Land Transformation in Agriculture
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CHAPTER 3
Transformation of the Land in Pre-industrial Time

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3.1 INTRODUCTION

This chapter aims to provide a perspective upon land transformation before the advent of industrialism, i.e. in the period from approximately 10 000 BC to 1890 AD. It is acknowledged that there may have been instances of human alteration of ecosystems before the Holocene (consider, for example, the antiquity of fire in Africa demonstrated by the evidence from Chesowanja in Kenya (Gowlett *et al*., 1981) and the equivocal but suggestive pollen-stratigraphic analyses from the Hoxnian interglacial in England at Marks Tey and Hoxne itself (West, 1980; Turner, 1976)), but we shall ignore these for present purposes. In spatial terms the spread of different types of land transformation has always been uneven, and by 1890 there were many parts of the world to which even the faintest echoes of the new noises of industrialization had not penetrated, and even today there are people whose way of life is little affected by the industrialized world except perhaps in the possession of iron-based tools. Such people are usually living in remote areas and are usually either hunter-gatherers or pastoralists, as with the Tasaday of the Phillipines, the Panare of Amazonian Venezuela and the Dinka of the Sudd region of the Sudan. These groups are in general disappearing as either their ecosystems or their culture, or both, are subject to transformation by processes emanating from the industrial world. There are also many thousands of agriculturalists whose ways can be described as 'traditional' even though the processes of development are gradually bringing about an infusion of ideas and techniques from the 'modern' world. It can be generally said, of course, that the mid-nineteenth century was a dividing point between those regions of the world which fully adopted an industrial way of life and which have become today's developed countries, and those which did not.

The tenure of the earth by human societies in the period 10 000 BC to 1890 is best illustrated by a series of maps (Figures 3.1–3.5). Figure 3.1 is for *ca* 10 000 BP (8000 BC), when the Pleistocene ice had retreated to positions not too far short of the final postglacial positions. At that time, agriculture was in its incipient stages in south-west and south-east Asia, and so the greater proportion of the populated world was occupied by hunter–gatherers. (Note that practically the whole land surface, with the exception of a few islands, was now populated by *Homo sapiens sapiens*). By 6000 BP/4000 BC (Fig. 3.2), agriculture was firmly established from the Balkans to the Irrawaddy and on the coastal margins of mainland and peninsular east and south-east Asia, with incipient stages like the Saharan Neolithic being visible, and a penumbra of the pastoralism of domesticated animals developing around the Mediterranean–west Asia focus of agriculture. But the world was still mostly the preserve of the hunter–gatherer, though the period through to 4000 BC (Fig. 3.2) shows some erosion of their position with the extension of agriculture into peninsular Europe, savanna Africa, most of east and south-east Asia (with attendant pastoralism in arid, semi-arid and mountainous zones) and the apparently independent nascence of agriculture along the Pacific side of the Americas from Mexico to Peru. But there was still a great deal of land, including coastal margins, where both nomadic and settled huntsmen and fishermen were innocent of the presence of domesticated biota (except the dog) in their lives, though by AD 1 this area was severely diminished (Fig. 3.3), with the Americas, south-east Africa, Australia and

