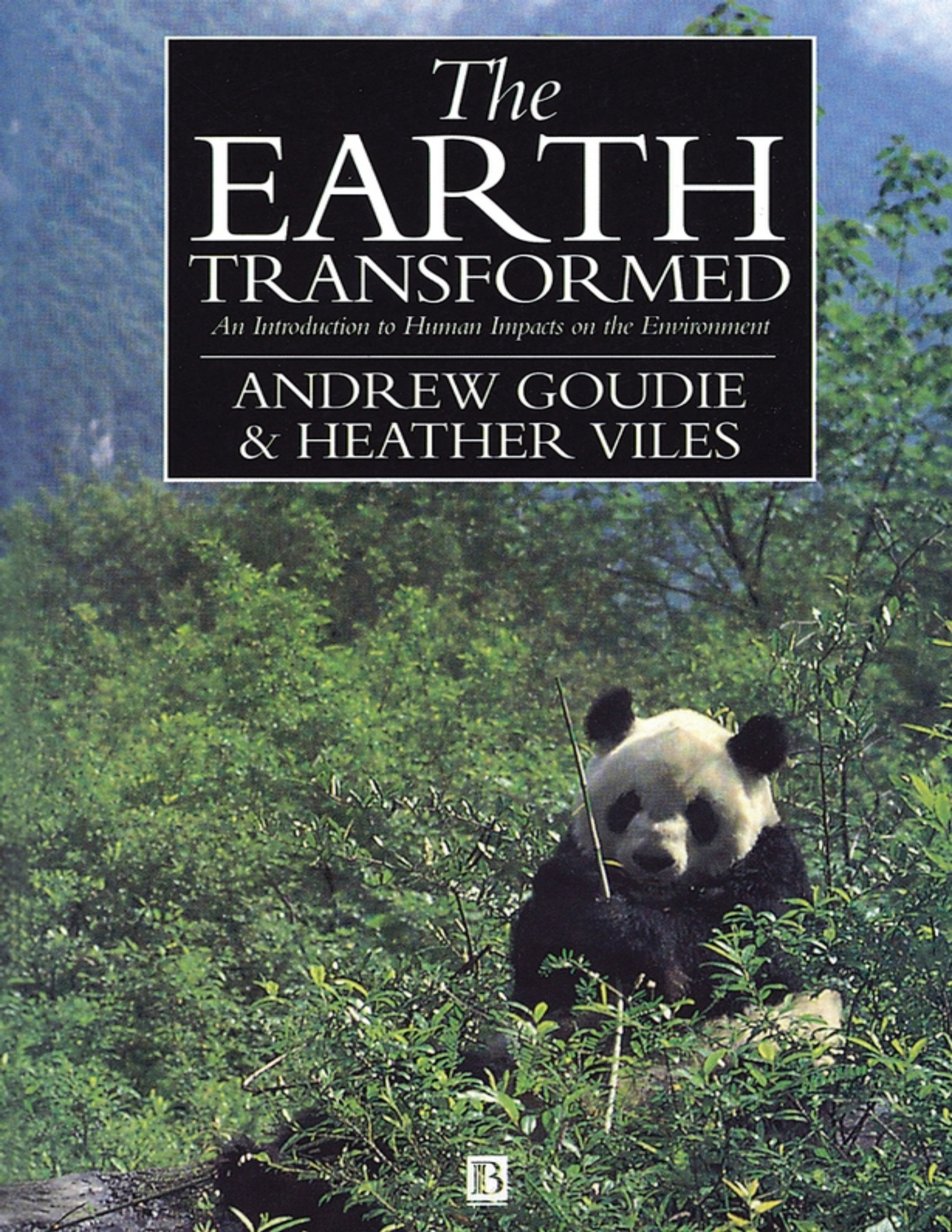
The EARTH TRANSFORMED

An Introduction to Human Impacts on the Environment

ANDREW GOUDIE
& HEATHER VILES



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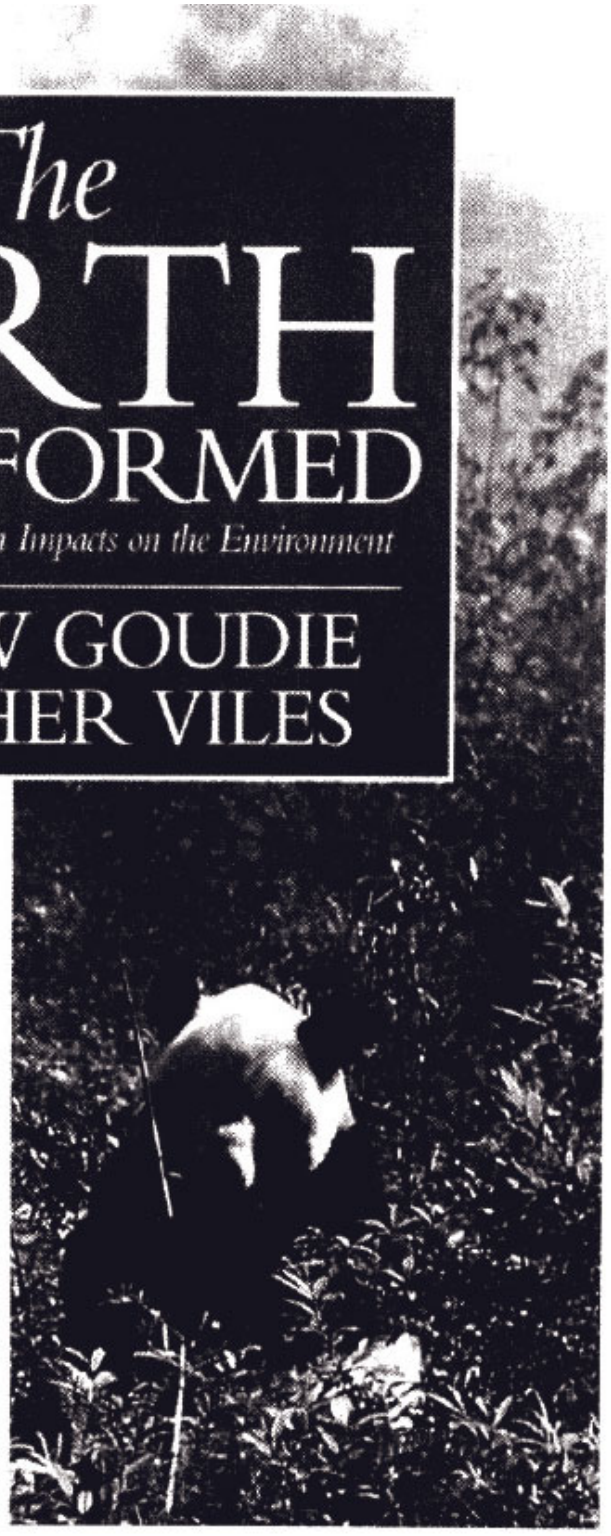

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Introduction to the Developing Environmental Impact

1 EARLY DAYS

In this book we explore the many ways in which humans have transformed the face of the Earth. We start by placing

these transformations into an historical context and seeing how they have changed through time.

Human life probably first appeared on Earth during the early part of the Ice Age, some 3 million years ago. The oldest human remains have been found in eastern and southern Africa. For a very long time the numbers of humans on the planet were small, and even as recently as 10,000 years ago the global population was probably only about one-thousandth of its size today. Also, for much of that time humans had only modest technology and limited capacity to harness energy. These factors combined to keep the impact of humans on the environment relatively small. Nonetheless, early humans were not totally powerless. Their stone, bone and wood tool technology developed through time, improving their efficiency as hunters. They may have caused marked changes in the numbers of some species of animals and in some cases even their extinction (see part II, section 13). No less important was the deliberate use of fire (see part II, section 2), a technological development that may have been acquired some 1.4 million years ago. Fire may have enabled even small human groups to change the pattern of vegetation over large areas.

