Eighth Edition

Human Impact on the Natural Environment

Past, Present and Future

Andrew S. Goudie

with website

WILEY Blackwell

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Preface to the Eighth Edition

It is now three-and-a-half decades since the first edition of this book appeared, and only around 14% of the literature cited in this new edition pre-dates 1981. Indeed, this is the most thoroughly revised edition that I have produced. This period has seen a remarkable transformation in interest in the impact that humans are having on the environment, together with an explosion of knowledge. In this edition, I have made substantial changes to the text, figures, tables, and references, and have tried to provide updated statistical information. I have also divided the book into sections, which I hope will facilitate cross-referencing. The original stimulus for writing this book came from that greatest of editors, the late John Davey, to whom I shall always be indebted.

About the Companion Website

This book is accompanied by a companion website:

www.wiley.com/go/goudie/human-impact-natural-environment

The website includes:

- Powerpoints of all figures and tables from the book for downloading
- A web-only Glossary

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Introduction

CHAPTER OVERVIEW

In this chapter the first issue that is addressed is the development of ideas over the last 300 years about the relationship between humans and their environment and in particular the development of ideas about how humans have changed their environment. The historical theme continues with a brief analysis of the changes that have taken place in human societies from prehistoric times onwards, culminating in the massive impacts that humans have achieved over the last three centuries and in particular during the so-called 'Great Acceleration' since the Second World War.

1.1 The Development of Ideas

To what extent have humans transformed their natural environment? This is a crucial question which became very important in the seventeenth and eighteenth centuries (Grove and Damodaran, 2006) as Western Europeans became aware of the ravages inflicted in the tropics by European overseas expansion. It was a theme that intrigued the eighteenth-century French natural historian, Count Buffon, in his colossal series, *L'Histoire Naturelle*. He can be regarded as the first Western scientist to be concerned directly and intimately with the human impact on the natural environment (Glacken, 1967). He contrasted the appearance of inhabited and uninhabited lands.

Studies of the torrents of the European Alps, undertaken in the late eighteenth and early nineteenth centuries, deepened immeasurably the realization of human capacity to change the environment. Jean-Antoine Fabre and Alexandre Surell studied the flooding, siltation, erosion, and division of watercourses brought about by deforestation in these mountains (Ford, 2016). Similarly Horace-Bénédict de Saussure showed that Alpine lakes had suffered a lowering of water levels in recent times because of deforestation. In Venezuela, Alexander von Humboldt concluded that the lake level of Lake Valencia in 1800 (the year of his visit) was lower than it had been in previous times, and that deforestation, the clearing of plains, irrigation, and the cultivation of indigo, were among the causes of the gradual drying up of the basin (Cushman, 2011). Comparable observations were made by the French rural economist, Jean-Baptiste Boussingault (1845). He returned to Lake Valencia some 25 years after Humboldt and noted that the lake was actually rising. He described this reversal to political and social upheavals following the granting of independence to the colonies of the erstwhile Spanish Empire. The freeing of slaves had led to a decline in agriculture, a reduction in the application of irrigation water, and the re-establishment of forest.

Boussingault also reported some pertinent hydrological observations that had been made on Ascension Island in the South Atlantic:

> In the Island of Ascension there was an excellent spring situated at the foot of a mountain originally covered with wood; the spring became scanty and dried up after the trees which covered the mountain had been felled. The loss of the spring was rightly ascribed to the cutting down of the timber. The mountain was therefore planted anew. A few years afterwards the spring reappeared by degrees, and by and by followed with its former abundance. (Boussingault, 1845: 685)

Charles Lyell, in his *Principles of Geology*, one of the most influential of all scientific works, referred to the human impact and recognized that tree-felling and drainage of lakes and marshes tended 'greatly to vary the state of the habitable surface'. Overall, however, he believed that the

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forces exerted by people were insignificant in comparison with those exerted by nature:

> If all the nations of the earth should attempt to quarry away the lava which flowed from one eruption of the Icelandic volcanoes in 1783, and the two following years, and should attempt to consign it to the deepest abysses of the ocean they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption. (Lyell, 1835: 197)

Lyell somewhat modified his views in later editions of the *Principles* (Lyell, 1875), largely as a result of his experiences in the United States, where recent deforestation in Georgia and Alabama had produced numerous ravines of impressive size (Figure 1.1).

One of the most important physical geographers to show concern with our theme was Mary Somerville (1858) (who clearly appreciated the unexpected results that occurred as man 'dextrously avails himself of the powers of nature to subdue nature'):

> A farmer sees the rook pecking a little of his grain, or digging at the roots of the springing corn, and poisons all his neighbourhood. A few years after he is surprised to find his crop destroyed by grubs. The works of the Creator are nicely balanced, and man cannot infringe his Laws with impunity. (Somerville, 1858: 493)

This is in effect a statement of one of the basic laws of ecology, much championed by Alexander von Humboldt (see Wulf, 2015): that everything is connected to everything else and that one cannot change just one thing in nature.

Considerable interest in conservation, climatic change, and extinctions arose amongst European colonialists who witnessed some of the consequences of Western-style economic development in tropical lands (Grove, 1997). However, the extent of human influence on the environment was not explored in detail and on the basis of sound data until George Perkins Marsh (Figure 1.2) published *Man and Nature* (1864), in which he dealt with human influence on the woods, the waters, and the sands. The following extract illustrates the breadth of his interests and the ramifying connections he identified between human actions and environmental changes:

> Vast forests have disappeared from mountain spurs and ridges; the vegetable earth accumulated beneath the trees by the decay of leaves and fallen trunks, the soil of the alpine pastures which skirted

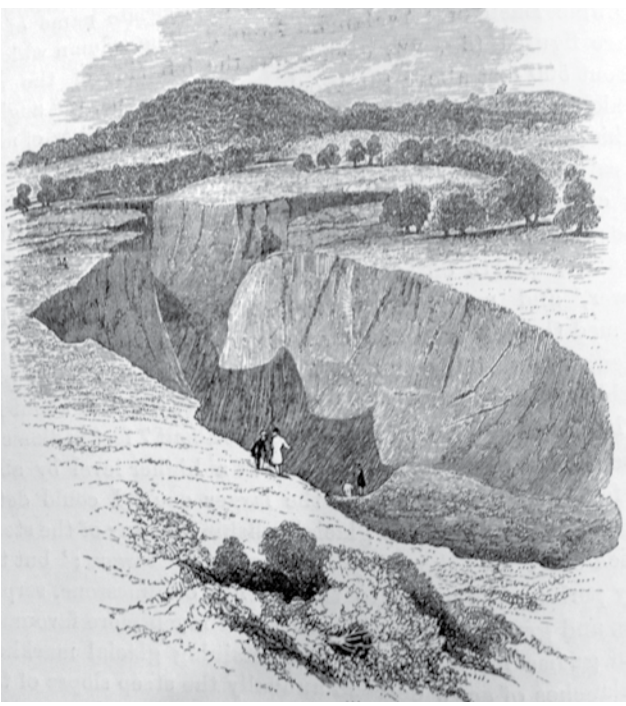

Figure 1.1 A newly formed ravine or gully that developed at Milledgeville, Georgia, USA, following deforestation. *Source:* Lyell (1875: 338).