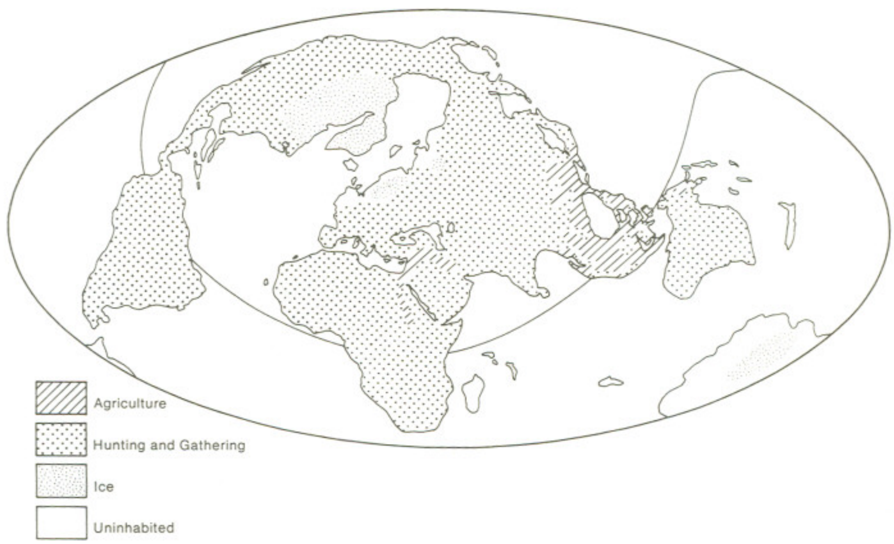

Figure 3.1 Tenure of the earth *ca* 10 000 BP

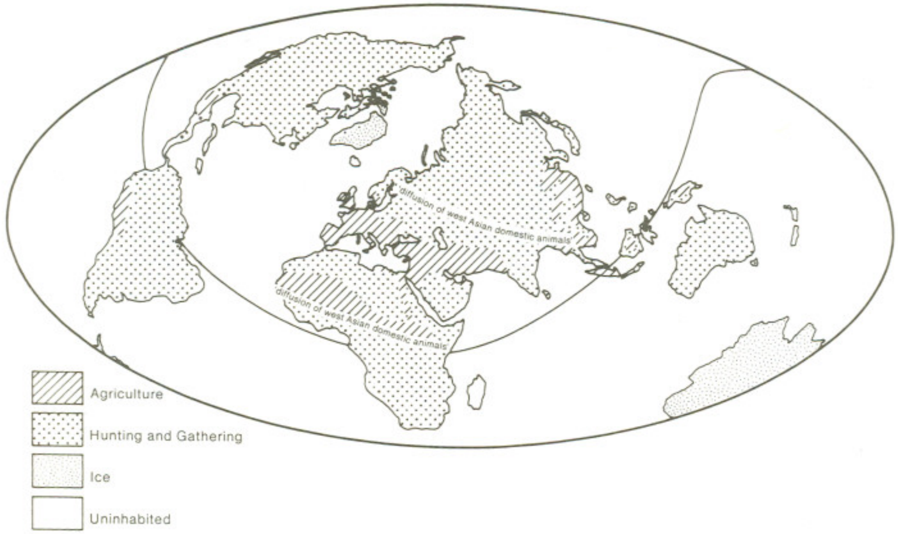

Figure 3.2 Tenure of the earth *ca* 6000 BP/4000 BC

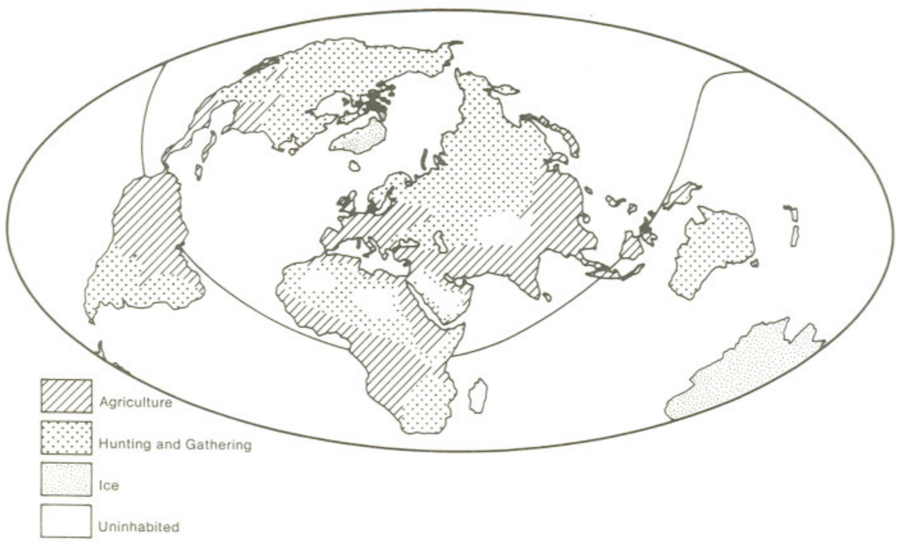

Figure 3.3 Tenure of the earth *ca* AD 1

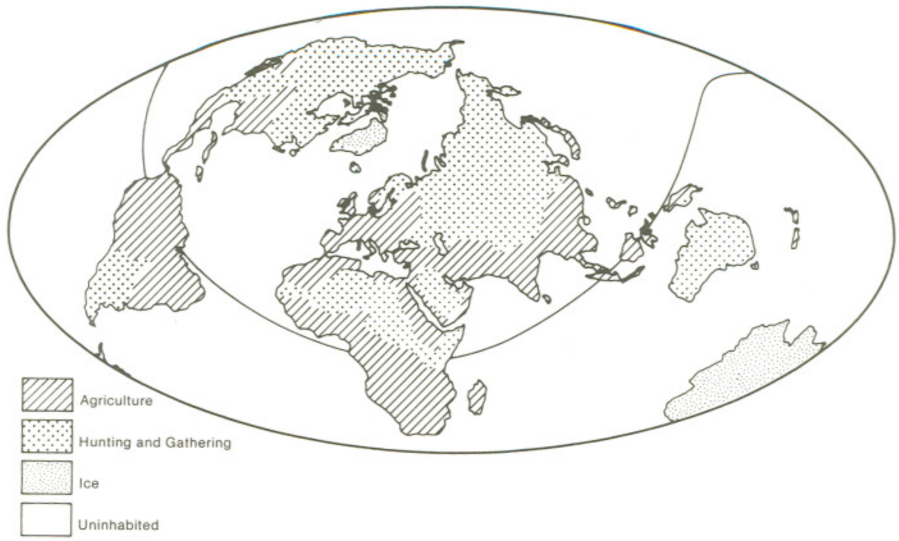

Figure 3.4 Tenure of the earth at 1000 AD

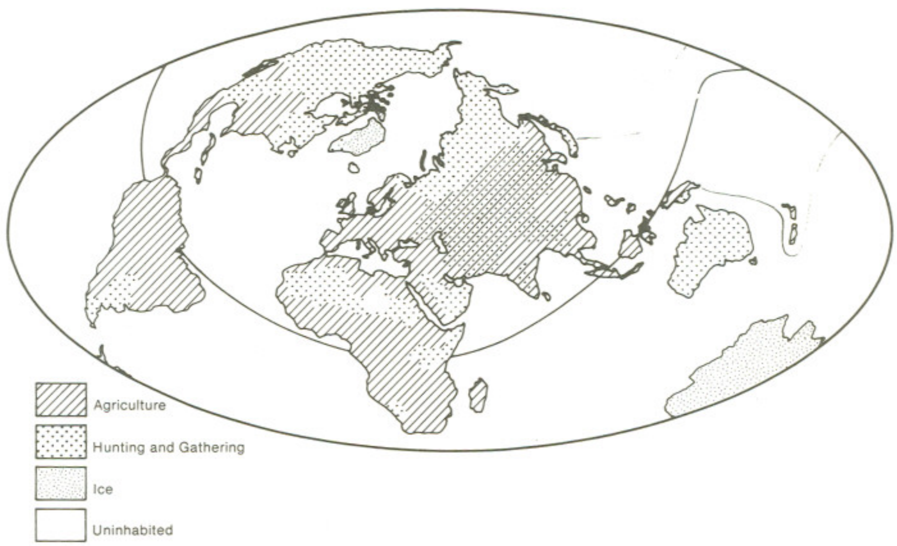

Figure 3.5 Tenure of the earth at 1500 AD

Siberia now being the heartlands of hunter–gatherer activity, including distinctive coastal cultures in many circumpolar regions. Pastoralism, too, now occupied large areas of the interiors of Africa and Asia. This position was consolidated by 1000 AD (Fig. 3.4), with further expansions of indigenous agriculture into both South and North America, so that the grasslands of North and South America, together with Australia, held most of the remaining hunter–gatherer populations, though there were significant numbers of coastal hunters in the far north of the globe. By 1500 AD (Fig. 3.5), the world population of perhaps 350 million numbered only 1% of hunters, compared with virtually 100% at 10 000 BC. European agriculture was starting to be established overseas (e.g. in North America) and pastoralists had replaced hunters in some grasslands. Only Australia remained untouched by agriculture until the coming of European settlers: there was no indigenous development of that mode of subsistence. After 1500 and before 1890, this pattern was again reinforced, with European colonization being one of the major causes of the ousting or assimilation of many hunters (e.g. in North America, Patagonia, South and East Africa) and so progress was made towards the present situation (Fig. 3.10), where hunter–gatherers number about 0.001% of world population; agriculturalists having risen to a peak in proportion in the early nineteenth century are now falling quite rapidly.

This brief account provides us with two pointers. The first is the growing importance of agriculture through most of the period under consideration and its antiquity in certain places where it has had a long period in which to be the agent of land transformation. The second, however, is that hunting and gathering for long periods and in many places held sway as the dominant economic type. So although most attention will be directed at agriculturally induced land transformations, some attention will have to be given to the food-collectors (as distinct from food-producers) to see if they too were the promulgators of ecological change. Immediately, though, we shall consider briefly the technical means by which pre-industrial societies were able to manipulate their environments.

3.2 TECHNOLOGY OF PRE-INDUSTRIAL SOCIETIES

3.2.1 Access to Energy Sources

Numerous writers have pointed out the role of access to energy sources in mediating human relations with the natural environment, and Table 3.1 shows a summary of the sources available at different stages of human history. The greatest turning points were perhaps the control of fire, acquired certainly by 500 000 BP but quite probably before that, and access to the stored energy of the sun in the form of fossil hydrocarbons, the large-scale development of which we call the industrial revolution. The lesson to be gained from

Table 3.1 Energy sources available to different types of culture

Earliest hunter–gatherer	Solar energy via plants and animals
Advanced hunter–gatherer	As above, plus stored solar energy as fire
Early agriculturalist	As above, plus domestic animals (traction, dung)
Advanced agriculture (pre-industrial)	As above, plus wind and water power
Early industrialist	As above, plus power from coal
Advanced industrialist	As above, plus oil, natural gas, hydropower and geothermal power
Contemporary	As above, plus technological methods of trapping solar and tidal power, nuclear power from fission and fusion

Table 3.2 Comparative energy statistics

(A) Historical

Type of society	Energy consumption per capita per day (kcal)	$J \times 10^6$
Hunter–gatherers	2 000	8.4
Agriculturalists	10–12 000	42–50.4
19th c. industrial society	70 000	294
20th c. industrial society	120 000	504

(B) Contemporary

Nation/development stage	Energy consumption per capita per day (1970s)[a] (kcal)	$J \times 10^6$
USA	219 000	919.8
DC average	117 000	491.4
Nepal	300	1.2
LDC average	6 800	28.5
World average	37 400	157

[a]Not food or fuel wood.

this historical perspective is that not only has the spectrum of energy availability increased, but so has the magnitude of it (Table 3.2). Thus industrial societies have under control quantities of energy far in excess of their predecessors and are able, as this volume shows, to effect transformations on hitherto impossible scales, some of which are of an irreversible character. This does not mean, though, that the impact of pre-industrial societies was negligible, for the input of solar, human and animal energy, and fire, channelled through technology, was responsible for widespread ecological changes.

3.2.2 Implements and Agents of Change

By the time of the emergence of *Homo sapiens sapiens* (*ca* 35 000 BC) the control of fire was accomplished, and it had spread with human societies out of Africa into much of Eurasia and was reaching the New World and Australia. This meant that many environments were subject to manipulation by fire, and there is a long list of proven instances of perhistoric and pre-European contact societies using it for manipulation. Indeed, most major biomes are susceptible to fire at some season, with the obvious exception of deserts with little vegetation. Intact, moist tropical forests are also probably unburnable, but secondary forests are vulnerable: in 1983, a fire consumed 3.5×10^6 ha of secondary forest in Kalimantan after a period of abnormally low rainfall (P. Buringh, personal communication). In temperate forests, the ecology of the regular use of fire is such that it increases the value and nutritional quality of food for ungulates by a factor of 10, since it increases the quantity of browse as well as improving the protein content of leaves (via the mechanism of mineralizing litter and thus enhancing the nutrient status of the soils), so opening the way for an increased density of animals either on an absolute basis or in the form of a concentration at a chosen place.

The ability to affect the movement of animals by attracting them to food sources or by making them flee in particular directions (as with some of the North American plains buffalo hunts) must have been a major positive contribution to the energetics of hunting, since it reduces by many times the amount of effort that has to go into harvesting: human energy is replaced by the release of energy stored in dead or otherwise combustible plants. It seems likely, too, that the use of fire reduces uncertainty in the hunt: used as a catalyst of improved forage, this is obvious; in other contexts, it appears that burning to reduce the shrub layer of a forest improves sight-lines and hence kill-frequency; and at the very least if a large area is burned, something edible is almost bound to flee the fire in the direction of a party of hunters (Mellars, 1976). But energy can find its application in fabricated tools as well. Many of them act as concentrators of energy, taking the essentially diffuse energy of, for example, muscles and directing it down a narrower channel with greater force. The blowpipe, the bow and arrow, the spear thrower all do this for hunters, the plough and the hafted axe for agriculturalists; the grinding wheel concentrates the diffuse energy of wind and water for those living off cereal agriculture, and the windmill brings water to (or removes it from) crops.

The energy contained in some chemicals was harnessed in pre-industrial times as well, with gunpowder being used in warfare and in quarrying, which is a distinctly non-reversible land transformation.

All these technologies had two effects: to facilitate the spread of pre-industrial human societies into most parts of the earth, and once they were established, to enable them to deflect the natural flows of energy and matter to their own ends.

3.2.3 Processes of Transformation of Natural Systems

3.2.3.1 Direct Transformations

The application of technology (including fire) to many natural systems results in a perturbation of those systems. Their response is varied and depends *inter alia* upon the intensity of the perturbation (i.e. the quantity of human-directed energy per unit area) and the time over which it is applied. Some systems are extremely resilient, and if the disturbance ceases will undergo succession back to their pre-existing state or something very like it; other ecosystems will not recover and will find a new level of equilibrium in a different condition, even if the hand of man is removed. Any attempt at a complete list of such transformations is bound to include gaps, but we may quote a number of major examples:

(1) fire in the burning of grasslands and dry forests;
(2) forest clearance by axe or fire;
(3) soil manipulation with plough, hoe, digging stick; production of ridges and furrows;
(4) construction of boundaries, like fences, dykes, ditches, bunds;
(5) pasturing of domesticated or semi-domesticated animals;
(6) drainage works and irrigation canals;
(7) continued hunting of wild animals and collection of wild plants;
(8) building of agricultural terraces;
(9) construction and maintenance of domestic and other buildings;
(10) impact of wood gathering for domestic use upon many kinds of vegetation community.

The resulting land transformations, as suggested above, vary greatly. Some hunting communities are both so small in number and peripatetic that they affect the vegetation and animal communities scarcely at all, and their low level of material possessions makes very little impact even at their former dwelling sites. At the other extreme, the irrigation agriculture of the Nile, founded in the early years of agriculture itself, has persisted to the present day and the original reedswamps, wet grasslands and seasonally inundated scrub have never had a chance to come back. Some of these transformations, then, affect only short-cycle components of ecosystems such as plants and animals, but others affect long-cycle constituents like the soils, parts of the hydrological cycle and even the rocks themselves, as in the quarrying which heavily scarred parts of classical Greece (Hughes, 1975).