2 DEVELOPING POPULATIONS

There are at least three interpretations of global population trends over the last 3 million years (Whitmore et al., 1990). The first, described as the ‘arithmetic-exponential’ view, sees the history of global population as a two-stage phenomenon: the first stage is one of slow growth, while the second stage, related to the industrial revolution (see section 4 below), displays a staggering acceleration in growth rates. The second view, described as ‘logarithmic-

logistic', sees the last million or so years in terms of three revolutions – the tool, agricultural and industrial revolutions. In this view, humans have increased the **carrying capacity** of the Earth at least three times. There is also a third view, described as 'arithmetic-logistic', which sees the global population history over the last 12,000 years as a set of three cycles: the 'primary cycle', the 'medieval cycle' and the 'modernization cycle'. These three alternative models are presented graphically in figure I.1.

Plate I.1 The Olduvai Gorge in Tanzania is one of a group of sites in the Rift Valley of East Africa where some of the earliest remains of humans and their stone tools have been found. (A. S. Goudie)

Plate I.2 A grass fire in the high grasslands of Swaziland, southern Africa. Fire was one of the first ways in which humans transformed their environment and was probably used deliberately in Africa over a million years ago. (A. S. Goudie)

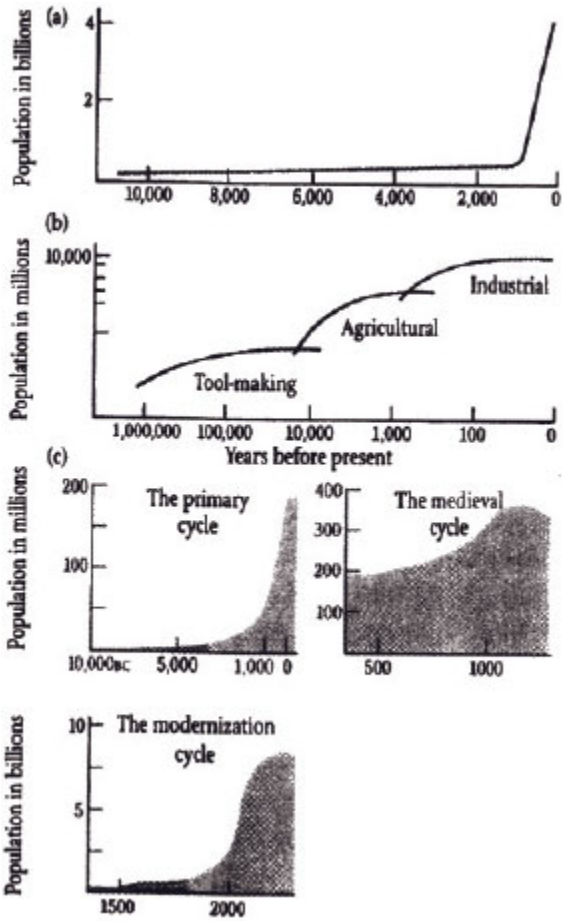
3 AGRICULTURAL REVOLUTIONS

Until the beginning of the **Holocene**, about 10,000 years ago, humans were primarily hunters and gatherers. After that time, in various parts of the world, increasing numbers of them started to keep animals and grow plants. **Domestication** caused **genetic** changes in plants and animals as people tried to breed more useful, better-tasting types. Domestication also meant that human populations could produce more reliable supplies of food from a much smaller area than hunter–gatherers (table I.1). This in turn created a more solid and secure foundation for cultural advance, and allowed a great increase in population density. This phase of development is often called the first agricultural revolution.

As the Holocene progressed, many other technological developments occurred with increasing rapidity. All of them served to increase the power of humans to modify the surface of the Earth. One highly important development, with rapid and early effects on environment, was irrigation. This was introduced in the Nile Valley and Middle East over 5,000 years ago. At around the same time the plough was first used, disturbing the soil as never before. Animals were used increasingly to pull ploughs and carts, to lift water and to carry produce. Altogether the introduction of intensive cultivation and intensive **pastoralism** (the use of land for keeping animals) had a profound effect on many environments in many parts of the world.

Figure I.1 Three interpretations of global population trends over the millennia: (a) the arithmetic-exponential; (b) the logarithmic-logistic; (c) the arithmetic-logistic

Source: Whitmore et al. (1990), figure 2.1.



A further significant development in human cultural and technological life was the mining of ores and the smelting of metals, begun around 6,000 years ago. Metal artefacts gave humans greater power to alter the environment. The smelting process required large quantities of wood which caused local **deforestation**.

