important to note that the production of farm products differs substantially from the production of manufactured goods or the provision of services, largely because of the biological basis of farming and certain social characteristics of agricultural populations.

THE ECONOMIC DISTINCTIVENESS OF AGRICULTURE

The role of land

In the location of manufacturing industry land is of little importance on the macro-scale, although the availability of land for building warehouses, blastfurnaces or assembly lines is important within a particular locality. In contrast land is a fundamental part of agriculture. The total amount of land that is available is fixed in quantity, as is that of any one nation, save for exceptional cases such as the reclamation of the Zuider Zee. It is also fixed in position. Labour, entrepreneurial skills and inputs such as fertilizer or machines can all be moved from one place to another; land cannot. Land also differs greatly in quality as has been seen (Chapters 3, 4 and 5): some land has abundant rainfall and a long growing season, and will grow a wide range of crops and give high yields; other land is too cold or dry to grow any crops except at prohibitively high costs. These differences will help determine what crops can be grown in any particular region.

It follows from this that there is a fundamental difference between the study of location in agricultural geography and in other branches of economic geography. In the study of industrial location it is the optimum location for a new plant that is sought. The entrepreneur seeks the best location with reference to the assembly of raw materials and access to market. But in agricultural geography the location and environment of the farm is given, and the farmer has to decide what combination of crops and livestock will give the most profit or, in the case of the subsistence farmer, what crops will satisfy most of his or her consumption needs. It is rare that a farmer will decide to raise a particular crop and then seek the optimum location.

Dependence upon nature

Because farmers deal with living things they are more dependent upon nature than industrialists. First, as has already been noted, climate limits the crops the farmer can grow. Second, the time between the decision to grow a crop and the time when it is available for sale is rarely short; it may be as little as six months, but in the case of some perennial crops several years. Third, farmers have a limited control over the quantity they produce, for the size of the harvest varies with fluctuations in rainfall or temperature, and is liable to loss from disease and pests. Fourth, farmers do not have complete control over the quality of their product; thus the timing of a grape harvest influences the quality of wine, while frosts may damage fruit. Lastly, all foodstuffs are perishable. Milk must be drunk within a day or two of milking, and vegetables once harvested soon become unpalatable.

Smallness

Agriculture, unlike manufacturing industry, has a very large number of small producers. Although in the developed countries big farms account for an increasing proportion of total production, output is rarely dominated by a few large-scale producers. Thus, the behaviour of a few farms cannot influence total output, and as the output of individual farmers is such a small part of total output, response to price changes is apt to be slow. As most farms are small there are few workers on a farm, and this limits the possibilities of the division of labour. Indeed most farmers, unlike the managers of industrial firms, combine management with manual labour. The smallness of farms also makes it difficult to raise capital or benefit from economies of size.

Multi-products

In manufacturing industry most plants produce only one good with perhaps an incidental by-product. In agriculture most farms produce several different crops. The subsistence farmer needs a variety of crops to produce an adequate diet, and to avoid the risk incurred if one crop fails. Some crops or livestock yield more than one product; sheep, for example, give mutton and wool. There are also advantages in combining livestock and crops on the same farm rather than specializing; livestock provide manure for the crops, and also draught power. For these reasons and in spite of trends towards specialization most farms still raise a number of products.

Farming and social life

For most people in the developed world there is a physical difference between home and place of work; manager and employee *both* commute to work. This is not so for farmers in either the developed or the developing world; family household and business are the same. On a majority of farms in the world the family provides all or most of the labour on the farm, and on many the family consumes most of the produce. Thus, more than in most forms of economic activity, the cultural, economic and social characteristics of the family determine how the farm is run.

For the preceding reasons many would argue that there are fundamental differences between the economic behaviour of farmers and people in other sectors of the economy, and that further, there is a difference between the economic behaviour of commercial farmers and subsistence farmers.

THE ECONOMIC BEHAVIOUR OF COMMERCIAL FARMERS

Economic theory has provided a number of principles that help to understand the rational farmer who aims to maximize profit. First the farmer has to decide which crops and animals to produce, and this will be determined by prices.

The laws of supply and demand

Farmers produce agricultural products to be consumed as food and raw materials, and the demand for these commodities is determined by a variety of factors. Typically, a demand curve is downward sloping, showing how much of a product will be purchased at a given price at any time, with the quantity purchased increasing as the price falls (Figure 7.1). A supply curve shows how much farmers are prepared to market at a given price. Typically this will slope upward so that as the price offered increases the amount marketed by farmers increases. Supply and demand are equated at the equilibrium price, A. Generally farmers are prepared to produce more of a crop or livestock products as prices rise, less as prices fall, but the biological and economic peculiarities of farming mean that this relationship does not always hold.

Farmers should change their products as prices change, for they areassumed to be aiming to maximize their profits. If so, then they must adjusttheir inputs and outputs towards this aim. They have to decide how muchof a single input to use, how to combine two or more inputs to produce agiven amount of produce at the least cost, and what combination ofproducts to raise so as to maximize their profit.

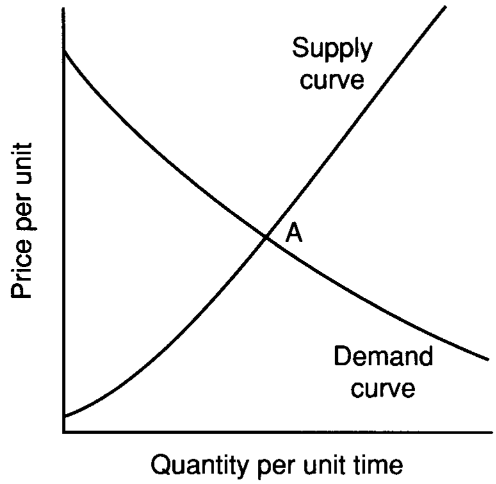


Figure 7.1 The determination of the equilibrium price: supply and demand curves

Intensity of farming

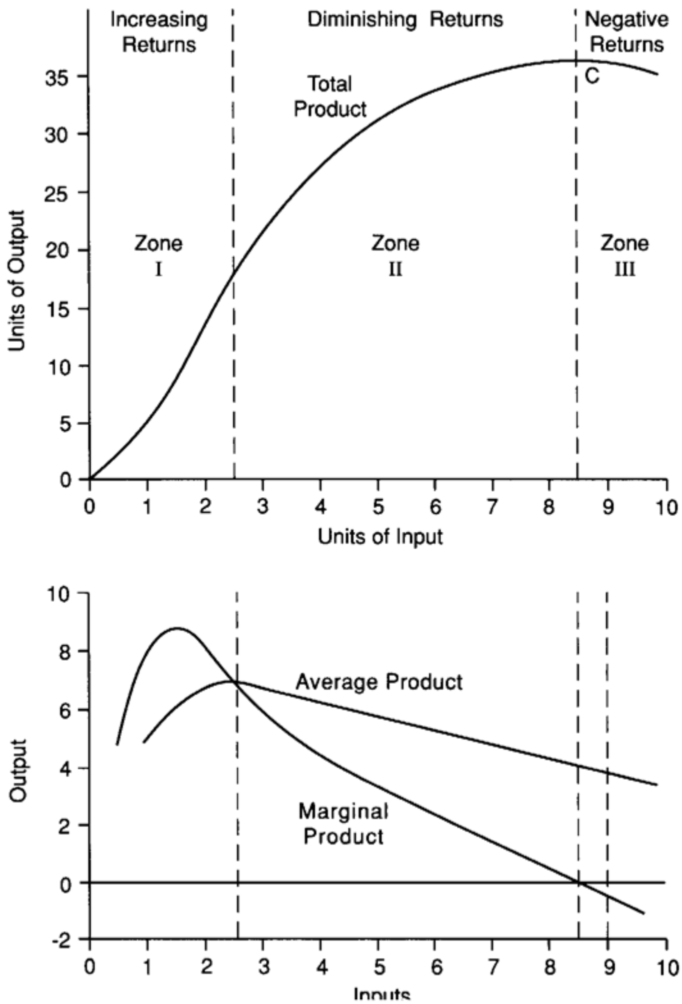
When a farmer decides to produce a crop or livestock he or she has a fixed amount of land, but can use varying amounts of labour or capital, such as fertilizers and pesticides. The amount of inputs used per hectare is described as the intensity of production; in *intensive* production a large number of inputs per hectare are used and give a high return per hectare; in *extensive* production relatively few inputs are applied, and returns per hectare are consequently relatively low. One way of measuring intensity is in terms of the cost of all the inputs applied to the land, but often either labour or capital alone are measured, so that production is described as labour or capital intensive or extensive. Types of agriculture can also be described as intensive or extensive. In England there is an obvious distinction between intensive horticultural production and extensive sheep rearing (Table 7.1). It should be noticed that net farm income per hectare is related—with the exception of specialist dairying—to the level of inputs, but the increase in income is not linear with the increase of inputs. This is because of the law of diminishing returns, or as it is usually described, the law of variable proportions.

Table 7.1 Measures of intensity of type of farming in England and Wales (£ per hectare)

	Labour costs	*Capital inputs*	*Total inputs*	*Net farm income*
Horticulture	152	432	585	277
General cropping[1]	55	222	277	166
Specialist dairying	49	348	397	144
Specialized cereal production	35	169	204	77
Sheep and cattle	22	114	136	60
Sheep	6	33	39	21

Note: 1 Includes cereals, sugar-beet and potatoes.
Source: Ministry of Agriculture, *Farm Incomes in England and Wales 1975–76*, No. 29, London, HMSO, 1977

Figure 7.2 Increasing, diminishing and negative returns



The law of variable proportions

It is a matter of observation that the increasing application of an input—of labour-hours or fertilizer, for example—to a unit area of land will increase output, but that output does not increase proportionally to the increase in the number of inputs. Doubling fertilizer application, for example, will not necessarily double crop yields.

At first (Zone 1) (Figure 7.2 and Table 7.2), an increase in the number of input units applied not only increases total output, but the additional or marginal output which results from adding an input also increases, as does the average output (Table 7.2). In Zone II the addition of extra inputs leads to further increases in total output, but the marginal product begins to diminish: each extra input brings a smaller increment of output. The average output also declines. A third zone occurs when the addition of an extra input leads to a decline in total output; the marginal product becomes negative.

Table 7.2 Inputs and total, average and marginal output

1 Input (x)	2 Total output (y)	3 Average output (y/x)	4 Marginal output (x)	
0	0	–	–	
			5	Zone I
1	5	5		
			9	
2	14	7		
			7	
3	21	7		
			5	
4	26	6.5		
			4	
5	30	6		Zone II
			3	
6	33	5.5		
			2	
7	35	5		
			1	
8	36	4.5		
			0	
9	36	4		
			−1	Zone III
10	35	3.5		

Source: C.E. Bishop and W.D. Toussaint, *Introduction to Agricultural Economic Analysis,* London, Wiley 1958, p. 37

These data suggest that the rational farmer will not operate in Zone I or III. In Zone III using extra inputs will *reduce* total output. Such instances are rare in practice. However, excessive inputs of irrigation water applied to arable land may cause waterlogging and reduce crop yield (total output), while allowing too many cattle to graze pasture may reduce fodder supply and hence the output of milk or meat per unit area; this would seem to be common in Africa. In Zone I farmers can gain in both total output and marginal output by adding an extra input, so it is equally irrational to operate in this zone. Again, instances of this are rare, although it is thought that many dairy farmers in Britain apply too little fertilizer to their grass, and would gain increases in the marginal output of fodder supplies by applying extra fertilizer. Most farmers operate in Zone II where marginal returns are diminishing. However, it is necessary to know the prices of products and the cost of inputs to calculate what the optimum input per unit area should be. If inputs are assumed to cost £5 each, and the price received for each unit of output is £2, then the optimum point is where the maximum total net revenue is obtained (Table 7.3, column 8). This is £36, and is reached when the marginal cost, £5 (column 6a), equals the marginal value of the product (column 5), which is obtained when between 5 and 6 physical units are applied.

The optimum number of inputs will vary if the price of inputs or the product changes. Thus, if the price of each input doubles, to £10 (Table 7.3, column 6b), the maximum net revenue becomes £12 which is obtained when the marginal cost of £10 equals marginal product, with between three and four physical inputs. Thus if the cost of inputs rises, the farmer must reduce inputs to maximize net revenue.

If the price of the product increases and there is no change in the cost of the input, then to obtain the highest net revenue (the point where marginal cost and marginal product are equal) will require an increase in the number of inputs; conversely, a fall in prices without a change in the price of inputs will mean that the optimum input will be lower. Thus, as product prices increase, to obtain the greatest net revenue more inputs should be applied; when they fall fewer inputs are needed. The cost of inputs includes the cost of purchasing an input such as fertilizer, and also the cost of transporting the fertilizer from the factory to the farm. Thus, input prices can fall if technological advances make them less costly to manufacture, or if advances in transport reduce the cost of moving them. If farmers buy their inputs from the same place as they sell their products then inputs will be cheaper for those farmers near the market and more expensive for those who are remote. This explains why farmers near the market will maximize revenue by farming *intensively,* and those in more remote situations will maximize revenue if they farm less intensively, or *extensively* (see pp. 114–19).

Combining two inputs

Farmers also have to decide how to combine two or more inputs to produce a given output. How this is achieved depends upon the technical feasibility of substituting one input for another, and the relative costs of the inputs. Some inputs can be combined only in *fixed proportions;* if one unit of an input is added, then another unit of the other input must also be added (Figure 7.3a). Thus, if one tractor is added then an extra man must be hired to drive it. Such instances are rare in agriculture. Inputs may also be combined at a *constant rate* (Figure 7.3b); here one input bears a direct and unchanging ratio to another input. Thus, in feeding cattle one bushel of maize gives the same feed value as a specified amount of sorghum or barley. Under these circumstances the farmer chooses either one or the other of the two feeds, depending upon their price, not a combination of the two. The most common condition in farming, however, is where inputs combine at a *varying rate* (Figure 7.3c). Here the farmer has to calculate what is the least cost combination which will give a given output. Farmers thus have to be aware of divergent trends in the cost of their inputs; wages, the price of fertilizer, the cost of purchasing and maintaining machinery, and the cost of energy to drive their machinery are all important.

Choosing a combination of products

Farmers have to decide how many products they will produce to maximize their revenue with a given number of inputs. In some cases the farmer automatically produces two products; examples of such *joint products* are beef and hides, wool and mutton, or cotton lint and cotton seed. There is no decision to be made about the product combination in the short run, although in the long run a farmer may shift to breeds of sheep that yield mainly wool or meat.

A second class of products can be described as *complementary*. Here some of the fixed quantity of inputs can be transferred from one product to another; both increase in output as a result. An example of this is the introduction of a legume crop into a continuous rotation of grains. Thus, if a year of soybeans is introduced after several years of sorghum the farmer gains the soybean output and an increased yield of grain from the fixation of nitrogen that occurs during the cultivation of the leguminous soybean. The introduction of clover into a course of wheat crops may have the same result.

Table 7.3 Total revenue, marginal cost and net revenue

1 Inputs	2 Total product	3 Total revenue	4 Value of average product	5 Value of marginal product	6a Marginal cost a when inputs cost £5	6b Marginal cost b when inputs cost £10	7 Total cost	8 Total net revenue when inputs cost £5	9 Total net revenue when inputs cost £10
0	0	0	–				0	0	0
				10	5	10			
1	5	10	10				5	5	0
				18	5	10			
2	14	28	14				10	18	8
				14	5	10			
3	21	42	14				15	27	12
				10	5	10			
4	26	52	13				20	32	12
				8	5	10			
5	30	60	12				25	35	10
				6	5	10			
6	33	66	11				30	36	6
				4	5	10			
7	35	70	10				35	36	5
				2	5	10			
8	36	72	9				40	32	−8
				0	5	10			
9	36	72	8				45	27	−18
				−2	5	10			
10	35	70	7				50	20	−30

Note: In columns 4–8 each input costs £5 and each unit of product receives £2. Column 3 shows net revenue when each unit of input costs £5. Column 6b and column 9 show marginal cost and net revenue when each input costs £10. The other columns have not been altered for this case.

Source: C.E. Bishop and W.D. Toussaint, Introduction to Agricultural Economic Analysis, London, Wiley, 1958, p. 47.

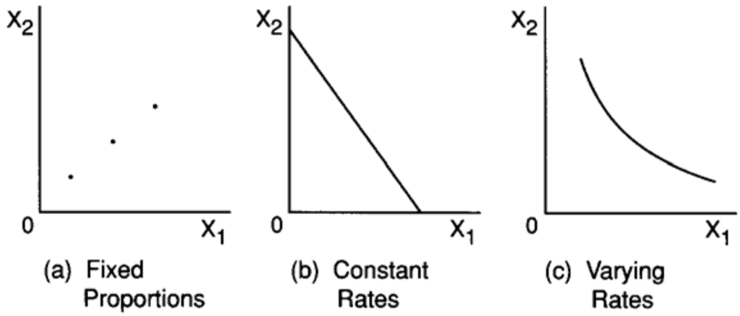


Figure 7.3 Input substitution at differing rates

More commonly, however, farms grow *competitive* crops. With a given quantity of inputs available, if some of the inputs are transferred from one crop to another, the output of the latter will increase, the former decline. If the farmer is operating in the zone of diminishing marginal returns, the more of Y1 that is produced, the greater the number of units of Y2 that must be given up (Figure 7.4). The farmer has to decide what combination of Y1 and Y2 will give the maximum revenue, and thus requires knowledge of the price of the product. Suppose a farmer can produce either sheep or steers or a combination of the two; the production possibility curve is shown in Figure 7.5. If sheep fetch £7.20 and steers £80, it is possible to draw *isorevenue lines* linking all combinations of sheep and steers which produce an equal total revenue. One such case is the line AB. The sale of 1450 steers would fetch £116,000, but so would 16,100 sheep or any combination of sheep and steers on the line AB. The farmer could choose one of the two points C or D, where the isorevenue line cuts the production possibility curve. But the farmer's profit is not then maximized, for any isorevenue line cutting the curve between CE and DE will give a greater return. The highest net revenue is the line which is tangential to the curve at E, giving a revenue of £167,200.

Specialization and diversification

Under the farming conditions of the developed countries, there has been a trend towards specialization. Farmers may concentrate upon one crop because this is the optimum 'combination'. However, there are reasons why diversification may take place even though the solution to the optimum 'combination' of products suggests one crop only. First, if the work on one crop is concentrated in clearly defined seasonal peaks, then the labour force will not be utilized in other parts of the year. If a second crop has different seasonal requirements, it can be grown without reducing labour inputs for the first crop. Second, there may be agronomic reasons for

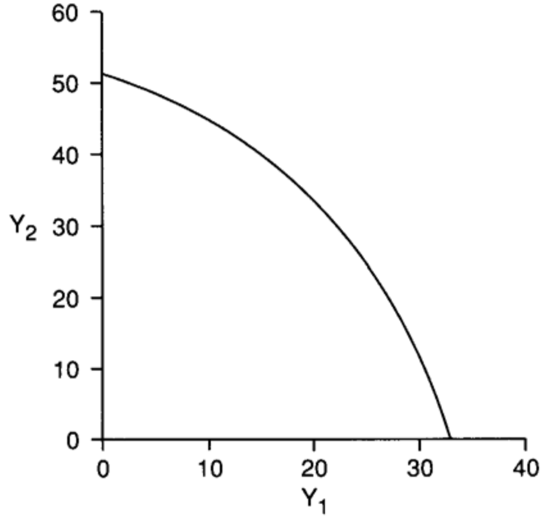


Figure 7.4 Production possibilities curve for a given input level for competitive products substituting at a given rate

combining a number of products. Thus in areas where chemical fertilizers are too expensive for farmers to purchase, livestock may be kept to provide manure. Third, farmers may be reluctant to risk growing only one crop. The fear of unexpected falls in price, or the risk of disease and weather hazards may cause farmers to diversify even though the production of one crop would maximize net revenue (see below, p. 82).

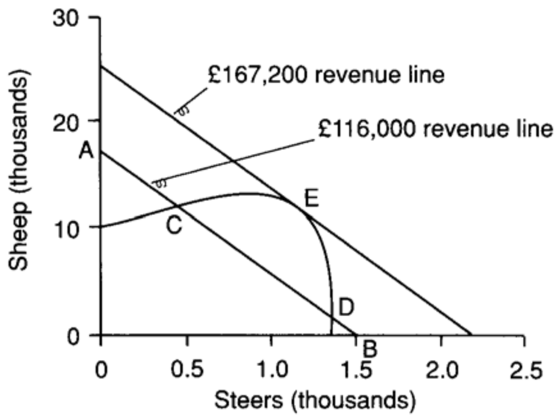


Figure 7.5 The combination of sheep and steer output that maximizes net revenue

Criticisms of the profit maximizing model

There have been many criticisms of the idea that farmers are profit maximizers who respond automatically to changes in prices. Studies in Britain have attempted to identify the economic aims of farmers, and they suggest that there are two other motives which are as important as maximum profit. First, farmers aim at security and stability in their incomes; maximization is less important. There are good reasons for this. Although England has a temperate climate with few extremes, the income of farmers varies from year to year more than that of firms in other sectors of the economy. Under these circumstances farmers are loathe to take risks with new crops or methods, and reluctant to switch into new enterprises. Second, farmers value the independence that farming as a livelihood gives them, in contrast to most other occupations. This is particularly relevant to the farmer with a small amount of land. Under modern technological and economic conditions small farmers cannot produce as efficiently as large farmers; indeed many in Britain and especially in Western Europe earn less than they would as farm labourers or as industrial workers. One of the reasons why such farmers stay in agriculture is that they value independence.

Economic theory assumes that farmers will adjust their inputs in response to price changes, and shift from one enterprise to another as relative product prices change. But there are good reasons why this may not always hold. In post-war Europe and North America new technologies that give higher yields have become available to farmers at comparatively low cost. Increased output combined with the limited increases in demand have caused prices to fall or stagnate. Farmers responded, not by reducing inputs or reducing output, but adopting further new technologies that reduced costs—a process described as the treadmill. Falling prices do not always lead to a reduction in supply for other reasons. Some farmers may increase supplies in order to increase their aggregate income, thus compounding the decline in prices. Not all farmers can switch into alternative enterprises. Thus, the small farmers of much of the west of England lack the area or a suitable environment to become large-scale cereal producers, and continue to produce milk. Most of the problem regions of agricultural Europe are in areas of poor soils and small farms, where alternative enterprises are difficult to find (see below, pp. 108–10).

Nor, might it be said, is it easy to define the maximum profit. Farmers have to calculate two types of cost. *Fixed costs* are those they would have to bear even if they sowed no crops and kept no livestock, such as rent, taxes and interest on the capital borrowed to buy machinery or buildings. *Variable costs* are those that arise in actual production, such as the purchase of seed, fertilizer and feeds. It is not always easy to allocate fixed costs to specific enterprises and calculate their profit. The farmer must also differentiate between *long-run* and *short-run* profits. Thus, profit may be maximized in the short run by growing cereals continuously without break crops; in the long run this may lead to soil exhaustion, falling yields and falling incomes. This happened in the Great Plains in the USA in the 1930s, and is a common occurrence in parts of the tropics when no effort is made to protect the soil from high temperatures and high rainfall impact.

THE ECONOMIC BEHAVIOUR OF SUBSISTENCE FARMERS

The economic behaviour of farmers described above applies to farmers who sell most of their production off the farm, and are thus dependent upon changes in price over time, and also spatial differences. Further, they purchase many of the inputs they use, and differences in the price of these will effect whether they use labour or machines, or large or small amounts of fertilizer. But many farmers in the developing world purchase few inputs, and sell litde off the farm: their main aim is to provide food for their family. They are thus less influenced by price changes, and so their behaviour may differ from that of commercial farmers.

First, if subsistence farmers seek to provide their families' consumption needs they will aim to maximize gross output rather than profit, and yield per hectare rather than output per head. As land and labour are the main inputs, it is unlikely that the onset of diminishing returns will affect their behaviour. Farmers will work until they have achieved a sufficient supply of food; it is a point on the total output curve that is important, not maximizing returns by equating marginal cost and revenue. Second, they are not likely to specialize in one product. An adequate diet requires cereals, legumes and preferably a source of animal food. Thus, traditional farmers in every part of the world grow a combination of crops. This has agronomic as well as dietary advantages. In Western Europe farmers in the past kept livestock and grew crops, the livestock being fed on rough grazing and stubble. Manure maintained crop yields, and peas and beans — legumes— both provided food and helped maintain nitrogen supplies in the soil. In many parts of the tropics in shifting agriculture and bush fallowing systems a variety of crops are grown; these are grown intermixed, and a combination of tree crops, bush crops and cereals provide a cover to the soil that protects it from soil erosion. Even in the densely-populated regions of East and South Asia the monoculture of rice is rare. The need to grow a variety of crops means that some crops may be grown on soils to which they are unsuited.

Third, subsistence farmers try to produce as much of their own food as they can, with the minimum of risk. Their farms are small, and in many parts of Afro-Asia fluctuations in rainfall lead to considerable annual variations in crop yields. The result of harvest failure may be starvation or the forced sale of their land. They are thus averse to taking chances with new crops or methods. Further, if they sell some of their crops, they may choose to grow a combination of crops that is likely to give them a *secure* income rather than maximum profit. Thus, farmers may have a choice of growing three different crops or crop combinations A, B and C (Table 7.4). In four consecutive years there are very different weather conditions. The profit maximizer might choose, on the basis of this experience, combination C, for it gives an average profit of £100. The next best profit is combination B, with £56, but suppose a farmer needs £40 a year for the family's needs. The farmer will not then choose B, for in two of the four years income falls below this amount. Instead the farmer will choose A, with the lowest average profit, but which gives £40 in each year.

Table 7.4 Income and weather conditions

	1	*2*	*3*	*4*	*Average income*
A	£45	£55	£60	£50	£52.5
B	£70	£30	£90	£34	£56
C	0	£100	0	£300	£100

Note: A, B and C are different crops or crop combinations: 1,2,3 and 4 are years each with different weather conditions.
Source: After Gould, 1963

CONCLUSIONS

The economic behaviour of farmers in the developed countries is for the most part rational, and a body of economic theory exists both to describe and predict their actions. In recent years, however, it has been shown that farmers may prefer stability and security to profit maximization, but this for the most part does not invalidate the general principles. Yet, economic theory as developed in the West has limited value in explaining the behaviour of farmers in the command economies of socialist countries. More important, the assumption of profit maximization as the prime aim in the subsistence economies of much of the developing world may have to be modified.

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Chapter 8
The modernization of agriculture

Over the last century and a half agriculture in the developed countries has been profoundly altered. Output and productivity have greatly increased and there have been major changes in technology. Farmers who once produced mainly for home consumption now sell nearly all their produce, and whereas the inputs used were once produced on the farm, most are now purchased from industry. In addition much of the farmers' produce is sold not directly for consumption, but to food processors. These great changes, which can be described as modernization, are closely related to the progress of industrialization and the general process of economic development. Not surprisingly there are striking spatial differences in the degree of agricultural modernization, which give rise to great differences in agricultural productivity. The principal difference is between the developed and the developing regions, although modernization has been experienced in some regions within developing countries, such as in the Indian Punjab or parts of Brazil.

THE EXTENT OF SUBSISTENCE FARMING

Some of the differences between traditional and modern farming are shown in Table 8.1. The degree of commercialization is of first importance, but it is not easy to define or measure the extent of subsistence farming. Farmers who sell nothing off their farms are rare; on the other hand those whose first aim is to provide their family's food and other necessaries, and for whom sales for cash are secondary are dominant in much of Asia, tropical Africa and parts of Latin America; they may be described as semi-subsistence farmers.

In tropical Africa three-quarters or more of all food crops are consumed upon the farms where they are grown, and in India two-thirds of all the grain. In China in the 1970s four-fifths of total food production was consumed by the families that produced it, although this proportion has since fallen. In Latin America agriculture is more commercialized. For about half the farm population the first aim is to grow their own food, but these small peasant farms also contribute food for the home market and some export crops. In the past the now developed countries also had a semi-subsistence agricultural economy; in the 1820s about three-quarters of food production in the USA was consumed on the farm but today virtually all food output in developed countries is sold off the farm; commercial farmers, like non-farmers, buy their food from shops.

A number of factors explain the degree of commercialization. First, the size of the urban population, where no one grows their own food, determines the size of the market for farmers. In tropical Africa towns are a small proportion of the total population, and so little of the total output is sold off the farms. Similarly, before 1800 three-quarters of the population of Western Europe were employed in farming, so the market was limited. Now less than 5 per cent work in farming and most of the population has to buy its food.

Second, is the size of farm. In Asia and Africa a majority of farms are only a few hectares in size, and most of this land is needed to provide the family's food, so little can be marketed. Third is location; farms that are remote from towns, and where the cost of transport to market is high, find it difficult to sell crops or livestock upon a regular basis, unless their products have a very high value per unit weight.

THE PURCHASE OF INPUTS

Traditional subsistence farmers produce most of the inputs they use on their farms (Table 8.1). Seed for the next crop is taken from the current harvest; livestock provide manure; human labour and draught animals—oxen, water buffaloes and horses—provide all the power; livestock are fed grass or fodder crops grown upon the farm. In the 1860s purchased inputs in Swedish agriculture were only 5 per cent of the gross value of output; today they form over 50 per cent, and this is so in nearly all developed countries. Far fewer inputs are used in the developing regions, particularly in Africa (Table 8.2). The use of these purchased inputs is a key to international differences in agricultural productivity.

Table 8.2 Share of the value of inputs in the value of gross output (per cent)

	1982/4
Developed countries	c.50
Near East and North Africa	36
Latin America	25
Asia (excl. China)	24
SubSaharan Africa	10

*Source: N. Alexandratos, World Agricult*ure: Toward 2000. *An FAO Study,* London, Belhaven Press, 1988, p. 135

Table 8.1 Differences between subsistence and commercial farmers

	Traditional, subsistence	*Modern, commercial*
1 Proportion of output sold off the farm	Low	High
2 Destination of foods	Local direct consumption and some processed locally	High proportion processed and to food manufacturers
3 Origin of inputs		
i Power	Draught animals, human labour	Petroleum, electricity
ii Plant nutrients	Legumes, ash, bones, manure	Chemical fertilizers
iii Pest control	Crop rotations, intercropping	Insecticides, fungicides, break crops
iv Weed control	Rotations, hoeing, use of plough	Herbicides
v Implements and tools	Hoe, plough, sickle, scythe.	Machinery, often self-propelled combine harvesters
vi Seed	From own harvest	Purchased from seed merchants
vii Livestock feeds	Grass and fodder crops grown on farm or common land	Purchased from compound feed mixers
4 Economic aims	i Prime aim to provide family food	Profit maximization
	ii Land and labour main inputs; few capital inputs	Capital and land major inputs; labour a declining input
	iii Diversity of crops grown	Specialized production
	iv Aims at maximizing gross output and yield per acre	Aims at maximizing output per head and minimizing production costs.
	v Prime aim avoidance of risk; reluctant to innovate	Innovation

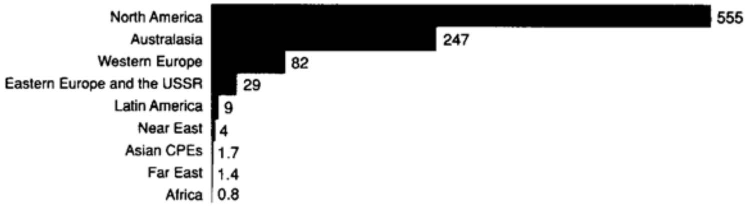

Figure 8.1 Use of commercial energy in agriculture production, per agricultural worker: 10^9 joules

POWER AND MACHINERY

One of the most notable innovations of the industrial revolution was the application of steam-power to machines. This was long delayed in agriculture, but since the invention of the internal combustion engine, petroleum and also electricity have replaced human labour and draught animals. However, there is great spatial difference in the amounts of energy used in agriculture, as can be seen in Figure 8.1. Here energy includes not only that used on farms but also in the production of chemical fertilizers.

North American consumption is nearly seven times that of Western Europe, but Western Europe uses much more commercial energy than any of the developing regions. Indeed in the developed world nearly all power is now provided by petroleum and electricity, and draught animals and human labour make only very limited contribution. This is not so in the developing regions where the labour force does nearly three-quarters of the work and tractors are of significance only in Latin America (Table 8.3). The distribution of tractors corresponds quite closely to the level of economic development (Figure 8.2). There are more tractors per 1000 hectares of arable land in Europe than *anywhere*, else, although this underestimates their importance in the USA. Tractors in the USA are larger and more powerful than in Europe; if data on horsepower per hectare were available rather than simply numbers of tractors, North America would rank higher, as would Australia and Argentina.

	Labour force	*Tractors*	*Draught animals*
Sub-Saharan Africa	89	1	10
Near East and North Africa	69	14	17
Asia (excl. China)	68	4	28
Latin America	59	22	19
All developing countries	71	6	23

Table 8.3 Contribution to total power use on farms, 1982–4 (per cent)

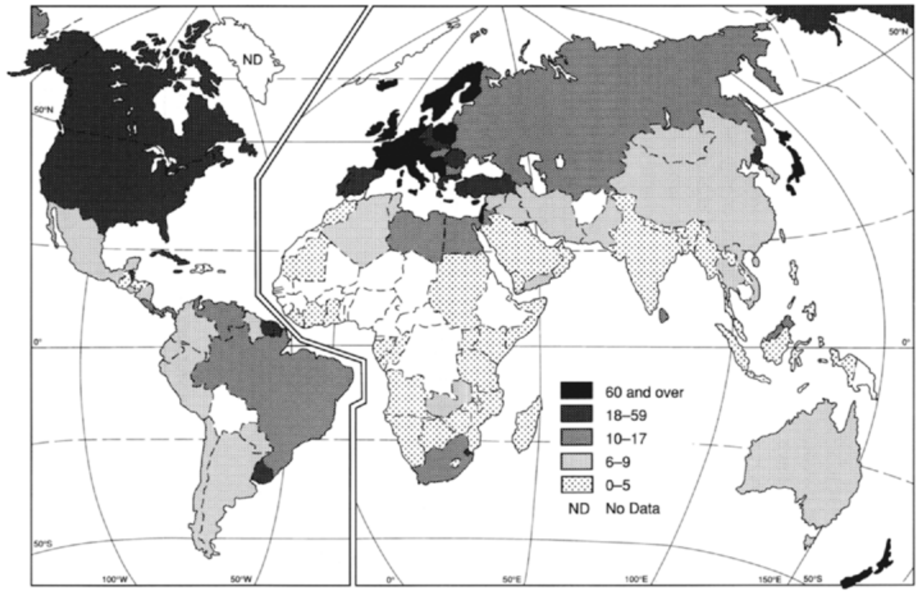

Figure 8.2 Number of tractors per 1000 hectares of arable land, 1986

Source: Food and Agriculture Organization,Production Yearbook 1989,vol.43,Rome 1990

Tractors are not, of course, the only machinery used by commercial farmers (Table 8.4) who have a wider range of machines, implements and tools than the traditional farmer. It is in the industrialized parts of the world that the use of machinery has been widely adopted, and power used so liberally. This is first because in most of these regions migration from the countryside to the towns in search of higher wages has reduced the availability of agricultural labour, and farmers have had to substitute capital —machinery—for labour (see below, Chapter 12). Second, industrial countries have the capacity in their engineering and vehicle industries to produce machinery, which the developing countries for the most part have not. Third, farmers in the developed countries are more prosperous than those in the developing, partly *inter alia,* because they have larger farms and because prices are subsidized by the state, and they can therefore afford to purchase machines. Fourth, farms in much of the developing world are generally too small to justify the use of machines, whilst the low cost of labour makes the use of machinery of dubious value. The substitution of power and machinery for labour has gready increased output per head in the industrial countries; there remain, however, great differences in output per capita between the developed and developing countries (Figure 8.3). Labour productivity is highest in North America, Australasia and Latin America; it is lowest in tropical Africa, South, South-East and East Asia.