3.2.3.2 Indirect Transformations

Considered spatially, each impact has an epicentre, whether this be the killing of individual animals, or the clearing and ploughing of a patch of forest. But ecosystems being interactive systems of biotic and abiotic components, the purposeful impact is likely to have unconsidered (and sometimes undesired) consequences elsewhere. To kill a particular male animal may be to disrupt the social and reproductive unit and lower the chances of replacement of that animal; clearing a patch of forest and cultivating the soil may result in the permanent loss of perhaps 1 m of topsoil and its deposition in a river flood plain or in a delta many kilometres away. Because of the silt load, the river basin hydrology may undergo very large-scale changes indeed, with new patterns of flooding, for example, affecting agriculture or urban life in the riverine lowlands.

To exemplify these generalities we shall now consider separately the two major pre-industrial ways of life and give some examples of ways in which they have effected land transformations in various places and at different times. These examples, together with Figures 3.1–3.5, give some idea of temporal and spatial impact, but the treatment will not be comprehensive.

3.3 HUNTER–GATHERERS AND THEIR ENVIRONMENTS

3.3.1 Increasing Access to Energy

The early development of human societies can be seen in some ways in terms of increasing access to energy sources: the development of hand-held tools is carried further by the invention of hafted types, the spear is complemented (probably not until the Upper Palaeolithic of Europe) by the bow and arrow. Indeed the European Upper Palaeolithic marks a sudden burst of technological invention unparalleled since the start of tool making chronicled at Olduvai Gorge (Leakey and Lewin, 1977, 1979) and the control of fire. Access to energy is low compared with today (Tables 3.1 and 3.2), but we have to remember that (a) hunter-gatherers account for 90% of the time since human evolution, and (b) they have occupied most environments, from the ice-margins of the Neanderthals and near-recent Inuit to the near-deserts of the Saharan neolithic and near-recent Bushmen.

Not only are some of these environments fragile because of the extreme physical conditions, but some have been affected by rapid environmental change during, for example, the sudden climatic changes which mark the end of the Pleistocene (Lewin, 1983). At that time there occurred an apparently sudden and irreversible demise of about 200 genera of large warm-blooded animals, a phenomena which has been labelled 'Pleistocene overkill'. There has been, as might be expected, some investigation into whether natural events were entirely responsible, or whether human agency was involved (Martin, 1967). The phenomenon is perhaps most closely observable in North America: here, two-thirds of the mammalian megafauna (species with adults weighing 50 kg) of the end of the Pleistocene (*ca* 11 000 BP) disappeared, including 3 genera of elephants, 6 genera of giant edentates (armadillos, ant-eaters, pangolins and sloths), 15 genera of ungulates, and various giant rodents and carnivores. There is no evidence of such extinctions in earlier periods which might have been expected if previous Pleistocene climatic changes had been the proximate cause, nor any firm evidence of survival of these genera past the 500-year period during which the extinctions appear to have taken place. These data have led to the hypothesis that it was the introduction of *Homo sapiens* as a predator against which these animals had no genetically evolved defence behaviour which was the cause of the extinctions. In North America, the date of introduction of man via the Bering Strait land bridge is usually taken as being about 12 000 years BP, and a simulation of the extinction pattern supposes a wavefront advance by hunters whose population periodcially exploded because of the new and favourable habitat (Martin, 1973; Mosimann and Martin, 1975). At the advancing front, an annual human population growth rate of 3.4% may have given a density of 0.4 persons/km and a forward movement (due to hunting-out of the large mammals) of 16 km/year. Thus the front could sweep from Canada to Mexico in 350 years (Martin, 1973) and extirpate the large mammals through superior predation techniques.

Some support is given to this hypothesis by the effects of the arrival of man into other hitherto unpeopled places. The disappearance of the moa from New Zealand occurred within a few hundred years of the human occupance of the islands; the megafauna of Madagascar disappeared within a similar period after the first human occupation in 1000 AD, including a large terrestrial bird *Aepyornis*, and a pygmy hippopotamus. In Java and Celebes, populations of dwarf elephants did not long survive the coming of man. It would appear, therefore, that when introduced into a new habitat man the hunter is capable of rapidly exterminating flightless birds and large mammals. By contrast, the end of the Pleistocene in the Old World presents a somewhat different picture (Reed, 1970), for in Eurasia only a total of 9 species were made extinct, compared with the New World total of at least 24 genera. The Eurasian losses comprised the woolly mammoth (*Mammuthus primigenius*), woolly rhinoceros (*Coelodonta antiquitatis*), giant Irish elk (*Megaloceros giganteus*), musk-ox (*Ovibos moschatus*), steppe-bison (*Bison priscus*), a buffalo of northern Africa (*Homoioceros antiquus*) and three species of associated carnivores. All except the buffalo are animals of the cold steppe which was widespread outside the ice-sheets of Europe during the last glacial phase and all the herbivores, especially the mammoth and bison, had been hunted for tens of thousands of years yet survived in large numbers until about 12 000–10 800 years BP. But this time-horizon does not mark the introduction of man to Eurasia, not even a particularly great cultural change, so that it appears much more likely that climatic amelioration leading to forest growth of birch and pine was the main cause of the animals' disappearance. At any rate, when their habitats returned briefly in the cold period of 10 800–10 510 years BP, the animals did not. Some other species of the cold steppe proved more adaptable: the reindeer persisted on the tundra, and both the saiga (*Saiga tartarica*) and wild horse (*Equus przewalskii*) took to the grasslands of central Eurasia. A site in New South Wales, Australia, seems comparable with Eurasia since it appears to show 7000 years of coexistence of man and megafauna without any evidence that the human societies were the cause of the eventual extinction of the other animals (Gillespie *et al*., 1978).

As added evidence there has emerged the picture from the North American prairie in the Holocene of the killing of large numbers of animals without any lasting effect upon their populations. We have a picture of the Indians (in the days before their possession of horses) killing in the autumn large numbers of animals in order to provide both an immediate feast and meat for the winter (Frison, 1978). In the open environment of the High Plains the animals had to be trapped in some way, either so that they could be killed at close range or so that they killed themselves. Butchery then took place at or near the kill site, which was then probably abandoned for some time, at least until the rotting remnants of the carcasses had ceased to be noxious: at one site a layer of maggot cases 2.5 cm thick testifies to the fact that not all the meat was eaten. At the Olsen–Chubbuck site in south-east Colorado, dated 8200±500 BC, the hunters stampeded a herd of buffalo into a narrow canyon or *arroyo*, some 2–3 m wide and 2 m deep. The age of the calves suggests this happened unusually early, in late June rather than the autumn. The remains extended some 57 m along the arroyo and about 190 animals were killed (a typical herd would number 200–300 at that time of year). The bone analysis shows that 57% of the animals were mature, 37% immature and 6% juvenile; but no fetal remains were found, either because no gravid animals were killed or because the fetuses were taken away as a particular delicacy. At one time during the years 1670–1740 AD another group of hunters used a spectacular site in central Wyoming, where a bluff 14 m high was used. The vertical part of the cliff is restricted, and the animals had to be carefully controlled: a metre or two either side and they would likely escape down steep but not lethal slopes. In this case, the drive lane suggests the control of the buffalo herds' movements for 1.5–4.5 km before they were finally stampeded over the edge. The bones suggest that this and similar bluffs might be used in rotation: one hundred buffalo stomachs left to rot might not be approachable for a year or two, even to people less easily made queasy than ourselves.

To summarize, the evidence suggests that kill operators were bringing in bison to kill sites from several kilometres round each site, usually but not always in the autumn. Fire was often used in this as in other types of buffalo hunting. So men were reaching out and removing several hundred cows and calves from the breeding population and perhaps doing this in adjacent areas in the same season. Although doubtless plants were eaten, the bison was a staple; and although nobody suggests that the hunters were responsible for anything like the reduction in buffalo numbers that came later, we may surmise that the population dynamics of herds may sometimes have been affected with consequent effects upon vegetation and upon those areas of soil which they physically disturbed, as in wallowing areas.

3.3.1.1 The Later Mesolithic in Upland Britain

As an example of environmental impact in prehistoric times, we shall consider the last hunter–gatherer culture of Britain, groups of people who lived by hunting (most probably concentrating on red deer) and gathering, and probably by fishing. One of the environments they occupied was that of the uplands of England and Wales, and it is in this zone that palaeoecological research points to their role as manipulators of their surroundings. The period of their tenure of these lands in *ca* 8500–5000 BP, ending at *ca* 3500 BC with the arrival of farming (Neolithic) people.

The British uplands present today a largely treeless, peat-clad landscape, vegetated by various kinds of moorland dominated above 300 m by ericaceous shrubs, grasses, sedges and mosses. The land is now used as sheep-walk, grouse moor, watershed and recreation area, and some of it is afforested with exotic conifers. In spite of their wet and cool climate these uplands were largely covered in natural woodland (pine forest by 9600 BP and mixed oak by 5500 BP) during the mid-postglacial period, and it is with the beginning of the disappearance of this forest that this account is largely concerned. Because most of the uplands have extensive deposits of peat and have never been cultivated more than sporadically during historical times, they preserve to a considerable extent both the archaeological and the palaeoenvironmental evidence for the reconstruction of prehistory. They have therefore attracted more attention than some lowland areas (though there are notable exceptions like Star Carr and the Somerset Levels) and the findings given for a particular set of environments must not be taken to extend to other areas for which no comparable evidence is yet available.