4 URBAN AND INDUSTRIAL REVOLUTIONS

The processes of urbanization and industrialization are two other fundamental developments that have major environmental implications. Even in ancient times, some cities evolved with considerable populations. Nineveh (the

Assyrian capital) may have had a population of 700,000, Augustan Rome may have had a population of around 1 million, and Carthage (on the North African coast), at its fall in 146 BC, had 700,000 inhabitants. Such cities would have exercised a considerable influence on their environs, but this influence was never as extensive as that of cities in the last few centuries. The modern era, especially since the late seventeenth century, has witnessed the transformation of culture and technology through the development of major industries (table I.2). This 'industrial revolution', like the agricultural revolution, has reduced the space required to sustain each individual and has seen resources utilized more intensively.

Part of this industrial and economic transformation was the development of successful ocean-going ships in the sixteenth and seventeenth centuries. As a result, during this time countries in very different parts of the world became increasingly interconnected. Among other things, this gave humans the power to introduce plants and animals to parts of the world where they had not previously been. The steam engine was invented in the late eighteenth century and the internal combustion engine in the late nineteenth century: both these innovations massively increased human need for and access to energy, and lessened dependence on animals, wind and water.

Table I.1 Five stages of economic development

Source: Adapted from Simmons (1993), pp. 2–3.

Economic stage	*Dates and characteristics*
Hunting–gathering and early agriculture	Domestication first fully established in south-western Asia around 7500 BCE**;** 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.

Plate I.3 A simple irrigation system in use in the drier portions of Pakistan. Such irrigation was probably introduced in the Old World drylands around 5,000–6,000 years ago. (A. S. Goudie)

5 THE MODERN SCENE

Modern science and modern medicine have compounded the effects of the urban and industrial revolutions, leading to accelerating population increase even in nonindustrial societies. Urbanization has gone on speedily, and it is now recognized that large cities have their own environmental problems, and produce a multitude of environmental effects. If present trends continue, many cities in the less developed countries will become unimaginably large and crowded. For instance, it is projected that by the year 2000 Mexico City will have more than 30 million people – roughly three times the present population of the New York metropolitan area. Calcutta, Greater Bombay, Greater Cairo, Jakarta and Seoul are each expected to be in the 15–20 million range by that time. In all, around 400 cities will have passed the million mark by the end of the twentieth century, and UN estimates

indicate that by then over 3,000 million people will live in cities, compared with around 1,400 million people in 1970.

Modern science, technology and industry have also been applied to agriculture. In recent decades some spectacular progress has been made. Examples include the use of fertilizers and the selective breeding of plants and animals. **Biotechnology** has, however, immense potential to cause environmental change (see part II, section 14).

Plate I.4 A limestone pavement developed on the Carboniferous limestone of north-west England. Although they were formed in glacial times by glacial abrasion, they may be exposed at the surface today because of soil erosion produced by forest clearance since the Mesolithic. (A. S. Goudie)

We can recognize certain trends in human manipulation of the environment during the modern era. First, the number of ways in which humans are affecting the environment is growing rapidly. For example, nearly all the powerful

pesticides post-date the Second World War. The same applies to the increasing construction of nuclear reactors, to the use of jet aircraft and to many aspects of biotechnology. Secondly, environmental issues that once affected only particular local areas have become regional or even global problems. An instance of this is the appearance of substances such as DDT (a major pesticide), lead and sulphates at the North and South Poles, far removed from the industrial societies that produced them. Thirdly, the complexity, magnitude and frequency of impacts are probably increasing. For instance, a massive modern dam like that at Aswan in Egypt has a very different impact from a small Roman dam. Finally, a general increase in **per capita** consumption and environmental impact is compounding the effects of rapidly expanding populations. Energy resources are being developed at an ever-increasing rate, giving humans enormous power to transform the environment. One measure of this is world commercial energy consumption, which trebled in size between the 1950s and 1980.