Figure 1.2 George Perkins Marsh (1801–1882). *Source:* from the Library of Congress Prints and Photographic Division, Washington DC, http://loc.gov/pictures/resource/cwpbh.02223/ (accessed January 2018).

> and indented the woods, and the mould of the upland fields, are washed away; meadows, once fertilized by irrigation, are waste and unproductive, because the cisterns and reservoirs that supplied the ancient canals are broken, or the springs that fed them dried up; rivers famous in history and song have shrunk to humble brooklets; the willows that ornamented and protected the banks of lesser watercourses are gone, and the rivulets have ceased to exist as perennial currents, because the little water that finds its way into their old channels is evaporated by the droughts of summer, or absorbed by the parched earth, before it reaches the lowlands; the beds of the brooks have widened into broad expanses of pebbles and gravel, over which, though in the hot season passed dryshod, in winter sealike torrents thunder; the entrances of navigable streams are obstructed by sandbars, and harbours, once marts of an extensive commerce, are shoaled by the deposits of the rivers at whose mouths they lie; the elevation of the beds of estuaries, and the consequently diminished velocity of the streams which flow into them, have converted thousands of leagues of shallow sea and fertile lowland into unproductive and miasmatic morasses. (Marsh, 1965: 9)

More than a third of the book is concerned with 'the woods'; Marsh does not touch upon important themes like the modifications of mid-latitude grasslands, and he is much concerned with Western civilization. Nevertheless, employing an eloquent style and copious footnotes, Marsh, the versatile Vermonter, stands as a landmark in the study of environment (Thomas, 1956; Lowenthal, 2000, 2013).

Marsh, however, was not totally pessimistic about the future role of humankind or entirely unimpressed by positive human achievements:

> New forests have been planted; inundations of flowing streams restrained by heavy walls of masonry and other constructions; torrents compelled to aid, by depositing the slime with which they are charged, in filling up lowlands, and raising the level of morasses which their own overflows had created; ground submerged by the encroachment of the ocean, or exposed to be covered by its tides, has been rescued from its dominion by diking; swamps and even lakes have been drained, and their beds brought within the domain of agricultural industry; drifting coast dunes have been checked and made productive by plantation; sea and inland waters have been repeopled with fish, and even the sands of the Sahara have been fertilized by artesian fountains. These achievements are far more glorious than the proudest triumphs of war . . . (Marsh, 1965: 43–44)

Elisée Reclus (1873), an anarchist and one of the most prominent French geographers of his generation, was an important influence in the USA and recognized that the 'action of man may embellish the earth, but it may also disfigure it; according to the manner and social condition of any nation, it contributes either to the degradation or glorification of nature' (p. 522). Reclus (1871) also displayed a concern with the relationship between forests, torrents, and sedimentation.

In 1904 the German geographer Ernst Friedrich coined the term 'Raubwirtschaft', which can be translated as 'economic plunder', 'robber economy' or, more simply, 'devastation'. He believed that destructive exploitation of resources leads of necessity to foresight and to improvements, and that after an initial phase of ruthless exploitation and resulting deprivation human measures would, as in the old countries of Europe, result in conservation and improvement. This idea was opposed in the USA by Carl Sauer (1938) and Joe Russell Whitaker (1940), the latter pointing out that some soil erosion could well be irreversible (p. 157):

> It is surely impossible for anyone who is familiar with the eroded loessial lands of northwestern Mississippi, or the burned and scarred rock hills of north central Ontario, to accept so complacently the damage to resources involved in the process of colonization, or to be so certain that resource depletion is but the forerunner of conservation.

Nonetheless Friedrich's concept of robber economy was adopted and modified by the great French geographer, Jean Brunhes, in his *Human Geography* (1920). He recognized the interrelationships involved in anthropogenic environmental change (p. 332): 'Devastation always brings about, not a catastrophe, but a series of catastrophes, for in nature things are dependent one upon the other.' Moreover, Brunhes acknowledged that the 'essential facts' of human geography included 'Facts of Plant and Animal Conquest' and 'Facts of Destructive Exploitation'. At much the same time other significant studies were made of the same theme. Nathaniel Shaler of Harvard (*Man and the Earth*, 1912) was very much concerned with the destruction of mineral resources (a topic largely neglected by Marsh).

Sauer led an effective campaign against destructive exploitation, reintroduced Marsh to a wide public, recognized the ecological virtues of some so-called primitive peoples, concerned himself with the great theme of domestication, concentrated on the landscape changes that resulted from human action, and gave clear and far-sighted warnings about the need for conservation (Sauer, 1938: 494):

> We have accustomed ourselves to think of ever expanding productive capacity, of ever fresh spaces of the world to be filled with people, of ever new discoveries of kinds and sources of raw materials, of continuous technical progress operating indefinitely to solve problems of supply. We have lived so long in what we have regarded as an expanding world, that we reject in our contemporary theories of economics and of population the realities which contradict such views. Yet our modern expansion has been affected in large measure at the cost of an actual and permanent impoverishment of the world.

The theme of the human impact on the environment has, however, been central to some historical geographers studying the evolution of the landscape. The clearing of woodland (Darby, 1956; Williams, 2003), the domestication process (Sauer, 1952), the draining of marshlands (Williams, 1970), the introduction of alien plants and animals (McKnight, 1959), and the transformation of the landscape of North America (Whitney, 1994) are among some of the recurrent themes of a fine tradition of historical geography.

In 1956, some of these themes were explored in detail in a major symposium volume, *Man's Role in Changing the Face of the Earth* (Thomas, 1956). Kates et al. (1990: 4) write of it:

> *Man's role* seems at least to have anticipated the ecological movement of the 1960s, although direct links between the two have not been demonstrated. Its dispassionate, academic approach was certainly foreign to the style of the movement . . . Rather, *Man's role* appears to have exerted a much more subtle, and perhaps more lasting, influence as a reflective, broad-ranging and multidimensional work.

In the last five decades many geographers have contributed to, and been affected by, the phenomenon which is often called the environmental revolution or the ecological movement. The subject of the human impact on the environment, dealing as it does with such matters as environmental degradation, pollution, and desertification, has close links with these developments, and is once again a theme in many textbooks and research monographs in geography (see Turner et al., 1990; Meyer, 1996; Middleton, 2013).

Concerns about the human impact have become central to many other disciplines and to the public, particularly since the early 1970s, and a range of major developments in literature, legislation, and international debate have taken place (Table 1.1). The concepts of global change or global environmental change have developed. Wide use of the term 'global change' seems to have emerged in the 1970s but in that period was used principally, though by no means invariably, to refer to changes in international social, economic, and political systems (Price, 1989). It included such issues as proliferation of nuclear weapons, population growth, inflation and matters relating to international insecurity, and decreases in the quality of life. Since the early 1980s the concept of global change has taken on another meaning which is more geocentric in focus. This can be seen in the development of the International Geosphere-Biosphere Programme: A Study of Global Change. This was established in 1986 by the International Council of Scientific Unions, 'to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human activities'. The term 'global environmental change' has in many senses come to be used synonymously with the more geocentric use of 'global change'. As Castree (2015) has stressed, global change has become a major research thrust, and it can provide a major focus for a more integrated discipline of Geography (Goudie, 2017).