Environmentally, the later Mesolithic occurs within the ‘Atlantic’ period of postglacial climate. Rainfall was probably on average 11% above present-day levels, and average temperatures approximately 2°C above those of today. In the uplands, the higher rainfall would have been amplified by years with rainfalls 25% or even 50% above the average, and evaporation hindered by the lapse rate effect of the altitude upon temperatures. Whereas high summer air temperatures in the lowlands in the late Mesolithic might have averaged at 17.5°C at 500 m, the equivalent would have been more like 15.4°C. This oceanicity was, of course, inherent in the position of Britain, but exacerbated by rising sea-level which finally insulated Britain *ca* 7500 BP, i.e. near the beginning of the later Mesolithic. Nevertheless, postglacial vegetation succession had proceeded so far as to cover most of England and Wales with mixed deciduous forest in which oak and probably lime were important trees. The climatically determined tree-line on the uplands seems in places to have been upwards of 700 m, evidence being provided by tree remains in peat at such altitudes.

Yet pollen analysis shows that on some uplands (e.g. southern Pennines, Dartmoor, North York Moors), the tree-line was, during late Mesolithic times, well below the climatically feasible limit; an upper level of forest of 320–290 m was more characteristic. In the Southern Pennines, Tallis (1975) has postulated an upward extension of tree-lines after Mesolithic times (during a period of deteriorating climate), noting that the organic deposits of Mesolithic age in the upland contain not tree remains but charcoal. Similar evidence from the North York Moors has been found (Simmons and Innes, 1981). A number of types of evidence have been described:

(a) 'Clearance phases' in pollen diagrams. These are analogous to the *landnam* phases (*sensu* Iversen, 1949) found in agricultural phases of prehistory in that woodland appears to have been cleared but later regeneration takes place.
(b) Forest recession in pollen diagrams. The pollen indicators of mature forest recede and are replaced by indicators of open ground (e.g. grasses, bracken fern, *Ericaceae*) which stay permanently. Both this type and type (a) sometimes contain small quantities of pollen of aquatic plants at the appropriate horizons, suggesting the nearby presence of water.
(c) Many pollen diagrams contain very large frequencies of the pollen of hazel (*Corylus avellana*). This shrub flowers prolifically when a forest canopy above it is removed, and stump-sprouts after cutting or burning, and will form a scrub. The nuts are nutritious and often turn up in excavations of Mesolithic sites.
(d) Organic deposits in basins show one or more 'inwash stripes' of inorganic matter during the Mesolithic. These stripes interrupt otherwise continuous organic materials and are presumed to have come from open ground yielding silt to the runoff, as would happen at times of deforestation. The

> pollen content of the deposits confirms the recession of forest at the time they were deposited. All these phenomena occur during later Mesolithic times and in areas with appropriate artifacts, but it should be stressed that they are not necessarily associated directly with layers of, for example, implements. Charcoal is, however, frequently found in deposits of appropriate age.

None of the evidence, quite naturally, shows any direct evidence for interference with animal populations; while culling of them must have affected numbers there is no way at present of telling whether the overall magnitude and composition of mammal populations would have been affected on anything other than a short-term basis. Pollen analysis does, however, provide evidence for forest recession during late Mesolithic times in places where lithic remains are found, and so these are usually attributed to human activity and called clearances. In lowland England they appear to be commonest on siliceous substrates, often at places which are now heathland such as the Weald of south-east England, and the Breckland in East Anglia. The quantity of silt suggests that sufficient tree cover had been removed to allow the runoff to transport soil material downhill into accumulating rivers (Richards, 1981) and to form spreads of inorganic material over and among the vegetation. In some places the forest limit is either pushed downhill or never attains its climatic potential with acid grassland or shallow peat forms. After the end of the Mesolithic period, deciduous forest colonized the shallow peats and grasslands and in this case the opening was held for hundreds of years. The presence of charcoal in the organic deposits draws attention to the probable role of human communities. Another type of sequence is found on the highest parts of uplands where the angle of slope is low. Forest clearance was followed by acid grassland, then heath vegetation dominated by heather (*Calluna vulgaris*), and then blanket peat (2–3 m deep is common). This process is not reversible in the manner of the other two instances; once the forest has gone it does not return.

In the context of these data, some speculation about possible reasons for environmental manipulation may be made. For example, if in summer the red deer scattered (and roe deer are not herd animals at any time) then they must have been attracted by the combination of abundant browse and water. Culturally, this might coincide with Zipf's principle of least effort: it is easier on the limbs and lungs to attract the beasts than to run after them. There is, as well, the possibility of circumstances in which several millenia of occupation even at a very low density and rate of population growth had filled up the terrain to the point where no 'free.' land existed for any people who could not be supported on a particular territory. Then (a) seasonal movement and (b) burning would be seen as adaptations (i) to increase food supplies by tapping as wide a set of food resources as possible; and (ii) as a form of intensification of land use in which the logical hypothetical sequence would be free hunting: manipulative hunting, herding and, eventually, agriculture.

3.3.1.2 Examples of Transformations by Near-recent Hunter–Gatherers

Near-recent examples of the utility of fire to hunter–gatherers are plentiful, but perhaps the most notable concentration is in the Antipodes. In the Cape York peninsula of Australia, Harris (1977) reports the usefulness of large stands of cycad trees (*Cycas media*) which, in yielding some 131 kcal/m^2/year of edible kernels, equal some cultivated crops. He suggests that these stands are a consequence of firing the area repeatedly, thus encouraging the fire-resistant cycad at the expense of other trees. The cycad *Macrozania*, if fired, produces all its seeds simultaneously and at 7–8 times the unfired quantity. Further into the interior, the aborigines used fire for hunting, land clearance and communications as well as for domestic purposes, with a total of 5000 bush fires a year being estimated for the years of early European occupance. Fire was used to 'clean up' a landscape, it was said (rather as we might—some of us—tidy up a room), and in effect it created a patchy array of habitats with greater floral and faunal diversity than had previously existed, and many of the biota thus encouraged could be eaten with some of the animals easily flushed out by the flames: long-necked turtle and granna lizard are still hunted in this way. At the southern extremity of Australia, the climax forest of Western Tasmania is *Nothofagus* (southern beech) forest, but a high fire frequency converts this to wet sclerophyll forest and thence (if fire is continually applied) via wet scrub to heath or tussock grassland. In the drier north-west of Tasmania the same process has produced large areas of open grassland like the English downlands. The fire enhances the growth and spread of edible plants like the bracken fern *Pteridium esculentum*, which colonized newly burned areas and became a carbohydrate staple; the patchy environment encouraged wallabies, bandicoots and possums, all of which were edible (Jones, 1975).

In New Zealand, there is evidence that at European contact time, the bracken fern was the starchy staple of the Maori and that firing was used regularly to encourage its growth and spread. Burning was extended to the podocarp forests which covered most of the eastern half of the South Island in the period 1000–1400 AD, and much of this forest land became grassland and scrub. Along with the forests and with the first arrival of man, many animal species became extinct: six genera containing 20 species of moa became extinct within 500 years of man's arrival, along with 20 other species of bird, and the extinction of elephant and fur seals except in remote areas. So predation and environmental change brought an analogy to 'Pleistocene overkill' in remote New Zealand.

For a more distant period, we have evidence from south-western Victoria during the period 40 000–7000 BP of the construction of large-scale artificial drainage channels in swamps. This appears to have been a management system for the procurement of eels. The channels were more than harvesting devices, for they retained water in swamps during drought and kept up the supply of eels in what was in fact a margical part of their range. A high density of semi-sedentary hunter–gatherer people (equal to that attained under shifting agriculture in New Guinea) was achieved thanks to a broad-based subsistence base supplemented with the products of these water controls (Lourandos, 1980).

If vegetation cover is affected by subsistence hunters, then we would expect soils likewise to be affected. Following repeated fire, and deforestation, for example, we might expect the loss of soil and perhaps regolith from sloping areas and its downhill and downstream aggregation as a fluviatile deposit. It is very difficult to tie such deposits to hunter–gatherer populations, but we may note in passing recent dating of fluvial sediments in river valleys in southern England and the North York Moors of northern England, which suggests that they were the erosion product of openings in the largely closed deciduous forest of the Mesolithic (terminal hunter) period of those regions. Aboriginal burning in the mountainous areas of Tasmania and eastern Australia is thought to have led to soil loss following large-scale vegetational change.

3.4 PRE-INDUSTRIAL AGRICULTURE AND ITS ENVIRONMENTS

As Figures 3.1–3.5 show, agriculture has not been quite so successful as hunting and gathering in its occupation of the earth's surface. Nevertheless, if we include the pastoralism of domesticated beasts, then not only have the obvious zones of valleys and temperate lowlands been colonized, but mountains, forests and semi-arid lands as well; the barley fields of Zanskar and the cattle herds of Karimojo have been as much part of pre-industrial agriculture as the wheatfields of eighteenth century Europe, the cotton of the American south or the rice terraces of dynastic China.

The access to energy by farmers down the ages has aided the processes of colonization and subsequent adaptation, for they have added to fire and human energy the power of domestic animals as well, and have been able to harness the force of the wind not only in the processing of agricultural products, but also to help with drainage and irrigation. Power generated by falling water, though useful for processing, did not in general lead to land transformation until the development of hydroelectric power.

In general terms, though, we must not under-estimate the role of human energy in pre-industrial agriculture: most of the inputs to farming come from this source, especially where construction is involved, e.g. of wells, fences or terraces. Only when the task is virtually totally repetitive—such as ploughing, lifting water and leading crops—can domestic beasts be of much use in arable farming systems. Fire, too, is still of crucial importance in shifting cultivation and in certain types of pastoralism.