COMMERCIAL FERTILIZERS

Traditional farmers have a variety of means of maintaining soil fertility and hence crop yields. Fallowing, the growth of legumes, and the use of livestock manure are all practised (see Chapter 2). Since the middle of the nineteenth century these methods have been supplemented by the use of factory-made chemical fertilizers, compounds of nitrogen, potassium and phosphorus. Until 1950 fertilizers were only intensively used in north-western Europe, but since then their application has increased both there and in the rest of the world. Differences in fertilizer usage are not, unlike the use of tractors, a simple function of the level of economic development. The lowest levels of application are found in Africa, Latin America and mainland South-East Asia (Figure 8.4), the highest are found in Europe and the USSR, but also in China, Korea and Japan, whilst quite high levels obtain in South and South-West Asia. But the usage of fertilizers in Australasia and North America falls below what might be expected. This is because much of the crop production is extensive: the farmers grow large areas in wheat and other cereals, with few yield-increasing inputs but with the use of machinery. In Asia in contrast, with notably high densities of population, farmers strive to maximize output per hectare, and the liberal use of chemical fertilizer is one way in which this is achieved.

Table 8.4 Different methods of farming

	Semi-subsistence	*Commercial*
Power	Human muscle, oxen, horses, water buffaloes	Electricity and internal combustion engine
Machinery	Implements and tools only. Machete, axe. Simple ploughs. Hoes, spades. Sickle, scythe or knife for harvesting. Flail or oxen hooves for threshing	Machines, tractors cultivators, drills, pesticide spreaders, combine harvesters
Weed control	Weeding by hand or hoe during fallow or with row crops during growth	Herbicides before and during growth
Disease control	Rotations, fallow, mixed cropping, immune varieties	Break crops, rotations, immune varieties, pesticides, fungicides and insecticides
Livestock	Used for draught; meat and milk incidental. Little selective breeding. Limited veterinary services	Selective breeding, specialized for meat or milk. Veterinary services, antibiotics preventive health measures, immunization. Intensive feeding, factory farming of pigs and poultry
Livestock feeds	Grass, some fodder crops. Little feed purchased	Grass, cereals, purchased concentrates. Balanced rations

MODERN CROP VARIETIES

In the past the farmer obtained the seed for the next sowing by retaining part of the crop just harvested. Over very long periods many varieties evolved adapted to local micro-conditions, and were often selected to give an adequate yield under poor environmental conditions. Farmers would improve their seed by buying it from other farmers, but until there were advances in plant genetics it was not possible to breed specific characteristics into new varieties. This has been possible since the

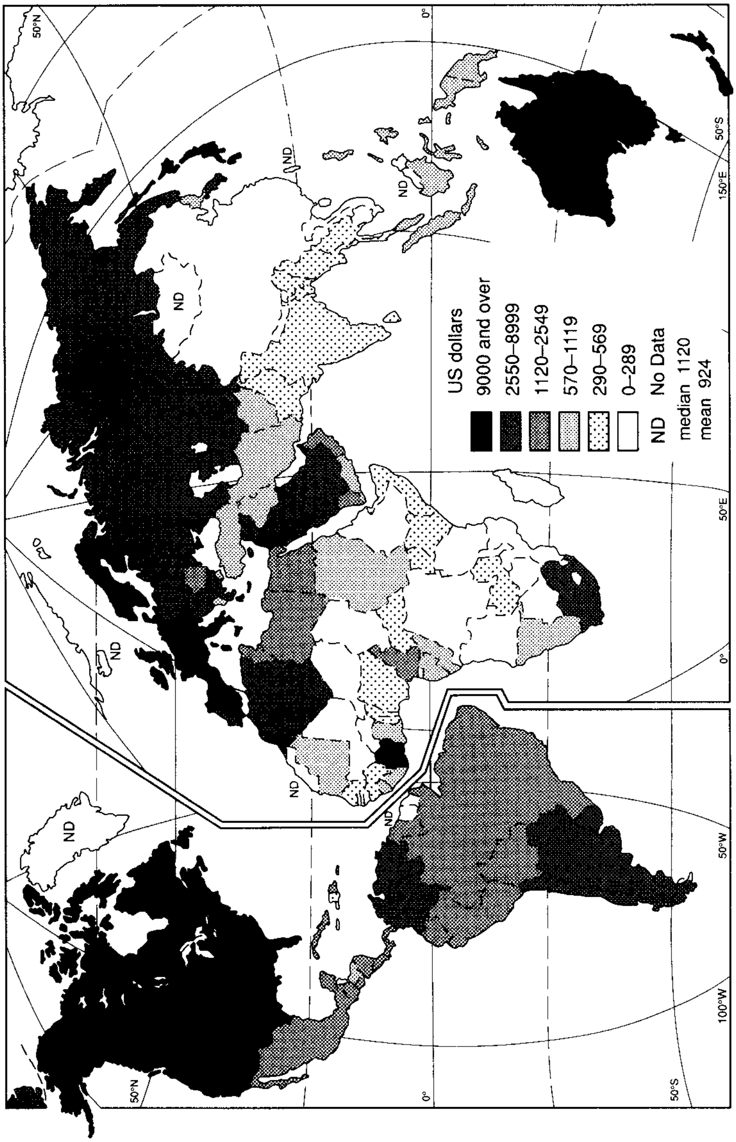

Figure 8.3 Agricultural gross domestic product per capita of the agricultural labour force, US dollars, 1988

Source: D. Grigg, 'World Agriculture: production and productivity in the late 1980s', *Geography*, 1992, beginning of this century, and since then plant breeders have been able to breed into new varieties immunity to specific diseases, an ability to mature in a shorter growing season, allowing the extension of the crop into cold areas, a greater tolerance of drought, and above all a greater response to chemical fertilizers, giving much higher yields. New varieties have been constantly provided by plant breeding institutes and adopted by farmers. Between the 1930s and the 1970s cereal yields doubled in the USA and Great Britain, and half of this increase was due to the adoption of new varieties, the rest to the use of pesticides, fertilizers and other improved practices. Most seed in the developed world is purchased from seed-merchants and is of improved modern varieties.

Far less progress in breeding new varieties had been made in Afro-Asia or Latin America, except with some export crops such as sugar-cane and bananas. In the 1960s new high-yielding varieties of wheat and rice were introduced into Asia; with shorter stems than traditional varieties, they gave much higher yields, provided that fertilizers, pesticides and irrigation were used. At much the same time improved maize varieties, first developed in the USA in the 1920s, began to be adopted elsewhere. By the 1980s modern varieties occupied half the sown area of maize, wheat and rice in the developing countries, and contributed to the very substantial increase in cereal output between the 1960s and 1980s (Table 8.5). Africa has gained least from these advances, for wheat and rice are very little grown there and sorghum, millets and root crops, that make up a substantial proportion of the total food crop area, have not experienced much improvement in their seed.

Table 8.5 The adoption of modern crop varieties in the developing countries, (per cent of area in crop sown with modern varieties, mid-1980s)

	Wheat, 1982–3	*Rice, 1982–3*	*Maize, 1983–6*	*All three crops*
Asia (non-Communist)	79.2	44.9	35.5	49.3
Asia (Communist)	30.6	81.0	71.1	63.2
Near East	30.6	8.4	46.4	32.5
Africa	50.6	4.7	14.9	45.5
Latin America	77.6	32.9	27.3	55.4
All LDCS	50.7	72.6	79.4	49.3

Source: M.Lipton and R.Longhurst, New Seeds and Poor People, London, Unwin Hyman, 1989, p. 2

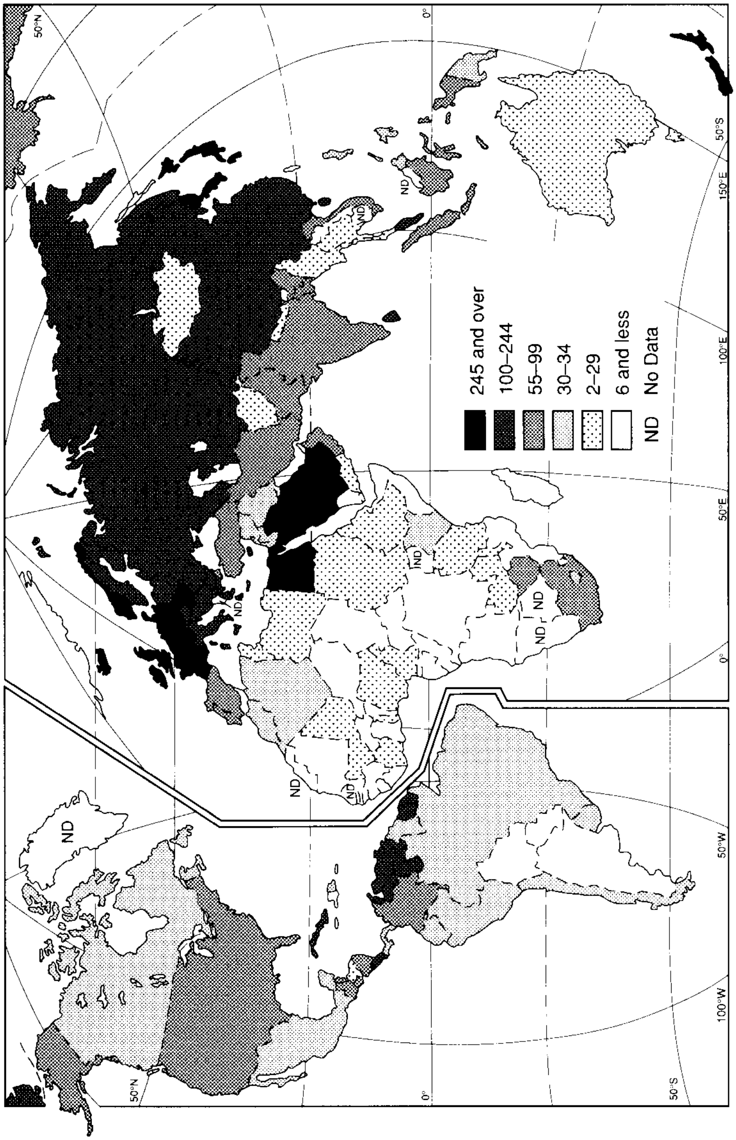

Figure 8.4 Chemical fertilizers, kilograms per hectare of arable land, 1986

Source: Food and Agriculture Organization, The State of Food and Agriculture 1989, Rome, 1989

INSECTICIDES, FUNGICIDES AND HERBICIDES

Traditional farmers can control weeds by careful cultivation, but this requires a very substantial use of labour for frequent ploughing and hoeing. The use of herbicides which destroy weeds reduces this labour input. This has revolutionized farming in developed countries, where the use of herbicides, available only since the 1940s, has been largely confined. Traditional farmers had very little control over pests such as insects, rodents, bacterial disease and fungi, although the use of rotations, mixed cropping and frequent ploughing between crops could effect some reduction. Since the 1940s there has been a considerable increase in the use of insecticides and fungicides. Expenditure upon pesticides increased 15 fold in the non-Communist world between 1955 and 1978, most of this increase being in the developed countries. In developing countries spraying is limited mainly to export crops.

IRRIGATION

The provision of water for crops other than from rainfall has a long history in Asia, but most of the present irrigated area has been established comparatively recently. In 1800 the world's irrigated area was only 8 million hectares, but had increased to 40 million by 1900. Between 1900 and 1950 a further 80 million hectares were added, and between 1950 and 1988 the figure rose from 120 million to 228 million hectares.

Irrigation has three benefits. First, it allows the cultivation of land where rainfall is insufficient for any crop growth, such as in Egypt, much of Pakistan or the oases of the Peruvian coast. Second, it is an important supplement in regions where rainfall in the growing season is variable; and third, it allows water to be stored in the wet season and used in the dry season, thus allowing two crops to be obtained during the year. A controlled water supply allows much higher yields, and also ensures that fertilizers can be fully utilized; in dry areas a low proportion of fertilizers that are applied are actually taken up by the plants roots. As a result the world's irrigated area, 14 per cent of the total arable, provides 35 per cent of the value of the world agricultural output.

But whereas the inputs so far considered are most intensively used in the developed countries, nearly three-quarters of the world's irrigated land is to be found in the developing countries, half of it in China and South Asia. (Table 8.6). There is little in Latin America; in tropical Africa, where half the continent has insufficient soil moisture for crop cultivation only 3 per cent of the arable land is irrigated.

Table 8.6 Irrigated areas of the world, 1988

	Irrigated area (million hectares)	*Total arable (million hectares)*	*Irrigated area as a % of total arable*
Developed	63.2	674.1	9.4
North America	18.9	235.9	8.0
Western Europe	11.5	94.4	12.2
Australia	2.1	47.4	4.4
USSR	20.7	232.4	8.9
Eastern Europe	5.8	45.7	12.7
Other developed	4.2	18.2	23.2
Developing	165.3	801.2	20.6
Africa	5.3	156.2	3.3
Latin America	15.6	179.8	8.7
Near East	19.5	82.4	23.7
Far East	76.8	271.4	28.3
India	41.8	169.5	24.7
Pakistan	15.7	20.9	75.1
Asian CPEs	48.1	110.0	43.7
China	44.9	96.6	46.5

Source: Food and Agriculture Organization, Production Yearbook 1989, vol. 43, Rome, FAO, 1990

DIFFERENCES IN LAND PRODUCTIVITY

Regional variations in output per hectare are different from those of output per head. They reflect not only differences in crop yield, which in turn reflect the relative intensity with which inputs are applied to land, but also whether high value crops, such as fruit or vegetables, or low value crops, such as cereals, are grown and also whether land is farmed intensively or extensively, and whether it is in crops or livestock. The highest values per hectare are found in Europe, and in East and South Asia, the lowest in tropical Africa (Figure 8.5). In Australasia, the USSR and North America values are low because so much of this land is devoted to extensive crop production or extensive rearing of livestock.

It is not possible to measure output per unit of *all* resources of land, labour and capital. However, a grouping of countries, according to whether they stand above or below the median figure for output per hectare and output per capita does produce a grouping of countries into four classes (Figure 8.6):

1 Those below the median for both land and labour productivity; this includes most of tropical Africa.
2 Those above on both counts, which include Europe, Japan, South Korea, Egypt and New Zealand.

3 Those with below median values per hectare but high output per capita: this includes the USSR, North and Latin America, and Australia.
4 Lastly the countries with low labour productively but comparatively high output per hectare which include nearly all of east, south-east and east Asia.

THE PROCESSING OF FARM AND FOOD OUTPUT

So far it has been shown that there are two salient characteristics of the modernization of agriculture: the increasing proportion of output which is sold off the farm rather than being consumed by farm families, and the intensification of production, with a sharp increase in the purchase of inputs from the industrial sector. The latter also includes the purchase of services—of accountants, veterinary surgeons, and information from farm advisory services; indeed in some countries farmers can have special contractors to undertake parts of the farm operations such as spraying or even harvesting.

A third characteristic of modernization is said to be the increasing proportion of farm produce which is processed by food manufacturers. The processing of farm produce is not new; grain has always been ground in flour mills, sugar-beet sold to factories that refine sugar, barley converted into malt or distilled into spirits. Three features, however, characterize modern agriculture in contrast to traditional agriculture.

First has been the introduction of methods of preserving perishable foods, such as canning and freezing. Second, much of the processing of products has moved from the farm to factories. Until the 1850s cheese and butter were produced only on farms; now they are largely made in factories. In addition products which were once processed off the farm in a large number of small, local firms are now dealt with by a small number of large-scale processors, which benefit from economies of scale. Thus in Britain as elsewhere in northern Europe, breweries were found in most small towns until this century, but beer output is now highly concentrated. Whereas once every village had a miller, now a small number of firms, mainly in coastal locations, undertake the milling of home produced and imported wheat. Third, much of the increase of food processing has resulted from the transference of activities which were once performed in the kitchen, to factories. These range from the washing and packaging of potatoes to the production of pre-cooked foods, the mass production of cakes or the preparation of sauces. Indeed in many developed countries the numbers employed in food processing now exceed the numbers employed on the land, as do the numbers employed in the industries supplying

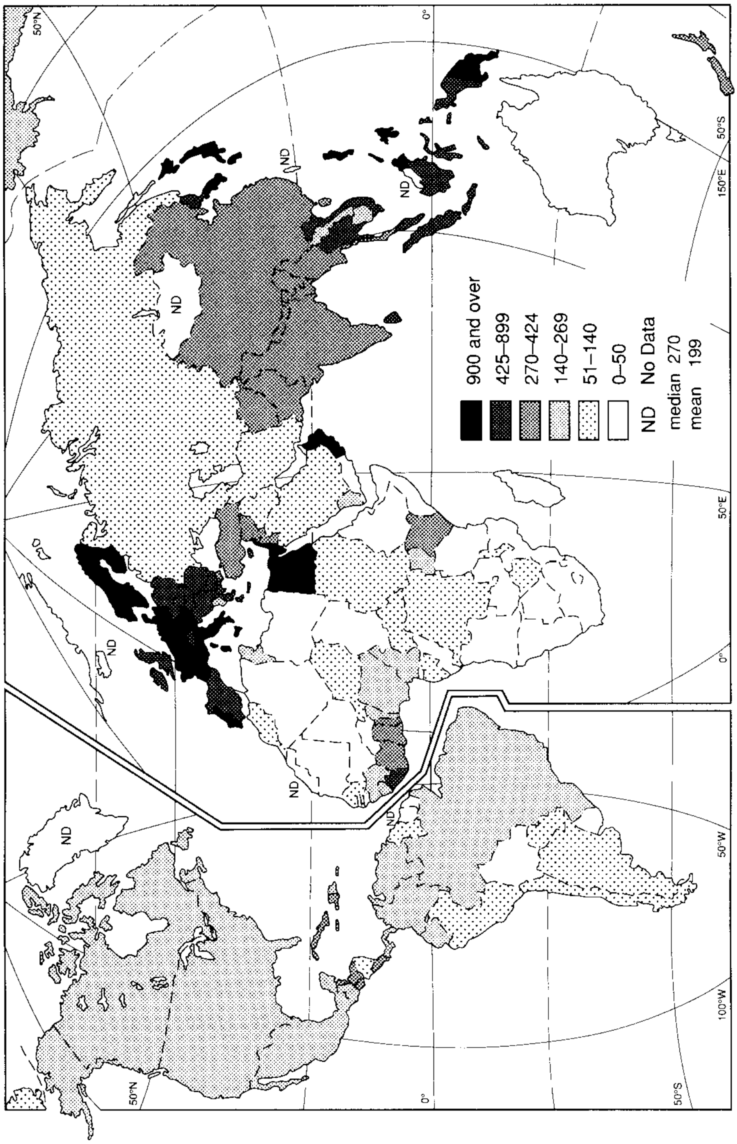

Figure 8.5 Agricultural gross domestic product per hectare of arable land and permanent grass, US dollars, 1988

Source: World Bank World Development Report, 1990, Oxford, Oxford University Press, 1990; Food and Agriculture Organization, Production Yearbook 1989, vol. 43, Rome, 1990

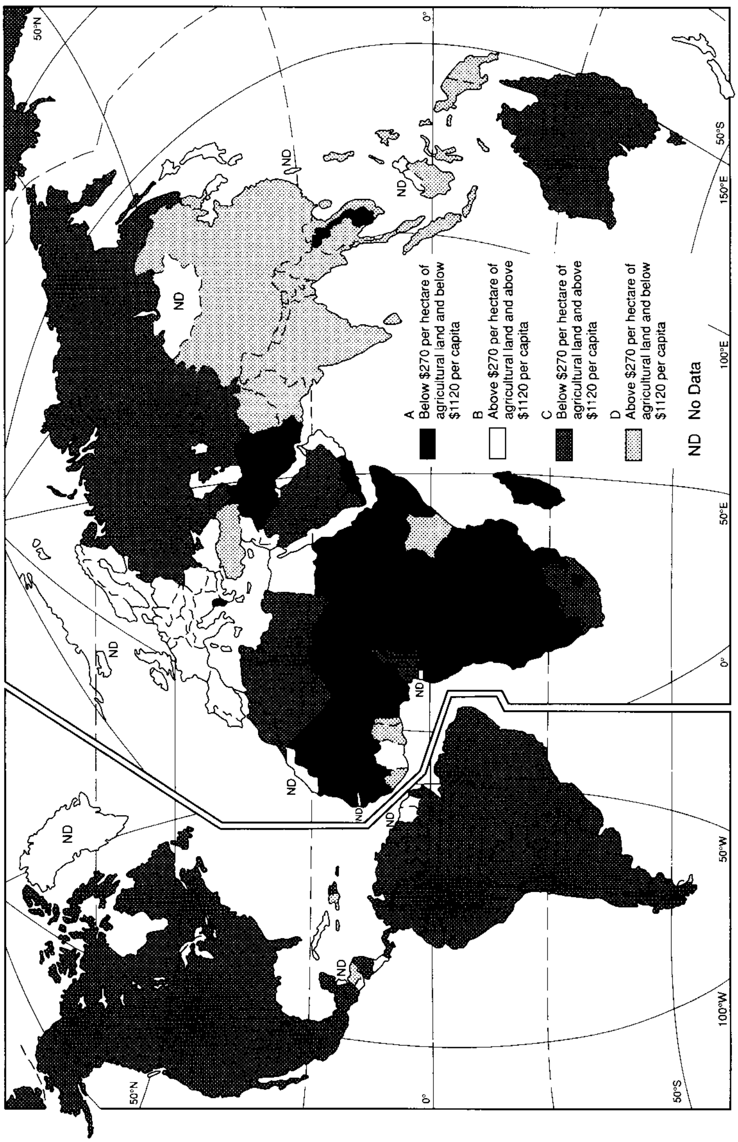

Figure 8.6 Productivity classes, 1988

Source: D.Grigg, 'World agriculture: production and productivity in the late 1980s', Geography, 1992, vol. 77, pp. 97–108 inputs. In short the farmer has become increasingly a supplier of raw materials; the food production system has benefited from the increasing specialization of all those involved in the chain, thus leading to the long-term decline in the real price of food in shops.

ECONOMIC DEVELOPMENT AND AGRICULTURAL PRODUCTIVITY

One of the paradoxes of the world pattern of agricultural productivity is that it is lowest in those countries where agriculture employs the highest proportion of the labour force, and contributes the highest proportion of the agricultural Gross Domestic Product; and that it is highest in the developed, or industrialized countries, where agriculture plays only a small part in employment or the value of total output. This leads to a further paradox: the developed countries, with only 5 per cent of the world's agricultural labour force, only a quarter of the world's total population and only 41 per cent of the total agricultural area produce more than half of the world's agricultural output. There are a number of reasons for this.

First, nearly all the developing countries lie within the tropics, and so a high proportion of their total area is arid or lies within the humid tropics, and there are agronomic difficulties in farming these areas. Yields are higher for crops grown in the temperate areas than in tropical areas, and this is not simply due to differences in the intensity of inputs. Furthermore, livestock production in the tropics is hampered by the greater prevalence of animal diseases and the inferior yields of forage crops grown there (see Chapters 2 and 3).

Second, in the industrial countries the growth of urban employment with higher wages than in agriculture has led to outward migration, a decline in the rural population and hence a fall in the agricultural labour supply. Machinery has been substituted for labour with consequently greater output per capita. In contrast in developing countries the agricultural population in spite of outward migration, continues to increase, and there is much surplus rural labour, so reducing output per capita (see Chapter 12).

Third, the industrial nations have engineering and vehicle industries and chemical industries that produce most of the world's agricultural machinery, pesticides and chemical fertilizers, and so these inputs are available more cheaply in real terms, than to farmers in developing countries.

Fourth, in developed countries non-farmers have high incomes which enable them to purchase livestock and horticultural products that have a higher price than cereals, roots and pulses, which make up most of the demand for food from the much poorer populations of the developing countries. Hence gross income of farmers is higher in the developed countries (see Chapter 6).

Fifth, over the last fifty years in the developed countries, farmers have been protected by the state, maintaining artificially high prices; in contrast developing countries have, for political reasons, protected consumers rather than farmers, and the often low prices for foodstuffs have reduced the incentive to increase output.

Sixth, in developed countries the process of industrialization has been accompanied by the spread of an elaborate transport network; the real cost of moving agricultural products and inputs has been falling, and is lower than in developing countries.

Finally the basis of modern agriculture has been the application of advances in science and technology; only the developed countries have educational institutions capable of carrying out this research. Furthermore most developed countries have agricultural advisory services that help farmers to use new crops and methods, whilst the farmers are better educated than those in developed countries.

CONCLUSION

It was shown in the first part of this book that differences in environment profoundly influence the location of crop and livestock production. In this chapter an equally important factor has been discussed—the level of economic development—for the growth of manufacturing industries, the improvement of transport, the spread of urbanization and the increase of effective demand all influence the commercialization of agriculture, and the intensity of production, and hence differences in agricultural productivity.

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Chapter 9
The state and the farmer

The economic laws that effect the farmer (Chapter 6) only operate if there is a free market for products, land, labour and capital. Yet governments in most parts of the world, but particularly the developed countries, intervene in nearly every aspect of farming life. They try to encourage the growth of particular crops by supporting or increasing prices; conversely, they may try to reduce output of others by limiting the area which can be cultivated. New technologies can be encouraged by subsidizing the use of fertilizers, new seeds or machines. The distribution of landownership can be changed by the expropriation or purchase of land and redistribution to the landless; in some countries ceilings have been placed on the amount that one person can farm. Trade in agricultural produce is limited by tariff barriers and encouraged by export subsidies. In many countries the marketing and export of cash crops is organized by the state, while in others farmers are provided by the government with expert advice on how to grow crops. In nearly all countries fundamental research on agriculture is financed by the state, and its results are freely available to farmers. In short, there are few parts of the world in which the state is not a potent force in the farmer's life. Thus the role of the state may be of major importance in determining spatial variations in agricultural activity.

REASONS FOR GOVERNMENT INTERVENTION

There are a variety of reasons for the wide-scale intervention of the state in farming matters. First is the need to ensure a secure home-grown supply of food in time of war. Most countries do in fact provide 95 per cent or more of the minimum food requirements for their populations. Few leading countries import any substantial proportion of their needs, Japan and the United Kingdom being notable exceptions. In the mid-nineteenth century the United Kingdom abolished duties on the import of grain, and later of other foods; by the eve of the First World War the country was importing about two-thirds of its food consumption. During the war, U-boats put the nation's food supply at risk. However, little protection was afforded to agriculture after the end of the war in 1918, and British agriculture was in a parlous state between the wars; food supplies were again at risk in the war of 1939–45. Thus, the 1947 Agricultural Act, which introduced an elaborate system of government support for agriculture, was prompted by (among other things) a need to secure home food supplies. British agriculture now provides 62 per cent of consumption needs. Although selfsufficiency is not an explicit aim of the Common Agricultural Policy of the European Community, the system of protection has made the member states far less dependent upon food from outside.

Second, farmers in all countries suffer from the instability of the prices of agricultural products. Crops are subject to unpredictable variations in output, owing to fluctuations in climate from year to year, and the ravages of disease and pests. Such variations in supply give rise to marked fluctuations in prices, which are accentuated because farmers find it difficult to store their produce and large quantities are marketed simultaneously. The problems of instability are particularly marked in the case of perennial crops. A period of short supply prompts plantings that begin to yield some years later. Periods of over-supply and under-supply thus alternate. International associations have attempted to stabilize the prices of products such as sugar, cocoa and coffee.

Third, most developing countries have problems in producing enough food for their populations, and in those countries where agriculture still employs a majority of the population, in providing land for those who want it. To assist in the former aim, many developing countries have encouraged the adoption of new farming methods. So the spread of the Green Revolution through Asia—the adoption of new high-yielding wheat and rice varieties—has been encouraged by government distribution of seed and the subsidizing of fertilizers. Equally important has been the creation of new farms. Governments in many developing countries have expropriated or purchased land and allocated it to landless people, while much—indeed most –clamation of new land has been promoted by the state.

Fourth, and of most importance, over the last fifty or sixty years the agricultural sector has become of declining importance in the economies of the developed countries; at the same time the gap between farm and nonfarm incomes has grown larger. Most governments have attempted to give some form of support to farmers to try and diminish this gap, or at least to prevent farm incomes falling further behind non-farm incomes, prompted partly by the power of the farm vote, partly by the feeling that this gap, which exists in developed and developing countries, is inequitable. Yet few of these policies have been successful in closing the gap. There are many reasons for this but three deserve attention.

First, in the developed countries consumer incomes are high, and most needs for food and drink are satisfied. As a result little of any increased income is spent upon food, and so the farmers' market is increasing very slowly. Second, the improved farm technologies of the post-war period have gready increased food output in North America and Western Europe. Indeed output has run beyond demand for many products, creating the familiar surpluses of the European Community and preventing any free market increase in price. Third, improved efficiency has caused the real price of food to fall continuously for much of this century but the cost of inputs like fertilizers and machinery has risen, so that farmers' real incomes have fallen. Overproduction has been compounded by the fact that there are many small producers in farming, and they frequently respond to falling prices by producing more to maintain incomes, and so depress the price even more. Indeed it is the presence of so many small producers that depresses average agricultural incomes. In most other economic activities small inefficient producers go out of production or are absorbed by larger firms. In the European Community the number of small farmers has fallen dramatically since the 1950s, but not fast enough to lead to parity of incomes with the non-agricultural sector.

As result of these and other causes farm incomes are lower than non-farm incomes, generally between a half and three-quarters (Table 9.1). Parity is most nearly achieved in developed countries, where government protection bolsters farm income; incomes are lowest relative to non-farm incomes in agrarian countries with, however, a valuable non-agricultural export, such as petroleum in Saudi Arabia.

METHODS OF INTERVENTION

Government intervention in farming in the developed countries has two main purposes: first to maintain farm incomes and second to contain or reduce farm output.

Several methods have been used to maintain farm incomes. In the past tariff protection was the most common; a commodity entering a country was subject to a levy that raised the cost of the imported food above the home produced commodity. The Common Agricultural Policy of the European Community currently imposes a levy on a wide range of temperate agricultural imports, but not on those products not grown in the community.

Table 9.1 Agriculture's share of total employment as a percentage of agriculture's share of total gross domestic product, 1990

Denmark	1.1	Ethiopia	0.6
France	0.8	Pakistan	0.5
Australia	0.8	China	0.4
Greece	0.7	Mexico	0.3
Tunisia	0.7	Saudi Arabia	0.2
Germany	0.6	Peru	0.2
Nigeria	0.6		

Note: Where shares are equal, index is 1.0.
Source: Food and Agriculture Organization, Production Yearbook 1990, vol. 44, Rome, 1991; World Bank, *World Development Report 1992,* Oxford, 1992

A second method is that of parity prices. Prices of foods are allowed to fluctuate within the country, but each year the government establishes a parity price; if farmers sell below this price, they are given the difference between the sale price and the parity price. This method is used in the USA and the European Community. In both areas there is a further protection if the farmer cannot sell; government will buy at a threshold price below parity and store the commodities. This gave rise to the celebrated butter mountains and wine-lakes in the European Community.

A third method of protection is indirect; governments in many countries, including the European Community, are prepared to subsidize farm improvements by paying part of the capital costs of new buildings, under-drainage and reclamation, and even inputs such as fertilizers.

Since 1950 the combination of new technology and government protection of farming has led to periodic surplus production of many farm commodities, and governments have tried several ways of reducing output. The most obvious is to dismantle the elaborate apparatus of price support, but this has proved politically impossible. In the European Community two methods have been tried. First, in the 1980s the parity price—known as the target price—was not increased as fast as inflation; indeed in 1992 the Community was prepared to cut target prices by onethird. Second, farmers have not received the target price on quantities produced above a given threshold.

More common have been physical methods to limit output. In the European Community each country cannot plant more than a given quota of sugar-beet or potatoes, and dairy farmers have been limited in the volume of milk they can produce. In the USA in the 1930s the government introduced schemes whereby farmers were paid to withdraw land from cultivation for crops such as cotton and wheat that were in surplus. These schemes have continued intermittently to the present day. In 1987 68 million acres, 18 per cent of the total cropland, was temporarily withdrawn from cultivation.

At the heart of the problem of low farm incomes, however, is the existence of large numbers of small farms that cannot produce enough to provide a satisfactory income, which are too small to utilize fully the labour available, and too small to benefit from the economies of scale in the utilization of labour. The European Community has therefore employed rather half-hearted schemes to reduce the number of uneconomic holdings by providing pensions for farmers who retire early, and paying part of the costs of farm amalgamation.

The best way to deal with the spatial impact of government policy upon farm production is by example. Two commodities, sugar and cotton, are discussed below, and then the effects of European Community efforts to limit output are examined.

SUGAR-BEET AND SUGAR-CANE

The history of sugar production illustrates the importance of two centuries of political intervention in agriculture. Europeans obtain their sugar from either sugar-cane or sugar-beet. Sugar-cane was introduced into the Mediterranean basin by the Arabs after the seventh century AD, and taken in the sixteenth century to the Americas. Sugar was not commercially extracted from beet until 1799, and as late as the 1850s sugar-cane still provided 85–90 per cent of world consumption. There are three problems. First, sugar-cane is a subtropical crop produced mainly in the developing countries; sugar yields are generally higher than those obtained from beet, and production costs lower. Second, sugar-beet is grown mainly in cool temperate regions, in developed countries, and owes its origin to state subsidies and tariff protection. Third, most of the sugar in world trade comes from sugar-cane and moves mainly to the developed world. There has thus been a constant problem of over-production since the beginning of this century. International conferences, beginning in Brussels in 1903, have attempted to resolve this problem, but without much success.

The sugar-beet industry in Europe can be traced back to the Napoleonic Wars. Britain's blockade of the Continent limited the import of cane-sugar from the Caribbean, which was then the major source of supply. Napoleon encouraged experiments with sugar-beet factories, which had been first established in Silesia in 1799, but at the end of the wars cane-sugar was again available. However, sugar-beet production became well established in Germany with the aid of subsidies upon home-produced beet and duties on imported sugar. Such a system spread to other European states, and the growth of beet-sugar production was rapid in the late nineteenth century, so that by 1900 it provided 47 per cent of world consumption.