Table 1.1 Some environmental milestones.

1864	George Perkins Marsh, *Man and Nature*
1892	John Muir founds Sierra Club in USA
1903	President Theodore Roosevelt establishes a federally protected wildlife refuge at Pelican Island, Florida. The first of fifty-three wildlife sanctuaries he creates as president
1905	The Bureau of Forestry in the Department of Agriculture becomes the US Forest Service
1916	USA National Park Service established
1935	Establishment of Soil Conservation Service in USA
1949	USA National Trust for Historic Preservation created
1956	*Man's Role in Changing the Face of the Earth*
1961	Establishment of World Wildlife Fund
1962	Rachel Carson's *Silent Spring*
1969	Friends of the Earth established
1970	US Environmental Protection Agency created

Table 1.1 (Continued)

1971	Greenpeace established
1971	Ramsar Treaty on International Wetlands
1972	United Nations Environmental Programme (UNEP) established
1972	*Limits to Growth* published by Club of Rome
1973	Convention on International Trade in Endangered Species (CITES)
1974	F.S. Rowland and M. Molina warn about CFCs and ozone hole
1975	Worldwatch Institute established
1979	Convention on Long-Range Transboundary Air Pollution
1980	IUCN's World Conservation Strategy
1985	British Antarctic Survey finds ozone hole over Antarctic
1986	International Geosphere Biosphere Programmme (IGBP)
1987	World Commission on Environment and Development (Brundtland Commission). *Our Common Future*
1987	Montreal Protocol on substances that deplete the ozone layer
1988	Intergovernmental Panel on Climate Change (IPCC) established
1989	Global Environmental Facility
1992	Earth Summit in Rio and Agenda 21
1993	United Nations Commission on Sustainable Development
1994	United Nations Convention to Combat Desertification
1996	International Human Dimensions Programme on Global Environmental Change
1997	Kyoto Protocol on greenhouse gas emissions
2001	Amsterdam Declaration
2002	Johannesburg Earth Summit
2002	Introduction of the term 'Anthropocene'
2007	United Nations Bali Climate Change Conference
2010	United Nations Copenhagen Climate Change Conference
2010	Nagoya Biodiversity Summit and International Year of Biodiversity
2012	Rio + 20 United Nations Conference on Sustainable Development
2015	Paris Conference on Climate Change
2015	28th Meeting of the Parties to the Montreal Protocol to phase out HFCs
2015	China introduces Environmental Protection Law

In addition to the concept of global change, there is an increasing interest in the manner in which biogeochemical systems interact at a global scale, and an increasing appreciation of the fact that the Earth is a single system. Earth System Science has emerged in response to this realization (see Steffen et al., 2004). Earth System *Science*, a modern manifestation of Global Change which concentrates on modelling, treats the Earth as an integrated system and seeks a deeper understanding of the physical, chemical, biological, and human interactions that determine the past, current, and future states of the Earth's lithosphere, hydrosphere (including the cryosphere), biosphere, and atmosphere. While it has its antecedents in the work of people like Humboldt (see Wulf, 2015; Stott, 2016), it came into prominence in the last two decades of the twentieth century. It has emerged in response to (1) the realization that biogeochemical systems operate globally and (2) an increasing appreciation that Earth is a single system. It includes societal dimensions and the recognition that humanity plays an ever-increasing role in global change. It represents humans as internal components of the Earth system not just an external 'forcing agent'.

1.2 The Anthropocene

Early in this millennium, Crutzen and colleagues introduced the term 'Anthropocene' (e.g. Crutzen, 2002; Steffen et al., 2007; Röckstrom et al., 2009), as a name for a new epoch in Earth's history – an epoch when human activities have 'become so profound and pervasive that they rival, or exceed the great forces of Nature in influencing the functioning of the Earth System' (Steffen, 2010). In the last three hundred years, they suggest, we have moved from the Holocene into the Anthropocene. They identify three stages in the Anthropocene. Stage 1, which lasted from c. 1800 to 1945, they call 'The Industrial Era'. Stage 2, which extends from 1945 to c. 2015, they call 'The Great Acceleration', and Stage 3, which may perhaps now be starting, is a stage when people have become aware of the extent of the human impact and may thus start stewardship of the Earth System. Good reviews of the Anthropocene concept are provided by Castree (2014a, b, c).

However, it has been argued that the Anthropocene was initiated much more than three centuries ago. Indeed, one of the great debates surrounding the Anthropocene is when it started and whether it should be regarded as a formal stratigraphic unit with the same rank as the Holocene (Waters et al., 2016). Walker et al. (2015), for example, raise the possibility that the Anthropocene might be designated a unit of lesser rank, and hence could become a subdivision of the Holocene rather than an epoch in its own right. On the other hand, there are those who think the Anthropocene should replace the Holocene, which would become downgraded and reclassified as the final stage of the Pleistocene (Lewis and Maslin, 2015). Conversely, there are those who think the Anthropocene only started with the Industrial Revolution and that 1800 AD is a logical start date for the new epoch (Steffen et al, 2011; Zalasiewicz et al., 2011). At the other end of the spectrum, there are archaeologists (Balter, 2013), who believe that substantial human impacts go back considerably further. They have drawn attention to the deep history of widespread human impacts (Ellis et al. 2013a, b; Albert, 2015; Braje, 2015; Piperno et al., 2015). Smith and Zeder (2013) argued that the Anthropocene started at the Holocene/Pleistocene boundary (around 10,000 years ago), with the first domestication of plants and animals and the development of agriculture and pastoralism (see Section 1.5). Certini and Scalenghe (2011) preferred to place the lower boundary at around 2000 years ago when major civilizations flourished.

Foley et al. (2013) proposed the term 'palaeoanthropocene' for the period between the first signs of human impact and the start of the Industrial Revolution, whereas Glikson (2013) suggested a sub-division of the Anthropocene into three phases. He regarded the discovery of ignition of fire (see Section 2.3) as a turning point in biological evolution and termed it the Early Anthropocene. The onset of the Neolithic he referred to as the Middle Anthropocene, while the onset of the industrial age since about 1750 AD he called the Late Anthropocene. Ruddiman (2014) argued that early deforestation and agriculture caused large greenhouse gas (carbon dioxide and methane) emissions slightly later, but nevertheless quite early in the Holocene.