Although it may not show in the landscape, the permanence of transformation requires that the nutrient cycles be maintained: the export from cities of night soil, horse-dung and pigeon manure, the keeping of stalled beasts for their manure output, the use of lime and marl, the gathering and spreading of seashells and seaweed, were all employed at some time to nourish the growing crops.

3.4.1 General Examples of Transformation

The imprint of agriculture has been strong since its apparent evolution in the 9th–6th millenia BC in south-west and south-east Asia. Animal populations, the vegetation, the form of slopes and valleys and the soil cover of those land units, have all been altered, many of them in apparently irreversible ways. The processes of tillage and fallow, of terracing, of irrigation and of drainage have had considerable consequences for such features as the transformation of soil type (like from brown earth to podzol on siliceous substrates in north-west Europe or from skeletal to deep colluvial in the Mediterranean), for the erosion of slopes (as when forests have been cleared in many regions of the world, increasing the sediment yield by perhaps 20 times) and the subsequent aggradation of valleys (which may have been accidental, as in the river valleys of southern England during the Bronze Age, or deliberate where systems of weir terraces were constructed), and the formation of deltas in oceans and lakes where silt from the land surface came to rest. At a smaller scale, the ridging of fields in pre-Columbian South America was a widespread practice (Parsons and Denevan, 1967).

These generalizations can be amplified by a few selected examples of the imprint of agriculture; we may note in passing that even where the agricultural system has gone out of use, the transformations may remain in relict form, as with abandoned terraces, for example, or deserted field systems where the boundaries remain; and soil lost from deforested and subsequently cultivated slopes is unlikely to be regenerated unless a new generation of forest trees reclaims the site and is undisturbed for perhaps tens of years in the tropics, and longer still in the temperate zone.

3.4.2 Regional Examples

3.4.2.1 Prehistoric Central America

In Central America the remains have been found of a complex urban society to be ranked with those of highland South America and of ancient Mesopotamia. Recent work has excavated not only the cities and ceremonial centres of the culture, but has also thrown considerable light on its subsistence base and its environmental relations. The Maya inhabited what is now parts of Guatemala, Mexico (Yucatan), Belize and the fringe of Honduras, mostly in the lowlands but with some extension of occupied area into the upland areas that interrupt the plains. The chronology usually adopted has an emergent phase ('Preclassic Maya') from 2000 BC to 250 AD, a 'Classic Maya' phase from 250 AD to *ca* 1000 AD, followed by the collapse of 800–900 AD (with a sudden decline of population and the desertion of cities); thereafter the Post-classic Maya continued at a lower level of complexity until the advent of the Spaniards in 1520 AD completed the disintegration of the ancient culture.

The original vegetation of the area had a number of elements, the chief of these were:

(1) the swamp or *bajo* dominated by buttressed trees;
(2) an evergreen mesic forest;
(3) monsoon forest on well-drained sites and clay-filled valleys, interspersed with palm forest also on well-drained and gentle slopes;
(4) *aqadas*: small depressions that hold water throughout the year but surrounded by a high forest with a closed canopy;
(5) oak woodland on alluvial clay soils;
(6) an orchard-like savanna vegetation of shrubs with grassland beneath;
(7) an open grassland with trees; and
(8) *campo*, an open grassland on level plains.

Within this matrix the Maya elaborated a subsistence base with a number of lineaments. The Pre-classic period was dominated by swidden agriculture of the 'slash and burn' type, mainly growing maize in the lowlands so that these areas were a mosaic of temporary cornfields (*milpas*) and scrub; the uplands were not occupied. It was once thought that this system was the economic base of the Classic Maya civilization, but scholars now believe that a suite of agricultural techniques occupied the different ecological niches; during the Collapse there was a transition from an agriculture-dominated landscape to one dominated by forest, apparently resulting from an all-embracing catastrophe. In the Post-classic era, the forest reigned with flickers of agriculture until the Maya civilization as such was extinguished by the *Conquistadores*.

There now seems no doubt that the Classic Maya were underpinned economically by a set of subsistence techniques. Of these, the most important spatially was probably swidden agriculture of maize, with sweet potato and manioc as other important crops. Each cultivator probably had several plots to reduce the risk of failure and equally to minimize the effects of soil loss which would have been a constant difficulty on exposed soils. A variation of this technique was the intensive *milpa* practised in areas of year-round rainfall. This involved multi-cropping with a high diversity of crops and high ground coverage to reduce the hazard of soil loss. Even though fallow periods were short, this system was appparently stable. Even the most intensive variant needed some fallow time, but in some lowland areas an artificial rain-forest of trees, vines, roots and seed agriculture was created, growing cassava and yams as well as the basic maize, beans and squash.

Another important element in the diet may have been the nuts of the *ramon* tree (*Brosimium alicastrum*), which may have been harvested from a mono-cultural orchard system or perhaps from a more mixed arboriculture with *guayo* and *aquacate* trees. At any rate, yields of 1245 kg/ha/year of nuts could be obtained and stored underground for long periods, so that these nuts would have been a valuable addition to the subsistence base. It seems, too, that dooryard gardens were a feature of rural areas: these were small fenced areas which experienced much fertilizing and mulching and so yielded a diverse crop of shade trees, fruit, herbs, spices and medicines.

Of greater relevance for our theme, it appears that large-scale alteration of the land surface was within the capability of the Maya, including the creation of raised fields in areas of swamp and river flood plain. These raised fields (*chinampas*) are especially characteristic of the valley of Mexico, but some 21% of the land surface of the Peten area seems to have been devoted to them. Basically, canals are dug and the mud dredged up forms a rich soil. The canal harbours fish and turtles. The crops grown included maize and cotton, but in Maya times, cacao may have been an important product of these areas. Each year the act of keeping free the canals added more rich silt to the fields, and some of the waterways had raised sills at each end to act as traps for silt or fish, or both. (Figure 3.6).

On the upland areas which interrupt the lowlands, large areas were terraced, including one tract of 10×10^3 km^2 in the Rio Bec region. These increased the available agricultural land while avoiding erosion and continual leaching of soils, and there is evidence that soils were carried upslope within the terrace systems and perhaps even from inundated lowland areas. Such terrace systems (Fig. 3.7) were supplemented by simple devices such as rows of stones set into the slope, and by silt trap terraces and weirs set in the valleys where they might accumulate more than 50 cm of soil.

The presence of such large areas of terracing argues for a more or less total land use, since all the available lowland arable would be undertaken, and other land uses besides agriculture must also be considered. Hunting was one of these, although there is very little information on its environmental impact. Another important environmental resource was wood. Each family would need about 15–20 cords a year, with one cord of wood equivalent to 120 trees. Since short fallow cycles would yield insufficient wood of the right size from their regeneration phases, woodlot plantations were probably necessary: either in the form of swidden areas with a long fallow for its wood harvest, or isolated wood-yielding 'plantations' grown within other agricultural systems. Lastly, we may note that the Classic Maya practised water management: they