Sugar-beet was then grown in considerable amounts in every West European state except Great Britain, which continued to rely upon sugar from its cane-growing colonies in the West Indies, Mauritius, Natal and Fiji (although West European beet growers were also supplying the British market). Attempts had been made to grow sugar-beet in Britain in the nineteenth century, but these had failed. However, the problems of securing supplies in the First World War, and the depressed conditions in British agriculture in the 1920s encouraged the government to introduce a subsidy on British beet-sugar in 1925. Sugar-beet not only provided sugar, but also the residue of the plant could be sold back to farmers as cattle feed. Sugarbeet fitted easily into rotations in eastern England, and the need for fertilizers and intensive cultivation benefited following crops. After 1925 there was a rapid expansion; in 1924 there were only three factories, by 1928 there were seventeen. The area in sugar-beet rose from 8855 ha in 1924 to 139,568 in 1930, and by the late 1980s was not far short of 200, 000 hectares. In Western Europe, Britain's area is exceeded only by Germany and France.

EEC policies on sugar-beet have included both tariffs on imported sugar-cane (except from former British colonies and some French colonies), and quotas which decide how much each country can grow. This has led to considerable surpluses of sugar, both from high production at home and quota imports of cane-sugar. Exports from the EEC, mainly by France, are only possible with export subsidies. The British sugar-beet industry, largely a result of state protection (as indeed were the other beet-sugar producers), is now vulnerable, as yields are the lowest in the EEC and annual variability the highest.

COTTON IN THE USA

In the 1920s, the USA produced about 12 million bales of cotton a year, half of which was exported. Two-thirds of this output was grown in, or east of, the lower Mississippi valley, much of it on small farms. The depression, beginning in 1929, reduced demand for cotton at home and overseas, and the price of cotton fell. Subsequently, the introduction of synthetic fibres further reduced demand, and the expansion of cotton production elsewhere in the world, often at much lower cost than in the USA, further exacerbated the problems of over-production of cotton. In 1933, the United States Congress passed an Agricultural Adjustment Act, the first of a series of measures which tried both to maintain the incomes of small cotton producers and also to reduce output. From 1933, the government annually announced a parity price, usually well above the world price; the government was obliged to buy cotton not sold at parity, and so accumulated stocks. But the government also annually announced a quota, the total area of cotton that could be grown; each individual farm received a quota, normally a percentage of previous years—a system abandoned in 1971. Other measures included payments to farmers who planted land to hay, pasture or legumes.

The result has been a remarkable decline in the United States cotton area, from over 16 million hectares in the 1920s, to an average of 4.5 million in the mid-1980s. This has not been entirely due to government action. Soybeans has proved a profitable alternative to cotton in the south, and the decline of the labour supply, a result of migration to northern cities, has made it increasingly difficult for many farmers to grow cotton. However, although the area planted with cotton has contracted, output has fallen far less. When farmers had to withdraw land from cotton, they abandoned the poorer land, concentrating its cultivation on better soils, while there have been considerable increases in cotton yields due to increased use of fertilizer. Thus output is not far short of the level of the 1920s, although the location of production has radically changed. Three-quarters of the area under cotton now lies west of the valley of the Mississippi, and is grown on large, mechanized and irrigated farms. In the traditional south cotton is no longer king. Ironically, state intervention did little or nothing to reduce stocks. Not until price support was reduced in 1971 did stocks begin to fall substantially.

THE COMMON AGRICULTURAL POLICY OF THE EUROPEAN COMMUNITY

The Common Agricultural Policy came into effect in 1967, when there were only six members, and still applies in 1994, much modified with twelve members. More radical changes will occur in the 1990s as a result of new policies established at the GATT agreement of 1993. For many years the European Commission established annually target prices high enough to provide the least efficient producers with a living and large farmers with considerable profits, for lower priced foreign products were excluded by a levy on imports. The Commission also undertook to buy and store any produce that could not be sold. Not surprisingly many commodities were in surplus, but it was not until the 1980s that any serious efforts were made to constrain output.

Milk quotas

In the 1970s milk yields rose throughout the European Community, and by 1983 milk output was 111 million tonnes, of which 25 million tonnes was surplus. The European Commission therefore decided to control output by allocating each country a quota of milk on which target prices were to be paid; surplus product was penalized. In the United Kingdom each registered milk producer was given a quota, which was 1 per cent below 1983 output, and the quota has since been progressively reduced. This has had widespread implications, for 30 per cent of all the European Community farms keep dairy cows. Farmers reacted in a number of ways. Some cut the feeding of concentrates to reduce milk yields; others culled their older cows, yet others left milk production altogether. But some produced more, for the quota allocated to a particular farm could be sold to others, and many large, efficient producers bought the quota of small farmers. In the 1980s the European Community's dairy herd fell by 17 per cent; this was mainly due to the decline of the number of small herds. Herds under 20 cows accounted for nearly four-tenths of all herds in 1979, but by 1987 accounted for only one-quarter. But yields did not fall in the long run, and milk is still in surplus, albeit not on the scale of the early 1980s.

Set aside

Milk and cereals were the principle surpluses in the European Community; various attempts to curtail cereal output by manipulating prices failed, and in 1988–89 a policy of acreage contraction based on the United States setaside scheme was introduced. Farmers were to be paid £200 per hectare if they were prepared to withdraw 20 per cent of their land in supported crops for five years. The initial reaction was limited in the European Community; only 1 per cent of the total arable area was withdrawn in 1988–89, generally on poor land or near towns. American experience suggests that set aside will not necessarily reduce output, for farmers withdraw their poorer soils and use more fertilizers on their better land.

Regional policies

Very few state agricultural policies are confined to one region, but, in 1975 the European Community, which has attempted to encourage modernization, farm amalgamation and the retirement of older farmers on small farms, asked member countries to identify poorly-endowed regions which deserved subsidies, to be allocated on the basis of either the area in crops or head of livestock. Member countries were to make the payment, but the European Community would refund 25 per cent of the subsidy. Three types of region were identified (Figure 9.1). First, mountain areas with problems of steep slopes and high altitudes. Second, areas threatened with depopulation, and with farm incomes below the national average. This included upland regions in southern Germany and areas of sandy soil on the North European plain, while in Britain this zone encompassed the upland areas of Wales, Scotland and northern England. A third category embraced areas where support for farming was necessary to preserve the countryside for tourism, or for other special reasons. The million farms in these three regions occupied one-quarter of the agricultural land of the European Community but produced only one-tenth of its output.

The upland regions of Britain have long presented problems, and in the last half-century the British government has provided some support for hill farmers. Since the middle of the nineteenth century, out migration of the young has led to depopulation; sparsely populated, it has been costly to provide services, and as numbers have fallen so services have been even more difficult to sustain. The essential problem has been, however, the poverty of the environment. High rainfall, acid soils and a short growing season preclude the growth of all but the hardiest crops for fodder, while even permanent pasture is rare (see Chapter 4). Three-quarters of the agricultural area of British sheep farms is in rough grazing. Farmers are thus limited, except in the lower hill areas, to hill sheep farming. The flocks of ewes produce lambs which are sold to lowland farmers for fattening, mutton from ewes past lambing, and wool, which, however, is in competition with imported wool. Hill sheep farming gives the lowest net return per hectare of any English farming type, and although farms are large— averaging 200 ha—farm incomes are low. Thus half of Welsh sheep farmers in the 1970s had *less* than a farm labourer's wage to live on, and with which to pay interest on any capital borrowed, while a further quarter had incomes only equal to a farm labourer's wage.

The British government has in effect implemented regional subsidies since the Second World War. Since 1940, a subsidy has been paid annually on each ewe kept on rough grazing, while after 1943 subsidies were paid on hill cows (cows kept on poor land over 100 m above sea level). In addition, the state financed half the capital improvements made on farms above 244 m. These payments have not greatly improved the standing of upland farmers; subsidies were rarely more than one-third of gross income, although a much higher proportion of net income. Without subsidy, however, there would be fewer hill sheep farmers.

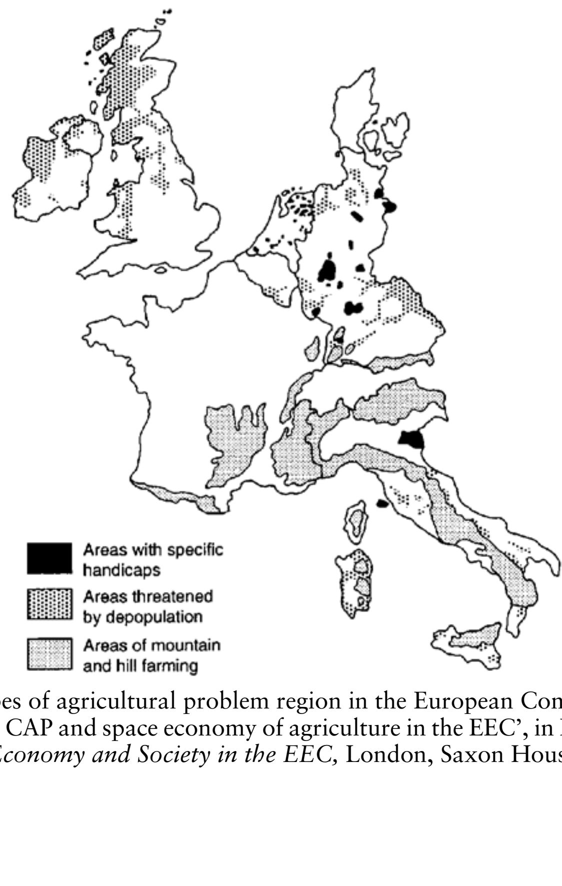

Figure 9.1 Types of agricultural problem region in the European Community After I. Bowler, 'The CAP and space economy of agriculture in the EEC', in R. Lee and RE. Ogden (eds), *Economy and Society in the EEC,* London, Saxon House, 1976

LAND COLONIZATION AND LAND REFORM

In the developing countries the central problem is to produce more food, and so the state has often provided assistance to increase production. But there is a further problem. In most developing countries a large proportion of the population relies upon farming for a living; these numbers are rapidly increasing, and there are few opportunities for employment outside agriculture. A need exists, therefore, to provide farms for the landless, and there are two ways in which this can be done. First, where much of the land is owned by a small number of landlords and farmed in large units, this land can be purchased or expropriated by the state and divided up into smaller farms for the landless. Second, land not used for agriculture can be reclaimed and the landless settled upon new farms. The state has played such a role in many countries in Afro-Asia and Latin America since 1950.

Since the Second World War, there has been a considerable increase in the area sown to crops in the developing countries. In some cases this has been achieved by increasing the amount of land double cropped; sometimes it has involved reclaiming poorer land on the edge of villages. But substantial areas have been added by the colonization of hitherto unpopulated or sparsely populated waste land. Such schemes invariably require the support of the state, for on poor land the cost of clearing the land, providing irrigation and building roads is beyond the individual. There are a variety of reasons for state support of such schemes. In some cases it is to provide a cash crop to export, as in the case of the Gezira cotton scheme in the Sudan, and in many of the irrigated projects in the savanna interiors of west Africa. Elsewhere the reclamation of new land is for welfare reasons. For example, in India after Independence there was a need to provide land for the refugees of partition, and the Indian government has continued to try and supply farms for the landless. About half those settled on state colonization schemes in India between 1947 and 1971 had been landless. But in most of the developing countries, a fundamental reason for colonization schemes has been to increase food output for a rapidly growing population. Government-sponsored colonization schemes have had an apparently important contribution to make in Asia. Thus, between 1950 and 1963, 200,000 colonists from Java were settled in Sumatra; in Malaysia over half a million were resettled during the Emergency, 1949–53, and a further 20,000 in more peaceful conditions, 1956–64. In Ceylon 128,823 ha were reclaimed, mainly in the Dry Zone, between 1947 and 1966. By far the largest schemes have been in India where, from Independence to 1971, 600,000 ha were brought into cultivation, providing homes for 800,000 people. But however large this may seem, it is a minute fragment of India's cultivated land, and an even smaller fraction of rural population growth in this period. Some have argued that the extension of the cultivated area is too expensive, and that money would be better spent supporting the more intensive farming of existing cropland. But this of course neglects the welfare aims of colonization schemes.

Immediately after the Second World War, it was thought by many that a better standard of living and higher productivity in agriculture were only possible if land reform was carried out. There were several strands of thought behind this contention. First was the obvious injustice of the unequal distribution of landownership in many countries. In many Latin American states much of the land was—and still is—concentrated in a small number of large estates, while the bulk of the rural population had too little land for a reasonable living, or none at all. Even where land ownership was not so inequably distributed, it was argued that tenancy was unjust, and that farmers who owned their land would be more efficient and productive. Thus the last fifty years have seen wholesale changes in landownership in the developing world.

The most radical changes have come in those countries which have come under Communist rule, most notably China and Eastern Europe. Here, the landlord was first expropriated, and the peasant given the land. Then the peasant farms were grouped in collectives. But there were almost as radical changes elsewhere, for example in Iran beginning in 1951, or in Kenya after independence. Some of the most impressive results of land reform can be seen in Taiwan. Reform began with Acts in 1951 that provided the tenant with security and controlled rents. In 1953 the government compulsorily purchased private land in holdings above 6 ha of wet-rice land and 12 ha of dry land, and provided purchasers with comfortable credit terms. As a result the proportion of farm land cultivated by owner-occupiers rose from 56 per cent of the total in 1948 to 86 per cent in 1959. Taiwan has achieved a remarkable rate of productivity increase in agriculture since the Land Reform.

CONCLUSIONS

It is impossible in such a short space to do more than touch upon the widespread influence of the state in agriculture. There are few parts of the world where the state has not influenced the spatial pattern of farming, either by encouraging land settlement in particular regions, protecting particular products, or encouraging new farming methods. It is a factor that cannot be neglected by the agricultural geographer.

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Chapter 10
Markets and transports

The first model of agricultural location was put forward by a German economist, J.H. von Thünen, in his book *The Isolated State,* published in 1826. He argued that distance from the market was the main determinant of what combination of crops a farmer should grow and with what intensity. His model has been much criticized by later writers, and attempts have been made to modify it.

VON THÜNEN'S RINGS

Von Thünen's book contained two theories, the intensity theory and the crop theory, and to demonstrate them he devised an imaginary state in which all the other factors that might influence land use patterns were held constant. The isolated state was a plain without any climatic or soil variations; farm produce could be marketed in only one place, a town in the centre of the plain. The plain was bounded by a wilderness and there were no imports or exports. The price of farm goods was set in the town; farm produce was transported by waggon to this central point, and the cost of movement was paid by the farmer and was directly proportional to the weight of the produce and the distance it travelled. As the farmer paid the cost of transport to market, the amount a farmer received for produce diminished with increasing distance from the market. Farmers were assumed to be attempting to maximize their profits, and made prompt responses to changes in prices.

Von Thünen used two terms in his analysis which need explanation. He did not refer to profit but to land rent, usually called economic rent by modern writers. This was the total revenue received by the farmer for the sale of his or her goods minus production costs on the farm, interest on the capital invested in the land and buildings, the cost of the farmer's own labour and a wage for the farmer's managerial skills. Land rent was thus a residual, a return due to the land alone as a factor of production. Von Thünen also used the term *intensity,* and by this meant the cost of labour per hectare. At the time when he wrote, land and labour were the most important farming inputs. Production with few labour inputs per hectare was called extensive; that with many labour inputs per hectare, intensive. The terms were used in a relative sense rather than on an absolute scale, and are now also used to describe types of agriculture or farming system, as well as the production of one crop (see above, Chapter 7).

THE INTENSITY THEORY

Von Thünen began by imagining that only one crop was grown in the isolated state. By using farm accounts he showed that growing the crop without a fallow, and thus using much labour, would give a high economic rent near the town, but with increasing distance from the market the price received by farmers fell, for the price at the market was reduced by the cost of transporting the crop to market. Consequently economic rent would also decline with increasing distance from the market (Figure 10.1a and 10.1b, Crop I in 10.1c).

If the crop was grown in a rotation which had a fallow—a year when no crop was grown—then fewer labour inputs were necessary. This would give a lower economic rent near the market (Figure 10.1c, Crop II) but economic rent would decline less steeply with increasing distance from the market. Eventually the more extensive system would give a greater economic rent than the intensive system (Figure 10.1c, at E). The rational farmer who wished to maximize profit would switch from intensive methods to less intensive beyond E.

Von Thünen came to this conclusion by studying farm accounts of two different farms, but it can be justified by marginal analysis (see above, Chapter 7). Farmers who wish to maximize profit, revenue or economic rent will increase or decrease inputs until the price of the marginal input equals the marginal revenue. A farmer who is near the market has little to pay for transporting grain to market and will use much labour to maximize revenue. The farmer at a distance receives less for his or her grain because of the cost of transporting it to market. This farmer will maximize revenue by using fewer inputs than the farmer near the market (Table 7.3, p. 76).

THE CROP THEORY

It is von Thünen's second theory, the crop theory, that is best known today. He argued that the farmer who wished to maximize economic rent would change the combination of crops and animals that he or she kept—or type of agriculture—as distance from the market increased, and hence the price received at the farm gate declined. As prices declined at an equal rate in all directions from the town, this gave rise to a series of rings of different land uses around the market. However, the intensity of these different land uses, or farming systems, did not necessarily diminish with increasing distance from the market, as is often stated.

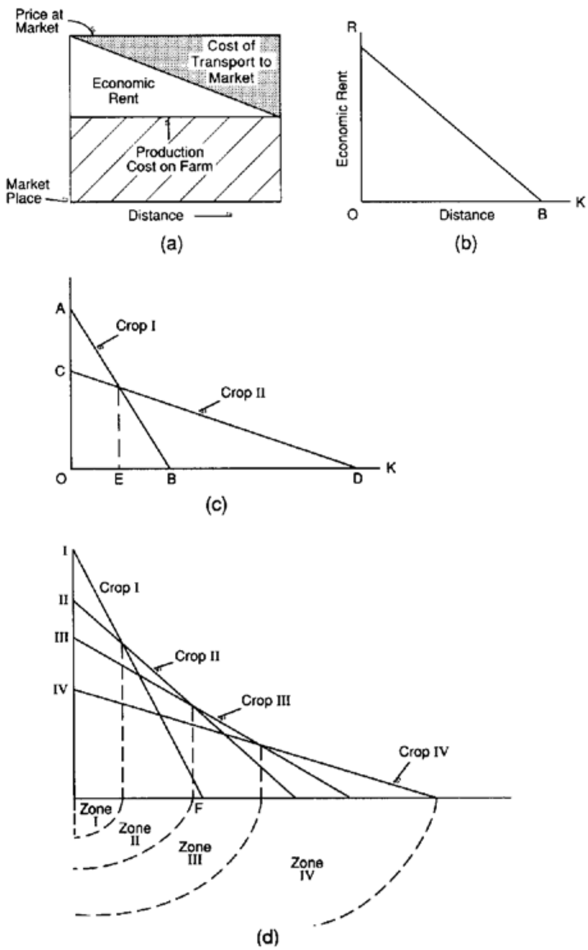

Figure 10.1 The formation of land use rings around a central market

In the free cash cropping zone (Figure 10.2) two types of commodity were produced: those which were highly perishable, like milk or fresh vegetables, and those with a very low value per unit weight, like straw or potatoes. The second zone was devoted to forestry; the inner part to firewood, the outer to timber. Timber was, of course, more widely used in von Thünen's time. It was not, however, an intensive system, for there were few labour inputs per hectare, and its location was due to its low value per unit weight of product, which could not be profitably marketed in the town if grown a great distance away. This zone was followed by three farming systems with a progressive increase in fallow outwards, and hence fewer labour inputs. In these cases intensity did diminish with distance from the market, and this sequence was justified by the intensity theory. The outer zone was described by von Thünen as one of stock farming; it certainly produced wool, store cattle for fattening near the town, and butter, but cereals were also grown for distilling into alcohol, rape-seed for oils, and tobacco.

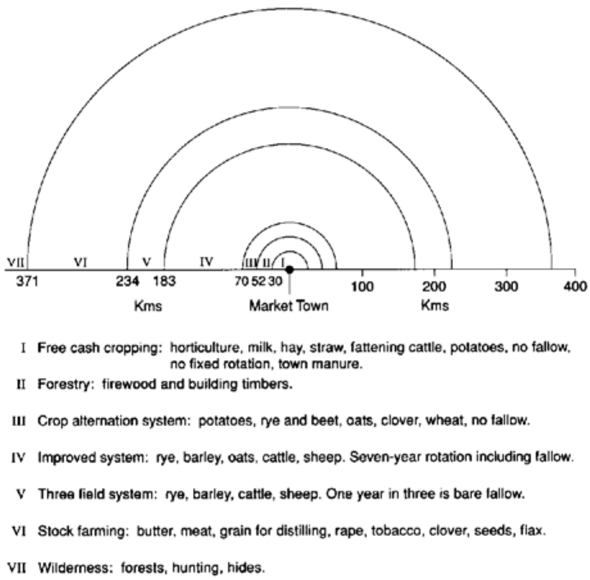

Figure 10.2 Von Thünen's land use zones After W.B. Morgan, 'The doctrine of the rings', *Geography,* 1973, vol. 58, pp. 301-12

It is in fact difficult to discern the principles that determine the zones, but four can be inferred from von Thünen's analysis.

1 Highly perishable commodities like milk must be produced near the market.
2 Products with a low value per unit weight, such as wood or straw, must be produced near the market because the cost of transporting a unit will equal the price received at the market after only a very short distance.
3 Products with a high value per unit weight, such as wool or tobacco, *may* be produced at some distance from the market, for they *can* tolerate the high cost of transport to market.
4 Some goods which are perishable may be processed into less perishable commodities which also have a higher value per unit weight, and can

then be produced at a distance. Milk for fresh consumption must be produced near the market, but at a distance it can be converted to butter or cheese, which are less perishable and more valuable. Similarly, low-value products can be processed to give more expensive products; thus grain can be converted to alcohol.

CHANGING TECHNOLOGY AND VON THÜNEN'S MODEL

When von Thünen wrote, there were few effective ways of preserving foods for long periods, and freight rates were high and a large proportion of the total cost of producing and marketing agricultural produce. Since then there have been significant changes. The introduction of bottling, canning and refrigeration have made it possible to move perishable products long distances, and railways, lorries and aeroplanes have allowed perishable produce to be moved much faster as well as much further. The consequence of this is that, while the production of fresh milk and vegetables is still found near cities, it is possible for both to be produced at some considerable distance away from the major markets.

In the United Kingdom, London's milk supply, once limited to the city's immediate hinterland, can now be drawn from as far away as Cornwall and Derbyshire, areas whose better grass growth gives a comparative advantage in dairying. Similarly, crops of low value per unit weight such as the potato are no longer confined to areas near the market. Much of England's potatoes are now grown in the Fens, with its deep loam soils, while early potatoes and other vegetables are grown in the south-west where milder temperatures allow early production. In North America the principal market for vegetables and fruit was and remains the north-east, but the adoption of canning, refrigeration and the spread of the railway in the late nineteenth century have allowed California and Florida, with their climatic advantages for the production of fruit and vegetables, to compete in the north-east. In the nineteenth century, fruits and vegetables were widely grown in the Mediterranean but were consumed only locally, even though the large urban population of north-west Europe provided a potential market. The introduction of refrigeration on ships, and the replacement of sail by steam and later made it possible to send citrus fruits as well as vegetables northwards, and have led to horticultural specialization in many areas on the Mediterranean shores.

Since the 1820s there has been continuous decline in real freight rates and the cost of moving agricultural produce has become a decreasing proportion of the combined cost of farm production and transport. However, this decline has not removed two important transport differentials. First, the transport of most farm produce is still cheaper by water than overland, as indeed von Thünen recognized. One of his modifications of the Isolated State was to allow a river to cross the plain to the market; then all the rings extended further out. Second, the reduction of freight rates has not removed the differences in the value per unit weight of agricultural products. There is still a limit to the distance that a cheap, bulky product can be moved, while in contrast high value goods can be moved much further.

Some writers have argued that transport costs have fallen so low that they are no longer of much significance for the location of agricultural production. Farm products will now be grown where there is an advantage in terms of good soils, a favourable climate, or a cheap labour supply. Unfortunately there is little information on the cost of moving farm goods. In the USA in the 1950s the cost of transporting farm products from the farm to the first point of consumption was 10 per cent of the combined cost of farm production and transport, and this proportion has declined since. In New South Wales in the 1960s transport costs were less than 5 per cent of gross returns for wheat, lambs, wool and beef; only for milk, where the figure was 15 per cent, was location near to market likely to have been a significant factor.

MODERN MODIFICATIONS OF VON THÜNEN

Some modern writers have attempted to improve the theoretical structure of von Thünen's model. They have confined themselves to the crop theory, and have shown, using the following formula, how farmers will try to maximize economic rent at given distances from the market:

$R=E(p-a)-Efk$

R=economic rent per unit area of land

k=distance from the market

E=yield of crop

p=market price per unit of commodity

a=production cost per unit of commodity

f=transport cost per unit of distance for each commodity

The relationship between economic rent and the market place O is demonstrated in Figure 10.1b. At O, transport costs to market are zero and the farmer receives the full market price. But for farmers anywhere between O and K, economic rent declines as transport costs increase and the price received at the farm gate declines, until at B economic rent becomes zero and cultivation ceases. If, however, the price of the good increases, the margin of cultivation can extend outwards; similarly if the price declines, then the margin of cultivation contracts towards O. Farmers are assumed to be commercial farmers, and will not grow crops beyond B, although subsistence farmers may do so. It is the absence of transport that explains the persistence of subsistence farming in parts of South-East Asia and Africa (see above, Chapter 7).

In Figure 10.1c two crops are considered. Crop I produces the higher economic rent near the market, and is therefore cultivated in preference to Crop II. However, the gradient of the economic rent line of Crop I is steeper than that of Crop II. Hence the farmer aiming to maximize economic rent will change from Crop I to Crop II at E. A similar transfer from Crop II to Crop III will take place at F (Figure 10.1d) and for the same reasons. This gives rise to the sequence of rings and differing land uses around the central market place. Clearly, the precise nature of these rings will depend upon the figures fed into the formula R=E (p—a) — Efk. This exposition also depends upon the assumption that the higher the economic rent per hectare a crop gives on the farm, the more rapidly transport costs will reduce this. There are few empirical studies that support this contention.

TESTING VON THÜNEN

There have been many attempts by modern geographers to test von Thünen's belief that crop combinations and crop intensity change with increasing distance from the market, but this testing is far from easy to carry out.

First, there are few parts of the world where the conditions of the Isolated State are to be found. Few large areas have no internal variations in climate or soil type, nor are there many states or large regions where there is only one market for agricultural produce. There are, however, some approximations to this condition: the north-east of the USA has a high proportion of the non-rural population of the country, but a low proportion of the agricultural land. Several writers have argued that land values, land use and net farm income per hectare change with increasing distance from the north-east, and that the great metropolitan region of the north-east influences United States agriculture in much the way that von Thünen envisaged.

Second, von Thünen assumed that there were no spatial variations in soil type and climate within the Isolated State. Not only is such uniformity rare over large areas but, as the real cost of transporting farm products has fallen, so the advantages offered by optimum climates or soils have increased the concentration of production in such areas.

Third, it is difficult to test von Thünen by comparing the location of types of farming in relation to market because some of his types of farming are no longer found in Europe: the three mixed farming systems with fallow which occupy so much of the Isolated State no longer exist in their early nineteenth-century form, while few of his types are to be found in the tropics.

Fourth, it is difficult to test using von Thünen's measures of economic rent and intensity. Economic rent is not easily measured: the value of land

and buildings, and contract rent, which have been used as surrogates by some writers, are certainly not the equivalent of economic rent. Nor is von Thünen's measure of intensity applicable today. Labour has greatly declined as an input; in modern Britain it accounts for only one-fifth of total agricultural production costs, excluding horticulture, pigs and poultry. There are, however, still considerable variations in intensity between types of farming (Table 7.1, p. 72). Horticulture, dairying and general cropping, which includes the cultivation of sugar-beet and potatoes, are all intensive whether measured by the number of man-days worked in a year, the cost of labour per hectare, or the cost of *total* inputs per hectare. In contrast, specialized cereal production and livestock rearing are extensive types of farming by all three measures of intensity, and net farm income per hectare is much lower than in the intensive types of farming.

DISTANCE AND FARMING TODAY

Although it is difficult to show that distance from the market is the exclusive or even dominant factor in determining spatial variations in agriculture today, it is none the less important not only at the scale that von Thünen considered, the national scale, but at the farm level and on the world scale. Many such examples are documented in Michael Chisholm's book *Rural Settlement and Land Use,* and only a few examples are considered here.

Villages and farms

In parts of Western Europe, Australia and North America farmers live in isolated farmsteads, with their fields surrounding the farm house and at some distance from other farms. Elsewhere the homes of farmers and their farm buildings are grouped together in villages and their fields lie some distance away. Either way farmers have to spend time travelling to the more distant fields to cultivate them. Where tractors are available and the fields are compact these costs may be small. But where fields are remote —research suggests over 2 km—and there is no cheap farm transport, it is likely that less time will be spent on the outer fields. Thus, the nearer fields will be farmed intensively, the remoter fields will be farmed extensively or be in less time-consuming crops.

A good example of the latter case comes from the area around Agogo, a small town to the east of Kumasi, which in 1946 was in Ashanti Crown Colony, now part of Ghana. The natural vegetation of the area was rain forest, but most of this had been cleared for cultivation; on land abandoned to fallow the natural vegetation was recolonizing. Two types of crop production were found. Small patches of forest were cleared for food crops, including cocoyams, maize and cassava; after two or three years in

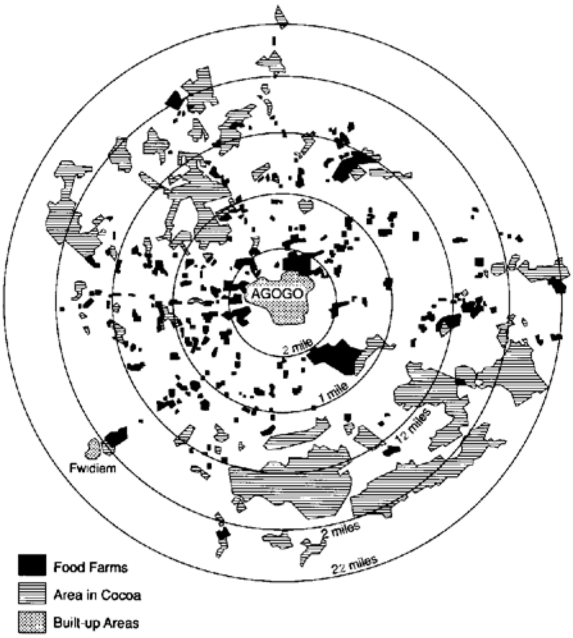

Figure 10.3 Land use in Agogo, 1946 After M. Fortes, R.W. Steel and P. Ady, 'Ashantia Survey, 1945–6; an experiment in social research', *Geographical Journal,* 1947, vol. 110, pp. 149–79

crops the land was abandoned and left to be colonized by trees and grass. In contrast there were quite large areas in cocoa bushes. Once this land had been cleared the bushes would yield cocoa beans for several years, requiring little attention. Food farms, in contrast, required frequent attention. Thus, most of the food crop farms were within 1.5 km of Agogo, a majority of the cocoa farms beyond this (Figure 10.3).

In modern farming capital inputs are more important than labour, and intensity should perhaps be measured in terms of total inputs. This is not always easy to do. A study of farms around the three small towns of Bega, Barraga and Bemboka in New South Wales used livestock units per hectare of farmland as a measure of intensity (Figure 10.4), on the grounds that the number of cattle which could be supported was a function of capital inputs such as fertilizer, improved seed and purchased feeds. In this area of dairy farming, intensity did decline away from the towns.

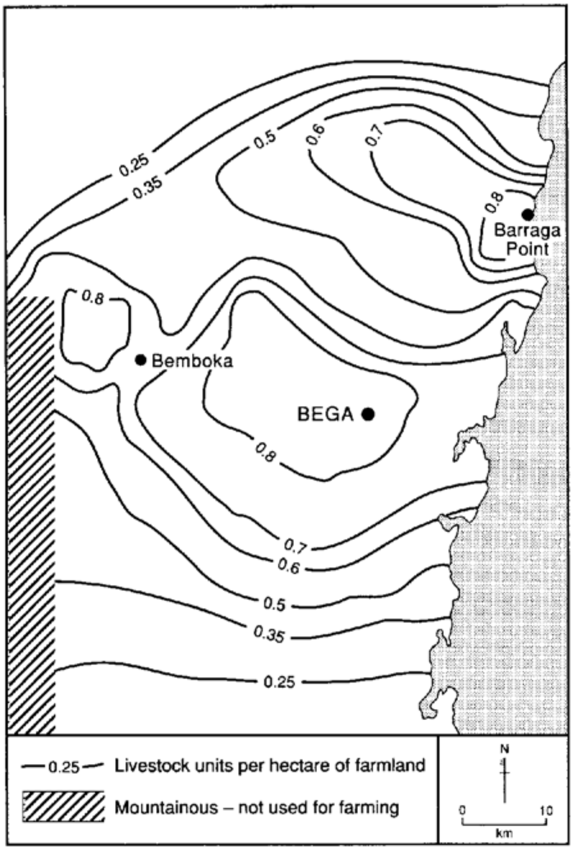

Figure 10.4 Intensity in dairy farming in New South Wales After E. Dayal, 'The present pertinence of Von Thünen theory in an advanced economy: a case from south east Australia', *Proceedings of the International Union Regional Conference 1974,* Hamilton, New Zealand, 1975

Zones within a country

Uruguay appears to conform quite closely to the conditions of the Isolated State. Most of the country is a low-lying plain with uplands only in the east. There is litde trade westwards across the Rio Uruguay, or northwards with Brazil, and most of Uruguay's trade flows through Montevideo, which has 43 per cent of the country's population and is the dominant market. A rail network extends radially outwards from the capital; there are no east-to-west lines. Uruguay has a warm subtropical climate, with no significant internal contrasts. Under these circumstances a zonation of land use around Montevideo might be expected, and indeed at first sight this is borne out (Figure 10.5). Viticulture and orchards are found to the north of

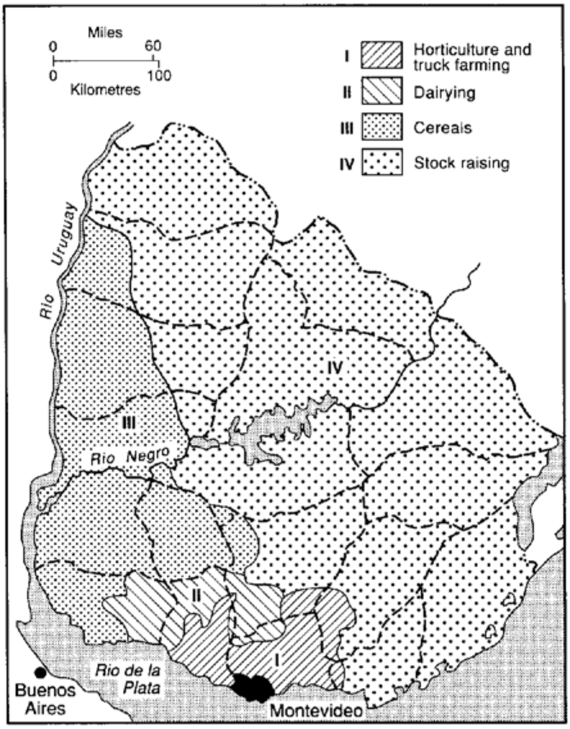

Figure 10.5 Land use regions in Uruguay After E. Griffith, 'Testing the von Thünen theory in Uruguay', *Geographical Review,* 1973, vol. 63, pp. 500-16

Montevideo; the town is surrounded by an arc of intensive crop production, to the north of which lies a zone of dairying. Beyond this, but not in concentric circles, lie cereal and livestock production. But these zones are aligned north-south, not east-west. Most of northern, central and eastern Uruguay is devoted to sheep rearing and cattle ranching. This is largely explained by the distribution of soil types, the good and medium soils being confined to the south and west, where the more intensive farming is found.