Lewis and Maslin (2015) reviewed the evidence for a 'golden spike' which might provide an incontrovertible, globally relevant mark in the sedimentary record for the start of the Anthropocene. They proposed that there were two candidates. The first of these is a dip in atmospheric CO_2 levels around 1610 as recorded in high-resolution Antarctic ice cores, while the second is a spike in ^{14}C concentrations in 1964 (associated with atom bomb testing prior to test bans coming into force) as recorded within tree-rings of a dated pine in Poland. The 1610 dip in CO_2 values, which they regarded as the most convincing golden spike, resulted from the arrival of Europeans in the Americas. This led to a large decline in the indigenous population, the accompanying near-cessation of farming, a reduction in fire use, and the regeneration of over 50 million hectares of forest, woody savanna, and grassland. This caused a carbon uptake by vegetation and soils and a reduction in atmospheric CO_2 levels. In similar vein, Rose (2015) postulated that a stratigraphic marker for the start of the Anthropocene was provided by spheroidal carbonaceous fly-ash particles (SCPs), which are by-products of industrial fossil-fuel combustion. He found that data from over 75 lake sediment records showed a global, synchronous, and dramatic increase in particle accumulation starting in c. 1950, driven by the increased demand for electricity and the introduction of fuel-oil combustion, in addition to coal, as a means to produce it. He argued that SCPs are morphologically distinct and, being solely human in origin, provide an unambiguous marker. In contrast, Gale and Hoare (2012) argued that the worldwide diachroneity of human impact makes it impossible to establish a single chronological datum for the start of the Anthropocene, and the validity of a search for these sorts of golden spike has been rejected by Hamilton (2015). Thus the controversy rumbles on, though a large number of earth and environmental scientists are now firm in their opinion that the Anthropocene Epoch can be so defined (Waters et al., 2016).

The huge increase in interest in the study of the human impact on the environment and of global change has not been without other great debates and controversies, and some have argued that environmentalists have overplayed their hand (see e.g. Lomborg's *The Skeptical Environmentalist*, 2001) and have exaggerated the amount of environmental harm that is being caused by human activities. There has also been much debate about whether or not the Anthropocene is an era for hope (a 'Good Anthropocene') or an era of impending disaster (a 'Bad Anthropocene') (see Dalby, 2016).

In this book, I take a long-term perspective and seek to show the changes that mankind has caused to a wide spectrum of environmental phenomena. The current fixation with global warming should not blind us to the importance of other aspects of global change, including deforestation, desertification, salinization, pollution, and the like (Slaymaker et al., 2009).

1.3 The Development of Human Population and Stages of Cultural Development

During the history of humans on Earth, there have been some key milestones in cultural and technical development (Goudie and Viles, 2016):

Years before present (log scale)	*Driving force*
100	The Great Acceleration Internal combustion engine Industrial revolution European colonization of Americas, Australia, etc.

1000	Peopling of New Zealand, Madagascar, Oceania, etc.
	The classical era
	Secondary products revolution
	Irrigation
	Metals and mining
	Settlements and urbanization
	Domestication, agriculture, land clearance
10,000	Pleistocene extinctions
	Peopling of Americas and Australia
	Dying out of Neanderthals
100,000	Modern humans
1,000,000	Use of fire and stone tool manufacture
	Arrival of *Homo*

Some six or so million years ago, primitive human precursors or hominids appear in the fossil record (Wood, 2002). The earliest remains of a small, bipedal hominim, *Sahelanthropus tchadensis*, have been found in Chad (Brunet el al., 2002). Studies in Turkana, Kenya, have recently identified evidence of early hominin tool-making activity at Lomekwi 3, a 3.3-million-year-old archaeological site (Harmand et al., 2015). The oldest remains of *Homo* have been found either in sediments from the rift valleys of East Africa (as in the Afar region of Ethiopia) (Villmoare et al., 2015) or in caves in South Africa. The first recognizable human, *Homo habilis,* evolved about 2.5–2.8 million years ago, more or less at the time that the Pleistocene ice ages were developing in mid-latitudes. Since that time the human population has spread over virtually the entire land surface of the planet (Oppenheimer, 2003) (Figure 1.3). *Homo* may have reached Asia by around two million years ago (Zhu et al., 2008b) and Europe not much later (Moncel, 2010). In southern Europe there are stone tools in Italy associated with *Homo* that date back to 1.3–1.7 Ma (Arzarello et al., 2007) and also in Spain (Carbonell et al., 2008). In north-west Europe and Britain the earliest dates for human occupation are >0.78 Ma (Parfitt et al., 2010). Modern humans, *Homo sapiens*, have generally been thought to have appeared in Africa around 160,000 years ago (Stringer, 2003; White et al., 2003), though an even earlier date of c. 300, 000 years is possible based on remains from Morocco (Richter et al., 2017). They then spread 'out of Africa' to other parts of the world.

Table 1.2 gives data on recent views of the dates for the arrival of humans in selected areas. The dates for Australia are controversial, and they range from c. 40,000 years to as much as 150,000 years, but with a date of c. 50,000 years ago being widely accepted (Balme, 2013; Clarkson et al., 2017; Veth et al., 2017). There is also

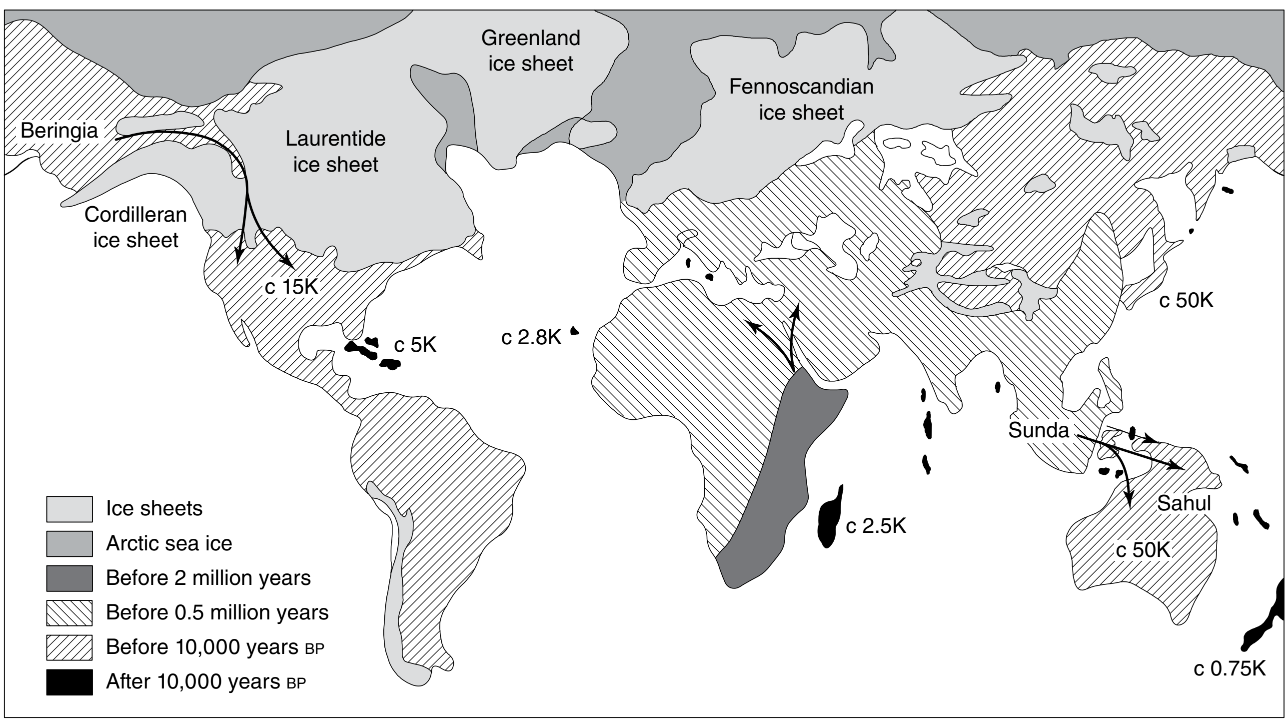

Figure 1.3 The human colonization of Ice Age Earth. Dates for some islands are given in thousands of years.