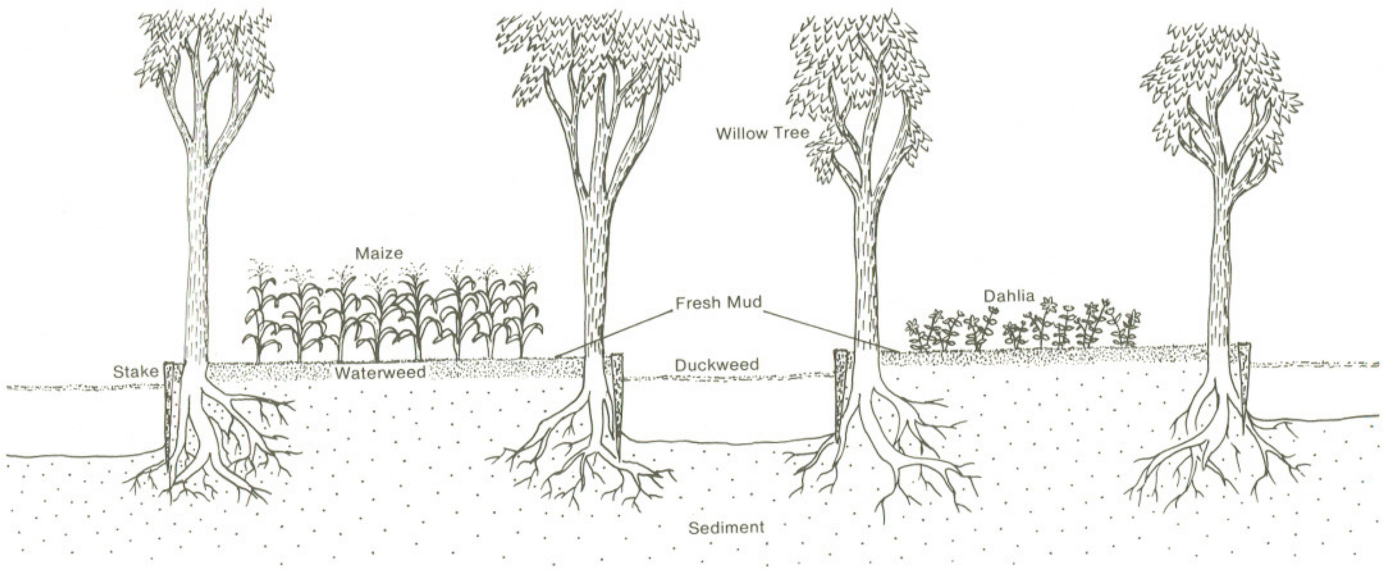

Figure 3.6 Part of a typical *chinampa*

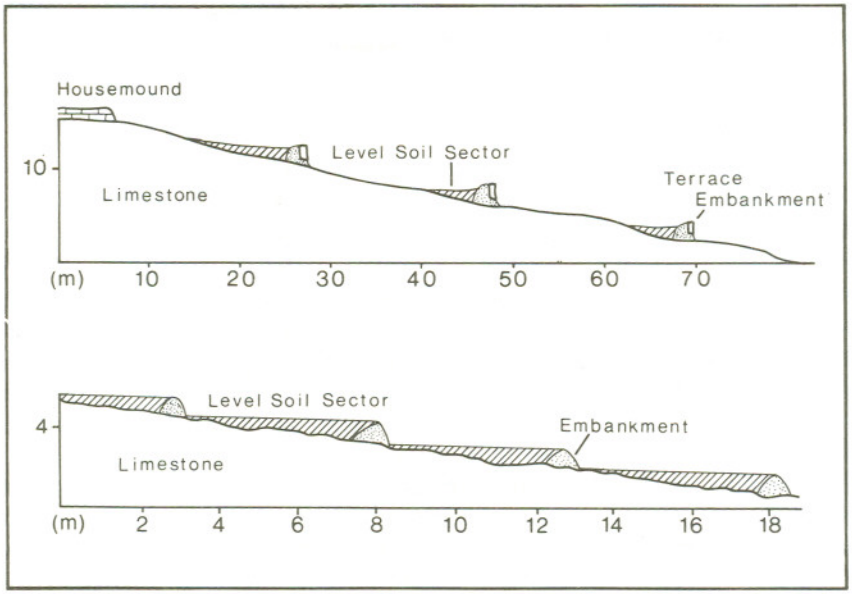

Figure 3.7 Terrace systems

collected water from limestone caves in Yucatan, lined pools with stone, cut chambers into solid rock with stone 'catchments' leading to their mouths, dug wells, and fed moated fortresses by canals as well as erecting water storage systems for cities which covered 17 km^2.

It seems very likely, therefore, that the Maya transformed much of the landscape they inhabited, though presumably patches of virgin savanna, grassland forest remained in the uplands, and there were areas of open water and swamp whose ecology remained undiverted by human acitivity; but in general an airborne observer at the time, were such possible, would have seen a largely cultural, rather than natural, landscape. Beyond this certainty, questions remain: did swidden agriculture in fact precede more intensive forms, or was the core area the lowland production areas which were supplemented by slash-and-burn as the population grew? And could the problem of intensification of agriculture be at the heart of the Maya collapse? Had perhaps the population grown to the extent that the battle between men and loss of soil fertility was lost: that the society could no longer keep up the nutrient cycles; that in effect so much natural cover had been lost that many soils were exposed to leaching and chemical weathering and too little organic matter was going back into them? Further research may illuminate this problem but we can, *interim*, note that no very sophisticated technology (no plough, for example) was needed for a numerous population to transform a set of natural tropical ecosystems into an equally diverse set of man-directed ones (Harris, 1978; Wiseman, 1978; Matheney, 1982).

3.4.2.2 Other Examples

An agriculturally based land transformation with a long history and a wide distribution (Fig. 3.8) is terracing, 'stamping', as Spencer and Hale (1961) put it, 'the permanent imprint of man on the surface of the earth'. As those authors point out, it transforms the natural slope of landforms, alters the patterns of natural drainage, changes the profile and development of soils, counteracts natural cycles of erosion, produces culturally controlled sedimentation and the growth of softer than natural landform profiles. It is interesting, too, that its distribution does not conform to the harshlands of the earth and so is a matter of culture more than environment; and in this it is different from the great river valleys in which the major hydraulic civilizations developed their systems of flood control. Terracing is not a uniform phenomenon, although its aims are relatively simple: to produce a relatively horizontal cropping surface with adequate water at the appropriate time. To achieve this there are, for example, terraces which are built in open, non-entrenched drainage channels and which employ a simple weir to spread water over a surface wider than in the natural condition so as to soak the surface and to cause the accumulation of silt; more common perhaps are rock-embanked contour terraces with sloping fields which start out near a channel from which irrigation water may be diverted to irrigate the terrace; and uppermost in the

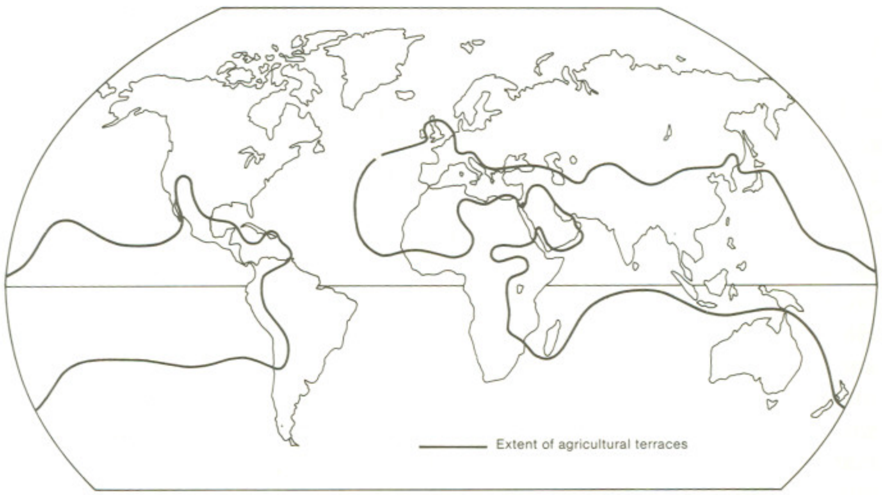

Figure 3.8 The worldwide distribution of agricultural terracing

public conception is the contour terrace laid out laterally across slopes using embankments to impound water on wet fields, using water derived from higher terraces or upland sources.

The origins of terracing are probably in the semi-arid foothill margins of the ancient Near East in the period 9000–5000 BP, with diffusion outwards to other areas. Northern Indochina acted as a secondary centre of invention and evolution out of which spread the complex wet-terrace systems for growing rice, which were then disseminated into southern China, Korea, Japan, the Phillipines and south-east Asia, Sri Lanka and Madagascar, the Himalayan front and the margins of lowland India. Some of the terraces visible in the landscape today are relatively recent (e.g. eighteenth and nineteenth century in China and peninsular India) but yet others are ancient: the much photographed systems of northern Luzon in the Phillipines are thought to be 2000 years old.

We may look in more detail at the growing of wet rice, or *padi*. This is a Malaysian word meaning 'rice on the straw', and has been anglicized to refer to the growth of rice in conditions which require it to be submerged beneath 100–150 mm of slowly moving water for three-quarters of its growing period. Most of it is thus found in flat lands near rivers, but in some places there is an elaborate terracing of slopes which represents a considerable environmental impact. Today, only a relatively small part of the total area of Asia is under wet-rice cultivation, but it supports a large part of the rural population.

Cultivated rice (*Oryza sativa*) was a dryland crop, usually grown in swidden systems, before it became a wetland staple. The early history of *padi* is uncertain, with an apparent reference as early as 5000 BP to the Emperor of China as being the only person allowed to sow *padi*. More solid references refer to wetland rice in the Wei valley of Shansi in 781–771 BC, and in the Yangtse valley of 148 BC we read of areas 'where the land is tilled with fire and hoed with water'. Quite firm dates tie the cultivation of *padi* rice to India, Indonesia and the Phillipines in the second millenium BC, to Sri Lanka in 400 BC and to Egypt in 375 BC. Thereafter the spread included Sicily in Roman times, northern Italy in the fifteenth century and subsequent export by European colonizers to such places as Brazil, the Spanish Americas, South Carolina (1685) and Louisiana (1718), Hawaii (1853) and by German influence to New Guinea and French carriage to New Caledonia.

The classical ecological description of pre-industrial *padi* is by Clifford Geertz (1964) writing about Java in the early 1950s before mechanization had any significant effect. He notes that after 10–20 years of cultivation the yields tend to remain stable almost indefinitely. Geertz suggests that the characteristic nutrient poverty of tropical soils is circumvented through the nutrients brought by water from the higher volcanic slopes on to the terrace; through the fixation of nitrogen by the blue–green algae which proliferate in the warm water; the release of nutrients by the decay of stubble and of other organic matter used to fertilize the fields; and as a *sine qua non*, good community-based control of the water. The working of the waterlogged soil produces 'puddling' so that the soil becomes impervious to moisture and the loss of nutrients by downward moving water is minimized. So the *padi* is a fertile environment: a farmer may add 10–15 cartloads/ha of manure (the water buffalo is a normal concomitant of *padi* farming), ashes, straw, alluvium and perhaps green compost from leguminous crops. Further, there can be 16 t/ha fresh weight of algae which may accumulate 100 kg/ha of nitrogen, and other N_2-fixing organisms also exist in the root zone of the rice plants. Given that the flooded *padi* may also yield animal protein in the form of fish or crustacea, then its virtues as a food-producing system are convincing. As Geertz says of its environmental relations,

> . . . wet rice cultivation is essentially an ingenious device for the agricultural exploitation of a habitat in which heavy reliance on soil processes is impossible and where other means for converting natural energy into food are therefore necessary . . . here we have . . . the fabrication of an aquarium.