Value, perishability and trade

In von Thünen's model, perishability and the value of the produce were important determinants of location, and there was no trade outside the state. It may of interest to see if either of these factors influence presentday trade in agricultural products. In Figure 10.6 the value per unit weight of products is plotted against the proportion of world output entering world trade, the assumption being that the higher the value per unit weight, the more that could move long distances; conversely the lower the value, the shorter distances that can be moved and hence the lower the amount in world trade.

In the case of high value non-perishable commodities (Figure 10.6) a high proportion of total product does enter the world trade. It is of course the high value that allows countries as remote from the major markets as Australia and New Zealand to export wool. Coffee also illustrates this point. Some of the leading coffee producers are not only remote from Western Europe, but some distance from the coast and the cheaper sea routes. The interior of West Africa and Kenya are cases in point. Uganda's exports also illustrate this. Uganda is a leading producer of bananas, for which there is a high demand in Europe, yet none are exported. Not only is Uganda remote from Western Europe, but it has no coastline, and the need for bananas to reach market within fourteen days precludes their export. Cotton on the other hand is not perishable and has a higher value per unit weight, and thus is exported. A low percentage of the total output of low value commodities such as rice, oats and barley enter international trade. However, wheat and maize, despite their relatively low value per unit weight do enter international trade in large quantities. In the case of wheat this is partly explained by the elaborate systems of handling and marketing grain that have been developed over the last hundred years; special bulk carriers on land and sea have greatly reduced freights, and grain is easy to handle in bulk.

Although the preservation of foods has been greatly improved by the development of canning, refrigeration and rapid transport, only a small proportion of the world output of perishable commodities enters world trade, regardless of their value (Figure 10.6). This is the most apparent with fresh milk, although dried and canned milk is exported. Since the 1880s chilled and frozen meats have entered world trade in increasing quantities; none the less a comparatively small proportion of all the meat produced is exported. Thus, in spite of the advances in food preservation and falling transport costs, perishability and value still influence the nature of world trade.

CONCLUSION

The cost of moving agricultural products is clearly an important factor in explaining the location of different types of farming. But the fall in real transport costs has reduced its significance; in the last twenty years geographers have perhaps exaggerated its importance, just as before then they exaggerated the importance of climate and soil type.

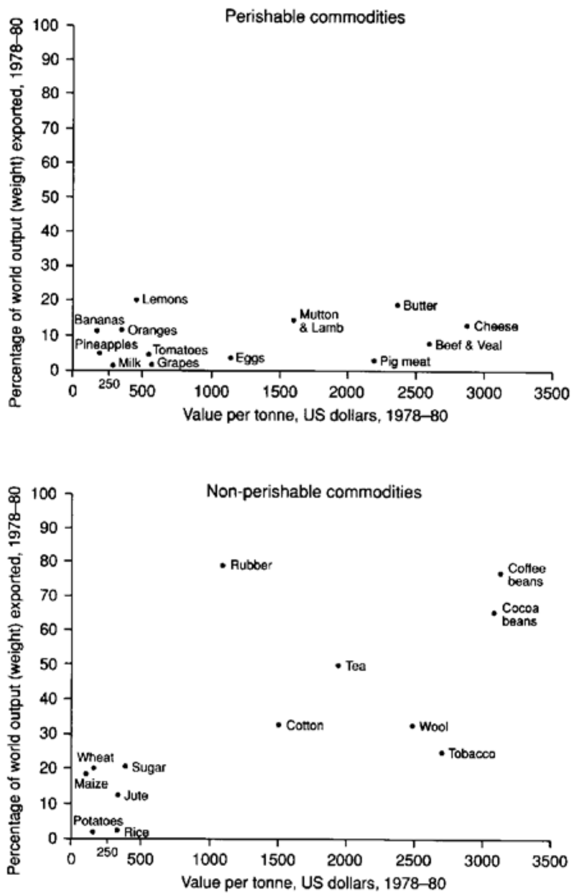

Figure 10.6 The value per unit weight of agricultural commodities plotted against the proportion of world output exported for perishable and nonperishable commodities

Source: Food and Agriculture Organization, Production Yearbook 1981, vol. 35, Rome, 1982; *Trade Yearbook 1981,* Rome, 1982

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Chapter 11
Agriculture in peri-urban regions

At the time when von Thünen wrote not only could perishable products be transported only short distances, but a very small proportion of Europe's population lived in towns and so very little farmland was directly influenced by cities. Now, however, a much higher proportion of the population live in towns, which have expanded physically to cover much greater areas than was possible in the early nineteenth century. In some regions, such as the West Midlands of England, the Randstadt region of the Netherlands and the Ruhr in Germany, a number of towns have grown towards each other, leaving only patches of farmland between. Not surprisingly this has profoundly influenced the agriculture of these areas. But the influence of the city has spread further into the countryside. Improvements in transport have allowed an increasing number of city workers to live in villages and small towns and commute to work. As the city physically expands, the zone on the edge of the city becomes more urban in its nature. The social and demographic characteristics of this zone are distinctive and it has been described as the urban fringe. A rather larger area is influenced by the city and this has been called the peri-urban region, although it has not been satisfactorily defined. A report by the Organization of Economic and Cultural Development (OECD) stated the peri-urban region to be that area 'whose structure and activities are modified by the presence or extension of one or more agglomerations'. This is clearly difficult to define in practice, but none the less would seem to include a substantial part of the total farmland of the developed countries.

In France, those communes defined by the census as industrial or urban contain one-fifth of the total farmland and one-quarter of the active agricultural population. Such areas have increased rapidly in the last fifty years; in West Germany there were marked changes between 1950 and 1970 (Table 11.1). In Belgium and the western Netherlands, few farms are any great distance from a town, while in the USA there is a remarkable urban sprawl, called Megalopolis by Jean Gottman, from Boston to Baltimore. In England, London has expanded dramatically; its physical area doubled between 1918 and 1939.

Table 11.1 Share of peri-urban areas in land and population in West Germany

	1950	*1970*
Land area		
Urban	3.0	4.2
Peri-urban	8.9	21.8
Rural	88.1	74.0
Population		
Urban	31.4	36.0
Peri-urban	14.7	27.3
Rural	53.9	36.7

Source: OECD, *Agriculture in the Planning and Management of Peri-Urban Areas,* vol. 1, *Synthesis,* Paris, 1979, p. 13

The physical encroachment of urban areas has given rise to distinctive features in the farming of these zones (Table 11.2). However, some qualifications must be made about the generalizations listed. First, not all the changes taking place in the agriculture of the peri-urban regions are due solely to urban influence. Thus, the loss of farm labour is part of a national trend. Second, not all farmers in the zone react alike to the anticipation of urban development.

THE LOSS OF FARMLAND

The loss of farmland is obviously a distinctive feature in areas of urban expansion. Land under urban uses gives a far higher economic rent than any agricultural enterprise, and so farmland has been bought up on the edge of cities and converted to residential or industrial purposes. The urban fringe has steadily advanced in the last fifty years, except where checked by zoning regulations such as the United Kingdom's Green Belt policy. The loss of farmland in England and Wales was at its highest in the 1930s, when 240,000 ha of farmland were lost each year; between 1945 and 1965 the loss was 15,000 ha a year, with the rate at its highest in Lancashire, the West Midlands and the south-east. Other parts of the world have lost farmland to urban expansion. In California half a million hectares of farmland were built upon between 1940 and 1950. In Germany the Ruhr did not experience industrialization until the second half of the nineteenth century so that in 1893 85.5 per cent of the core area was still farmland or forest, but by 1960 this had fallen to 47.7 per cent.

THE ANTICIPATION OF URBAN EXPANSION

The expansion of towns into surrounding farmland means those farmers within a few miles of the city edge may soon have the opportunity to sell their land at very high prices; they may be subject in some countries to compulsory purchase. It has been argued that anticipation of this sale will influence the intensity with which the land is farmed. Farming types will become more extensive, and less attention will be paid to preserving soil fertility or maintaining buildings and fences. Farmers are unlikely to start long-term improvements or plant orchards or other perennial crops. There are other reasons for a shift to more extensive practices. On the edge of cities the decline in the agricultural labour force is particularly strong, and it may become insufficient for some labour-intensive crops. Further, there are many part-time farmers near cities, and they are less likely to farm intensively. In some places land is left idle because the building of roads or houses has cut off a field from the main part of the farm.

Table 11.2 Agricultural characteristics of peri-urban regions

Land use
1. Percentage of total area in farmland is high
2. Percentage of land in crops is high
3. Percentage of land in fallow is low
4. Percentage of land in multiple cropping is high
Farm types
5. Percentage of all farms that are horticultural is high
6. Percentage of all farms that are dairying is high
7. Percentage of all farms that are pigs and poultry is high
Inputs
1. Labour inputs per hectare are high
2. Capital inputs per worker are high
3. Wage rates are high
4. Total inputs per hectare are high
5. Price of agricultural products are high
6. Net income per hectare is high
7. Rent per hectare and value of land sales are high
Structure
8. Percentage of small farms is high
9. Percentage of farms that are tenanted is high
10. Percentage of part-time farms is high
11. Percentage of farms that are fragmented is high

Note: 'High' is relative to regional or national average.

This is, of course, all contrary to von Thünen's argument that farming would be most intensive near the city and decline with distance from it. There have, however, been few attempts to test the hypothesis that intensity is low in the urban fringe, increases in the zone away from anticipated building, and then declines with increasing distance. Some instances have been noted. Around Rockford, Illinois, labour inputs are lower in the more urban counties than in the rural counties, and extensive cash grain farming more common than intensive dairying. East of Belfast, in Northern Ireland, much land is given over to extensive beef fattening; dairying, a more intensive activity, only occurs further away from the town.

LAND USE AND FARM ENTERPRISES

Most peri-urban regions are still dominated by specialized and intensive farming systems. In 1982 the Metropolitan Statistical Areas of the USA contained only 16 per cent of the total farmland, but produced three-quarters of all the sales of nursery and greenhouse products, and nearly 70 per cent of the vegetables, fruits and nuts. Thirty years earlier, in 1950, this effect was already pronounced. Megalopolis, Jean Gottman's term for the urbanized north-east of the USA, had only 1.8 per cent of the total farmland but produced 5 per cent of the total farm sales. The dominant production in this region was of high value goods with high labour and capital inputs. Fresh vegetables, fruits, cut flowers and nursery plants for urban gardens were typical. Livestock enterprises included the production of poultry and milk for fresh consumption. Poultry were fed not on locally grown feed, but grain imported from further west. Nor is such a pattern atypical. A wide range of enterprises is to be found around London, but horticulture, poultry, and pig production are the dominant types.

In recent years, two other trends have become noticeable. Nearness to towns has been a declining advantage for farmers for some time because of the increased ease of transport. However, in the last twenty years the high cost of harvesting fruit, flowers and some vegetables has led farmers to invite the public to pick their own produce, while farm gate sales have also increased. In both cases proximity to a large urban market is an advantage. In a sample of farmers north-east of London in Essex, 29 per cent had farm gate sales, providing 19 per cent of their income.

FARM SIZE AND LANDOWNERSHIP

In many countries there are marked spatial variations in farm size and landownership. It has often been noted that farms near towns are smaller than the regional or national averages, that a relatively high proportion of the farmers are tenants, and that part-time farming is common. There have, however, been few surveys to substantiate these assertions. In some areas— around Sydney, for example—farms near the town are small, and they increase in size with distance from the town. The reasons for the small size of farms is unclear. It is true that the expanding town may lead to the sale of part of the farm, and that land is expensive and therefore few farmers can increase their holding. The small size of farms may also provide an alternative explanation of the intensity of farming near the town; occupiers of small farms must choose enterprises with high net returns per unit area in order to make a living, and such farming is usually intensive—horticulture, pigs, poultry, or dairying.

Similar reasons have been offered to explain the prevalence of tenancy in some peri-urban regions. Farmers who wish to increase the size of their farm cannot afford to buy high-priced land, and have to rent instead. Historically, urban dwellers have often bought land around the town both as a long-term investment and as a way of controlling the town's food supply, and have rented this land to tenants. But perhaps more noteworthy is the growth of part-time farming in peri-urban regions. The importance of part-time farming depends very much upon its definition, and can easily be exaggerated. Thus, in 1980, 92 per cent of all US farm families had some non-agricultural income, but the fact that one member of the family had a job off the land hardly makes it a part-time farm. In 1955 in England and Wales there were 370,000 holdings of agricultural land. On 49 per cent of these, less than 275 man-days were worked in a year. As this means that they failed to occupy one person for a year, they could be defined as part-time farms. It does not follow, however, that half English farmers only work part-time upon their farms.

However difficult it may be to define part-time farmers, they are clearly divided into two types. There are those with land who take another job to increase their income, and those with a full-time job who buy land as an investment, as a tax loss, to provide themselves with a pleasant home, or as a hobby. The former category, called worker-peasants in Europe, has a long tradition. In the nineteenth century many smallholders in the new coal-mining areas in France, Poland and the Ruhr became miners, but the greatest expansion has come since 1945. The rapid growth of industrial employment with its comparatively high wages combined with the difficulty of obtaining an adequate living on a small farm led many small farmers in Europe to work in a factory during the day and on their land in the evenings and weekends. Worker-peasants reached their zenith in the 1960s when one-quarter of all the farms in Germany were so defined and one-third of those in Poland. Since then the number of workerpeasants has declined. As farms become vacant due to retirement or death, few young people are willing to begin such a hard life.

Of increasing importance in the peri-urban regions of Western Europe and North America is the person with a full-time—and usually well-rewarded—job who buys a farm as a hobby. In some areas such farmers are quite numerous. Of a sample of farmers in Essex, on the outskirts of London, 20 per cent were part-time; and in a sample near London, Ontario, 13 per cent were hobby-farmers. Such farmers are often different from full-time farmers. Their farms are smaller than the local average and, with limited time at their disposal, they adopt less intensive farming methods and avoid livestock with its need for regular and long hours.

THE DISADVANTAGES OF PERI-URBAN FARMING

Although proximity to large urban markets is thought to be advantageous to farmers, there are disadvantages. The high cost of buying or renting land has already been noted, and this makes it difficult for successful farmers to expand their business. Wages for farm workers are high, for the attractions of employment in the town are more apparent. Indeed, it is often said that the decline of the agricultural labour force, which is common throughout the developed countries, is most marked in the peri-urban regions, although this has rarely been substantiated. But nearness to towns has other drawbacks. The purchase of land for building roads and houses may divide farms and make access to fields difficult. Industrial pollution may lower crop yields, and open land may be used for dumping rubbish. Vandalism may damage growing crops, and dogs worry livestock, particularly sheep. In parts of North America, farms incorporated into towns have to pay much higher taxes than those in rural areas, although in England rates on agricultural land are lower than on urban land, Yet, whatever the hazards they rarely drive farmers away.

PERI-URBAN FARMING IN THE USA

Most of the generalizations about farming near urban areas rely upon sample surveys of farms around a few cities in many different countries. However, in the USA the collection of agricultural data includes information upon farms in the Metropolitan Statistical Areas, which include not only densely populated areas on the edge of cities, but also less densely populated areas where urban occupations, habits and attitudes predominate. In 1982 farmland in these areas accounted for some 16 per cent of all US farmland. They are of particular importance in the north-east and California (Figure 11.1). The statistics bear out many of the generalizations made about peri-urban farming (Table 11.3). Farms are smaller than in the non-Metropolitan areas, and there are more part-time farmers, reflecting the greater opportunities for off-farm employment; farmland values are twice as high. Farming intensity is higher than in non-Metropolitan areas, whether measured by the use of fertilizers or labour, or by the type of farming; the value of farm sales per acre is twice that of the nonMetropolitan areas, and the Metropolitan areas have a disproportionate share of the output of more intensive crop production, such as vegetables and fruits, whereas grain production is less important. Of

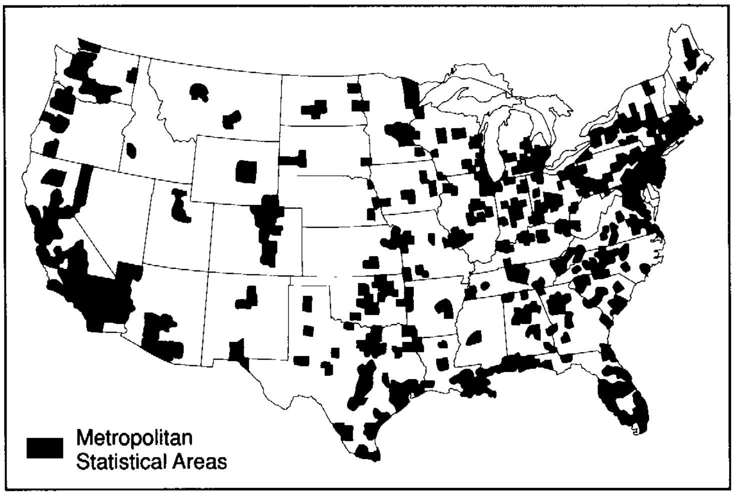

Figure 11.1 Metropolitan Statistical Areas in the USA

the livestock enterprises dairy products are important near to urban areas, but the others — pigs, beef, cattle and sheep—far less so.

CONCLUSION

The very rapid extension of urban areas in the last forty years, combined with much greater mobility, means that an increasing part of national farm areas is directly influenced by cities. Because of the differing reactions of farmers to this expansion, it is difficult to make generalizations about the structure and land use of such regions, but it is clearly a condition that will increase, and one that merits further study.

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Table 11.3 Farming in the Metropolitan Statistical Areas of the USA, 1982

	Metropolitan	*Non-Metropolitan*
Percentage of all land in farms	16.1	83.9
Percentage of all farms	28.7	71.3
Average farm size, acres	247	518
Percentage of farms under 100 acres	71.4	44.3
Percentage of farmland owner operated	57.7	62.2
Percentage of farmland tenant operated	41.2	38.0
Percentage of farmers for whom farming is the principal occupation	47.5	58.2
Value of land and buildings, US dollars per acre	1429	661
Value of farm sales, US dollars per acre	243	113
Commercial fertilizers, US dollars per 1000 acres of cropland	32.5	21.4
Cost of all hired labour, US dollars per 1000 acres of cropland	10.6	1.7
Percentage of total US farm sales:	29.3	70.7
Nursery and greenhouse	76.0	24.0
Vegetables	69.0	31.0
Fruits, nuts and berries	68.3	31.7
Hay and silage	49.0	51.0
Dairy products	37.9	62.1
Hogs and pigs	16.3	83.7
Cattle and calves	18.0	82.0
Grains	19.8	80.2
Sheep, lambs and wool	22.8	77.2

Source: R.E. Heimlich and D.H. Brooks, *Metropolitan Growth and Agriculture. Farming in the City's Shadow,* United States Department of Agriculture, Economic Research Source, Agricultural Economic Report 619, 1989

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Chapter 12
Population, labour supply and agriculture

Much has been written on the relationships between population growth and food supply, rather less on the influence of population growth and regional differences in density upon farm structure and land use. Yet differences in the amount of labour used in agricultural production are of paramount importance in determining spatial differences in the way farming is carried on. In this chapter a brief account of world differences in agricultural densities is given, followed by an outline of Ester Boserup's theory that links changes in land use intensity to population increase. Some empirical relationships between population density and agricultural characteristics are then discussed.

AGRICULTURE AND ECONOMIC DEVELOPMENT

Two centuries ago, four-fifths of the working population of most countries in the world were engaged in agriculture. Since then, Europe, North America, Japan, the Soviet Union and Australasia have experienced industrialization. During this process the absolute numbers working in manufacturing industry and the services have increased, and the proportion engaged in agriculture has fallen to below 15 per cent in most of these countries, and to less than 3 per cent in the United Kingdom, Belgium and the USA. Elsewhere, industrialization is in its early stages, and the proportion engaged in agriculture remains high, particularly in Asia and tropical Africa (Figure 12.1). In all the developed countries, the numbers employed in agriculture are now in rapid decline (Figure 12.2); industry has offered higher wages than agriculture, and the introduction of labour-saving machinery has reduced the need for labour on farms. But this is a relatively recent trend. In the early stage of industrialization, Phase I, the agricultural population increased (Figure 12.3), for rural natural increase was higher than the rate of migration from country to town. Then, in the middle stages of industrialization, migration and natural increase were much the same, and the agricultural labour force stagnated or slowly declined (Phase II).

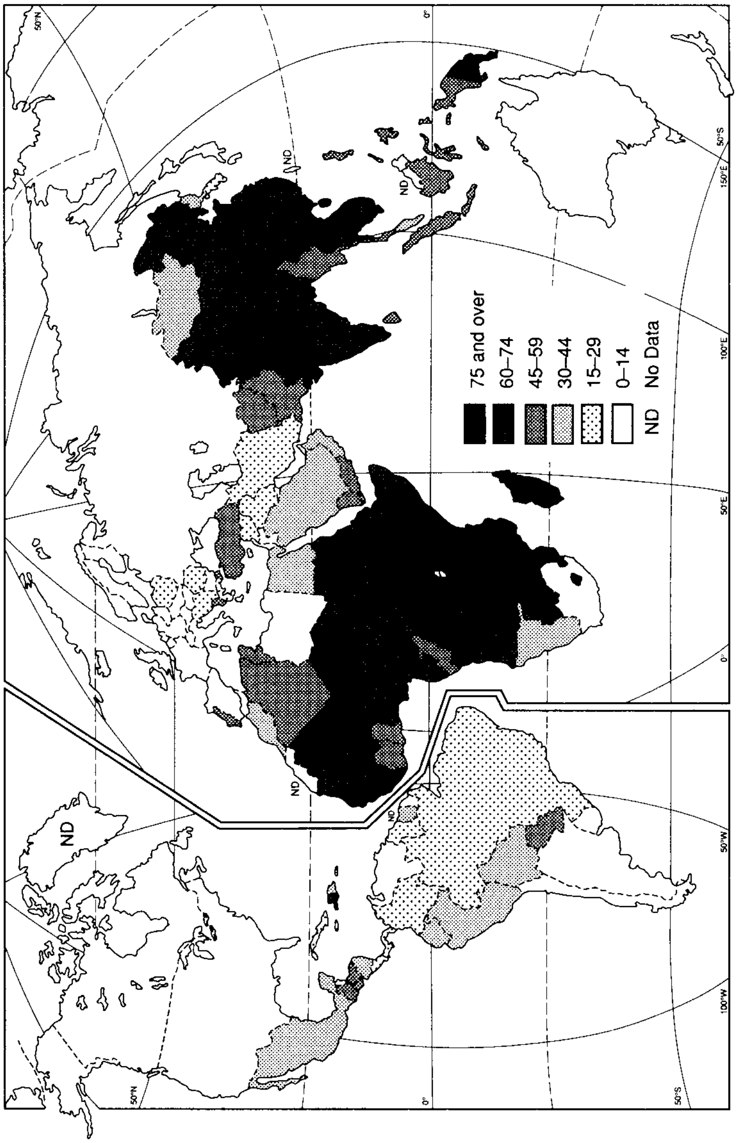

Figure 12.1 Percentage of the economically active population engaged in agriculture, 1990

Source: Food and Agriculture Organization, Production Yearbook 1991, vol. 45, Rome, 1992

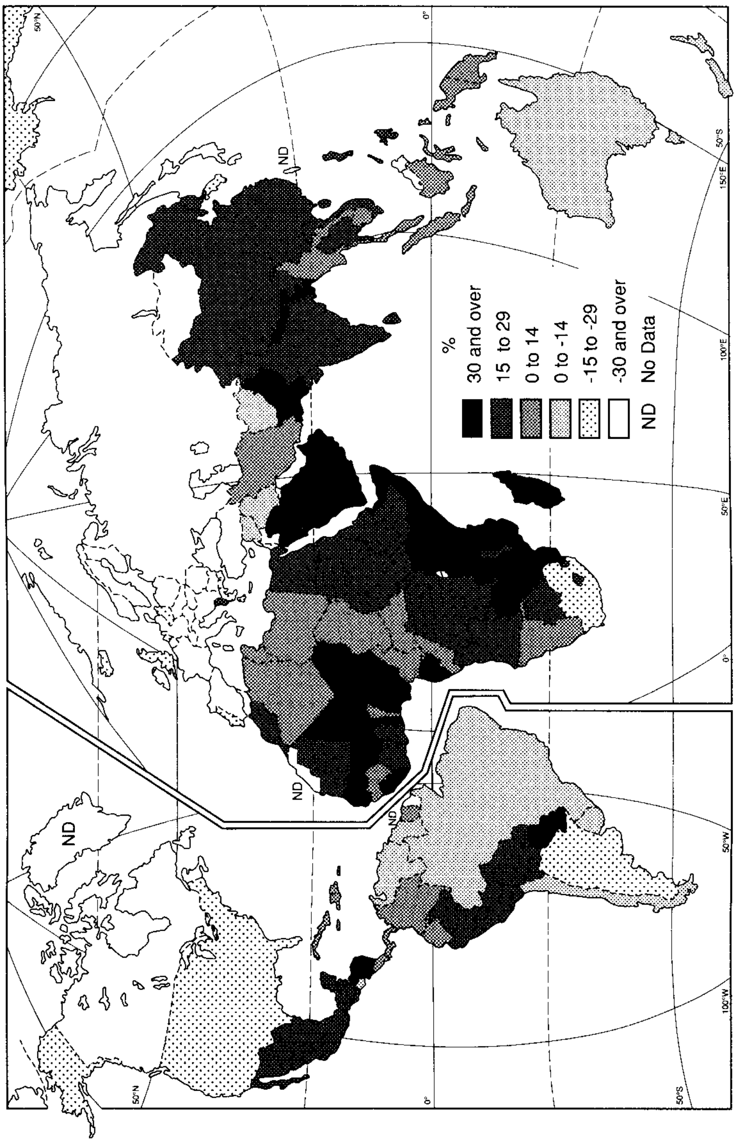

Figure 12.2 Changes in the numbers economically active in agriculture, 1975–90
Source: Food and Agriculture Organization, Production Yearbook 1991, vol. 45, Rome 1992

Finally, in Phase III migration from the country greatly exceeded natural increase, and the labour force fell sharply. Most developing countries remain in Phase I of this model of development. Although there is substantial migration to the towns, the rate of natural increase in the rural areas is very high, often over 2 per cent per annum. Consequently, the numbers dependent upon agriculture are increasing. Indeed, in some parts of Africa the agricultural population increased by over 30 per cent between 1975 and 1990 (Figure 12.2).

Regional differences in agricultural population densities are shown in Table 12.1. However agricultural population density is measured, whether by using the agricultural population (which includes all those employed in agriculture together with their dependants), or simply the agricultural

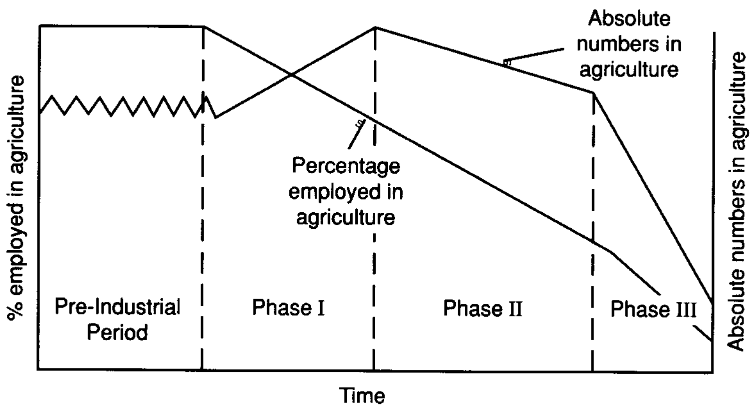

Figure 12.3 A model of changes in the agricultural population during industrialization

labour force (which includes only those employed in agriculture), the Far East and Africa have the highest densities, and North America, the former

Table 12.1 Agricultural population densities, 1989

	Agricultural population per Km²		*Agricultural labour force per Km²*	
	Arable	*Cultivated*	*Arable*	*Cultivated*
Far East	444	196	216	96
Africa	216	40	88	16
Near East	127	27	42	9
Latin America	66	16	23	5
Europe	32	20	16	10
USSR	17	2	9	7
North America	3	2	2	1
Oceania	2	0.2	1	0.1

Source: Food and Agriculture Organization, *Production Yearbook 1990,* vol. 44, Rome, 1990

Soviet Union, and Oceania (or Australasia) the lowest. However, these figures conceal important differences within continents.

When figures for each state are examined (Figure 12.4) it can be seen that the highest densities are to be found in East, South-East and South Asia, but there are also very high densities in much of tropical Africa and in the irrigated areas of the Middle East. The lowest densities are in North America, Australasia, temperate South America, the former Soviet Union and parts of north-west Europe. Densities in Latin America are higher than in Europe, but low compared with Afro-Asia: the highest densities in this area are found in the upland areas of the Andes and Central America. Within Europe there are still differences between the north-west, where densities are lowest, and the east and south. This is partly related to the date when industrialization began. It was earliest in the north-west, and the agricultural labour force there has been in decline for a century; industrialization was later in the east and south, and the decline began only some thirty years ago.

It is important to note that there is a considerable difference in density between Western Europe and the European settlements overseas. Europe has a long history of settlement, and agricultural densities had reached a high level by the early nineteenth century before the age of labour-saving machinery; out-migration has since reduced these densities. In contrast, much of western North America, temperate South America, southern and eastern Russia and Australasia were not settled until after 1850, by when machinery was available. Thus, densities in these regions were never as high as in Western Europe.

AGRICULTURE AND POPULATION IN DEVELOPING COUNTRIES

Many writers have asserted that population growth and density influences agriculture, but the only theory relating the two is that put forward by Ester Boserup. Her theory demonstrates how population growth over time forces changes in land use and farming methods, but she also believes that spatial variations in population density explain current geographical differences in farming practices.

Her model makes a number of assumptions:

1 It is confined to subsistence societies, where the aim is to preserve leisure once basic needs are satisfied, rather than to maximize profit.
2 Modern agricultural technologies are not available to farmers.
3 Farmers are thought to be aware of a wide range of traditional farming methods, but use only extensive methods. They will only adopt methods that need more labour if population increases.
4 Population increase is assumed to be due to external factors such as

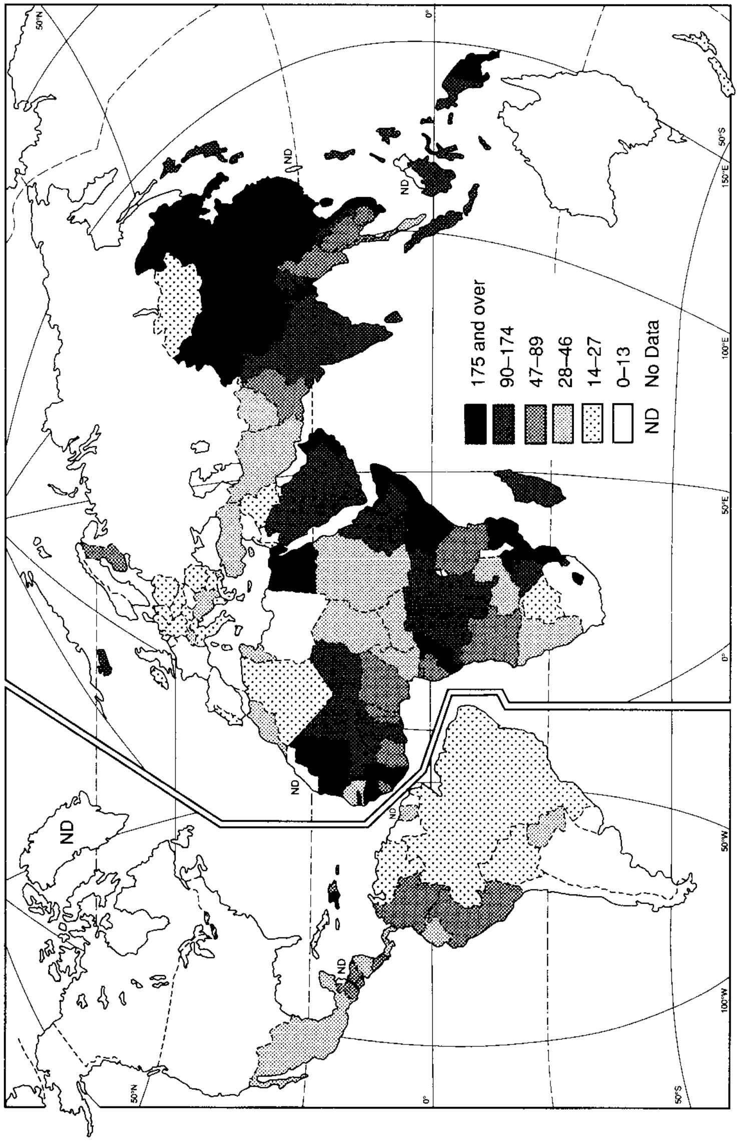

Figure 12.4 Number of persons economically active in agriculture per 100 hectares of arable land, 1989

Source: Food and Agriculture Organization, Production Yearbook 1990, vol. 44, Rome, 1991

improved public health conditions, and is not dependent upon an increase in the food supply. It is in fact the growth of population that requires extra work to be done in order to increase the food supply.

5 Variations in soil type and climate are assumed to have no influence on the intensity of farming. The theory thus applies to parts of developing countries with both low and high densities, but not to developed countries.

Boserup argues that in a sparsely settled area, with abundant land per capita, shifting agriculture or forest fallow will be practised (Table 12.2). This system requires few labour inputs other than those needed to clear the forest for cultivation, and output per capita is high. Farmers can obtain an adequate food supply with little work, and there is ample leisure time. If, however, population increases farmers need to increase their food supply. This they do in two ways. First, they reduce the amount of land in fallow between crops: thus a series of types of farming defined by the length of fallow results from each successive increase in population density (Table 12.2). Second, as the fallow is reduced, so the ability of the natural fallow to restore fertility diminishes. Farmers then have to increase labour inputs to maintain crop yields by preparing the seed-bed more carefully, carting manure and, in the later stages, by irrigation and terracing. Although crop yields are maintained or even increased in each stage, this does not compensate for the extra labour involved, and so output per capita falls at every stage. Increasing intensity of cultivation also requires changes in the implements used. In forest fallow no seed-bed is prepared, and the axe and the digging stick are all that is required. When the length of fallow is reduced, secondary forest is not re-established and a grass cover invades the fallow. Thus, a hoe is needed to remove the roots when the land is cropped again, and later a plough becomes necessary.