Table 1.2 Dates of human arrivals.

Area	Source	Date (years BP)
Africa	Klein (1983)	2,700,000–2,900,000
China	Huang et al. (1995)	1,900,000
Georgian Republic	Gabunia and Vekua (1995)	1,600,000–1,800,000
Java	Swisher et al. (1994)	1,800,000
Europe	Moncel (2010)	c. 1,500,000
Britain	Parfitt et al. (2010)	c. 790,000
Japan	Ikawa-Smith (1982)	c. 50,000
Australia	Geyer et al. (2017)	c. 65,000
North America	Goebel et al. (2008)	15,000
Peru	Keefer et al. (1998)	12,500–12,700
Ireland	Edwards (1985)	9,000
Taiwan	Rolett et al. (2010)	5000
Caribbean	Siegel et al. (2015)	5000
Balearic Islands	Burjachs et al. (2017)	4300
Remote Oceania	Matisoo-Smith (2015)	3000
Canary Islands	de Nascimento et al. (2015)	2800–2500
Polynesia	Kirch (1982)	2,000
Madagascar	Crowley (2010)	2500
New Zealand	Lowe (2008)	750

considerable uncertainty about the dates for humans arriving in the Americas (Goebel et al., 2008; Amick, 2016). Many authorities have argued that the first colonizers of North America, arrived via the Bering land-bridge from Asia around 12,000 years ago. However, some earlier dates exist for the Yukon (Bourgeon et al., 2017), and Florida (Halligan et al., 2016), and these perhaps imply an earlier phase of colonization. Indeed, very recently, Holen et al. (2017) claim to have found evidence of human butchering of mastodon bones in southern California, dating back to as much as 130,000 years ago. The settlement of Oceania took place relatively late, with colonization of the western archipelagos of Micronesia and eastern Melanesia taking place at c. 3500–2800 BP, of central and eastern Micronesia at 2200–2000 BP, and of eastern and southern Polynesia at 1100–700 BP (Anderson, 2009).

Estimates of population levels in the early stages of human development (Figure 1.4a) are imprecise and uncertain. At the peak of the Last Glacial Maximum around 20,000 years ago, the population of the old world was possibly between about 2 and 8 million (Gautney and Holliday, 2015). Human population estimates for the Holocene are diverse and controversial (Boyle et al., 2011). The mid-Holocene value was between 5 and 24 million, the value at the end of the Roman period was c. 200 million, the late medieval value was between c. 400 and 500 million, and the value at the start of the Industrial Revolution was around 900–1000 million. The total has now passed 7000 million.

Before the agricultural 'revolution' some 10,000 years ago, human groups were hunters and gatherers. Population densities were low, and the optimum territory for a band of hunter-gatherers in the Middle Eastern woodland–parkland belt would have been 300–500 square kilometres, while in the drier regions it would have been 500–2000 square kilometres (Bar-Yosef, 1998). However, the agricultural revolution probably enabled an expansion of the total human population to 500 million by AD 1650. It is since that time, helped by the medical and industrial revolutions and developments in agriculture and colonization of new lands, that human population has exploded, reaching about 1,000 million by AD 1850, 2,000 million by AD 1930, and 4,000 million by AD 1974. Victories over various diseases (e.g. smallpox, cholera, malaria) have caused marked decreases in death-rates throughout the non-industrial world, but death-rate control has not in general been matched by birth control. Thus the annual population growth rate in the late 1980s in South Asia was 2.64%, Africa 2.66%, and Latin America (where population increased fourteenfold between 1850 and 2000), 2.73%. In the period from 2005–2010 these rates had slowed down substantially, with Latin America down to 1.2% and Africa to 2.2%. The global annual growth in population has over the last decade been around 75–77 million people (Figure 1.4b).

The history of the human impact, however, has not been a simple process of increasing change in response to linear population growth over time, for in specific places at specific times there have been periods of reversal in population growth and ecological change as cultures have collapsed, wars occurred, diseases struck, and habitats been abandoned. Denevan (1992), for example, has pointed to the decline of Native American populations in the new world following European entry into the Americas. This created what was 'probably the greatest demographic disaster ever'. The overall population of the Western Hemisphere in 1750 was perhaps less than a third of what it may have been in 1492, and the ecological and atmospheric consequences were legion (see Section 1.2). It is certainly dangerous to think that in all places the human impact has shown a continually increasing trajectory, for there are many examples of ravages in one era being followed by phases of restoration, recovery, and stability in another. Trimble