In order to achieve this floodable environment and to keep its fertility high, a number of management practices are used. Murton (1980) lists 26 soil management techniques which are applied in wet-rice cultivation in southern Asia, and we may take it that most if not all of them are common in other regions. Animal manure, human manure, oil seed waste, green manure and leaves from trees, ploughing, wet and dry bunding and even soil transfer are prominent in the list. Water management is equally complex: the natural hydrological cycle is manipulated at several points in order to provide the right quantity of water to the fields at the right time, with a correspondingly complex social framework to ensure the equitable distribution of the resource. Again, Murton lists 23 forms of water management, including storage wells and tanks, lifting devices, delivery systems, application practices, and ways of preventing the flooding of *padi* by estuarine or river waters in low-lying areas, especially in the deltas of the major river systems. The greatest environmental impact, however, comes through slope control, with terrace construction, the levelling of fields so that they can be evenly flooded, and the construction of dams in runoff streams to trap any valuable silt which might otherwise escape.

Thus at some stage in history, whole landscapes were realigned so that flows of energy, moisture and nutrients were channelled year in and year out into a relatively small area of cultivated land. As there was relatively little fallowing and not a great deal of suitable wild land, draught animals (mostly water buffalo) were relatively few and so nutrients other than those of domestic stock were very important. Hence the reliance upon night soil, the nutrients brought by the water, and the blue–green algae of the *padi* itself. Where major nutrient leaks in the *padi* system took place (for example, to urban centres in eastern Asia), then the cycle was restored by the use of night soil from the cities.

In summary, we can perhaps say that *padi* rice is not such a radical transformation of an entire landscape as is perhaps commonly thought: it exists in a matrix of less-manipulated ecosystems except in particularly suitable places like riverine plains. But its potential for environmental change extends outwards from the *padi* fields themselves, both into the settlements as providers of fertilizer, into dryland ecosystems which may be able to do the same, and on to surrounding hillsides which supply the vital water (often with important nutrients in solution or suspension) without which the crop could not be grown. Given a stable 'natural' and 'social' ecology, then, *padi* rice is a heavily yielding crop even under traditional conditions. Moreover, the output of most terraces can be increased by attention to detail: seeds are transplanted rather than broadcast, shoots are planted in exactly spaced rows, the terrace is periodically drained and ploughed, and better varieties allow double and even triple cropping. So in pre-industrial times any extra pressure put upon food supplies by population growth could very often be absorbed by applying that labour to the fine tuning of the *padi* system for extra output.

Later than the original Near Eastern domestications of plants and animals, we see the development of a new form of economy, based upon the use of herds of mammals as the major source of food, with camels, cattle, sheep and goats being the most usual. From these animals, the staple food is milk, and the animals represent a food storage and conversion mechanism which gives them a certain buffering against the effects of short-term aridity, especially since mixed herds provide an additional insurance. An environmental feature of pastoralism is that the people make no attempt to improve the pasture of their beasts, and may not practice selective breeding. With some species interbreeding with wild animals was still common in pre-industrial times, as with the camel and reindeer, for example.

This way of using domesticated animals is clearly different from the pattern which developed in Eurasia, where the animals were closely integrated into the agricultural system, providing manure for the fields of the sedentary cultivator in return for a share of the crops. The pastoralist instead exploited a niche marginal to the agricultural zone. This may have been literally marginal in the sense of occupying the interstices of the cultivated zone (odd patches of scrub and grassland, and the edges of field, road and village); or it may have been marginal at an entirely different scale, occupying the semi-arid hill lands peripheral to the great river valleys which were the foci of permanent agriculture. But common to both systems is the characteristic that one area of pasture will not suffice and that the animals must be moved, either from a permanent base or by moving the human settlement along with the animals. The environmental relations of near-recent pastoralists encompass a number of defineable strategies: movement is the most obvious of these, as when they seek to utilize seasonal pastures or leave a drought-stricken area (Spooner, 1973; Swift, 1977; Equipe Ecologie, 1981). Collection of evidence about traditional pastoralism in the Sahel zone suggests that there was little probability of degrading the environment to any marked degree. Pastures were scattered, small-capacity wells the main water source, and animal disease prevalent. Damage to pasture around the wells was limited and the vegetation easily restored during the next wet period. (The same cannot be said of damage to the pastoralists themselves, who seem to have suffered famine at regular intervals since the sixteenth century.) A singular cultural practice which increases environmental impact is the provision of live sheep and goats to the valley of Mina, near Mecca, for sacrifice by pilgrims. The animals needed nearly equal the number of pilgrims and they must be ready for the 10th–12th days of the month of Dhu'l-Hijja; but since the Muslim calendar is lunar, each date falls ten or twelve days earlier in each solar year, so that if the sacrifices fall near the end of the dry season then large numbers of animals have to be kept on pastures least able to sustain them. Grazing lands are therefore denuded of their vegetation, and pasture is expanded at the expense of agricultural land and forest, all in a climate with a long dry season that may end with violent rainstorms (Stewart, 1978).

Pastoralism of a less intensive kind can of course cause a great deal of environmental change when pursued over a long time: in the Mediterranean during classical times, shepherds were renowned as the chief agents of deforestation, using fire and animal herds to increase the areas available to their animals. Stabilization of this and other land-use practices occurred, however, and until the downfall of the Ottoman Empire a kind of equilibrium in the non-cultivated upland ecosystems was achieved, with regular but not excessive burning. Grazing and coppicing produced a mosaic of scrub, woodlands and grasslands, closely interwoven with cultivated land in the form of terraces or small patches of tilled land. The twentieth century, however, has often seen the disintegration of this equilibrium: heavier grazing and cutting of wood for fuel has produced many areas of dense scrub dominated by the unpalatable scherophyll *Pistacia lentiscus* which alternate with grassy patches of inedible low grasses and herbs (Naveh, 1982). Great damage has also been done to the forests on the valley slopes of northern India by pasture of goats and sheep; like most Indian pastoralism this is done from a village base and so impact is greatest nearest the settlement and declines outward. In drier areas of the sub-continent (e.g. in Rajasthan and Baluchistan), semi-nomadism has been practised, with the pastoralists stopping at places within their territory to grow a little wheat, some onions and to tend date palms and fruit trees, where a small stream can provide some irrigation. As in most places, these pastoralists were not self-sufficient and they traded with sedentary agriculturalists: exchanging dates for ghee in Baluchistan, for example (Leshnik and Sontheimer, 1975). Only the nomads of the interior of Central Asia appear to have been completely self-contained; in South America the pastoralists integrate their economy with that of lower zones and there is perhaps more transhumance than nomadism; but mobility is high, aided by foods such as semi-dried meat, frost-dehydrated potatoes and parched maize (Webster, 1973).

Ecological change of varying degrees seems, therefore, to have been an inescapable accompaniment to pastoralism, and in many instances fire has been one of the tools used by the herders to increase the amount of forage (by encouraging early sprouting of fodder plants, for example, when other shading plants are burned off) in a pasture, or by extending scrub and grassland at the expense of woodland. Most pastoralism takes place in areas with a substantial dry season (Andean America is a notable exception) and so burning is rarely difficult; the impetus to carry it out in woodlands must have been even greater when forests held larger numbers of the carnivores which were potential predators of domestic herds: the wolf especially, but also the Asiatic lion, and the leopard for example. An example of reaction to this can be seen in the Edicts of As'oka, emanating from India *ca* 247–2 BC, where one law lays down that 'forest fire shall not be lit unnecessarily and with a view to killing living beings', and the prophet Joel encapulates some of the environmental problems of pastoralists in semi-arid climates when he says (1:20), 'the beasts of the field cry also unto thee: for the rivers of waters are dried up, and the fire hath devoured the pastures of the wilderness'. This and the later development of pastoralist economies led F. Fraser Darling (1955) to aver that subsistence pastoralism, if nomadic, might be able to last thousands of years, though not tens of thousands, for the land transformation—of plants, animals, soils and slopes—would be too great for it to remain without being changed into something else.

3.5 CONCLUSIONS

In conclusion, we might try to give a synoptic view of the degree of the making-over of the earth's surface by 1800 AD. General categories which might be proposed are:

(1) urban–industrial areas with intensive agriculture;
(2) areas of arable agriculture with considerable manipulation of soil and vegetation;
(3) areas of largely unmanipulated land with isolated areas of considerable manipulation, e.g. for minerals or forest;
(4) areas with some or little manipulation occupation occupied by hunter–gatherers, pastoralists or shifting cultivators in forests;
(5) virtually uninhabited areas.

An attempt is made at these divisions for the world in Fig. 3.9. If we except Antarctica and contrast categories (1)–(2) with (3)–(5), then we see that the