Boserup believes that all parts of the world have experienced these changes owing to increasing population density, and that present spatial variations in intensity are a function of density. But nowadays annual cropping is common in most regions outside Africa, and fallowing is practised for reasons other than conserving soil fertility. Thus, in many semi-arid regions two years' moisture is necessary for a crop, and land is alternately under crop and fallow. Purely subsistence societies are rare, and even in developing countries some modern inputs are purchased. In most developed countries the labour force is declining, and so the theory is not applicable. Thus, it is only in Africa and limited areas of Asia and Latin America that the early stages in the sequence are found. At the other end of the sequence multiple cropping may be a function of density, but it is only possible where irrigation and a long growing season allow it. Some contemporary examples of the relationship between density and intensity are now considered.

Table 12.2 Type of farming and population density

Type	*Typical densities (per km²)*	*Cropping length*	*Fallow length*	*Frequency[1] of cropping (%)*	*Type of fallow*	*Tools in use*	*Fertilizer*	*Labour needs*	*Labour productivity*
1 Forest fallow	0–4	1 to 2 years	15 to 25 years	0–10	Secondary forest	Axe, fire, digging stick	Ash	Land clearance with axe and fire. No cultivation or weeding	High
2 Bush fallow	4–64	2 or more years	8 to 10 years	10–40	Small trees, bush	Hoe	Ash, vegetation, turfs mixed in soil	Less land clearance but some weeding	Falls as yields fall and extra weeding needed
3 Short fallow	16–64	1 to 2 years	1 to 2 years	40–80	Wild grasses	Plough	Manure and human waste	Extra preparation of seed bed. Extra weeding and carting manure	Falls as extra cultivation, extra weeding, collecting and distributing manure, care of draught animals needed
4 Annual cropping	64–256	One crop each year	A few months	80–100	Legumes and roots	Plough	Manure, human waste, green manure, marling and silting, composts	Extra cultivation, weeding, terracing, irrigation, and water control	Falls as extra cultivation and weeding, collecting and distributing manure, constructing and maintaining irrigation, terracing water-control, etc. needed
5 Multi-cropping	256 and over	Two or more crops in each year	Negligible	200–300	–	Plough			

Note: 1 Average area in crops as a percentages of crops plus fallow.
Source: E.Boserup,The conditions of Agricultural Growth, London,Allen & Unwin.1965

SUBSISTENCE COMMUNITIES IN THE TROPICS

Three American geographers have tested the assertion that population density determines agricultural intensity. They collected data from twenty-nine studies of simple village communities in the tropics on population density, cropping frequency, the principal food crops, the presence of livestock and on three variables of environmental quality. Linear regression and correlation techniques were used to test a number of hypotheses. Their conclusions can be summarized as follows. They found that agricultural intensity—the ratio of the area in crops to the sum of the area in crops plus the fallow—did increase with population density. The best fit for the regression line was an exponential model, suggesting that as density increased so intensity had to increase more rapidly to overcome the problems of diminishing returns. They went on to distinguish between farmers who grew root crops and those who raised cereals, and found that for any given population density agricultural intensities were higher for cereal growers than those cultivating roots. This is because the root crops such as yams, sweet potatoes and manioc give a higher calorific yield than cereals (see above, pp. 10-12). There is thus a greater need for cereal growers to reduce fallow. In those communities that kept livestock, agricultural intensities were higher than in those communities with similar population densities but no livestock. This was because these communities had to keep some of their land for grazing; arable expansion was limited and fallow had to be reduced earlier than in villages without livestock.

DENSITY AND FARMING IN WEST AFRICA

West Africa has islands of high population density separated by very large areas of low density. Several geographers, independently of Ester Boserup, have argued that land use intensity in this region is a function of population density.

Shifting agriculture is distinguished by a very long fallow during which time secondary forest is established, which restores soil fertility. After two or three years in crops the land is abandoned, and the settlement itself moved, to clear another patch of forest. Such a system is only possible where there are very low population densities and abundant land. Although it is now found in only a few places in West Africa, it was more common in the past. When population densities reach about 10 per km^2, settlements become fixed and fallows much shorter.

Rotational bush fallowing has shorter fallows and longer periods in crops. Typical densities are from 2 to 20 per km^2 in the drier north where cereals are the staple crops, but from 27 to 77 per km^2 in the south where root crops, with their higher yields, can be grown. This farming type, the most common in West Africa, has fallow periods that are longer than the periods in crops. Unlike shifting agriculture, however, the land in fallow remains in the possession of the family that cultivated it, and the settlement is not moved.

The third type of farming, *permanent cultivation*, has longer periods in crops than in fallow, and is found in regions of very high density such as the Kano area of northern Nigeria. In this area farming practices are intensive. Land is frequently hoed, manure carted from the town, and Fulani pastoralists are encouraged to graze their stock on the stubble. In other high density regions, similar practices designed to increase yields and avoid soil erosion are found.

There are other possible explanations for these areas of high density and intensity. The spread of commercial agriculture has encouraged farmers to sell crops for profit rather than simply to feed their families, and this leads to increased intensity. Nowhere in the high density zones, it should be noted, has the plough replaced the hoe (except on experimental farms), and multiple cropping is confined to the state-financed irrigation zones of the savannah interior.

MULTIPLE CROPPING

Multiple cropping is rare in the high density areas of Africa, and is uncommon in the cool temperate areas where the growing season is too short for more than one main crop in the year. Multiple cropping may be related to population density in peasant societies, but even in the tropics and sub-tropics, where temperatures are not limiting, it depends upon a year-round supply of water, normally only available with irrigation. There is a weak positive correlation between density and double cropping (Figure 12.5). The more striking residuals are related to the availability of irrigation, which is low in both North and South Vietnam and very high in Taiwan and Egypt. However, the data does bear out a difference in population density between South Asia and East Asia. The lower densities in India, Pakistan, Thailand and Burma are reflected in the low indices of multiple cropping in these countries when compared with East Asia.

A more detailed study—of Assam—has shown a close relationship between population density and the intensity of cropping. Assam was sparsely populated in the nineteenth century, but the development of tea plantations attracted immigration which has continued since 1947 (during which time there has also been a high rate of natural increase). Two-thirds of the workforce are engaged in agriculture, and nine-tenths of the total population live in rural areas; there are few opportunities for work outside farming. M.M. Das has shown that there is a positive correlation of $r^2 = 0.69$ between rural population density and the percentage of the net sown area cropped more than once a year; a regression analysis showed that half the changes in the intensity of cropping could be explained by a change in population density.

CHARACTERISTICS OF AREAS OF HIGH POPULATION DENSITIES

Boserup's theory states that in subsistence societies population growth requires more intensive farming to provide the extra food supply needed by population increase, but although gross food output increases, output per

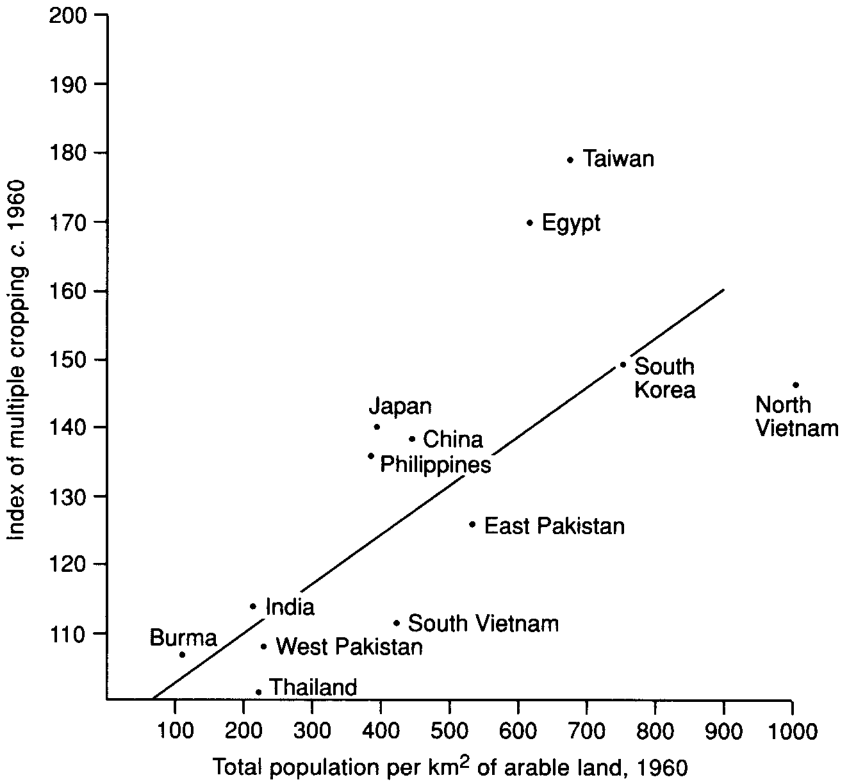

Figure 12.5 Population density and multiple cropping in selected countries, c. 1960 The index of multiple cropping is the proportion of the arable area sown twice or more during the year

Source: D.G. Dalrymple, *Survey of Multiple Cropping in* Less *Developed Nations,* Washington DC, US Department of Agriculture, 1971

capita declines as density increases. However, there are other changes as density increases, largely adverse. Most agricultural areas with very high population densities and without modern agricultural technology are areas of poverty and distinctive agricultural features. Nor can Boserup's theory be applied to most of the developed world, for here not only are modern technologies—such as fertilizers and machinery—in use, but the agricultural population is declining. These two contrasting regions are now discussed.

AGRICULTURAL CHARACTERISTICS OF REGIONS OF HIGH POPULATION DENSITY AND GROWTH

Areas of high density and rapid growth have distinctive agrarian features, some of which are shown in Table 12.3 In areas of dense and increasing agricultural population, farms are subdivided. Not only are they small, but frequently many of them are *too* small to provide sufficient food for the family, and additional sources of income have to be sought by working as labourers on larger farms, by temporary migration to the towns, or by home crafts. In much of the densely populated Far East farms are remarkably small. In Sri Lanka in 1971, 65 per cent of all farms were less than 1 ha, and 96 per cent less than 5 ha; in Bangladesh in 1974, 95 per cent of all farms were less than 3 ha. However, a predominance of small farms may not be due simply to high population densities. In Colombia the smaller farms, averaging 3 ha, constituted 60 per cent of all farms, but they occupied only 4 per cent of the farmland. Holdings of 100 ha, which constituted only 3 per cent of all farms, accounted for 60 per cent of the

Table 12.3 Characteristic features of agriculture in areas of high population density

1	Very small farms; often too small to provide minimum diet.
2	High degree of fragmentation.
3	Large proportion of rural population are without land.
4	Labour force on family farms are underemployed.
5	Landless labourers have low real wages and are often unemployed.
6	Abundance of cheap labour retards the adoption of labour-saving machinery.
7	Scarcity of land gives high rents and high land values.
8	Farmers concentrate upon food crops and can spare little land for fodder.
9	Livestock are relatively unimportant except as draught animals.
10	Cereal crops replaced by high yielding but nutritionally inferior crops e.g. cassava.
11	Expansion of arable land at expense of grazing leads to overgrazing and soil erosion.
12	Low incomes and variable harvests lead to indebtedness, bankruptcy, forced sale of farms, growth of tenancy and share-cropping.
13	Lack of capital means farmers are unable to purchase inputs such as seeds, fertilizer and irrigation water.
14	Although abundant labour inputs give high crop yields in the traditional context, farms are unable to reach the high yields that are possible with modern technology.
15	Low incomes, poor diet.

cropland. Much of Colombia is held in very large units of landownership, to which small farmers do not have access. Thus the pattern of landownership, as well as density, is of great importance in determining farm size.

As farms are subdivided over time the fields of a farm become scattered among the fields of neighbouring farms, and one farm may consist of widely scattered plots. Fragmentation, as this is called, means that farmers spend much time walking from plot to plot, land is wasted in a plethora of field boundaries, and plant disease is hard to control. Population, however, is not the sole cause of fragmentation. In some localities farmers want scattered plots to ensure that their farm has a variety of soil types (see below, pp. 165–8).

When farms are small and families large it is not possible for all children (sons) to acquire land, and so the landless populations of most parts of Asia have increased over the last thirty years, for it has not been possible to create enough new farms for them, nor has industrial growth been rapid enough to provide alternative jobs. At the beginning of this century landless labourers were a small proportion of the population of India, but by 1951 they were a third of the rural population. When the landless are so numerous real wages remain low, and there is much unemployment. On the very small farms that characterize much of Africa and Asia the family labour available is rarely fully utilized and so underemployment as well as unemployment is common. Thus, it has been estimated that 30 per cent of the labour hours available to farmers in South Korea are not used; in the Maghreb the figure has been put at 58 per cent. Similar conditions were found in Eastern Europe in the 1930s, although industrial growth and a falling rate of natural increase has since eased the problem. Even so, in 1953 31 per cent of the farm population of Yugoslavia was thought to have been surplus to requirements. This, combined with the low wages of farm labourers, provides little incentive to farmers to adopt labour-saving machinery.

With an acute shortage of land, few farmers can afford to grow crops other than those for direct consumption. Forage crops are rare and few livestock are kept, except those like pigs and poultry which can be fed the residue of human foods (although some oxen or buffalo are kept for draught purposes). In some very densely populated regions the preferred staple crop, usually a cereal, has to be replaced by nutritionally inferior but higher-yielding root crops. The continued increase in population may lead to the expansion of cropping on to physically marginal land, and this in turn, to soil erosion. In parts of Africa the growth of arable land has reduced the grazing area, and this in turn has caused overstocking and overgrazing.

Thus poverty is endemic in high density regions, and this very poverty prevents increased output. The high labour inputs in these areas mean that by the standards of traditional agriculture the yields are high, although output per capita may be low. Further increases in yields require not further labour inputs but new inputs such as fertilizers and improved crop varieties, like those used in the Green Revolution. But poverty prevents the smaller farmer purchasing these inputs.

Java

The problems of Java illustrate graphically the problems of high density agricultural areas. In 1980 the population of Indonesia reached 150 million, of which Java, with only 6.3 per cent of the area, had 95 million. The population of the island had doubled since the end of the Second World War. Not surprisingly 70 per cent of the total land area is in crops, and the area left in forest is now thought to be less than that necessary to prevent soil erosion and accelerated run-off in the upland regions. There is little land left that could be brought into cultivation. Both during Dutch rule and since efforts have been made to move farmers from Java to Sumatra and the other Outer Islands, but with limited success.

Farms in Java are remarkably small, four-fifths being less than 1 ha. Yet it has been estimated that a family needs 0.7 ha of wet-rice land or 1.4 ha in dryland crops to feed itself. Nor is this acute subdivision of farms due to any gross inequalities in landownership; less than 1 per cent of all farms are larger than 5 ha. At the other extreme, half Java's rural population has either no land or less than 0.1 ha. Nor is much land devoted to non-food crops.

Most of Indonesia's plantation crops are grown on the Outer Islands; only 7 per cent of Java's arable is occupied by these crops. Wet-rice is the most important of the food crops, grown with elaborate terracing and irrigation systems. Until the introduction of high-yielding rice varieties in the 1960s, much of the harvest was gathered in with a hand knife, although now that these varieties occupy about half of the island's rice crop the sickle is more common. Not surprisingly, with such high densities, much of the land is double cropped. Double cropping is found not only on the irrigated wet-rice land, called *sawah,* but also on dryland, or *tegalan,* on which maize is the main food crop.

Livestock necessarily play a small part in the agricultural economy, accounting for less than a tenth of the value of gross agricultural output. Arable per capita has halved since the 1930s, so that the problems of feeding the population have been acute. The typical Javanese spend four-fifths of their income on food. Even so the diet of many is inadequate: average daily consumption was less than 2000 calories per capita in the 1960s, although it has improved since. High population densities may not be the only cause of Java's poverty, but they are a significant contributor.

AGRICULTURAL CHANGE IN REGIONS OF DECLINING AGRICULTURAL LABOUR FORCE

In all the countries of the developed regions the agricultural labour force is in decline (Figure 12.2). In Western Europe this decline began in the later nineteenth century, in Eastern Europe not until after the end of the Second World War; since 1950 it has been dramatic. A combination of the attraction of higher wages in industry, and the adoption of labour-saving machinery upon farms has led to very large reductions in the labour force. In the USA the labour force in 1980 was less than a third of what it was in 1950, and in the United Kingdom it is less than a half. In Western Europe there has been no marked change in the agricultural area since 1950, so the density of the agricultural labour force has fallen and the amount of land per worker has doubled in nearly all countries since 1960 (Table 12.4). However, there is still a marked difference in the amount of land per worker between Western Europe and the Soviet Union on the one hand, and the overseas European settlements of Canada, the USA, New Zealand and Australia on the other. Hence differences in population densities help to account not only for differences between the developed and developing regions, but for some of the differences in farming practice between the low density regions of European settled areas overseas, and the higher densities of Europe itself.

Changes in farm size

Until the Second World War, the decline in the agricultural labour force was largely accounted for by the migration of hired agricultural labourers to the towns. Thus in Britain the number of labourers fell from 2,100,000 in 1851 to 1,110,000 in 1951, but there was little change in this period in the number of farmers. Since the end of the Second World War, not only have labourers continued to leave farming, but many small farmers have also left the land. On small farms it is difficult to make a living comparable to that of an industrial worker. In addition, with advances in agricultural technology there are considerable economic advantages in farming large units. The result has been that in nearly every country in Western Europe and the European settled areas overseas, the number of farms has declined. In the USA there were 5.6 million farms in 1950, in 1970 only 2.6 million. In the EEC the number of farms over 1 ha fell by one-fifth between 1960 and 1970; at the same time the number of larger farms increased. While the number of farms in all size categories below 20 ha declined in the same period, the number in all categories over 50 ha increased in every one of the nine member states. In England and Wales since 1950, the number of farms in each size category over 120 ha has increased, the number in each category below 120 ha has declined.

Table 12.4 Agricultural land per capita of the agricultural labour force, 1960 and 1989 (hectares per capita)

	Arable		*Cultivated area*	
	1960	*1989*	*1960*	*1989*
Italy	2.5	6.9	3.3	9.7
West Germany	2.2	6.6	3.8	10.5
France	4.9	13.7	7.9	22.0
USSR	4.9	11.8	12.8	30.7
United Kingdom	7.5	11.6	20.2	30.8
Canada	49.3	100.4	74.1	173.5
USA	39.5	63.8	94.3	145.0
Australia	68.7	118.2	1011.0	1127.0

Source: Food and Agriculture Organization, Production Yearbook, 1963, vol. 17 Rome, 1964; 1973, vol. 27, Rome, 1974; 1990, vol. 44, Rome, 1991

Although the number of small farms in Europe has greatly decreased since 1950, there is still a marked difference in farm structure between Western Europe and North America. Europe still has a greater proportion of its farms in the smaller size categories, and litde of its land is occupied by very large farms (see Chapter 13). Such differences are difficult to represent either statistically or cartographically, for national censuses of agriculture use different size categories to record farm numbers, and differ in the minimum size that is to be recorded as a farm. There are also differences in the area counted as farm area; some censuses include woodland and rough grazing, some do not. Thus, the mean size of holding is a far from accurate measure. None the less, there are very substantial differences between Western Europe, and North America and Australasia. In 1980 none of the countries in the latter area had a mean size below 200 ha, none in the former area (except the United Kingdom), a mean size over 35 ha (Figure 12.6). Although there is no linear relationship between farm size and agricultural density, size is clearly partly a function of agricultural density. In the future it is likely that further decline in the agricultural population, and the continuance of the advantages of economies of scale for large farms will lead to further increases in the mean size of holding in both Europe and North America, but the difference in size between the two regions is likely to persist for some time.

Other studies of farm size covering countries in the developing world, suggest that population density is an important, but not the sole, determinant of farm size. Mean size of holding in the major regions is loosely related to population density (Table 12.5). Asia has the smallest farms, Australasia and the Americas the largest. But as noted earlier, population density is not the sole determinant of farm size. In Latin America, the original allocation of very large land grants to the early

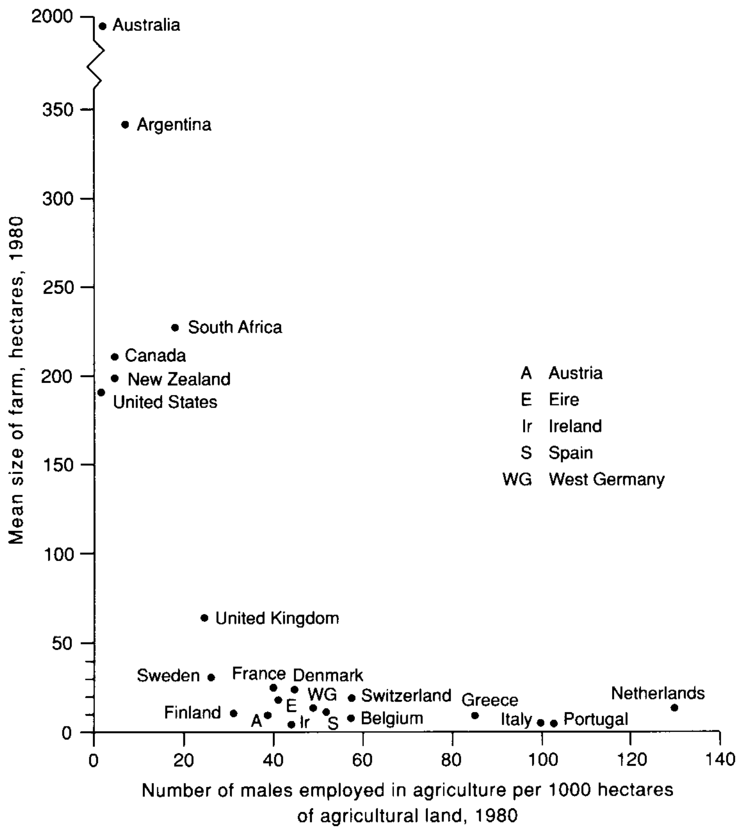

Figure 12.6 Mean size of farm and agricultural labour density, 1980

Source: Food and Agriculture Organization, Production Yearbook 1981, vol. 35, Rome, 1982

Spanish and Portuguese setders has been a major significant factor determining farm size. In Africa, the mean size of holding is below the figure population density might suggest. This may be because the simple implements most African farmers still use make it difficult for a family to cultivate more than a few hectares. It should also be recalled that in many parts of the developing world, in contrast to the developed, the mean size of holding is declining.

Table 12.5 Mean size of holding, 1960 and 1970 (hectares)

Australia and New Zealand	195.0
Canada and the USA	185.0
South America	68.0
Central America	14.5
Western Europe	13.1
Eastern and Southern Europe	7.7
Africa	3.7
Asia	2.7

Source: Food and Agriculture Organization, *Production Yearbook 1973,* vol. 27 Rome, 1974, p. 8

Land supply and the choice of technology

The great difference in the amount of land available to farmers in Western Europe and the European areas overseas has often been noted; many have argued that this difference will influence the farmers' economic aims and their choice of technology. In the more densely populated countries land is costly and labour relatively abundant and cheap. The farmer will thus select those enterprises that give a high return per hectare, and will spend much on inputs that increase crop yields, such as fertilizers, pesticides and herbicides. In contrast, farmers with large areas of land at their disposal can gain large total incomes even if they practise enterprises with a low return per hectare. They concentrate on maximizing output per capita, spend much on labour-saving machinery and less on yield-increasing inputs. This is to some extent borne out by present conditions, for there is a positive, if weak, relationship between the value of output per hectare and agricultural population density (Figure 12.7).

There is a substantial difference between output per hectare in the USA, Canada and Australia, and the more densely populated parts of Europe. The United Kingdom, with the largest farms and one of the lowest densities in Europe, lies nearer the extensive farming of overseas settlements than the intensive farming of the Netherlands. The major yieldincreasing input in agriculture is fertilizer. Fertilizer usage is certainly low in the overseas countries, and higher in every European country, but there is only a very weak relationship with density (Figure 12.8). This relationship is least close in the poorer (in 1980) economies of the Mediterranean basin where fertilizer consumption is much less than density would predict.

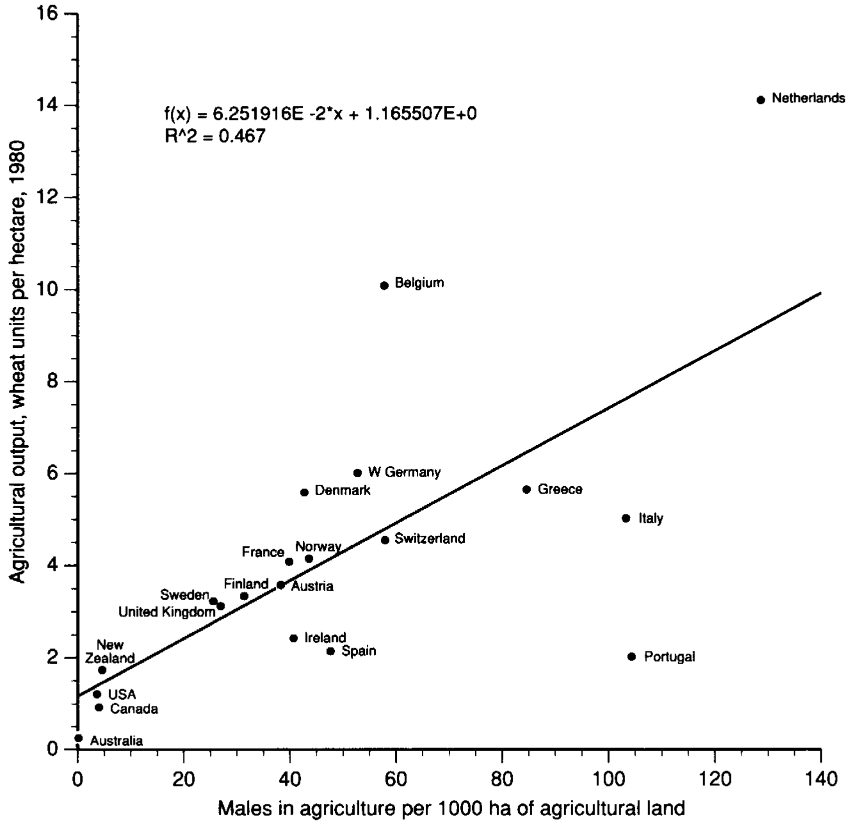

Figure 12.7 Agricultural output per hectare and the density of the agricultural labour force, 1980 (number of males employed in agriculture per 1000 hectares of agricultural land)
Source: Y. Hayami and V.W. Ruttan *Agricultural Development: An International Perspective,* Baltimore, Johns Hopkins University Press, 1985

It might be expected that in more sparsely populated countries the value of agricultural output would be high per capita of the workforce, and in densely populated countries it would be low, and this is borne out by the data for 1980 (Figure 12.9). Output per capita is higher in Canada, New Zealand, Australia and the USA than anywhere in Europe, and the lowest outputs are found in the more densely populated countries of Greece, Italy and Portugal, although the Netherlands is anomalous.

High outputs per capita have been obtained by the adoption of laboursaving machinery. The amount of tractor power per capita is inversely related to the density of the male agricultural labour force

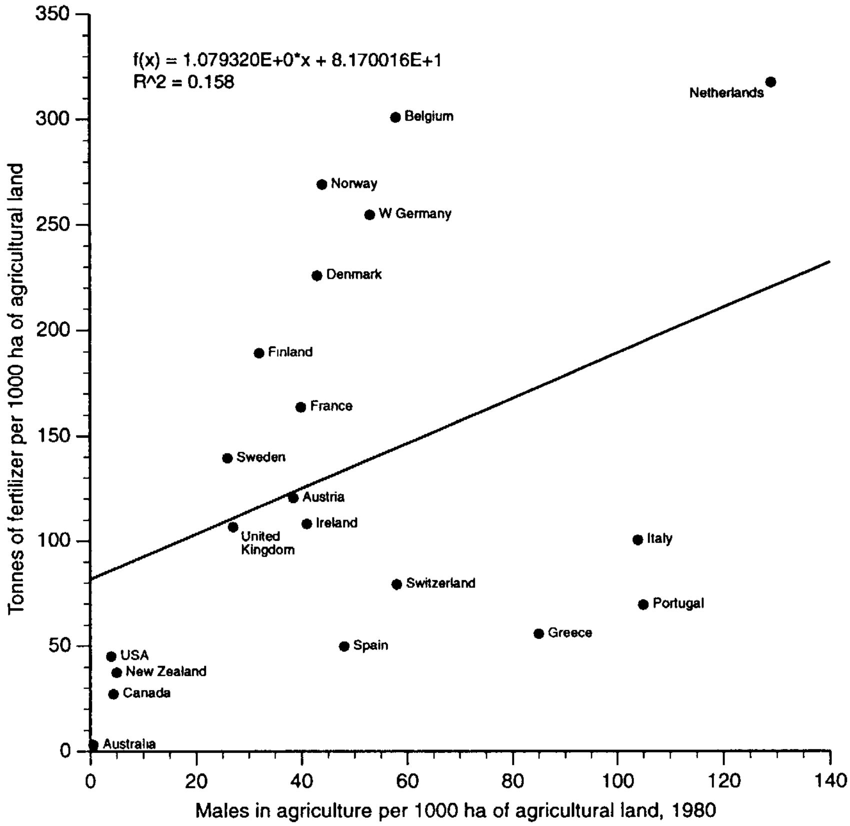

Figure 12.8 Fertilizer usage and the density of the agricultural labour force, 1980

Source: Y. Hayami and V.W. Ruttan *Agricultural Development: An International Perspective,* Baltimore, Johns Hopkins University Press, 1985

(Figure 12.10). However, although the USA and Canada with among the lowest densities, have the greatest tractor power per worker, Australia and New Zealand although much more sparsely populated than Europe, have less tractor power available than a number of more densely populated countries. This may be partly explained by the fact that tractors are only one of a great range of machines used on modern farms. But it also reflects the fact that since the 1950s the differences in agricultural productivity between Europe and its overseas settlements have diminished. In North America there has been an increase in yield-increasing inputs, in Europe there has been an widespread adoption of machinery in spite of the prevalence of small farms. With a long period of state subsidy European farmers have striven not only to increase inputs per acre, but with the decline in labour, have had to adopt machinery to increase output per capita.

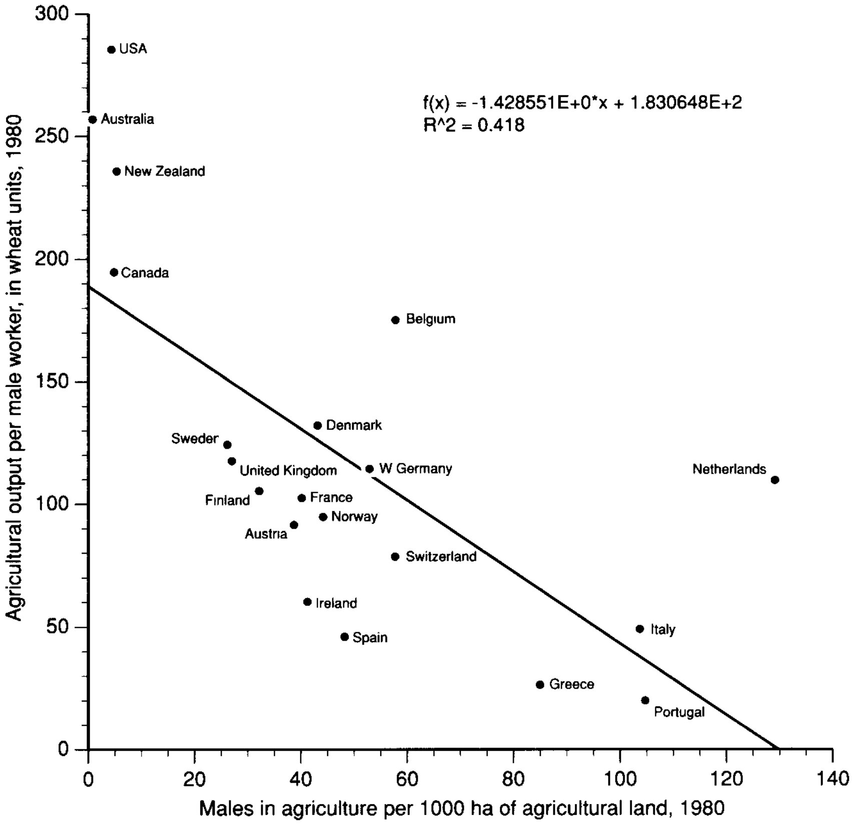

Figure 12.9 Agricultural output per capita and the density of the agricultural labour force, 1980

Source: Y. Hayami and V.W. Ruttan, *Agricultural Development: An International Perspective,* Baltimore, Johns Hopkins University Press, 1985

CONCLUSIONS

Clearly, population density—or more exactly agricultural population density — has a marked effect upon the type of farming. In the densely populated areas it encourages intensification but has adverse consequences for structure and land use, and the densely populated agricultural regions of the world are for the most part regions of poverty. In the developed world the declining agricultural labour force has led to changes in farm size and the type of technology that can be related to the differences in density.