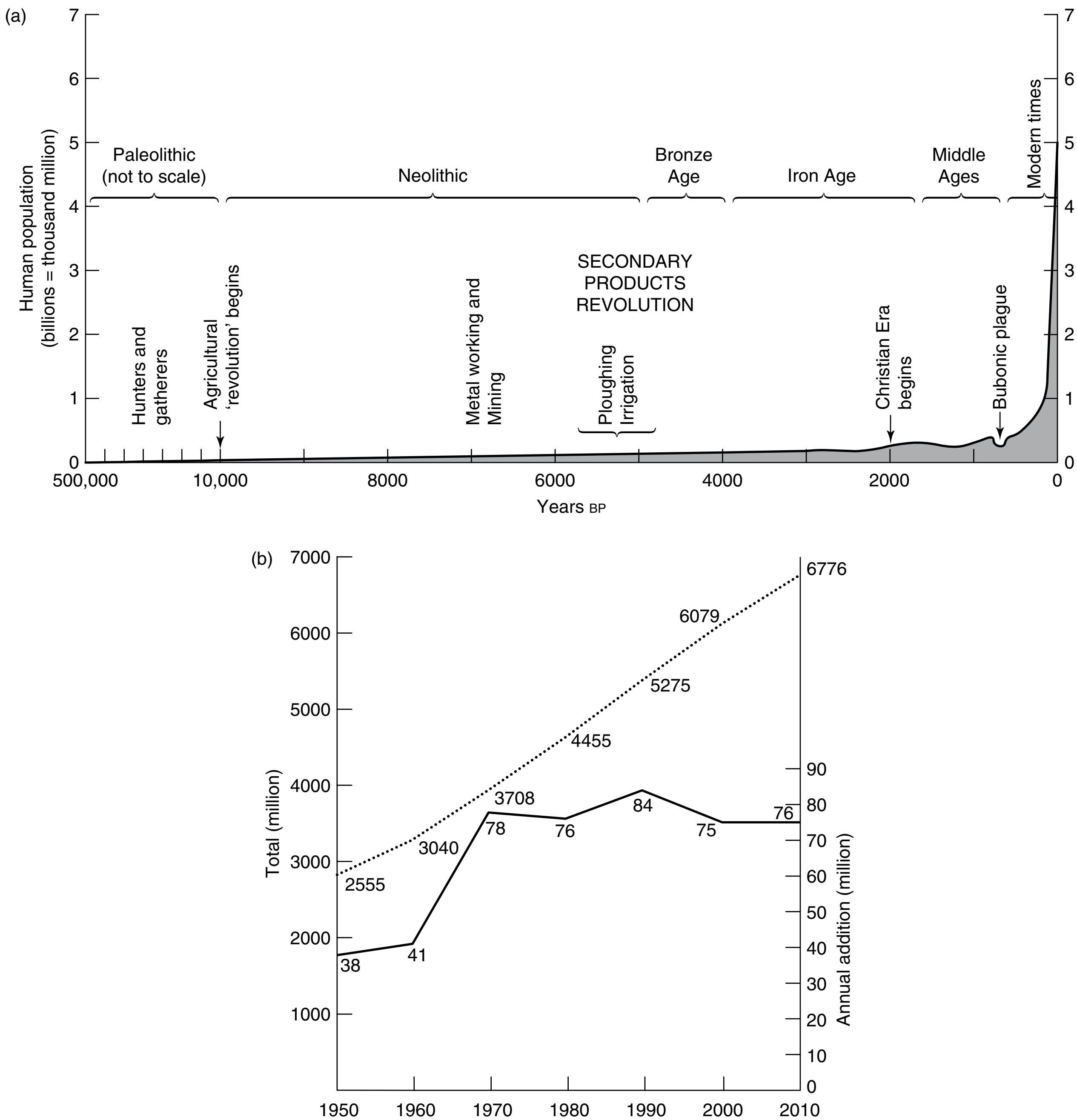

Figure 1.4 (a) The growth of human numbers for the past half million years. *Source:* adapted from Ehrlich et al. (1977: figure 5.2). (b) Annual growth of world population since 1950. *Source:* based on UN data.

(2013) demonstrates this in the context of the land use and land degradation history in the American Midwest.

The evolving impact of humans on the environment has often been expressed in terms of a simple equation:

$$I = P\ A\ T$$

where I is the amount of pressure or impact that humans apply on the environment, P is the number of people, A is the affluence (or the demand on resources per person), and T is a technological factor (the power that humans can exert through technological change). P, A, and T have been seen by some as 'the three horsemen of the environmental apocalypse' (Meyer, 1996: 24). There may be considerable truth in the equation and in that sentiment; but as Meyer points out, the formula cannot be applied in too mechanistic a way. The 'cornucopia view', indeed, sees population not as the ultimate depleter of resources but as itself the ultimate resource capable of causing change for the better. There are cases where strong population growth has appeared to lead to a reduction in environmental degradation (Tiffen et al., 1994). Likewise, there is debate about whether it is poverty or affluence that creates deterioration in the environment. On the other hand many poor countries have severe environmental problems and do not have the resources to clear them up, whereas affluent countries do. Conversely it can be argued that affluent countries have plundered and fouled less fortunate countries, and that it would be environmentally catastrophic if all countries used resources at the rate that the rich countries do. Similarly, it would be naïve to see all technologies as malign, or indeed benign. Technology can be a factor either of mitigation and improvement or of damage. Sometimes it is the problem (as when ozone depletion has been caused by a new technology – the use of chlorofluorocarbons) and sometimes it can be the solution (as when renewable energy sources replace the burning of polluting lignite in power stations).

In addition to the three factors of population, affluence, and technology, environmental changes also depend on variations in the way in which different societies are organized and in their economic and social structures (see Meyer, 1996: 39–49 for an elaboration of this theme). For example, the way in which land is owned is a crucial issue. The controls of environmental changes caused by the human impact are thus complex and in many cases contentious, but all the factors discussed play a role of some sort, at some places, and at some times.

We now turn to a consideration of the major cultural and technical developments that have taken place during the past two to three million years. Takács-Sánta (2004) argued that there have been six major transformations in the history of the human transformation of the environment: the use of fire, the development of language, the birth of agriculture, the development of cities and states, European conquests since the fifteenth century AD, and the Technological-Scientific Revolution, with the emergence of fossil fuels as primary energy sources. In this book, three main phases will form the basis of the analysis: the phase of hunting and gathering; the phase of plant cultivation, animal keeping and metal working; and the phase of modern urban and industrial society, culminating in the Great Acceleration. These developments are treated in much greater depth by Simmons (1996) and Ponting (2007).

1.4 Hunting and Gathering

The supposed uniqueness of humans as tool makers has been seen as false because of recent studies which have shown that wild monkeys are capable of flaking stone tools (Proffitt et al., 2016). Nonetheless, the oldest records of human activity and technology are pebble tools which consist of a pebble with one end chipped into a rough cutting edge. At Dikika in Ethiopia there is evidence for stone-tool-assisted consumption of meat at 3.42–3.24 Ma (McPherron et al., 2010). At Lake Turkana in northern Kenya, and the Omo Valley in southern Ethiopia, a tool-bearing bed of volcanic material has been dated by isotopic means at about 2.6 million years old, another from Gona in the north-east of Ethiopia at about 2.5 million years old (Semaw et al., 1997), while another bed at the Olduvai Gorge in Tanzania (Figure 1.5) has been dated by similar means at 1.75 million years. Indeed, these very early tools are generally termed 'Oldowan'.

Figure 1.5 The Olduvai Gorge in Tanzania – one of the great sites for the investigation of early man (ASG).

As the Stone Age progressed the tools became more sophisticated, varied, and effective, and Figure 1.6 shows some beautiful Palaeolithic hand axes from Olorgesailie in East Africa. Greater exploitation of plant and animal resources became feasible. Stone may not, however,

Figure 1.6 A cluster of Palaeolithic hand axes from Olorgesailie in East Africa (ASG).

have been the only material used. Sticks and animal bones, the preservation of which are less likely than stone, are among the first objects that may have been used as implements, although the sophisticated utilization of antler and bone as materials for weapons and implements appears to have developed surprisingly late in pre-history. There is certainly a great deal of evidence for the use of wood throughout the Palaeolithic Age and by modern and hunter-gatherer communities, for ladders, fire, pigment (charcoal), the drying of wood, and digging sticks. Tyldesley and Bahn (1983: 59) went so far as to suggest that 'The Palaeolithic might more accurately be termed the "Palaeoxylic" or "Old Wood Age", and experiments have shown the efficiency of wooden hunting tools in comparison with ones made of stone' (Waguespack et al., 2009).

The building of shelters and the use of clothing became a permanent feature of human life as the Palaeolithic period progressed, and permitted habitation in areas where the climate was otherwise not congenial. European sites from the Mousterian of the Middle Palaeolithic have revealed the presence of purposefully made dwellings as well as caves, and by the Upper Palaeolithic more complex shelters were in use, allowing people to live even in the tundra lands of Central Europe and Russia.

Another feature of early society which seems to have distinguished humans from the surviving nonhuman primates was their seemingly omnivorous diet. Whereas the great apes, though not averse to an occasional taste of animal food, are predominately vegetarian, our Palaeolithic ancestors, including *Homo sapiens*, lived as hunter-gatherers, eating wild animal-source foods (lean meats, internal organs, bone marrow, but no dairy) and uncultivated plant-source foods (mostly fruits, vegetables, and nuts). One consequence of enlarging the range of their diet was that, in the long run, humans were able to explore a much wider range of environments. Another major difference that set humankind above the beasts was the development of communicative skills such as speech. Until hominids had developed words as symbols, the possibility of transmitting, and so accumulating, culture hardly existed. Animals can express and communicate emotions, never designate or describe objects.