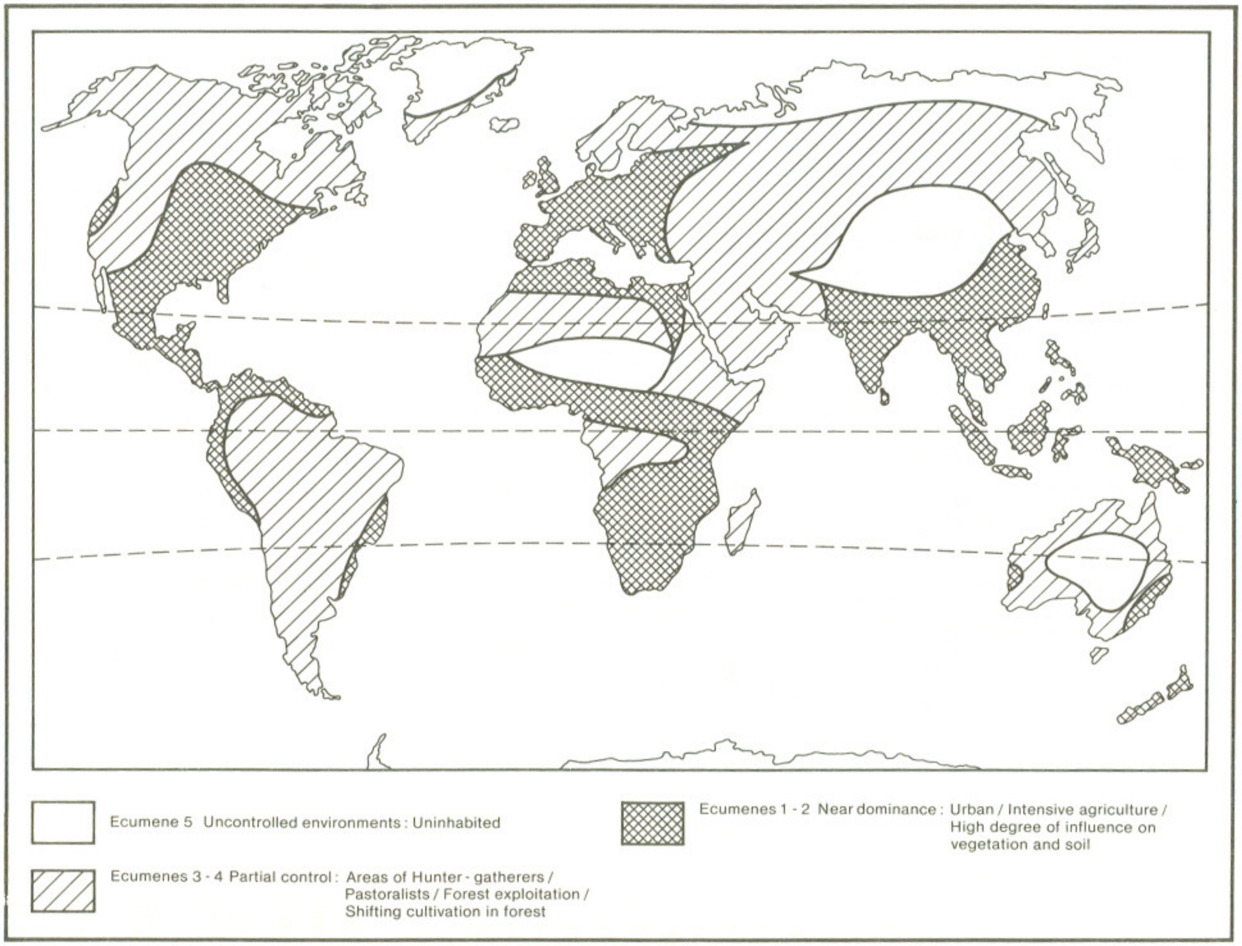

Figure 3.9 Estimation of the making-over of the earth's surface by 1800 AD

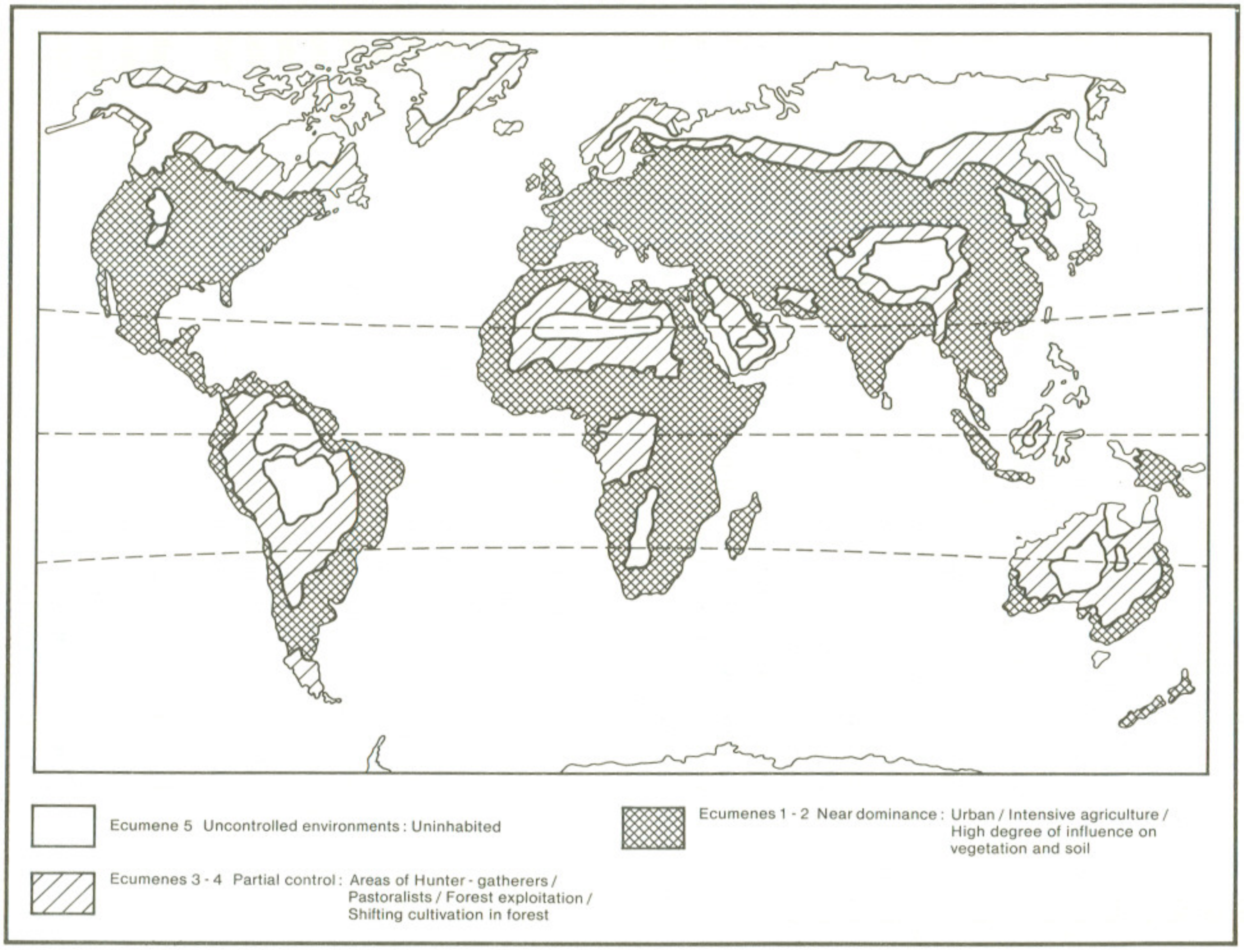

Figure 3.10 Estimation of the making-over of the earth's surface at the present day

highly manipulated areas are still relatively small, though made very large by the addition of the African savannas, considered as products of centuries of fire and shifting agriculture. But the remaining areas, although less intensively altered, are not necessarily natural environments, since fire, shifting, cultivation and pastoralism may well have altered ecosystems, especially in marginal areas of the globe where the soil–vegetation complex is especially fragile. We do not know, either, to what extent the moist tropical forests always returned to a pristine state after shifting cultivators had moved on.

This picture can be compared with Figure 3.10 which is an estimation of the position of the present day (Drew, 1983). As we would expect, areas (1) and (2) have expanded at the expense of the others. The world has experienced a considerable quantity of manipulation as the result of urbanization and industrialization this century (Hooke and Kaim, 1982), both in the centres of industrial development and at the periphery to which they have reached out—particularly during the period of European-dominated colonialism when many rural economies in Africa, Asia and South America were dominated by commercial agriculture and forestry which produced plantation-style crops for the economies of the home countries. So, whereas in 1800 the world pattern would in general look back to a predominantly rural economy with much self-sufficiency (albeit with a great deal of trade as well), by 1890 the major lineaments of today's pattern are well established.

3.6 ONWARD LINKAGES

To choose 1890 as a terminal date for this essay is to accept that there was already present in certain places a great deal of environmental impact, much of it *de facto* irreversible, caused by the early phases of the industrial revolution. In such cradles of industrialism as the English midlands, the economic nexus of coal, iron and textiles produced by deep mines and factories brought about places of heat, smoke and toxic wastes. The smoke and the toxic wastes that were discharged into the atmosphere and into watercourses wrought many changes, both on-site and at a distance. Streams were further diverted and upstream areas dammed to provide impoundments, and habitations for the burgeoning workforces replaced fields and other open areas.

Industrialization found its way into rural areas as well, particularly through the development of agricultural machinery (Gifford, 1981) and the application of chemical fertilizers. But for parts of England, western Europe (especially France, Belgium and Germany) and eastern North America, William Wordsworth's lines of 1814 sum up many of the changes:

> . . . From the germ
>
> Of some poor hamlet, rapidly produced
> Here a huge town, continuous and compact,

Hiding the face of the earth for leagues—and there,
Where not a habitation stood before,
Abodes of men irregularly massed
Like trees in forests—spread through spacious tracts,
O'er which the smoke of unremitting fires
Hangs permanent and plentiful as wreaths
Of vapour glittering in the morning sun.
And, wheresoe'er the traveller turns his steps,
He sees the barren wilderness erased
Or disappearing;

So from such beginnings came the full force of the nineteenth and twentieth centuries in their alteration of plant and animal genetics, biotic communities, soils, slopes and watercourses and the application of industrialism to agriculture in the form of 'development', whose results are evident in many chapters of this book, and whose results we see—and are concerned about—today. By comparison the impact of human societies in the years before 1890 AD were often less thorough-going, though there are some exceptions, like the irrigation of the Nile, the Yellow River basin, the great rice terraces of south-east Asia, and the stability of agriculture in western Europe, which must rank alongside any later achievements. But they were by no means insignificant: they affected much of the earth's surface, often irreversibly, and perhaps more significantly supported a great variety of cultural groups on a sustainable basis in which a resilient *modus vivendi* between man and nature was achieved. Will we be able to say the same of the transformations of the late nineteenth and twentieth centuries?

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