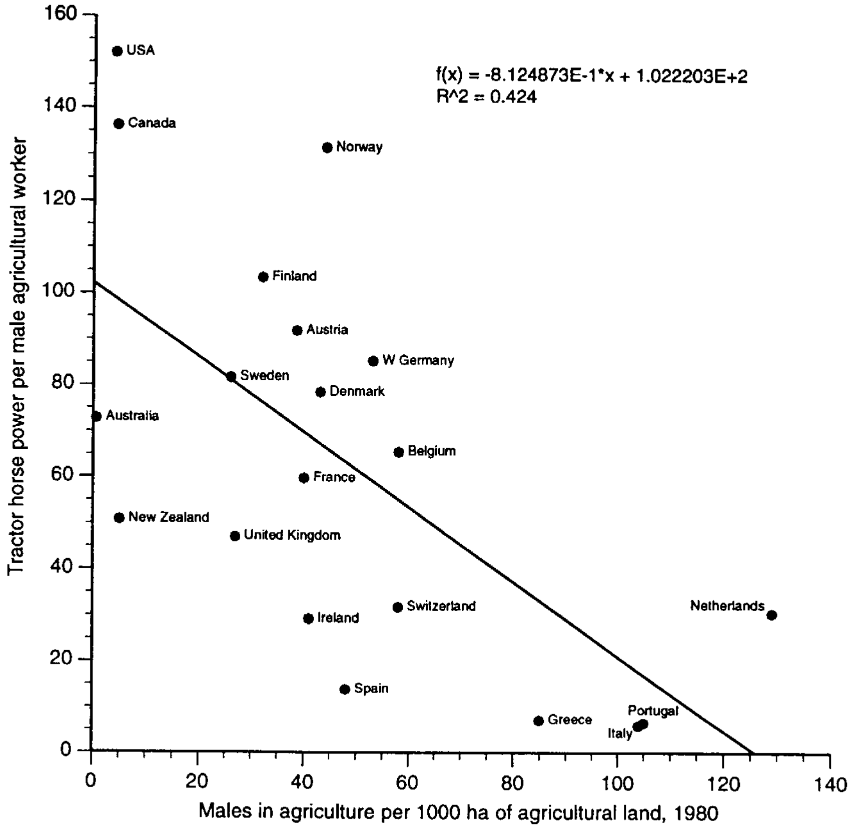

Figure 12.10 Tractor horsepower per male agricultural worker and male workers in agriculture per 1000 hectares of agricultural land, 1980

Source: Y. Hayami and V.W. Rurtan, *Agricultural Development: An International Perspective,* Baltimore, Johns Hopkins University Press, 1985

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Chapter 13
Farm size and landownership

Spatial differences in farm size and landownership are one of the most distinctive features of the agricultural geography of the world. Not only are there marked differences between continents in average size of holding (Table 13.1), but also within countries. For example, in England and Wales, large farms are more important in the east and the south-east than in the west; yet within the region dominated by large farms lies the fenland with its much smaller farms. Differences in landownership are also often a prominent feature of the agricultural landscape. Thus in the USA share-croppers are still found in the south, while in the north-east occupier-owners predominate. In Africa, there is a great difference between the systems of communal ownership found among the indigenous peoples, and (where they survive) the holdings of Europeans. Farm size and ownership must be considered when comparing two areas; they also affect other variables, influencing the type of crop chosen, the intensity with which it is grown and the efficiency of production.

THE SIZE OF FARMS

The size distribution of farms can be measured either by the percentage of the total *area* occupied by each size class, or by the percentage of the total *numbers* in each size class (Table 13.1). Invariably a small proportion of the number of farms occupy a disproportionately large proportion of the area, whilst even when small farms form a great majority of all farms, they often occupy a small proportion of the area. This discrepancy is at its most extreme in Central and South America where the landownership system imposed by the Spanish and Portuguese in the sixteenth and seventeenth centuries survives. Most of the land is divided into relatively large estates, occupying most of the agricultural land, but the majority of the farms are smallholdings that account for a very small proportion of the land. Although this discrepancy is found in every region, it is less marked in Europe, Asia and Africa where farms of under 10 hectares are a large majority of all farms, but also occupy a substantial proportion of the land.

Table 13.1 Farm size distribution by regions, c. 1970, percentage of total

	Under 5 ha	5–10	10–50	50–100	100–500	500–1000	1000 & over
Africa							
Area	48.6	14.4	14.7	2.1	3.3	1.4	15.5
Numbers	91.5	5.6	2.7	0.1	0.1	–	–
Central America							
Area	1.8	1.1	4.6	3.9	11.3	7.1	70.2
Numbers	73.3	8.5	11.1	2.6	2.8	0.5	0.8
South America							
Area	2.0	2.0	11.7	7.7	23.5	10.8	42.3
Numbers	48.7	13.7	25.3	5.3	–	0.8	0.6
Asia							
Area	46.5	20.6	26.0	4.6	1.0	0.3	1.0
Numbers	89.6	6.7	3.6	0.1	–	–	–
Europe							
Area	13.7	15.4	36.4	9.4	14.7	2.2	8.2
Numbers	65.9	16.4	15.8	1.2	0.6	–	–
Australasia							
Area	–	–	0.4	0.7	4.8	4.1	90.0
Numbers	13.1	7.1	19.3	13.1	28.7	8.5	10.2
North America							
Area	0.1	0.25	5.5	10.2	40.0	9.5	34.4
Numbers	7.0	5.5	31.7	23.1	28.9	2.3	1.5

Source: Food and Agriculture Organization, 1970 *World Census of Agriculture: Analyses and International Comparison of Results*, Rome, 1981

Very large farms—over 500 hectares—dominate the farm size distribution of Central and South America, Australasia and North America, accounting for more than half the agricultural land. The very large farm — state and collective farms—occupies an even greater proportion of the agricultural land in Eastern Europe and the former Soviet Union (not included in Table 13.1). Small farms—under 10 hectares—occupy half or more of the agricultural area in Africa and Asia, and nearly a third in Europe. However, in Europe it is the small medium-sized farm that is dominant, occupying a third of the area; very large farms account for only a tenth.

A rather different pattern emerges if the distribution by farm numbers is considered. In Asia and Africa nine-tenths of all holdings are less than 5 hectares, three-quarters in Central America, nearly two-thirds in Europe and a half in South America. In China since the abolition of the communes in 1985, it is estimated that there are 180 million farms averaging only 0.5 hectares in size. Only in Australasia and North America is the smallest category unimportant.

It might be thought then that the world's land use pattern is dominated by the very large farm, but its social structure by the farmer with a very small holding. Certainly farms over 1000 hectares occupy half the total land in farms (Table 13.2). However, very considerable proportions of the larger holdings are grass or rough grazing, particularly in Australasia and Latin America. If farms are measured by their arable land only then 70 per cent is on farms of less than 50 hectares, 45 per cent on farms of less than 10 hectares. Thus it is comparatively small farms that account for most of the world's crop production.

The reasons for the wide regional variations in farm size—which occur within countries as well as between continents—are numerous, and can only be touched upon here. Population density is a prime factor, with the lowest average sizes in the more densely populated regions. Land tenure is important, as already noted in the case of Latin America and the Soviet Union. Inheritance systems may be significant. Where owner-occupied farms are passed on at the death of a farmer, primogeniture, where only the eldest son inherits, gives rise to larger farms than partible inheritance, where the land is divided amongst all the children. This is a partial explanation of the greater average size of farm in England than in the rest of Western Europe, and the marked difference in size between West and East Germany.

Table 13.2 Distribution of total land and arable land by size of holding, 42 countries

	Total land in holding %	*Arable land %*
Under 1 ha	1.7	5.6
1–2 ha	2.3	7.4
2–5 ha	5.8	16.2
5–10 ha	6.3	15.6
10–20 ha	6.3	14.3
20–50 ha	6.8	11.8
50–100 ha	4.5	5.7
100–200 ha	4.8	4.2
200–500 ha	6.2	4.6
500–1000 ha	5.1	4.4
1000 ha & over	50.2	10.1

Source: Food and Agriculture Organization, *World Census of Agriculture: Analyses and International Comparison of Results,* Rome, 1981

The size of farm has a number of important effects upon agriculture. First, it affects the farmer's standard of living. In many parts of Asia a large proportion of the farms, however intensively farmed, are too small to provide an adequate supply of food for the farmer's family (see Chapter 12), and they have to seek other sources of income by working upon larger farms or in nearby towns. In Western Europe, the problem of the small farm is not one of providing enough food, but of producing an income comparable with that obtainable in other parts of the economy. In the last thirty years the incomes of small farmers have fallen below the incomes of those employed in industry. In Britain, many farmers with less than 40 ha, particularly those on poor soils, earn less than an agricultural labourer. In 1989, the farm with less than 5 ha was a considerable proportion of all farms in most parts of the EEC and only in exceptional circumstances can such farms provide an income comparable to that obtained in other parts of the economy (Table 13.3).

Second, farm size influences the type of farming practised. In the developing countries, occupiers of a hectare or less are rarely able to buy their food, and have to use all their land for growing crops. They are unable to spare land for cash crops or for fodder crops. Consequendy such livestock as they have are poorly fed and give low yields of milk and meat. In Western Europe, the problem of the farmer with litde land is different. To obtain an adequate income the farmer must choose an enterprise widi a high net return per hectare (such as dairying or horticulture), yet soils or location may make this difficult (Table 7.1, p. 72). On large farms, however, farmers can generate a good income even with enterprises with a comparatively low net return per hectare, such as cereals. For some enterprises, such as sheep rearing, returns per hectare are so low that few British farms are large enough to give an adequate income. However, in many sparsely occupied areas, such as Australia and Latin America, very large holdings are devoted to sheep or cattle. Although returns per hectare may be very low, total farm income is high.

Third, farm size in both the developed and the developing countries is an important determinant of intensity. On small farms in Kenya labour inputs per hectare increase as farm size decreases (Table 13.4). In India the index of multiple cropping and the proportion of land irrigated is higher on small than larger farms (Table 13.5), and on both the value of output per hectare diminishes as farms increase in size. However, generally the value of output *per capita* declines with an increase in farm size. High labour intensities are found on the small farms of Asia and Africa, because the use of labour is the main means of increasing output per hectare; farmers will utilize their labour force to maximize total gross output per hectare. They do not cease to work when marginal input equals marginal revenue (Chapter 7). In developed countries, small farmers have to select those enterprises that have a high net return per hectare, and these are invariably the more labour-intensive types of farming.

Table 13.3 Farm size distribution in Western Europe, 1989

	Number of farms in each class as a percentage of all farms			
	1–5 ha	*5–20 ha*	*20–50 ha*	*50 ha and over*
UK	13.5	27.7	25.4	33.3
Luxembourg	18.9	22.3	32.5	26.2
Denmark	1.7	41.6	39.4	17.2
France	18.2	30.8	32.8	18.1
Ireland	16.1	44.4	30.3	9.0
Netherlands	24.9	43.4	27.3	4.4
Belgium	27.7	42.6	23.9	5.8
West Germany	29.4	39.7	24.8	6.1
Italy	67.9	25.6	4.6	1.9
Greece	69.4	27.6	2.5	0.5
Spain	53.3	31.3	9.4	6.0
Portugal	72.5	22.2	3.4	1.9
European 12	49.2	30.3	13.7	6.8

Source: Commission of the European Communities, *The Agricultural Situation in the Community, 1992 Report,* Brussels, 1993, pp. T122/123

Fourth, efficiency of output is related to the size of farm. Efficiency is difficult to define, but is commonly measured by relating the value of total output to the value of all inputs. This ratio is held to increase as farms become larger, because of economies of size. Thus, overheads such as the cost of maintaining buildings are lower per hectare on a large farm than on a small one. Machinery can be more fully utilized; there is little point in having a combine harvester for a hectare of wheat, or a milking parlour for a couple of cows. Farmers with large farms can often negotiate lower prices for the purchase of fertilizers or feeds in bulk; the small farmer, with more modest requirements, has to pay a higher price. He or she may well also find it more difficult to obtain credit. On the large farms found in some parts of Britain, the labour force is large enough for individual workers to specialize in a particularly activity, and so become more efficient, while the farmer has no need to do manual labour and can improve his or her management techniques. On very large farms, however, the costs of supervision and the difficulties of controlling very large areas and labour forces may reduce efficiency; this undoubtedly occurred on the very large state farms in the former USSR. On the smaller farms in Britain and elsewhere the principal cause of low efficiency is that the farmer does not have enough land to occupy his or her labour and that of the family throughout the year, so that labour costs per unit of output are high. The optimum size of farm—that which maximizes efficiency—varies for different types of farming: it is smaller for dairying than for cereal cropping, and for some types of farming the advantages accruing to size diminish beyond a certain point (Figure 13.1). It should be noted, however, that most of the economies of size potentially available to farmers can be obtained on comparatively small farms. In the USA in the 1970s 90 per cent of the possible economies of size were available on farms of just over 300 acres.

Table 13.4 Farm size, output and labour intensity on settlement schemes in Kenya, 1967-8

Farm size class (acres)	*Gross output (Kenyan shillings per acre)*	*Labour inputs (Men equivalent per 1000 acres)*
Less than 10	635	808
10–19.9	250	399
20–29.9	156	234
30–39.9	161	159
40–49.9	113	124
50–59.9	98	111
60–69.9	98	109
70 or more	111	70

Source: W.M. Senya, 'Kenya's agricultural sector', in J. Heyer, J.K. Maitha and W.M. Senya, *Agricultural Development in Kenya. An Economic* Assessment, Nairobi, Oxford University Press, 1976

Table 13.5 Farm size and intensity in India, 1970–1

	Value of output (rupees per hectare)	*Cropping index*	*Percentage of area irrigated*
Under 2 ha	2026	151	50
2–6 ha	1651	139	51
6–10 ha	1253	128	38
10 ha and over	924	121	29

Source: G. Etienne, *India's Changing Rural Scene*, Delhi, Oxford University Press, 1982

THE LAYOUT OF FARMS

In Britain and the USA, most farms consist of a house and buildings surrounded by land divided into separate fields, the block of land being clearly distinguished from adjacent farms by a fence, hedge, wall or wire. This is not so in much of Western Europe or Asia. Here the farm buildings are in a central village which is surrounded by many small fields, and the fields of each farmer are not next to each other, but are intermixed with

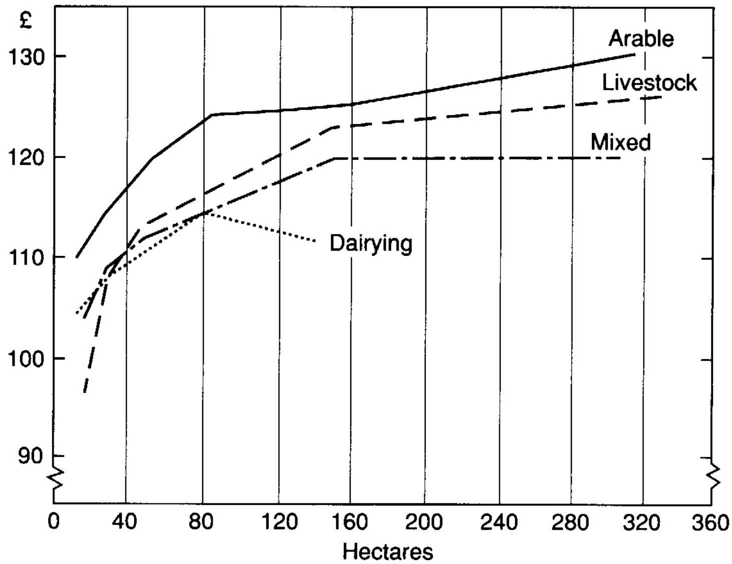

Figure 13.1 Average gross output per £100 of input by size of farm and by type of farming After Office for the Minister of Science, *Scale of Enterprise in Farming,* London, HMSO, 1961

those of other farmers (Figure 13.2). This dispersal or scattering of the plots or fields that make up a farm is called fragmentation. It was more common in the past in Europe when the open-field system prevailed. In the nineteenth century, land in Britain, Denmark, southern Sweden and northern Germany was enclosed, and the scattered plots of an individual farmer consolidated, so that he received a compact block of land. However, consolidation was slow in the rest of Western Europe—and indeed Eastern and Southern Europe—so that as recently as the 1950s much of Europe's farmland was still held in scattered, small and narrow fields.

The reasons for fragmentation are not clear. It is not simply a result of the fossilization of the open-field system, for it is also found in Asia and Africa. One possible explanation is partible inheritance. Where, at the death of a farmer, the land is divided among the sons or all the children, not only does the farm become subdivided, but the heirs may share the better and poorer land equably, so causing scattering. In periods of rapid population growth both the subdivision of farms and the fragmentation of plots increases. Fragmentation may also occur because farmers want a share of soils of different types; a farmer may want some good well-drained arable land and also wetter land, near a river, for meadow. In Asia, where

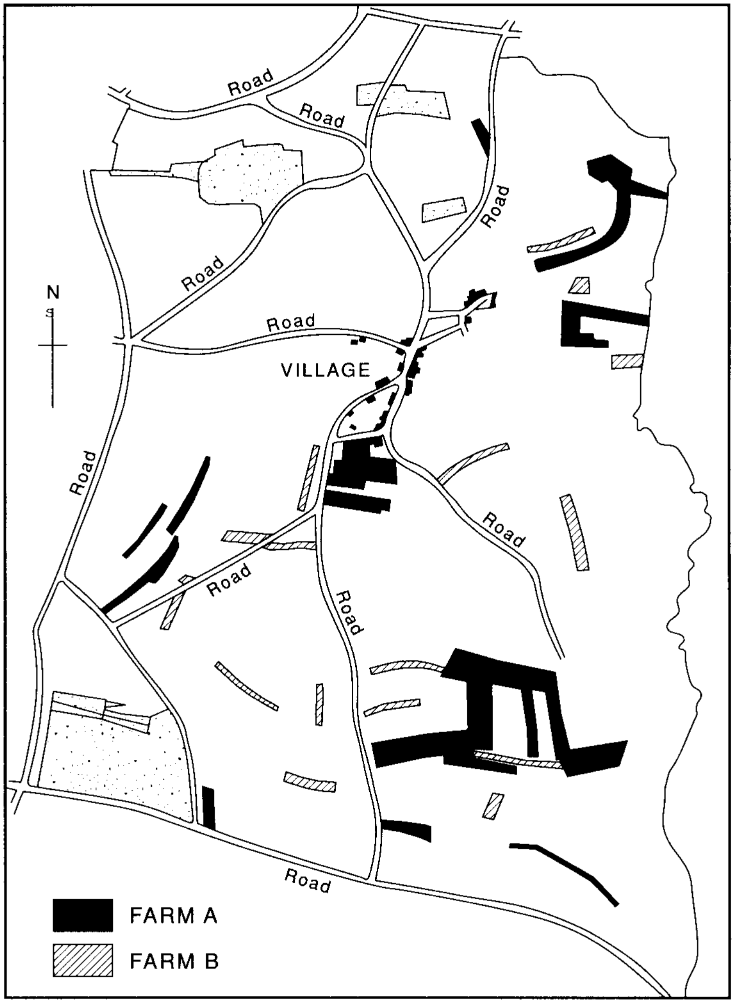

Figure 13.2 The fragmentation of farms in a Belgian community, 1949 After W.S. and E.S. Woytinsky, *World Population: Trends and Outlook,* New York, The Twentieth Century Fund, 1953

irrigated land is of great value, and where not all the village land is irrigated, it is likely that each farmer will have a share of both irrigated and dry land. Thus, scattering may be a conscious insurance against risk. If a farmer's land is on different soils and in different parts of the village land, the farmer may avoid complete disaster if there is flooding, localized frost, hail, or plant or animal disease.

Whatever the reasons for fragmentation, it has drawbacks for modern farming, retarding improvement and reducing efficiency. A farmer with widely spaced plots wastes time travelling from plot to plot, and the cost of moving machines and fertilizers is high. Most fragmented farms consist of small and often narrow fields, and the difficulties of moving machinery are considerable; not only is time wasted moving from field to field, but in small fields much time is spent simply turning tractors round. A notable feature of modern British agriculture is the removal of field boundaries to reduce this loss of work-time. This is not possible, of course, if the farm is highly fragmented, as is still the case in some parts of Europe. The desire to use machinery is probably the most powerful motive for consolidation. The intermixture of fields also makes it more difficult to prevent the spread of plant and animal disease, and also weeds, for farmers are victims of the least efficient neighbour. A further drawback is the loss of potential crop land in the proliferation of field boundaries and paths.

In the last thirty years, there have been attempts to consolidate fragmented holdings in many parts of the world, but particularly in Europe. Ironically, fragmentation now seems to be on the increase in Britain and the USA, where it has not hitherto been a problem. Modern farming in both countries needs machinery, which must not be under-utilized, thus farmers are constantly seeking to add to their land. Farm size in both countries— and indeed elsewhere—has been increasing, but farmers are not always able to buy or rent land adjacent to their existing farm, and have often acquired land at some considerable distance from it. This of course increases fragmentation; some argue that the benefits which accrue to the use of larger amounts of land with the stock of machinery are offset by the costs of movement and the increased difficulties of supervision.

LANDOWNERSHIP AND FARMING

There are few reliable statistics on the world pattern of land tenure. However, a survey based on the 1950 World Agricultural Census (which excluded the Communist countries) estimated that 68 per cent of the 988 million ha surveyed were farmed by occupier-owners, and 26 per cent by tenants. Since then the numbers who are occupier-owners have increased. In the developed countries, greater prosperity has allowed some tenants to buy their land. In England and Wales, for example, occupier-owners now hold 60 per cent of the farmland, compared with only one-tenth in 1900. In many developing countries in the 1950s and 1960s, notably in Iran, Japan and Taiwan, land reform schemes made tenants into freeholders by compulsory purchase or expropriation. However, in Communist countries, both occupier-owners and landlords have lost land; private property has been largely extinguished, and all agricultural land is the property of the state. Some 28 per cent of the world's total agricultural area is now in Communist or ex-Communist countries.

Although many believe that land tenure is a primary barrier to agricultural progress, and the redistribution of land is necessary for social justice, it is less easy to point to any obvious effects upon the type of crops grown or livestock kept. The principal consequences of land ownership differ ences are upon the control of decision-making and upon the farmers' willingness to innovate. In areas where the occupier-owner predominates, the decisions are made by the farmer and in most areas of tenancy the occupier is in control of the majority of decisions upon the farm. Where share-cropping is practised—a system where the landlord provides land and sometimes part of the seed, fertilizer and equipment, in return for a share of the harvest—the landlord may decide what is grown. But it is in the former Communist countries that many decisions about what, and how, to grow were taken not on the farm but in central planning offices. The system of agriculture in the former Soviet Union illustrates this.

Two types of farm were found in the Soviet Union: the collective and the state farm. The former was run by a committee of members of the collective, the latter by a manager with hired agricultural workers. National targets for agricultural output were established by the Ministry of Agriculture in each of the Five Year Plans. The targets were allocated to major regions, and then to lesser administrative regions, until eventually each farm received its targets. Both state and collective farms were required to deliver grain quotas to the state at fixed prices, any surplus above quota being sold to the state marketing system at more flexible prices. A third component of the system was the private plot to which all members of collectives and state farms were entitled. Although these occupied only 3 per cent of the sown area of the Soviet Union, they produced in 1988 26 per cent of total output. This is perhaps not surprising for the private plots produced a high proportion of vegetables, milk, meat and eggs, and accounted for 40 per cent of all the hours worked on Soviet land.

The centralized nature of Soviet agriculture has had numerous consequences for its agricultural geography. Three only are noted here. First, Soviet economists believed that farms could produce economies of scale comparable to those obtained in industry. As a result, the average size of farms has steadily risen since the 1930s; collectives in 1986 averaged 6360 ha and state farms 15,640 ha. Except for the private plots, there are no small or medium-sized farms, comparable with the family farms of Western Europe, or even with the larger family farms of the USA. Second, planners have always argued that there are few natural drawbacks to the expansion of the cultivated area in the Soviet Union, and so increases in output were obtained by bringing more land into cultivation; the Virgin Lands scheme of the 1950s added 40 million ha in a few years, but in areas with very low rainfall. As a result, measures to increase output per hectare have received less attention. This is in marked contrast to Western Europe where, in the last thirty years, the growth of output has been almost entirely due to yield increases; marginal land has been abandoned and land lost to urban expansion. Third, the centralized system has made it difficult to establish regional specialization, growing crops in those regions most suited to them. This is partly because national targets tend to be divided among regions in proportion simply to their area, rather than their climatic suitability, and partly because the state and collective farms pay no rent. There is thus no way in farm accountancy to allow for differences in environment, although attempts have been made to produce land classification maps to promote regional specialization.

The collapse of Communism in Eastern Europe and the former Soviet Union has not yet led to any radical change in the system; some private farms have been formed, generally only on the poorer land. However, in the late 1970s there were radical changes in the organization of farming in China. The commune was replaced by the household as the unit of direction, and farmers were allowed to sell their produce rather than deliver it to the state. The result was a great increase in output and productivity.

Differences between tenancy and occupier-ownership in the rest of the world produce less marked economic consequences. Where tenants are protected from excessive rents, and are compensated for improvements if they give up the lease of a farm (as they are in most of North America and Western Europe), then there are few differences in productivity or the type of farming followed. However, where tenancy systems leave the tenant prey to exorbitant rents or eviction, as they still do in parts of Asia and especially in Latin America, then there is little incentive for the tenant to improve farming methods, and tenurial conditions are a primary cause of backward agriculture. In some types of tenancy—notably share-cropping—the landlord rather than the tenant may decide what is grown and how it is grown.

Communal agriculture is far less common that it was, but is still found in parts of Africa. Here, land is the property of the group; each member of the tribe or village has the right to some land, and the land cannot be sold. Although such systems may ensure the well-being of all in the group, they do not work satisfactorily when population pressure increases, or when farming becomes commercialized. Thus in much of Africa such systems are being replaced by individual property rights, just as common land was in nineteenth-century Europe.

THE MODERNIZATION OF AGRICULTURE AND THE ORGANIZATION OF PRODUCTION

One of the most striking features of the past forty years has been the farmers' growing dependence upon inputs purchased from industry, and the greater proportion of farm output that is processed in some way in the food manufacturing sector. Indeed by the 1970s the agricultural input and the agricultural processing and distribution sectors produced a greater proportion of gross domestic product than production on the farm. This might be expected to lead to changes in the organization of production, and certainly most developed countries have experienced a decline in the number of small farms and an increase in the number of large. What also might be expected is the growth of vertical integration, where food manufacturers own and manage the land which produces the crops or animals that are processed. Sometimes firms such as these are referred to as agribusinesses, and it has been argued that they will eventually control large proportions of the farm output of US agriculture. This was already true of particular commodities such as broilers in the early 1980s. Another apparent sign of vertical integration was the growth of corporate farming, but most of these farm corporations are in fact family companies, which can benefit from tax and other allowances as companies rather than as individual proprietors. In 1979 only 6 per cent of US farm receipts went to true corporate farms; this type of farming is even less important in Western Europe. In most developed regions, however, contract farming is common, where particular crops such as peas or sugar-beet are grown by farmers under the fairly strict control of a food processor, but this is hardly a measure of vertical integration.

In the developing world corporate farming has perhaps made more progress. Many plantation crops have been produced by companies that own both the farm that produces the crop and the factory that processes it, generally for export to the USA or Western Europe. Such companies have been absorbed by large transnational agribusinesses that grow, process and market an increasing proportion of developing country agricultural exports.

CONCLUSION

It is .perhaps easier to show how differences in ownership, farm size and layout affect productivity, rather than the selection of different types of crop or livestock. None the less, it is a factor that must always be considered when comparing one farming area with another.

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Chapter 14
The diffusion of agricultural innovations

Most analyses of agricultural distributions concern themselves with the present alone, and this may be misleading. In Figure 14.1, the limit of a crop distribution lies at AB, some 50 km east of the coast on which there are a number of small ports. One possible explanation is that rainfall declines eastwards, and at AB yields are too low for its profitable cultivation. Alternatively, it may be that the product is perishable and, in the absence of refrigeration facilities on local trains and lorries, cannot be transported in fresh condition more than 50 km. But a consideration of earlier distributions of the crop might suggest a quite different reason for the present limit. Twenty-five years ago the crop was unknown, but was then introduced into the ports by immigrants. Farmers near the ports rapidly adopted the crop, and five years later its eastern limit was up to 10 km away (Figure 14.1). Its continued adoption by more distant farmers, who saw their neighbours growing the crop, explains its present limits. In ten years, if demand continues to grow, the eastern limit may lie 60 km from the coast. The crop, a cash crop for export, rarely occupies more than 30 per cent of a farmer's land. As the crop spreads eastwards, a transect from west to east (Figure 14.1) shows that farmers near the towns are the first to plant 30 per cent of their land in the crop. At some future time, all farmers may plant 30 per cent.

The diffusion of plants, animals and other agricultural innovations has long been a matter of interest to geographers, botanists, sociologists and anthropologists. More recently others have asked why it is that some farmers adopt a new method before others, and how the innovation spreads. Two distinct approaches have been adopted.

SOCIAL DIFFUSION

Rural sociologists and economists have asked why some farmers (a small percentage of the total) are always the first to adopt a new crop or method, while others are always last (Figure 14.2). It is argued that an adoption curve, over time, shows a slow cumulative rate of adoption at first, when

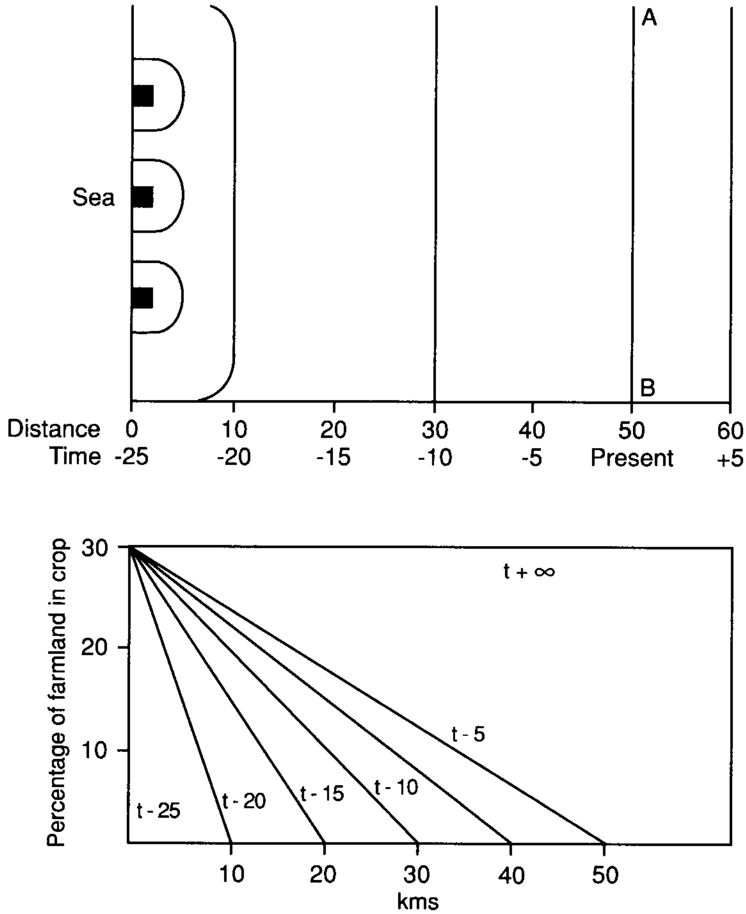

Figure 14.1 Models of diffusion

the innovators are the only ones to adopt it. Then the rate of adoption accelerates and finally slows when only the laggards are left.

Sociologists believe that this rate of adoption is a function of the flow of information. Innovators and some early adopters hear of the innovation from the radio, in farming magazines, from agricultural extension officers or from agents selling the new seed or fertilizer; late adopters, in contrast, hear of the innovation only from their neighbours, and adopt the innovation only after watching their neighbours' experience. The early adopters have a number of social characteristics in common. They are younger than average, better educated, have larger farms, are more business-like, have a high social standing, and mix more widely in the local community. Such views have been much criticized by economists, who argue that adoption is determined primarily by a farmer's economic assessment of an innovation; if it will increase profit, it will be adopted. It has also been noticed that in developed countries most farmers, and not a minority, hear of an innovation directly rather than from neighbours, so that the information lag assumed by sociologists does not exist.

The characteristics of the innovation may also prove important in the rate at which an innovation spreads. For example, new seed or fertilizers are divisible, and can be tried in small amounts at low cost to see if they work. Combine harvesters or new buildings are costlier and have to be brought in one lump. Simple innovations are likely to be adopted before complex machinery, and innovations that fit easily into the existing farming system will be adopted before those that require major changes in farming routine.

SPATIAL DIFFUSION

A new crop or method can spread from its source region in two ways. First, it can be taken by farmers or others migrating to a new country. Much of North America's livestock and crops were brought by setders from Britain and other West European countries, while the Spanish merino sheep was taken to Australia via South Africa. Second, new crops or methods also spread through an existing, setded population. One farmer grows the crop, neighbours observe and then adopt it themselves and so, like a ripple in a pool when a stone is dropped, the innovation spreads outwards. Spatial diffusion is rarely as simple as this: in particular, if a majority of farmers, rather than a minority, hear of the innovation and adopt it at the same time, there will not be the slow spread from farmer to farmer outwards from a limited source area that is assumed in most models of spatial diffusion.

THE DOMESTICATION OF PLANTS AND THEIR PRESENT DISTRIBUTION

All agricultural plants were originally wild; the earliest domestications took place some nine or ten thousand years ago. The places where they were domesticated were comparatively limited. Only a few regions have contributed domesticated plants to the farmer, South-West Asia, South-East Asia and Central America being the most important. Since then, crop plants have spread from their areas of domestication throughout the world. Much the same is true of the major domesticated animals, which

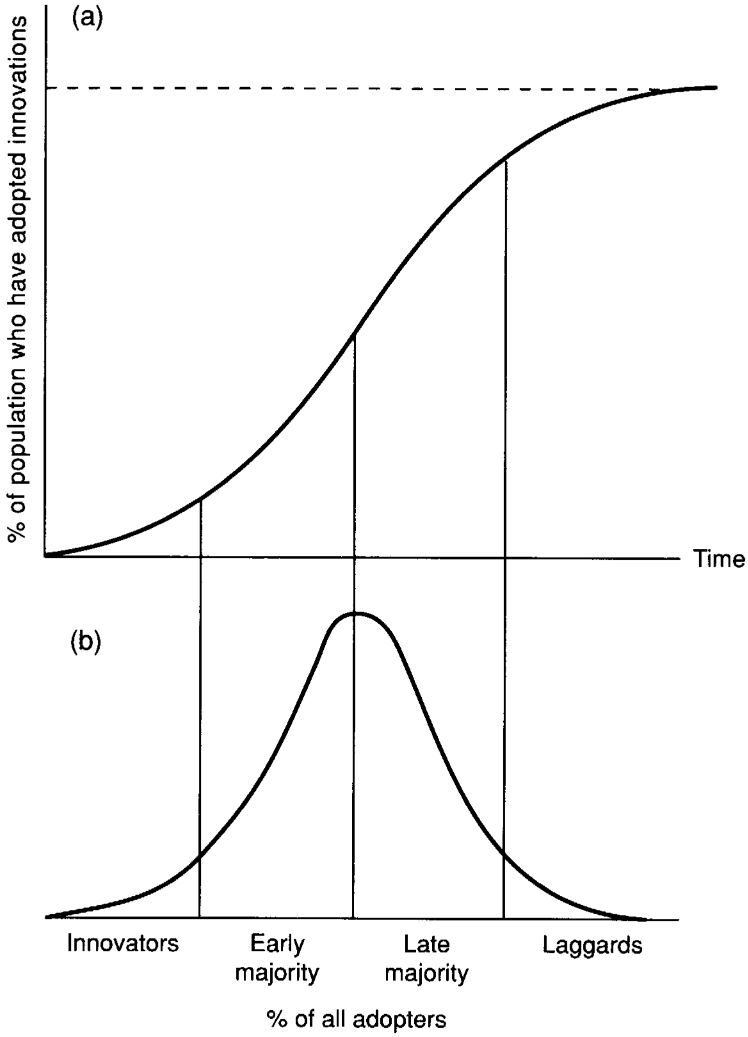

Figure 14.2 The adoption of an innovation (a) The adoption curve showing the cumulative percentage of all adopters who have adopted an innovation over time (b) Innovators and laggards as a percentage of all adopters

were all indigenous to Eurasia; the Americas and Australasia had no horses, cattle or sheep until these were introduced by European settlers.