Very early on in their history humans started using fire (Glikson, 2013; Bowman, 2014; Albert, 2015) (Figure 1.7). This, as we shall see (Sections 2.3–2.6), is a major agent by which humans have influenced their environment (Kinoshita et al., 2016). The date at which it was first deliberately employed is a matter of ongoing controversy (Caldararo, 2002; Gowlett, 2016). In South Africa, Beaumont (2011) and Berna et al. (2012) found some traces of repeated burning events from Acheulean cave sediments dating back to more than a million years ago. In East Africa, Gowlett et al. (1981) claimed to find evidence for deliberate manipulation of fire from over 1.4 million years ago. In Murcia, Spain, there is evidence for use of fire in the early Palaeolithic between c. 780,000 and 980,000 years ago (Rhodes et al., 2016). After c. 400,000 years ago (i.e. in the Middle Pleistocene) evidence for the association between humans and fire becomes compelling (Shimelmitz et al., 2014).

Figure 1.7 Fire was one of the first and most powerful tools of environmental transformation employed by humans. The high grasslands of southern Africa may owe much of their character to regular burning, as shown here in Swaziland (ASG).

It is apparent from many parts of the world that even small hunter-gatherer populations can cause great environmental changes through the use of fire (Lightfoot and Cuthrell, 2015). As Pyne (1982: 3) has written:

> It is among man's oldest tools, the first product of the natural world he learned to domesticate. Unlike floods, hurricanes or windstorms, fire can be initiated by man; it can be combated hand to hand, dissipated, buried, or 'herded' in ways unthinkable for floods or tornadoes.

He went on to stress the implications that fire had for subsequent human cultural evolution (p. 4):

> It was fire as much as social organisation and stone tools that enabled early big game hunters to encircle the globe and to begin the extermination of selected species. It was fire that assisted hunting and gathering societies to harvest insects, small game and edible plants; that encouraged the spread of agriculture outside the flood plains by allowing for rapid landclearing, ready fertilization, the selection of food grains, the primitive herding of grazing animals that led to domestication, and the expansion of pasture and grasslands against climate gradients; and that, housed in machinery,

> powered the prime movers of the industrial revolution.

Overall, compared with later stages of cultural development, early hunters and gatherers had neither the numbers nor the technological skills to have a very substantial effect on the environment. Besides the effects of fire, early cultures may have caused some diffusion of seeds and nuts, and through hunting activities (see Section 3.7) may have had some dramatic effects on animal populations, causing the extinction of many great mammals (the so-called 'Pleistocene overkill'). Locally some eutrophication may have occurred, and around some archaeological sites phosphate and nitrate levels may be sufficiently raised to make them an indicator of habitation to archaeologists today (Holliday, 2004). Equally, although we often assume that early humans were active and effective hunters, they may well have been dedicated scavengers of carcasses of animals which had either died natural deaths or been killed by carnivores like lion.

It is salutary to remember, however, just how significant this stage of our human cultural evolution has been. As Lee and DeVore (1968: 3) wrote:

> Of the estimated 80,000,000,000 men who have ever lived out a life span on earth, over 90 per cent have lived as hunters and gatherers, about 6 per cent have lived by agriculture and the remaining few per cent have lived in industrial societies. To date, the hunting way of life has been the most successful and persistent adaptation man has ever achieved.

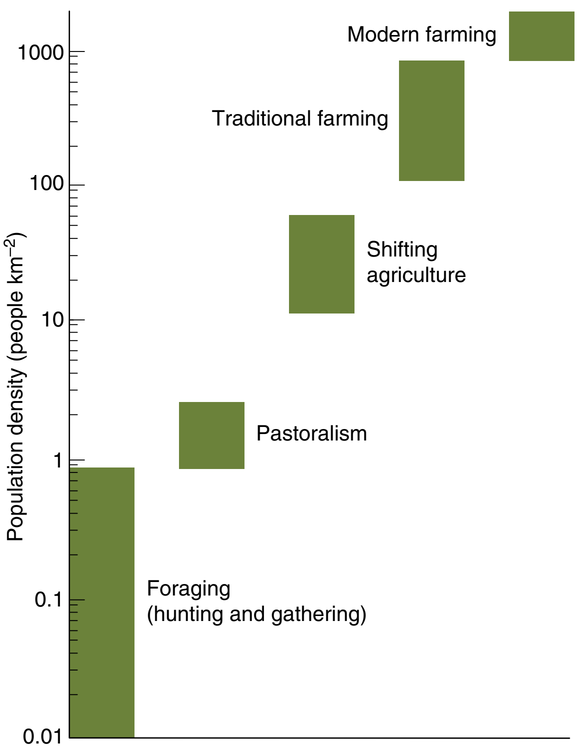

Figure 1.8 Comparison of carrying capacities of foraging, pastoralist, and agricultural societies.

Figure 1.8 indicates the very low population densities of hunter/gatherer/scavenger groups in comparison with those that were possible after the development of pastoralism and agriculture.

1.5 Humans as Cultivators and Keepers

Humans have been foragers rather than farmers for around 95% of their history, but during the end of the Pleistocene major changes were afoot. It is possible to identify some key stages of economic development that have taken place since then (Table 1.3). For example around 14,000–15,000 years ago, in the Middle Eastern region, now consisting of Jordan, Syria, Israel, Palestine, and Lebanon, the hunting folk – the Natufians – in addition to their hunting, began to build permanent houses of stone and wood, they buried their dead in and around them with elaborate rituals, gathered in communities of up to several hundred people, ground up wild cereals with pestles and mortars, and made tools and art objects from animal bones (Bar-Yosef, 1998; Barker, 2006; Balter, 2010). Then, round the beginning of the Holocene, about 10,000 years ago, the Natufians and other groups in various other parts of the world began to domesticate rather than to gather food plants and to keep, rather than just hunt, animals. This phase of human cultural development is well reviewed in Roberts (2014). By taking up farming and domesticating food plants, they reduced enormously the space required for sustaining each individual by a factor of the order of 500 at least (Sears, 1957: 54) and population densities could thus become progressively greater (Figure 1.9). As a consequence we see shortly thereafter, notably in the Middle East, the establishment of the first major settlements – towns.

It is now recognized that some hunters and gathers had considerable leisure and did not need to develop agriculture to avoid drudgery and starvation. Moreover, some believe that the mobile hunter-gatherer lifestyle was far more attractive than a sedentary one, which creates problems of refuse disposal, hygiene, and social conflict (Mithen, 2007). However, there is no doubt that through the controlled breeding of animals and plants humans were able to develop a more reliable and readily expandable source of food and thereby create a solid and secure basis for cultural advance, an advance which included civilization and the 'urban revolution' of Childe

Table 1.3 Five stages of economic development.