The principal farming regions now have a remarkable mixture of crops from different source regions. This is a result of several thousand years of diffusion which, however, was greatly accelerated by European expansion that began in the fifteenth century (Table 14.1). Only one-quarter of the crops grown in Europe north of the Alps are from plants indigenous to the region. The most important crops acquired from elsewhere were the cereals wheat, barley and oats—all indigenous to South-West Asia—which spread into Europe several thousand years ago. The most important subsequent introductions were the potato and maize, which are indigenous to Latin America. The potato was brought to Europe in the sixteenth century, although it did not become an important food crop until the nineteenth century. Neither North America nor Australasia had indigenous crops of any significance. When Europeans first settled in the USA and Canada, they brought with them the crops of Western Europe, but they later adopted some of the crops grown by the Indians in the east, which in turn had been acquired from Central and Southern America. Of these crops, maize was by far the most important. African crop patterns were profoundly changed by the discovery of the Americas. American food crops such as manioc and maize were taken from Brazil to Africa in returning slave-ships, and in the nineteenth century the two crops spread inland to become staple crops. Rice was probably domesticated somewhere in mainland South-East Asia, and was carried north into China and west into India at a very early date.

The exchange of non-food crops has also been important. Rubber is indigenous to Central and South America, but was litde used until the nineteenth century. The demand for rubber in Europe after the discovery of vulcanization was initially met by the collection of latex from rubber trees growing wild in the Amazon basin. Seeds of the tree were smuggled to Kew in London, and taken from there to Singapore, where they formed the basis for the remarkable expansion of rubber planting in the early twentieth century.

THE DIFFUSION OF HYBRID CORN IN THE USA

Until 1918, all corn sown in the USA was of the open pollinated variety. In that year it was shown that a cross between genetically unlike varieties was possible, and these hybrid varieties became commercially available by the 1930s. Hybrids could be bred for a specific locality, and they gave yields 15–20 per cent above open pollinated varieties. By the 1950s hybrid varieties had largely replaced the older varieties.

Hybrid corn was marketed by seed merchants. They first sold their seed in the heart of the Corn Belt, where a high proportion of total farm land was in corn, yields were highest and the potential profit to both farmer and merchant was greatest. It was here, too, that hybrids were most rapidly adopted. Iowa, for example, had only 6 per cent of its corn area in hybrids in 1934, but 80 per cent by 1939; Alabama, in contrast, did not have 5 per cent until 1947, and reached 80 per cent only in 1957. The spread of

Table 14.1 Crop combinations of major regions by area of plant domestication (percentage of area in major crops)

	Indigenous	*South-West Asia*	*South-East Asia*	*Latin America*	*Africa*	*Northern Europe*	*China*	*Other*
South-West Asia	79.5	I*	3.2	9.1	1.9	4.1	–	0.2
South-East Asia	69.9	0.4	I	22.3	2.6	–	1.7	–
Latin America	48.0	14.4	14.4	I	9.1	1.7	0.9	2.1
Africa	41.8	3.7	7.0	39.7	I	0.2	–	4.0
Northern Europe	24.2	47.9	0.1	21.4	0.1	I	0.1	4.0
China	16.9	29.1	22.2	12.0	12.5	1.4	I	2.0
India	1.2	21.7	28.8	14.6	26.2	–	–	–
Mediterranean	1.6	67.6	0.6	16.8	–	7.5	–	–
North America	0.1	40.9	1.4	26.1	5.7	9.2	14.3	0.5
Australia	–	84.3	0.3	1.7	0.3	10.6	–	–

Note: **I=Indigenous*

Source: *D.B.Grigg, The Agricultural Systems of the World*: An Evolutionary Approach, Cambridge, Cambridge University Press, 1974, p. 27

hybrid corn can be seen in Figure 14.3, where the date when a county first had 10 per cent of its total corn in hybrids is shown. Although the map indicates a slow spread outwards from the core area in the Corn Belt, as theory would suggest, there are some exceptions. First, the initial spread was more eastwards and westwards than southwards. This was because hybrid varieties were adapted to a particular growing season. Thus, it was easier for the early hybrids, bred for Iowa, to spread east and west, where the growing season was the same, than south, where the growing season was longer. Second, between 1940 and 1944, hybrids spread rapidly south-west but not south-eastwards. This seems to have been owing to the presence in the south-west of efficient agricultural experimental stations that rapidly bred seed adapted to local conditions. In the south-east, in contrast, there were problems with plant disease and insects, while not only was a small proportion of farmland in corn, but yields were low, so that potential profit to both farmer and seed merchant was lower than elsewhere. So, although the outward expansion of hybrid corn approximates the simple model of spatial diffusion, there were important exceptions.

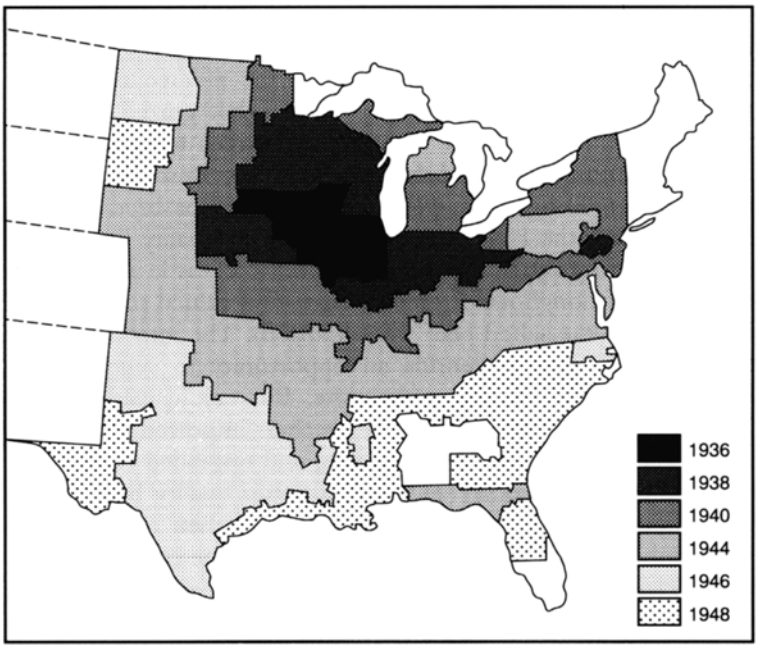

Figure 14.3 The diffusion of hybrid corn in the USA, 1936-48 The map shows the year that a county first had 10 per cent of its total area in corn sown with hybrid seed

After Z. Griliches, 'Hybrid corn and the economies of innovation', *Science,* 1960, vol. 132, pp. 275-80

THE DIFFUSION OF CATTLE: HEREFORDS AND THE ABERDEEN ANGUS

Cattle, sheep, goats and pigs were all domesticated in Eurasia, and spread slowly to other parts of the world. There were no sheep or cattle in the Americas until Europeans arrived. The Portuguese and Spanish introduced Longhorn cattle, which formed the basis of cattle stocks in much of North and South America until the mid-nineteenth century. Although adapted to dry conditions, and tolerant of being driven long distances, they gave a poor quality meat. In the USA in the second half of the nineteenth century, Texas Longhorns formed the basis of great herds that grazed the open range from Texas northwards. These animals were driven to railheads and thence taken to the more humid Midwest where they were fattened for market. In the 1880s, Longhorns were replaced or crossbred with an imported English breed, the Hereford, to give a better quality beef.

A similar sequence occurred in Argentina. Before 1876, cattle in Argentina were predominantly of Longhorn or creole origin, and valued primarily for their hides (although some salted beef was exported). The introduction of refrigeration into ships gave Argentina an opportunity to send beef to Britain, the leading export market at the time. But creole cattle gave a poor quality beef. From the 1870s Argentine ranchers imported Shorthorns (and to a lesser extent Herefords) from Britain, and upgraded their herds. These cattle fattened more quickly and gave a better quality beef. Shorthorns, however, gave a great deal of fat, which was then acceptable in Britain as it could be made into suet and dripping. But the rise of incomes in Britain after 1918 saw an increased preference for lean and tender meat; at the same time, animal fats, which had been used as ingredients in the manufacture of soap, cooking oils and margarine, were increasingly replaced by synthetic detergents and vegetable oils. Since 1945, Argentina has ceased to rely upon Britain as a market, but similar trends are apparent in its other export markets where there is a similar preference for lean beef. The response in Argentina has been to increase the number of Aberdeen Angus in the national herds, for the Angus matures more rapidly than the Shordiorn, has less fat and a more tender beef. In 1930, the Angus represented only 4 per cent of the nation's cattle, by 1947 10 per cent, and by 1970 40 per cent. The Angus, essentially a beef animal, has made no progress in the dairying region near Buenos Aires, nor in the drier and cooler regions, where the hardier Hereford still predominates, but in the south-east of the pampas—the breeding region on which other rearing and fattening regions rely for their supply of stock—it made up 40 per cent or more of all cattle by 1960.

THE GREEN REVOLUTION IN ASIA

Most studies of the adoption of agricultural innovations have emphasized the lag in adoption between innovators and laggards, and the slow spatial diffusion—from neighbour to neighbour—outwards from a source area. Yet not all farmers wish to adopt all innovations, nor are all innovations suitable to all areas. The introduction of a new milking parlour is of litde interest to cereal growers, and combine harvesters have no value to horticulturalists. Similarly, many innovations can only be adopted in suitable physical environments. Tropical crops cannot be transferred to the Arctic, not do animals bred for the cool, moist climates of Western Europe thrive in tropical regions. The adoption of improved hybrid wheats and rice in Asia since 1965 well illustrates that many agricultural innovations are specific to a particular type of environment.

New hybrid wheats from Mexico and hybrid rice bred in the Philippines were introduced into Asia in 1965. The new rice varieties had a number of advantages.

1 They were semi-dwarf, with a short, strong stalk that could carry a heavy head of grain. The long-stalked indigenous *indica* varieties collapsed under heavy grain yields, and could not be harvested.
2 They were more responsive to fertilizer than *indica,* giving a greater increase in output for each unit input of fertilizer.
3 They matured in a shorter time than most traditional varieties, allowing double cropping and hence an increase in the area sown in a year.
4 Unlike the traditional varieties they did not flower in response to day length; because they were photo-insentitive their sowing dates could be more flexible. If sown in the dry season (assuming irrigation was available) when cloud cover was less and the radiation received was greater, they could give higher yields than traditional varieties, which had to be grown in the monsoon which has extensive cloud cover.

The new varieties did not always give higher yields than traditional varieties if solely traditional methods of cultivation were followed. If, however, fertilizer and pesticides were used, and the water supply was adequate, they did perform dramatically better than the traditional varieties. Although there was a considerable increase in production cost, there was also a marked increase in net return per hectare.

There was a dramatic rise in the area under wheat and rice sown to the hybrid varieties between 1965 and 1977. By the latter year, 72 per cent of

Table 14.2 Percentage of area in crop sown with modern varieties

	1970–1	*1976–7*	*1982–3*
Rice			
China	n.d.	80.4	81.0
Rest of Asia	13.1	30.4	44.9
All Asia	n.d.	45.7	56.8
Wheat			
China	n.d.	25.0	30.6
Rest of Asia	39.1	72.4	79.2
All Asia	n.d.	48.4	48.7

Sources: D.G. Dalrymple, *Development and Spread of High Yielding Varieties of Wheat and Rice in the Less Developed Nations,* Washington, DC, 1978; M. Lipton, *New Seeds and Poor People,* London, Unwin Hyman, 1989

the wheat in Asia (excluding Communist countries) (Table 14.2) was sown to the new high-yielding varieties, as was 30 per cent of the rice: in the whole of Asia the figures were 45.7 per cent and 48.4 per cent respectively. However, in 1976/7 there were marked differences in the rate of adoption between countries, and between regions within countries (Figure 14.4). In Burma, for example, only 7 per cent of the rice area was sown with the new varieties; in the Phillipines, where the first successful hybrid rice, IR8, was bred, over two-thirds of the sown area was in the new varieties. Although the date of introduction was later in some countries (none was sown in South Korea until 1971/2), this was not the sole cause of the differences in the proportion sown in 1976/7.

Government influences were important: in India, for example, not only were extension agencies established to advise farmers, but fertilizers were subsidized, and the seed, initially, was free. Furthermore, India, unlike most Asian countries, had agricultural scientists who could breed varieties adapted to local conditions. Farm size may also have influenced the rate of adoption. Although in theory the new varieties could be as economically adopted on small farms as large—for there were no great economies of scale, and the inputs could be purchased in small amounts—there is some evidence that in the 1960s and early 1970s those with large farms were prepared to adopt the new package of inputs because they could borrow money to purchase it. Small farmers, on the other hand, could not bear the risk of borrowing. However, in the later 1970s there was little difference by farm size in the rate of adoption.

Of paramount importance was the availability of irrigation. Nearly all rice in Asia is wet-rice, but only a third of it has reliable supplies of water

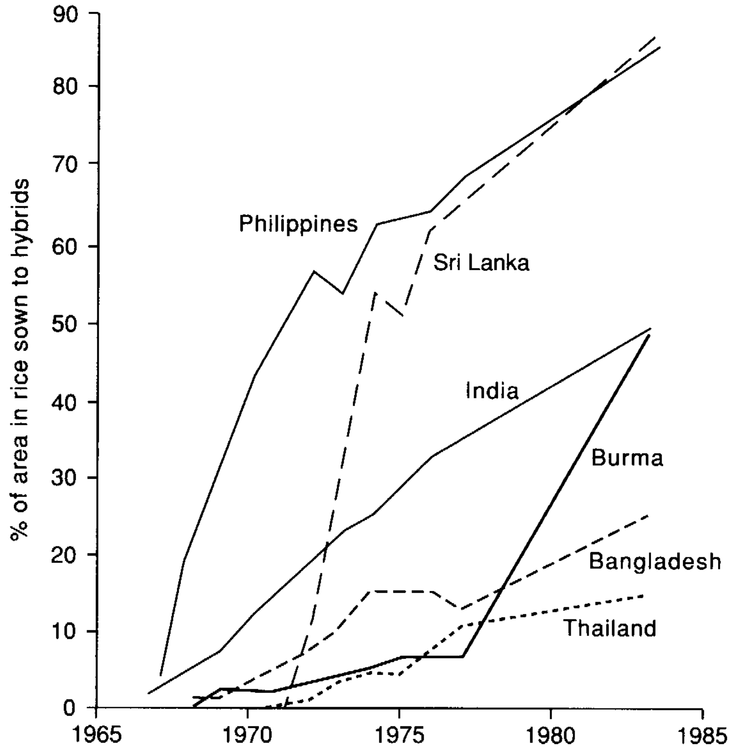

Figure 14.4 Increase in the area in hybrid rice in Asia, 1965–77

Source: D.G. Dalrymple, *Development and Spread of High Yielding Varieties of Wheat and Rice in Less Developed Nations,* Washington DC, US Department of Agriculture, 1978

during the growing season. Two-thirds rely upon rainfall from the monsoon, or the flooding rivers, and therefore are erratic and difficult to control. In these regions, the new varieties could not easily be adopted. In the flooded deltas, such as in Bangladesh or Thailand, only long-stalked varieties could be grown; the short-stalked hybrids would be drowned. Thus the adoption of hybrid rice shows a positive relationship to the proportion of the total rice area that is irrigated (Figure 14.5). This means that many of the more densely populated deltas and lower reaches of rivers, in most need of increased yields, have been slow to adopt the new varieties. In India on the lower plains and deltas of the Ganges, with problems of flooding in the monsoon, the new varieties were adopted less rapidly than in the drier middle and upper reaches—particularly in the Punjab—where tube-well irrigation was available.

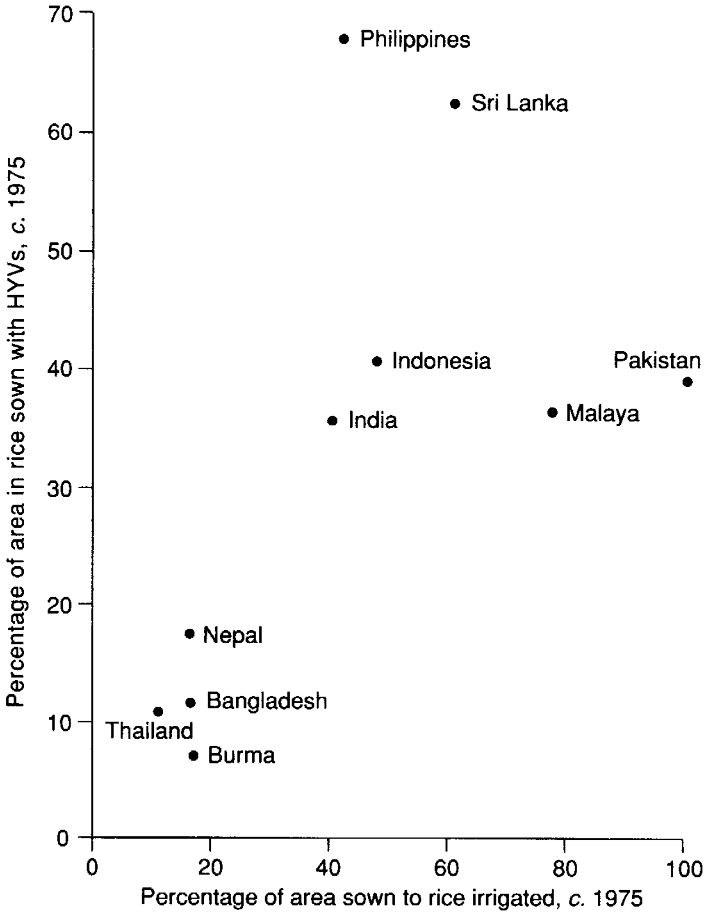

Figure 14.5 New high-yielding rice and irrigation in selected countries, 1975

CONCLUSIONS

Patterns of farming are constantly being changed by the adoption of new crops and new methods. The rate of adoption of innovations varies among farmers, according to their perception of the potential profit which will result. The spatial diffusion of an innovation takes some time to complete, so that at any one moment geographical limits of a crop or implement may be a result of the rate of diffusion, rather than of any climatic or economic factor.

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Chapter 15
The cultural framework of farming

In recent years there has been much criticism of economic determinism in agricultural geography and economics. It was seen earlier (Chapter 7) that many doubt that farmers are all profit maximizers. In developed countries farmers may prefer a secure and stable income to the risks of profit maximization; many farmers with smallholdings and low incomes choose to remain poor and independent, rather than leave farming to take a better paid job with an urban employer. In the developing countries many farmers aim to provide as much of their own food as possible, and thus aim to maximize output per hectare, not profit. But factors other than economic or environmental restraints may influence the farmer's behaviour.

In many parts of the world the traditional culture or way of life may require farmers to behave in an apparendy non-rational (in the eyes of Western economists) manner. Such cultural factors have been much emphasized by anthropologists and sociologists who have worked in the developing countries, for they are thought to explain why there is relatively slow progress in agricultural productivity. In Africa, for example, kinship obligations rather than the market may determine the production of food crops. In India, caste may decide who works upon a farm or at a particular task, and in both Africa and Asia there are traditional agricultural roles for men and women which may impede efficiency and progress. The family and its needs are a powerful factor in traditional agricultural societies, and the way property is passed on to the next generation may have a profound effect upon the size of farms, their layout and their prosperity. In this chapter our concern is with how such cultural features may determine spatial variations in agriculture. Two examples only are considered: the influence of ethnic differences and of religion.

ETHNIC FACTORS AND FARMING

In countries where immigrant groups have settled on the land, they may bring with them techniques and crops that differ greatly from those of the indigenous population. This, rather than environment or the market, may account for features of the agricultural geography.

Malaysia

In the Malay Peninsula the indigenous Malays were primarily rice producers. In the late nineteenth century the British established rubber plantations and tin mines, and indentured labourers were brought from India and China to work in these enterprises. Many of these immigrants did not return to their countries, and some of their descendants have become farmers. The Malays remain primarily rice producers or rubber growers. The Chinese have not unnaturally become rice and also rubber growers, but they have additionally developed two types of production rarely pursued by Malays or Indians: intensive vegetables and pigs—both part of the Chinese agricultural tradition. The Malays, who are Muslims, will not keep pigs, and neither the Malays nor the Chinese milk livestock (see below, pp. 193–5). In both Malaysia and Singapore, the great majority of cows and water buffaloes are kept by people of Indian origin; the cows were originally imported from India. Goats are even more ethnically specific, being mainly kept for milk by Tamils.

The Americas

Ethnic origins are also a significant force in the agricultural geography of the Americas. In the USA, many historians have stressed the importance of different European immigrants in the rise of particular types of farming; the role of Scandinavians in the dairy industry has been emphasized. Although such factors have litde contemporary significance, ethnic origins have great importance in understanding the broad pattern of farming in the Americas.

First, the original peoples, the Amerindians, had no plough, wheel, cattle, sheep, pigs or horses; their staple crops were maize, squash and beans in North and Central America, potatoes in the Andes, and manioc in the Amazon lowlands. Traditional agricultural systems, based upon the crops and methods the Amerindians practised before 1500, are still found widely.

Second, in North America, both the French in Quebec and the English in New England brought with them the idea of mixed farming, traditional European crops and livestock, and their initial systems of land holding, farm layout and village types were those of their homelands.

Third, further south, the English in the West Indies and in Virginia and the Carolinas at first tried to work smallholdings themselves, or with indentured labour from the British Isles. Later, however, slaves were imported from Africa, and the plantation system became established in the south of the USA, the West Indies and Brazil. At the abolition of slavery some plantations survived, with blacks becoming wage labourers; elsewhere share-cropping became the predominant mode, while in some regions freed slaves took up smallholdings to produce food crops and small amounts of cash crops. What was conspicuously absent from the plantation regions was the substantial middle-sized farm worked by its owner. However, this was typical of much of the northern USA.

Fourth, in Central and Southern America most of the land was seized by the Spanish and Portuguese in the sixteenth century. Two features of sixteenth-century Iberia were transplanted.

First, land was allocated in very large holdings; in addition the existing indigenous Indian population was used as a workforce, although they were not necessarily evicted from their own land. Thus a form of feudalism took root that has persisted to the present day.

Second, the Spanish and Portugese imported cattle from the south of Spain; they also brought methods of raising cattle which were typical of southern Spain in the sixteenth century but which were very different from the rest of Europe at that time. Cattle were allowed to run free on the open range for much of the year. Periodically each cattle owner rounded up his cattle, branded the calves and cut out older cattle for slaughter. The herders were mounted on horses, wore the bolero jacket, spurs, low-brimmed hats, and used a saddle based on the Moorish saddle introduced into southern Spain by the Arabs. Such a system of ranching was well established in northern Mexico—where the lasso was added—and in Texas, then part of Mexico, when immigrants from the USA arrived in large numbers in the 1830s. When the distinctive ranching of the Great Plains and the Rockies developed after the end of the Civil War, these methods were the basis of the system. Since then, the advance of agricultural setdement, the introduction of barbed wire, the use of irrigation for supplementary feeding, and the spread of motor vehicles and railways have destroyed the Hispanic nature of the American ranching industry, and it is now a blend of Spanish and Anglo-American mediods.

RELIGION AND CROPS

Religion has had a powerful influence upon farming, in both a positive and negative manner. Two positive influences can be seen in the distribution of viticulture and citrus fruits.

Viticulture

In the earliest references to wine in Eygpt and Mesopotamia, it was associated with religion. Much later, the development of the cult of Dionysus in Greece seems to have encouraged wine consumption and viticulture; as Greek influence and setdements spread westwards through the Mediterranean, so did viticulture. By the time of Roman hegemony in the Basin, wine was widely consumed and conspicuous in trade. It was the Romans who were influential in the spread of viticulture northwards into Europe. With the collapse of Roman power in the middle of the first millennium AD, viticulture declined except in monasteries, where the use of wine as a sacrament ensured its survival. In the high Middle Ages, viticulture revived and again became an important element in trade. By the sixteenth century, the grape and viticulture were taken overseas by the Spanish, and viticulture developed in suitable climates in the Americas. Indeed, with the exception of Australia and South Africa, the main wine producing countries outside Europe—Argentina, California and Chile—are all of Spanish origin.

Viticulture remains almost exclusively a product of European settled areas. In the Near East, the home of the domestication of the grape and of the first wine production, very little wine is now produced, for much of this region has been under Muslim influence since the seventh century AD, and alcohol is forbidden to Muslims. In Morocco, Tunisia and Algeria, viticulture was reintroduced by the Spanish and the French in the nineteenth century, and has persisted since the end of colonial times (although mainly for export). Indeed in the former Soviet Union the Muslim Republics of Central Asia have become leading producers of wine. The grape itself has not, however, been banished from Muslim areas. Raisins are an important product of Egypt, Iraq and Iran, and especially Turkey, and have replaced viticulture in some parts of Algeria.

Citrus fruits

Of the eight citrus fruits grown commercially, all—with the possible exception of the grapefruit and the citron—were domesticated in mainland and archipelago South-East Asia, yet there is very little commercial production of these crops in that region today. Although the citrus fruits were found wild in a hot, humid region, they are now widely grown in the tropics and the sub-tropics, and indeed some of the main areas of production are found on the margins of the natural limits, where frost is a threat. Two-thirds of world output (two-thirds of which is oranges) is found in only three regions: in the countries bordering the Mediterranean, both north and south of the sea; in the USA, principally in Florida and California; and in south-east Brazil. Other producers include Japan, South Africa and Central America.

Citrus fruits were grown at an early date in India, and from there taken to the early civilizations in the Near East. At the time of Christ, they had not spread westwards from the Levant. There are two explanations of their subsequent spread throughout the Mediterranean. One argument is that the crops and the techniques were taken westwards by the Jews in the Diaspora of the first four centuries after Christ. At some time in the late first millennium BC, the citron (now the least important of the citrus fruits) was used by the Jews in a religious festival, and naturally grown by them in Palestine. By the fourth century AD, Jews were found in large numbers in many cities around the shores of the Mediterranean, and there was also considerable Jewish rural settlement, particularly in North Africa, Turkey, Sicily and Corsica. The citron would have been cultivated, and Erich Isaac argues that it is likely that the Jews would also have taken other citrus fruits with them. So the initial distribution of citrus fruit occurred during the Diaspora.

A second, and more usual, explanation of the spread of citrus fruits also has an indirect religious basis. From an early date there was trade between the Red Sea, the Persian Gulf, Arabia and India, and citrus fruits were brought to the Near East at an early date, along with other crops and new techniques of irrigation. After the death of Mohammed in 632 AD, the Arabs expanded to convert peoples by force or persuasion to Islam. Within two centuries, the area of Muslim domination had reached Spain in the west and India in the east. Not surprisingly, citrus fruits and the techniques of growing them spread throughout the Mediterranean. Thereafter Christian Europe reasserted itself, and Spain was freed from Muslim rule in the fifteenth century. With the discovery of the Americas, it was natural that the Spanish should take citrus fruits to the New World. In the USA Spanish explorers probably brought the orange to Florida, for it was found growing wild there when settlement began, and in California it was Spanish missionaries who introduced the fruit.

RELIGION AND LIVESTOCK

Pigs and Islam

Of far more importance than the positive influence of religion on crops, is the negative influence upon the present distribution and utilization of livestock. The pig is absent from parts of the world today because the Koran declares it to be unclean—as do the Jews. In India, *ahimsa,* the reluctance to harm animals, has had a significant effect upon the cattle industry.

Although Jews and members of other religious sects in the Middle East and North Africa believed the pig to be unclean, and forbade its keeping, it was the similar prohibition found in the Koran that has led to the exclusion of the pig from large areas. By the seventh century AD Muslim power had spread through North Africa to Spain, east into Central Asia and India, and later was to include the Sudan zone of West Africa, Mongolia, Malaysia and Indonesia. In these regions the pig is now of negligible importance (Figure 15.1). In most countries where Muslims predominate, the pig forms less than 0.1 per cent of all livestock units, and is kept only by non-Muslims, for example the Chinese in Malaysia and Indonesia.

Religious taboo is probably not the only reason for the unimportance of the pig in some parts of the world, including the Muslim regions. The pig

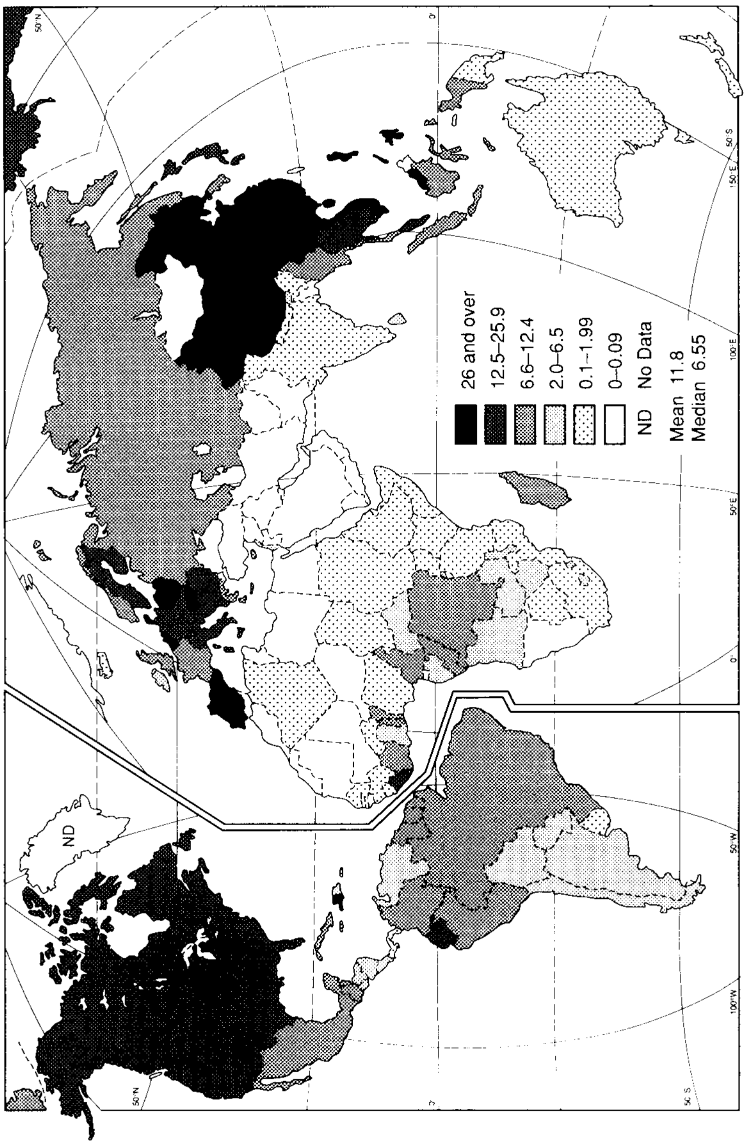

Figure 15.1 Pigs as a percentage of all livestock units, 1980

Source: Food and Agriculture Organization, Production Yearbook 1981, vol. 35, Rome, 1982

was independently domesticated in China and Europe, and was not found in Africa south of the Sahara until the arrival of Europeans. It remains unimportant in most of tropical Africa, although there is little Muslim influence there, outside the north. The pig has disadvantages compared with other domesticated livestock. It is not easily herded (and certainly not over long distances), and cannot graze on grass, as it is not a ruminant. It has no advantages for the nomadic pastoralist, and could not survive easily in drier regions. Unlike the ox or water buffalo, it cannot be used for draught purposes, the sow cannot be milked, and it gives no wool.

The pig has always been associated with sedentary arable civilizations. In Europe it was fed upon the residues of human foods and allowed to forage in forests. As the latter dwindled the pig became confined to its sty. In China it has been a scavenger, fed largely upon kitchen waste. In modern times it is of greatest relative importance in China, Europe and the European settlements overseas. Its advantage now is its high biological efficiency in producing meat (see Chapter 2); the modern pig is fed on skimmed milk and grain.

Cattle in India

India has 15 per cent of the world's cattle and half of the world's water buffaloes. Cattle densities are high compared with most developing countries, and indeed in the opinion of many outside observers, far too high. Yet this large number of cattle produces less than half of 1 per cent of the annual world output of cattle and buffalo meat. This is not to say that cattle have no role in the Indian agricultural economy. They still provide most of the draught power on Indian farms—buffalo are confined to the wet-rice areas—and supply one-third of India's milk output, the water buffalo providing most of the rest. Their dung is the principal source of manure, and is still used as a fuel in many rural areas. Cattle that the naturally provide some meat and hides, but less than 1 per cent of all cattle are slaughtered each year.

Thus, India's cattle provide very little meat, and there are several explanations for this. First, the low incomes of most Indians means that there is a limited demand for meat. Second, the cattle are very badly fed, relying upon waste land for their fodder, for in such a densely populated country little land can be allocated to forage crops, and the indigenous grasses are of poor quality. There has been little selective breeding among the zebu cattle, and they put on weight very slowly. However, the main reason for the small meat industry is the Hindu and Buddhist belief in *ahimsa* —that it is wrong to kill living creatures, and in particular cattle. This belief is not held by the lower castes or the hill tribes, but widely held by most other Indians. Indeed, in some states the slaughter of cattle is illegal, and homes for elderly cattle have been established.

Dairying and its distribution

Religious scruples do not limit the milking of cattle in any part of the world, but some peoples have an aversion to milk. Milk is obtained from sheep, goats, camels and water buffalo, but nine-tenths of the world's milk output comes from cows. Fresh milk is drunk as such or converted into products such as butter, cheese, ghee, ice-cream, and dried, powdered and evaporated milk. Dairy products are a major source of farm income in the European parts of the world, and not surprisingly it is these regions that produce much of the output. North America, Europe, the USSR and Oceania have half the world's cows but produce three-quarters of the fresh milk and butter and 85 per cent of the cheese. This remarkable concentration of dairy output in the European-settled areas is not due simply to the distribution of livestock. Cattle are widely distributed throughout the world —Asia alone has one-quarter of the world's cattle —and they are numerous in Africa and Latin America as well.

At first sight, this distribution may be explained in economic and ecological terms alone. First, dairy products are expensive because the production of milk requires more land than the production of an equivalent amount of calories or proteins from crops (see Chapter 2). Few people in the non-European areas can afford dairy products in any quantity. In the high income countries, however, dairy products make up a significant part of the diet.

Second, cows feed primarily upon grass. In the cool, temperate regions, grasses of high quality give a very high dry matter yield, and provide grazing in spring and summer and hay for winter feed. In contrast, grasses do not grow in deserts or in the shade of tropical forest, and if the forest is cleared the land is soon invaded by low quality grasses. Even the better tropical grasses give poor fodder. In Malaysia it requires 4 ha to give the feed equivalent of 1 ha in England. Consequently, in most tropical regions cows are badly fed and therefore give a low yield of milk.

Third, cows in most developing countries are not from specialized dairy breeds, unlike those of the developed regions, and thus milk yields are low. European breeds imported into the tropics do not easily adapt to the higher temperatures, and milk yields and reproduction rates are lower than in their homelands.