Economic stage	Dates and characteristics
Hunting-gathering and early agriculture	Domestication first fully established in south-western Asia around 7500 BC; hunter-gatherers persisted in diminishing numbers until today. Hunter-gatherers generally manipulate the environment less than later cultures, and adapt closely to environmental conditions
Riverine civilizations	Great irrigation-based economies lasting from c. 4000 BC to 1st century AD in places such as the Nile Valley and Mesopotamia. Technology developed to attempt to free civilizations from some of the constraints of a dry season
Agricultural empires	From 500 BC to around 1800 AD a number of city-dominated empires existed, often affecting large areas of the globe. Technology (e.g. terracing and selective breeding) developed to help overcome environmental barriers to increased production
The Atlantic-industrial era	From c. 1800 AD to today a belt of cities from Chicago to Beirut, and around the Asian shores to Tokyo, form an economic core area based primarily on fossil fuel use. Societies have increasingly divorced themselves from the natural environment, through air conditioning for example. These societies have also had major impacts on the environment
The Pacific-global era	Since the 1960s there has been a shifting emphasis to the Pacific Basin as the primary focus of the global economy, accompanied by globalization of communications and the growth of multinational corporations

Source: adapted from Simmons (1993: 2–3).

Figure 1.9 The growth of towns and cities was a major factor in the transformation of the environment. This image is of the Citadel in Aleppo, Syria. Aleppo is an ancient metropolis, and one of the oldest continuously inhabited cities in the world; it may have been inhabited since the 6th millennium BCE (ASG).

(1936) and others. Indeed, Isaac (1970) termed domestication 'the single most important intervention man had made in his environment'; and Harris (1996) regarded the transition from foraging to farming as 'the most fateful change in the human career'. Diamond (2002) termed it 'the most momentous change in Holocene human history', while Mithen (2007: 705) has said that 'The origins of farming is the defining event of human history – the one turning point that has resulted in modern humans having a quite different type of lifestyle and cognition to all other animals and past types of humans'.

A distinction can be drawn between cultivation and domestication. Whereas cultivation involves deliberate sowing or other management, and entails plants which do not necessarily differ genetically from wild populations of the same species, domestication results in genetic change brought about through conscious or unconscious human selection. This creates plants that differ morphologically from their wild relatives and which may be dependent on humans for their survival.

The origin of agriculture remains controversial (Scarre, 2005; Barker, 2006; Barker and Goucher, 2015). Some early workers saw agriculture as a divine gift to humankind, while others thought that animals were domesticated for religious reasons. They argued that it would have been improbable that humans could have predicted the usefulness of domestic cattle before they were actually domesticated. Wild cattle are large, fierce beasts, and no one could have foreseen their utility for labour or milk until they were tamed – tamed perhaps for ritual sacrifice in connection with lunar goddess cults (the great curved horns being the reason for the association). Another major theory – the demographic hypothesis – was that domestication was produced by crowding, possibly brought on by a combination of climatic deterioration (alleged post-Glacial progressive desiccation) and population growth. Gordon Childe's 'oasis propinquity hypothesis' held that increasing desiccation brought wild animals and plants into ever closer relationships, from which symbiosis and ultimately domestication emerged (Renfrew, 2006). Such pressure, may have forced communities to intensify their methods of food production. Current palaeo-climatological research tends not to support this interpretation, but that is not to say that other severe climatic changes could not have played a role (Sherratt, 1997).

Sauer (1952) believed that plant domestication was initiated in South-East Asia by fishing folk, who found that lacustrine and riverine resources would underwrite a stable economy and a sedentary or semi-sedentary life style. He surmises that the initial domesticates would be multi-purpose plants set around small fishing villages to provide such items as starch foods, substances for toughening nets and lines and making them water-resistant, and drugs and poisons. He suggested that 'food production was one and perhaps not the most important reason for bringing plants under cultivation'.

Yet another model was advanced by Jacobs (1969) which turned certain more traditional models upside down. Instead of following the classic pattern whereby farming leads to village which leads to town which leads to civilization, she proposed that one could be a hunter-gatherer and live in a town or city, and that agriculture originated in and around such cities rather than in the countryside. Her argument suggests that even in primitive hunter-gatherer societies particularly valuable commodities such as fine stones, pigments, and shells could create and sustain a trading centre which would possibly become large and stable. Food would be exchanged for goods, but natural produce brought any distance would have to be durable, so meat would be transported on the hoof for example, but not all the animals would be consumed immediately; some would be herded together and might breed. This might be the start of domestication. Indeed, settlements may have been a cause of agriculture rather than a consequence (Watkins, 2010).

Another hypothesis – the feasting hypothesis – is based on the idea that in many societies, those wishing to achieve rank and status do so by throwing feasts. The adoption of cultivation and the husbanding of domestic animals made it possible for ambitious individuals to produce increasing amounts of food which would give them an advantage in social competition (Hayden, 1995). It is also possible that as humans developed art and equipment to process plants, they developed new ideas and saw cultivation and domestication as a means of social prestige (Mithen, 2007). In other words, the origins of agriculture 10,000 years ago may perhaps be explained by a fundamental change in the way in which the human mind conceived of nature.

The process of domestication and cultivation was also once considered a revolutionary system of land procurement that had evolved in only one or two hearths and diffused over the face of the earth, replacing the older hunter-gathering systems by stimulus diffusion. It was felt that the deliberate rearing of plants and animals for food was a discovery or invention so radical and complex that it could have developed only once (or possibly twice) – the so-called 'Eureka model'. In reality, however, the domestication of plants occurred at approximately the same time in widely separated areas (Table 1.4). As Barker (2006: 412) has written:

> probably many more societies than commonly envisaged, in all parts of the world, started to engage in different kinds of animal and/or plant husbandry at or soon after the transition to the Holocene – in South-West Asia, South Asia, East Asia, Island South-East Asia, several parts of the Americas, and North Africa (and who knows when in tropical West Africa?). Independent of one another (at the regional scale, that is) and in many different ways, very many societies arrived at solutions to living in the transformed landscapes they were encountering which we can recognize as the beginnings of systematic husbandry.

Table 1.4 Dates which indicate that there may have been some synchroneity of plant domestication in different centres.

Centre	Dates (000 years BP)	Plant
Mesoamerica	10.7–9.8 9.0	Squash-pumpkin
		Bottle gourd
		Maize
Near East	11.0–9.3	Fig tree
		Emmer wheat
		Two-rowed barley
		Einkorn wheat
		Pea
		Lentil
		Flax
Far East	11.0–7.0	Broomcorn millet
		Rice
		Gourd
		Water chestnut
Andes	9.4–8.0	Chilli pepper
		Common bean
		Ullucu
		White potato
		Squash and gourd

So, the balance of botanical and archaeological evidence seems to suggest that humans started experimenting with domestication and cultivation of different plants at different times in different parts of the world (Figure 1.10) (Mithen, 2007; Fuller et al., 2014; Larson et al., 2014). It has been argued that domestication of plants can be divided into three stages: (i) *gathering*, in which people gathered annual plants from wild stands; (ii) *cultivation*, in which wild plant genotypes were systematically sown in fields of choice; and (iii) *domestication*, in which mutant plants with desirable characteristics were raised (Weiss et al., 2006). Cultivation is the essential stage, as the repetitive cycle of sowing, collecting, and sowing of wild plants which it involves gives rise to genotype accumulation that leads on to domestication.