These reasons might be thought to explain satisfactorily the comparative unimportance of dairying in much of the tropics, but there may be other factors. Until recently, there were substantial areas in Africa and Asia where milkable animals were kept but not milked. This seems to be related to the origins of milking and the spread of the practice from its source. The first evidence of milking is found in the Near East in the fourth millennium BC. Subsequently the practice spread into Europe, North Africa, Central Asia and India (the latter in about 1500 BC). In 1500 AD, before the age

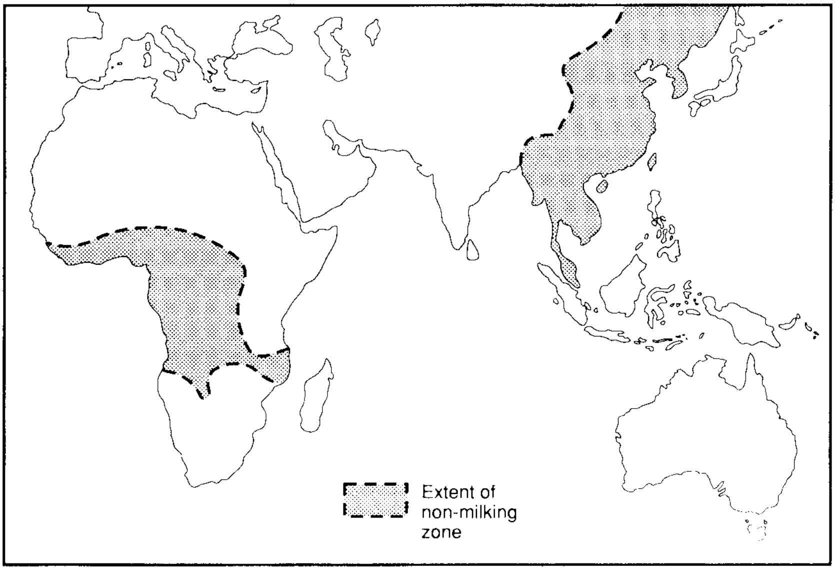

Figure 15.2 The traditional non-milking zones of Asia and Africa After F.J. Simoons, 'The non-milking area of Africa', *Anthropos,* 1984, vol. 49, pp. 58–66; 'The traditional limits of milking and milk use in southern Asia', *Anthropos,* 1970, vol. 65, pp. 547–93

of European expansion, the practice of milking was unknown in the Americas (which lacked domesticated livestock that could be milked), tropical Africa, China and South-East Asia (Figure 15.2). In Asia the line was between India and the countries of South-East Asia, including the archipelago, and in East Asia between the Mongol peoples of northern China and the sedentary Han Chinese. Such a distinction existed until comparatively recently, although milk consumption has increased in recent years in parts of Asia (notably in Japan). Why there should be such a non-milking zone in Eurasia is far from obvious. Among some African tribes milk is regarded as unclean as urine; in others it is thought suitable only for priests and chiefs. Among Buddhists it is thought unkind to deprive the calf of its sustenance—although such a view, though it could be linked to the belief in *ahismsa,* is not held among Indians. In China, the long conflict between the milk-drinking Mongols and the Han Chinese farmers may explain the distribution.

More recently a biological explanation for non-milking practices has been suggested. Milk contains lactose or milk sugar that is hydrolized in the small intestine. If this does not occur, vomiting and diarrhoea will follow. Tests on populations in various parts of the world suggest that only a small number of the sample suffer from adult lactose malabsorption in Europe, North Africa and India, a much higher proportion elsewhere. How such a genetic difference arose is unclear. As dairying has a long tradition in the Near East and its borders, it may be that natural selection has reduced the proportion suffering from lactose malabsorption. Whatever the explanation, it does suggest a further reason for the lack of milking in parts of Africa and East and South-East Asia.

CONCLUSIONS

It is not suggested here that environmental and economic reasons for spatial differences in agriculture activity are unimportant; simply that cultural features cannot be ignored. It is true, of course, that such explanations are of less importance in the developed world, for the process of modernization during the last two centuries has reduced the influence of religion and other traditional beliefs. None the less, it is unwise to ignore the possibility that some non-economic or non-environmental reasons may explain features of the agricultural geography of the Western world; while in the developing countries it would be unwise in the extreme to ignore the many cultural differences from the West.

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Chapter 16
Agriculture and the environment

Over the last forty years world agriculture has been remarkably successful in increasing the output of food and fibre. This has been particularly noticeable in the industrialized countries, but many developing countries have also had rapid increases. To a large extent this has been due to the adoption of new inputs purchased from industry, such as chemical fertilizers, pesticides and high-yielding seeds, petroleum and machinery. Greater output has been mainly due to increased crop yields per hectare, although expanding the area in cultivation has been important in some areas, notably in Latin America and tropical Africa. Not only has the output per hectare risen, but so too has output per capita, particularly in North America and Western Europe, where power in the form of the tractor and self-propelled machines have replaced the horse, oxen and human labour. These advances has not been regionally uniform. Output per capita is at its highest in North America, Australasia and Western Europe, and at its lowest in tropical Africa, East, South and South-East Asia (Figure 8.3 p. 90).

But all is not well in agriculture. First, although famines are now confined to tropical Africa, malnutrition is still widespread in many parts of the developing world. However, this cannot be attributed solely, or indeed mainly to the ineffectiveness of food production. Only in Africa has food output per capita fallen consistently over the last thirty years. Most writers now believe that low incomes amongst the purchasers of food is the main cause of malnutrition.

Second is the condition of agriculture in the developed countries. All the developed countries protect farmers in some way, principally by guaranteeing prices above the world level (see Chapter 9). This has had numerous consequences. It has meant that the prices paid by consumers are above those which would occur if free trade was permitted. The levies imposed by the Common Agriculture Policy have excluded would-be exporters from the developing countries, and also the traditional exporters of temperate crops and livestock in North America, Argentina and Australasia, leading to farm bankruptcies in the USA and Australasia in the 1980s. The subsidizing of exports from the European Community has penalized other exporters. Within the European Community and in North America public resentment at food surpluses and the high bill for agricultural protection has forced politicians to re-examine agricultural policies. Paradoxically farm real incomes have fallen for much of the last decade.

Third is the damage modern farming has caused to the environment. Since the 1960s there has been much research and much public comment on the damage to soil, water, flora and fauna caused by the use of agricultural chemicals; in the developed countries farmers have lost their status as guardians of the countryside. However, it is important to note that environmental damage is not new and not a product solely of the impact of industrial farming. Salinity was a major problem in the farms of the Euphrates and Tigris valleys in the second millennium BC, whilst overgrazing and other factors led to the deforestation of the hills surrounding the Mediterranean Sea over two thousand years ago. In this chapter an attempt is made, first to review some of the worldwide aspects of land degradation caused by farmers, and second, to consider those that are specifically a result of the adoption of modern farming methods.

DEFORESTATION

Few examples of environmental damage have aroused more interest in the last two decades than the destruction of the tropical rainforests, particularly those in the Amazon basin; about one-tenth of the Amazon forest in Brazil has been cleared, mainly in the last few decades. There have been many criticisms of this: it is destroying the last large area of rainforest, which contains a rich flora and fauna; it is destroying the habitat and way of life of the indigenous Amerindian population; by removing the protective covering it exposes the soil to the impact of raindrops and high temperatures increasing leaching of soil nutrients and making the soil more susceptible to water erosion; furthermore much of the clearance is for products such as cattle or timber that are exported rather than directly benefiting the home population; efforts to settle landless from the rest of Brazil have had very limited results; finally there are fears that deforestation may have adverse effects upon the local and possibly the global climate.

It is certainly true that the rate of deforestation of the moist tropical forests has accelerated in the last three or four decades, not only in the Amazon basin, but elsewhere. One much cited example is in Central America (Figure 16.1) where much of the Caribbean coastal forest has been cleared since 1950, mainly for the ranching of cattle. In the Philippines 57 per cent of the total land area was covered by forest in 1972, only 38 per cent in 1980, and in Thailand in the same period the proportion fell from a half to a quarter. Indeed one estimate is that half of the world's original tropical rainforest has been cleared for timber, fuel and to create agricultural land. If a broader definition of tropical rainforest is taken (Table 16.1 and Figure 16.2), it can be seen that substantial proportions of the world's tropical forest have been destroyed. Nor is this surprising. Although the tropical forests of Latin America are sparsely populated—except for that of the Brazilian coastal areas where the rainforest has been almost entirely removed since the sixteenth century—in Asia and tropical Africa much of the former forest areas are now densely populated; deforestation has been mainly for cultivation and has been going on for at least seven or eight thousand years.

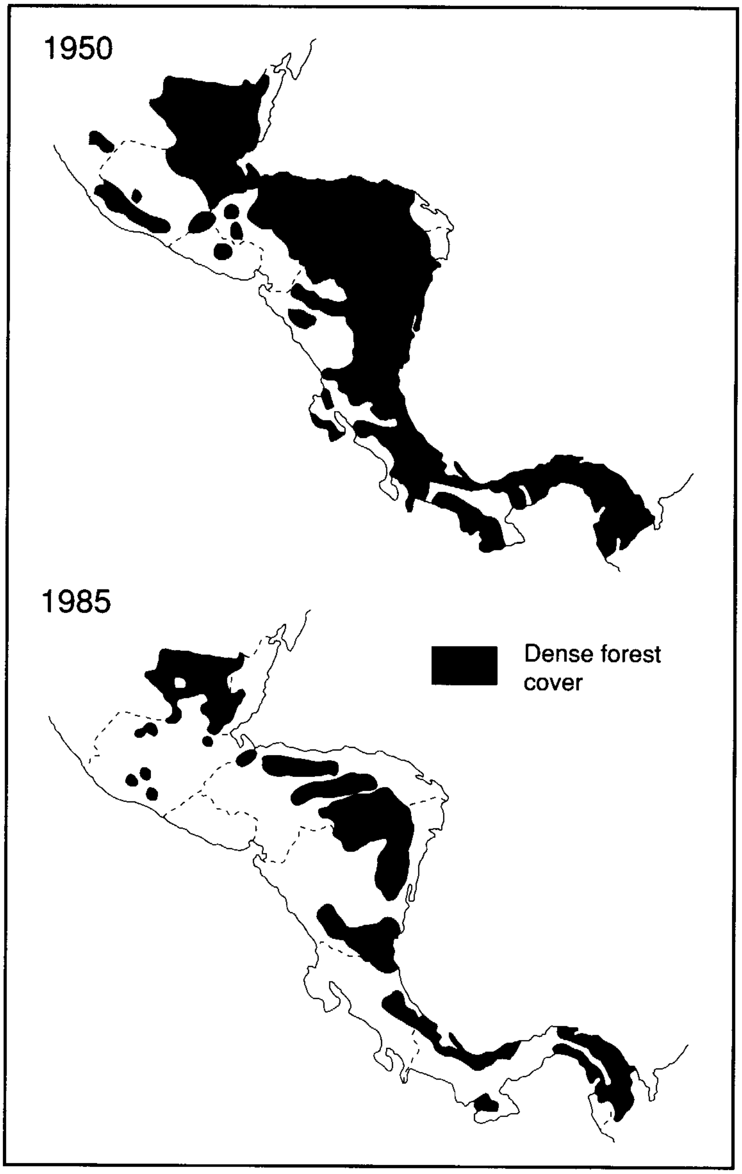
Nor has deforestation been confined to the tropics. The existence of much of the arable land that sustained the major civilizations of the eastern USA, Europe, India and China has been possible only because of the slow removal of woodland by populations which have expanded steadily for five thousand years, and rapidly for the last two centuries. Not only was the clearance of woodland essential for cultivation, but until the nineteenth century wood provided fuel for domestic and industrial purposes, timber for houses and for ships, waggons, furniture and a wide range of other goods which are now made from metals or plastics. The removal of the European forest was a slow process, with a major period of deforestation in the Middle Ages. However, in the USA it was rapid. In 1620 the forest covered 170 million hectares; it is now less than 10 million. Much of the deciduous woodland of the northern hemisphere has gone, and the more substantial forest areas are now to be found in the boreal forests of Scandinavia, Russia and North America, for the most part too cold for cultivation.

Estimating the extent and rate of deforestation, whether global or tropical is exceedingly difficult. Quite apart from the absence of accurate maps or air photos of much of the world at suitable intervals, there is difficulty in distinguishing different types of forest; are tropical forests to include only rainforest, for example? In many estimates secondary growth is excluded. Hence some writers believe that the extent of deforestation has been exaggerated. However, it is clear that without deforestation there would have been no agriculture, no food and no people. This does not preclude of course, the need for a sensible and planned control of forest removal, and of forest replanting.

LAND DEGRADATION: SOIL EROSION

Soil is continuously removed from the surface of the land by wind and

Table 16.1 Rainforest and moist deciduous forest



water; new soil is continuously but slowly created by the decomposition of the regolith and the activities of plants, animals and microbes. Soil erosion occurs when there is a significant net loss of soil. What is difficult to measure

Figure 16.1 Deforestation in Central America, 1950–85 After M.C. Brady, 'Making agriculture a sustainable industry', in C.A. Edwards, R. Lai, P. Madden, R.H. Miller and G. House (eds), Sustainable Agricultural Systems, Ankeny, Iowa, Soil and Water Conservation Society, 1990, pp. 20–32

	Percentage of original forest cut down	*Area surviving (million hectares)*
Africa	49	180
Latin America	63	400[1]
Asia	60	250[2]
World	60	830

Notes: 1 Amazon forests.
2 Indo-Malaysia forests.

is the intensity of soil erosion and its agricultural significance. In many parts of the world, particularly in semi-arid areas, large gullies caused by storms on highly friable soils lead to the abandonment of the land; it is a total loss to agriculture. On the other hand gentle sheet erosion may slowly remove plant nutrients in the soil which would lead, after many decades, to a fall in crop yields of a few percentage points, but that will almost certainly be masked by the use of chemical fertilizers. Thus it is difficult to describe the geographical distribution of soil erosion, because estimates rarely distinguish the intensity of erosion in different places. One exception to this is in the USA where soil scientists have measured soil losses against the T-factor; soil erosion is significant if it exceeds 0.4 tonnes per hectare per year on shallow soils, 2.02 tonnes on deep soils. Currently the rate of erosion in the USA exceeds 2 tonnes on 46 million of the 170 million hectares of cropland, 27 per cent of the total.

Soil loss has two consequences for crop production. First it reduces plant nutrients, the water holding capacity and organic matter, and so reduces crop yields. Second, it makes soils shallower and so restricts the type of crop that can be grown to shallow-rooted crops such as cereals; deep-rooted crops such as potatoes or sugar-beet cannot be grown. Such effects often take a long time to occur. The United States Department of Agriculture has estimated that if current rates of erosion continue, without any advances in agricultural techniques, crop yields will have fallen by 5–10 per cent in one hundred years time.

Estimates of the extent of soil erosion over larger areas must be treated with some caution. It has been estimated, for example, that over the last 7000 years 430 million hectares in the world as a whole have been 'severely degraded', about 29 per cent of the present world arable land. In India half of the total land area is said to be degraded by erosion, although the intensity of erosion is not distinguished, nor is it in the estimate that one-sixth of the total area of China is subject to soil erosion; in Australia 30 per cent of the usable land is 'significantly eroded'.

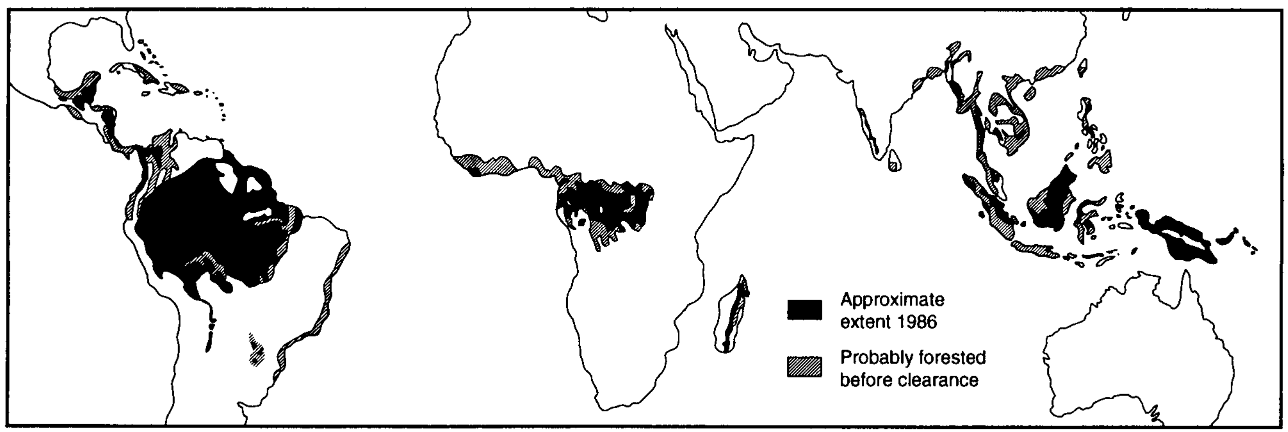


Figure 16.2 Original and 1986 extent of tropical rainforest After C.J. Barrow. Land Degradation. Development and Breakdown of Terrestrial Environment, Cambridge, Cambridge University Press, 1991, p. 74

However debatable some of these estimates may be there is no doubt that soil erosion is a threat to farming, both by causing the abandonment of land and by reducing crop yields. The causes of soil erosion are various, but removing the natural vegetation for cultivation immediately increases the risk of soil erosion, for the soil is no longer protected from the wind or the impact of raindrops, or in tropical climates from high temperatures and greater rates of chemical decomposition. Ploughing the land further increases the risk, as does the creation of a fine tilth in which to sow the seed. Agricultural soils are most prone to erosion when the soil is bare; in England for example much of the water erosion occurs in autumn, and wind erosion is most likely in spring before crops become established.

The ideal farming system is, therefore, where the soil is covered by secondary vegetation or crops for as much of the year as possible. Thus in the humid tropics the farming system most successful in reducing soil erosion is shifting cultivation. Land is cleared for crop production in small plots, which are surrounded by forest. The soil in not ploughed, and a digging stick is used to plant a mixture of cereals, root crops and bushes, so that the soil is covered for most of the year. The plot is abandoned after two or three years, and secondary forest becomes established, until it is cleared again after twenty years or more, when soil fertility has been restored. Such a farming system protects the fragile soils from rain and high temperatures, but it is possible only in areas of low population densities.

There are a number of factors influencing variations in the susceptibility of soils to erosion. First is the nature of rainfall; although wind may locally be a powerful erosive agent, most soil erosion is due to the action of running water, either in rills and gullies, or in slower mass movements over the surface of the soil, causing sheet erosion. The physical impact of raindrops is important; potential erosion is greatest in the violent storms of the tropics, least where the rainfall mainly falls in gentle drizzle, as in Western Europe. Second is the amount of vegetation cover. In the hilly watersheds of the Mississippi the loss of soil on land still forested is a few hundredths of a tonne per hectare per year, on land in pasture 4 tonnes, on land in corn 54 tonnes, and on land abandoned because of gullying, the rate reaches 450 tonnes a year.

Third is slope: the steeper the slope, the faster the water travels as run-off, and so the greater the capacity for erosion. In the last thirty years population growth in many developing countries has caused the expansion of settlement from the plains into upland areas where much of the land surface is in high angle slopes. In Colombia slopes of over 45 per cent have been cultivated and soil loss has reached 370 tonnes per hectare per year. Clearing the vegetation for crop production leads to soil erosion, destroying not only the soil on these slopes, but depositing the silt in down-stream areas, often causing flooding. In Britain the high prices for cereals has led some farmers to plough areas with high slopes. It is generally assumed that 11 ° is the maximum slope for crop production, yet slopes of up to 20° have been ploughed on the South Downs.

Soil texture is a fourth factor influencing the rate of erosion. Generally the most easily eroded soils are sand and gravels, which have large spaces between soil particles; in contrast soils with a high clay content are less susceptible. Thus in England the soils most likely to be eroded by wind are not those in the areas of highest average wind speed in the west, but on the areas of sandy soils in the east and south-east, such as the Bunter Sandstones, the Lower Greensand and the chalk. A fifth factor is the occurrence of semi-arid climates. Although rainfall is low and evaporation high in these regions, the vegetation cover is thin, even where not cleared for cultivation, and overgrazing has reduced the vegetation cover and so exposed the soil to the impact of rare but violent rainfall. These regions are considered separately (see below, pp. 205-7).

Soil erosion is clearly a significant problem for farmers. Its precise extent is difficult to establish: it is not a new phenomenon, but the rate of erosion has greatly accelerated in the last one hundred years. To some extent it is a result of modern farming methods (see below, pp. 207–9) but for the most part it is due to the rapid growth of population, and the adoption of unwise farming methods, either in response to greater subsistence needs or the search for greater profits.

LAND DEGRADATION: SALINITY AND ALKALINITY

Soil erosion is a mechanical process, but there are also adverse chemical effects upon soil. Change in the environment or in farming methods can lead to more acid or more alkaline soils (see Chapter 4). Although the removal of the European forest cover may have increased the acidity of soils since the Middle Ages, the most notable and most debated current cause of increased acidity is from acid rain. Industrial pollutants lead to the increase of sulphur dioxide and nitric oxides in the atmosphere, which reach the earth in rainfall as sulphur or nitric acid. The latter may increase soil acidity, and it is claimed that this has reduced crop yields in parts of eastern Canada by 10 per cent.

Of far greater importance, however, is the occurrence of saline and alkaline soils in the arid and semi-arid parts of the world. Saline soils occur under two circumstances. First, many semi-arid areas are naturally saline; ground water with a large salt content reaches the surface and the high rates of evaporation lead to the crystallization of salts which, according to their degree of concentration in the soil, can limit the type of crop that can be grown, reduce crop yields or cause the abandonment of land. There are over 5 million hectares of saline soils in Western Australia and salinity has led to the abandonment of some 260,000 hectares.

Second, and of far greater significance, is the salinity that occurs in irrigated and semi-arid regions. Irrigation causes the water table to rise to within a short distance of the surface. In the Punjab, for example, irrigation has raised the water table 7—9 feet since 1895. This has been the result of over application of water by farmers, leaks from canals and a lack of underdrainage to remove surplus water. Capillary action raises water and salts form in and on the surface of the soil. In the 1980s it was estimated that between a third and a half of all irrigated land was affected by salinity to some extent. Although only 14 per cent of the world's arable land is irrigated, it produces one-third of the value of world agricultural output and so salination may have serious consequences for world food output. In the long established agricultural settlements of South-West Asia and north Africa, half the irrigated land in Iraq is salinized, a third in Egypt, a quarter in Pakistan and 15 per cent in Iran. Nor is salinisation confined to the developing countries or ancient civilizations; it is a major problem in the areas of recent irrigation in the south-west of the USA. Salinization can be cured by draining the land; the use of tube-wells and pumping has been successful in parts of Pakistan.

DESERTIFICATION

In the 1930s it was claimed that the Sahara desert was creeping southwards; the droughts in the Sahel in the 1970s renewed the belief that the desert was expanding, and in the following years it was asserted that desertification was to be found in many other parts of the world. The causes of desertification and its precise definition have been a subject of considerable debate. It seems now agreed that the term should be applied to the degradation of ecosystems in arid and semi-arid regions which leads to a loss of plant productivity and species diversity. Thus on the edge of deserts the vegetation of semi-arid areas is reduced to the status of desert vegeta-tion, and the subhumid areas to semi-arid. This is due not to any long-term climatic change, although prolonged drought may be a powerful contributor, but to human mismanagement of fragile environments. The main forms of land degradation in the drylands are the deterioration of vegetation, soil erosion and salinity. Thus desertification is not a climatic process but simply a term used to describe land degradation in the drylands.

The world's drylands—arid, semi-arid and subhumid—occupy 47.2 per cent of the world's land surface. Of this nearly twenty per cent is defined as arid—already desert—so that it is the semi-arid and subhumid areas that are at risk, a quarter of the earth's land surface (Figure 3.9, p. 30). About one-fifth of the drylands are experiencing soil erosion by water and wind, and much of the natural vegetation is experiencing degradation. The main cause of this is poor land management which in turn is a result of population growth and the increasing commercialization of agriculture.

The United Nations Environment Programme work upon desertification provides some estimates of the distribution and intensity of soil degradation. Surprisingly the largest proportion of the total land area lies in Europe, but this includes the subhumid grasslands of the former Soviet Union (Table 16.2). In absolute terms Africa—particularly North Africa, the Sahel and south-west Africa—and Asia, notably the Middle East, Western India and northern China—have the greatest areas subject to erosion (Table 16.2). By far the largest areas suffering from *severe* degradation are to be found in Africa and Asia.

There are numerous causes of land degradation in drylands. Overgrazing is a prime cause. In much of the drylands the only possible utilization of the meagre natural vegetation is pastoralism. The increased human populations, together with advances in animal hygiene, have greatly increased livestock numbers, and this has led to overgrazing. This reduces the palatable species, encourages invasion by the less palatable, and increases the proportion of bare land; all this increases the possibility of soil erosion.

Two forms of crop production have encouraged land degradation. First is the expansion of cultivation into pastoral areas. In the Sahel a series of years with above average rainfall in the 1960s encouraged expansion into land once left to pastoral nomads. The droughts since the early 1970s have led to falling yields, soil damage and land abandonment. In Rajastan, in India, marginal land was ploughed in the 1960s and 1970s with comparable results. Second is the intensification of crop production, which has also had adverse results. In Africa, rainfed traditional agriculture requires a number of years in fallow to maintain crop yields but increasing population has led to a reduction of the period of fallow, and hence reduced soil fertility, crop yields, and an increased likelihood of erosion.

Deforestation has led to the deterioration of the vegetation and accelerated erosion. In Africa trees are cut primarily for fuel; wood is the only source of fuel for cooking, heating and other purposes for most of the rural population.

MODERN FARMING AND THE ENVIRONMENT

Since 1945 farming in North America, Australasia and Western Europe has been radically changed by new agricultural technologies: the tractor has replaced the horse, machines have replaced men and women, chemical fertilizers have replaced farmyard manure; herbicides are sprayed to weed, where harrows and hoes were once used; and insecticides and fungicides are used to control plant disease. But these developments have had

Table 16.2 The extent of soil by religion

	Total land area (million hectares)	Total area experiencing soil degradation (million hectares)	*Area experiencing soil degradation as a percentage:* Total land area	Area of drylands susceptible to erosion	*Percentage of area susceptible to erosion experiencing:* Low and medium degradation	High and very high degradation	High and very high degraded (million hectares)
Africa	2966	319	10.8	24.9	19.1	5.8	74.0
Asia	4256	370	8.7	25.0	22.0	3.0	43.7
South America	1768	79	4.5	15.0	13.8	1.2	6.3
North America	2191	79	3.6	9.6	8.7	0.9	7.1
Europe[1]	951	100	10.5	33.1	31.5	1.6	4.9
Australasia	882	88	10.0	13.0	12.8	0.2	1.6

Note:1. Including Europian Russia.
Source: N.Middelton and D.S.G.Thomas,World Atlas of desertification,United Nations Environment Programme, London, Edvard Arnold,1992.

undesirable effects upon the landscape, the soil, flora and fauna, and the water supply, although it must be said that the extent of these effects is still controversial.

The use of pesticides to destroy weeds and plant diseases accelerated in the 1950s; most of the sprays also affected plants and fauna other than the pest, and delivery by spray meant that only a small proportion of the pesticide affected the pest. It was soon discovered that sprays and seed dressings could kill birds. Seed-eating birds died from seed-dressings and hawks from eating infected birds, whilst egg-thinning led to later losses. Mammals do not seem to have been affected by pesticides. Butterflies have declined in the last forty years, but this has been due more to the destruc-tion of their habitats than to the direct effect of sprays. Residual pesticides have found their way into groundwater and surface waters, but at low levels of concentration. Legislation to control the safety levels of pesticides has led to the withdrawal of some sprays and work in the USA has led to doubts as to whether chemical spraying has been an effective economic or physical control of pests.

Before the Second World War most of the nitrogen, potassium and phosphorus added to the soil came from farmyard manure. Since then there has been a rapid increase in the use of chemical fertilizers, mainly in the form of straight nitrogen. This has led to a great increase in crop yields but also to an increase in the nitrates in surface and groundwater. In surface waters the increased nitrogen has caused eutrophication, a rapid growth of plants such as weeds that clog rivers, and encourage algae on the surface that cut out light, and so indirectly reduce the oxygen supply for fish. Nitrates have also reached very high concentrations in groundwaters which provide human water supplies, particularly in the east and south-east of England, which is where most of the fertilizer is used. In a number of areas nitrates in drinking water exceed the European Community safety levels; as yet, however, the connection between nitrites in drinking water and stomach cancer and the blue-baby syndrome is unproven. Nitrate levels have also been increased by the ploughing of grassland in the 1940s and 1950s, and the continued use of farmyard manure.

Before 1939 most farms in England kept livestock and crops, and the manure was used as fertilizer. Since then the use of chemical fertilizers has replaced farmyard manure, and the number of livestock in eastern England has fallen as farmers have specialized in crop production. Increasingly livestock have been kept in the west, crops grown in the east, and it has been too costly to move farmyard manure from the livestock areas to the crop areas. Large amounts of animal waste have had to be disposed of, and leaks from storage tanks and the use of slurry have added to nitrate levels, as have leaks from silos in which grass is made into silage.

The mechanization of agriculture has also led to much criticism; machines can be used more efficiently in large fields, and hence hedgerows have been uprooted, particularly in the arable east, reducing the habitat of birds and small mammals. The use of heavy machinery, in combination with other new practices has increased the risk of soil erosion. Heavy machines compact soils, and wheels leave rills that channel water. Finer seed-beds increase the risk of wind erosion, the increase in autumn sowing crops has left more land bare in winter, and the reduction of rotations which include grass and legumes has reduced the organic content of soils, and so increased the potential for erosion.

Finally, the combination of new technologies and the high guaranteed prices of the last forty years have encouraged farmers to increase the area under crops, and particularly cereals. This has led to the destruction of land with particular habitats for wildlife. Since the end of the Second World War a number of distinctive habitats in England and Wales have been destroyed (Figure 16.3)

TOWARDS SUSTAINABLE AGRICULTURE

The adverse effects of modern farming have been dealt with by piecemeal legislation. Attempts have been made to control the safety of pesticides; in Britain Environmentally Sensitive Areas have been designated in which farmers are paid to adopt less damaging practices; and some rare habitats have been declared Sites of Special Scientific Interest. But there have been advocates of much more decisive changes in farming practice. These new approaches have been described as organic farming, sustainable agriculture, low-input agriculture, alternative agriculture or radical agriculture. The general argument is that before the use of agro-chemicals farming practices were designed—as a result of centuries of experience—to maintain crop yields over the long run without damage to the environment. Thus in the mixed farming of Western Europe before 1945 livestock and crops were produced on the same farm; farmyard manure provided plant nutrients and organic matter for the soil, crops were partly sold as cash crops, partly retained to feed livestock, and the straw from cereals was used to make farmyard manure. Crops were grown in rotation and not continuously, and most rotations included leys of grass and clover, the latter adding nitrogen to the soil, the grass improving soil structure. Root crops such as sugar-beet, potatoes and fodder roots allowed thorough weeding during growth by hoe. Growing crops in rotation limited the build up of disease in the soil, for most diseases are specific to one crop.

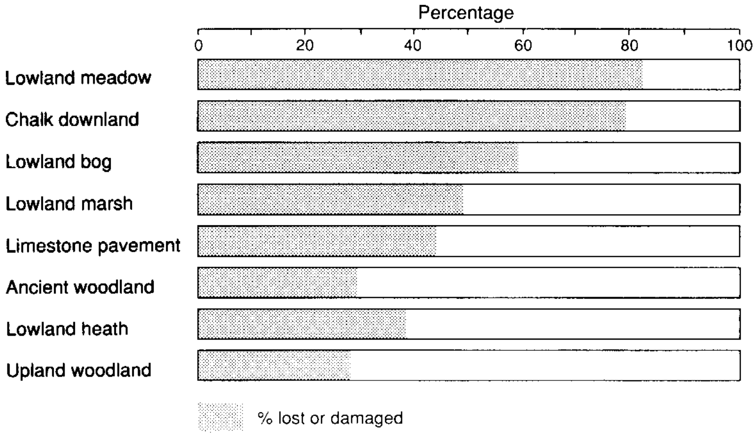


Figure 16.3 Percentage area of selected wildlife habitats destroyed in England and Wales since 1945 After T. O'Riordan, 'Agriculture and environmental protection', *Geography Review,* 1987, vol. 1, pp. 35–40

The use of herbicides has gready reduced the amount of labour necessary for weed control, and fertilizers have lessened the need to keep livestock, and so the basis of mixed farming has been undermined. Organic farmers have argued that pesticides and artificial fertilizers are unnecessary and that traditional farming methods produce a healthier and more palatable food. Some extreme advocates of organic farming would also eliminate the use of purchased energy in the form of tractors and electricity, on the grounds that non-renewable resources such as petroleum should be conserved for other purposes. In the USA low-input farming has been advocated, where agro-chemicals are not spurned, but used in much reduced and at safer levels. Thus Integrated Pest Control envisages the much more careful and less intensive use of sprays combined with crop rotations and biological control of pests.

As yet these new—or revived forms of agriculture—have been adopted by few farmers, and the evidence on their performance is limited. However, yields are generally lower, and although inputs are less, net returns per hectare are also lower than in chemical farming. At the moment the continuation of food surpluses and the challenges of limiting environmental damage may make these farming methods attractive to farmers in the developed world. They are less likely to appeal in the developing countries where continued rapid population growth requires continued increases of crop yields which are unlikely to be obtained with the traditional agriculture still practised in much of Afro-Asia and Latin America.

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Chapter 17
Conclusions

It was stated at the beginning of this book that the aim of agricultural geography is to describe and explain spatial variations in agricultural activity, and that the heart of the problem is the extraordinary diversity of agriculture.

That there is such diversity is not surprising. There are far more people involved in farming than in any other human economic activity. They are found in every physical environment, from the Arctic to the Equator, they speak every language, and vary in economic standing from great riches to abject poverty. This diversity is further emphasized by the fact that farmers deal with living things, with different environmental needs, which they manipulate to produce economic products, subject to the laws of economics. Yet at the same time, the farm is not only the farmer's workshop but also a home, so that the farmer's job and family life are often one and the same.

These conditions suggest that the explantions of spatial diversity are unlikely to be simple. Yet there are further complications. Agriculture attracts the attention of many academic disciplines; agronomy, botany, soil science, hydrology, climatology and biology all concern themselves with aspects of farming. So too do geographers, sociologists, anthropologists and economists. Not surprisingly there are many views on the behaviour of farmers.

It follows from the complexity of agriculture that it is unlikely that there will be one key factor that explains all spatial variations in agricultural activity in all parts of the world. This book has emphasized the many different variables which help explain why farmers do what, and where. But it is only a beginning, and it is not suggested that there are no other approaches to the subject. The main aim of an introductory text is to suggest that the subject of agriculture is of remarkable interest, and to encourage the student to find out more about it, in the field, the laboratory, the computer room and in the library.

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