Table I.2 Energy, technology and environmental impact time line

Time zone	*Global population*	*Daily energy use per person (kcals)*	*Energy source*	*Technological discoveries*	*Environmental impacts*
1 million to 5000 years BC	< 10 million	2,000–5,000	Food, human muscle	Tool production, fire	Local and short-term; animal kills and vegetation change
5000 BC to AD 1800	10 million –1 billion	12,000–26,000	Animals, agricultural crops, wind, water, coal	Cultivation, building, transport, irrigation	Local and longer-term; natural vegetation removal, soil erosion, urban air pollution
AD 1800 to 1950	1 billion–4 billion	50,000	Fossil fuels, electricity, steam	Industry	Local, regional and permanent; major landscape changes, air and water pollution common
1950 to present	>4 billion	300,000	Internal combustion engine, electricity, nuclear, fossil fuels	Industry, cultural globalization	Local, regional, global; permanent and perhaps irreversible, acid rain, global warming

Plate I.5 The power of humans to transform the land's surface in the modern era is illustrated by the size of the giant open-cast uranium mine at Rössing, Namibia. Modern technology allows humans to harness energy resources as never before. (A. S. Goudie)

The importance of the harnessing of energy can be clearly seen in the context of world agriculture. At the beginning of the twentieth century, more or less throughout the world, farmers relied upon domestic animals to provide both pulling power and fertilizer. They were largely selfsufficient in energy. However, in many areas the situation has now changed. Fossil fuels are extensively used to carry out such tasks as pumping (or, in many cases, mining) water, propelling tractors and manufacturing synthetic fertilizers (which in many cases cause pollution). The world's tractor fleet has quadrupled since 1950 and as much as two-thirds of the world's cropland is being ploughed and compacted by increasingly large tractors.

Above all, as a result of the huge expansion of environmental transformation it is now possible to talk about *global* environmental change. There are two aspects of this (Turner, Kasperson et al., 1990): 'systemic' global change and 'cumulative' global change. Systemic global change refers to changes operating at the global scale and includes, for example, global changes in climate brought about by atmospheric pollution, e.g. the **greenhouse effect** (see part III). Cumulative global change refers to the snowballing effect of local changes, which add up to produce change on a worldwide scale, or change which affects a significant part of a specific global resource, e.g. **acid rain** or soil erosion (see parts III and V). The two types of change are closely linked. For example, the burning of vegetation can lead to systemic global change through processes such as carbon dioxide release and **albedo** modification, and to cumulative global change through its impact on soil erosion and **biodiversity** (table I.3).

Table I.3 Systemic and cumulative global environmental changes

Source: Turner, Clark et al. (1990), table 1.

Type of change	*Characteristic*	*Examples*
Systemic	Direct impact on globally functioning system	(a) Industrial and land-use emissions of 'greenhouse' gases
		(b) Industrial and consumer emissions of ozone-depleting gases
		(c) Land cover changes in albedo
Cumulative	Impact through worldwide distribution of change	(a) Groundwater pollution and depletion
		(b) Species depletion/genetic alteration (biodiversity)
	Impact through magnitude of change (share of global resource)	(a) Deforestation
		(b) Industrial toxic pollutants
		(c) Soil depletion on prime agricultural lands

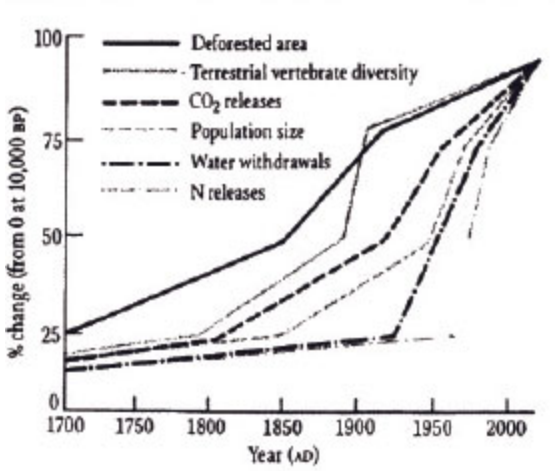
Figure I.2 shows how the human impact on six 'component indicators of the biosphere' has increased over time. This graph is based on work by Kates et al. (1990). For each component indicator they defined the total net change clearly induced by humans to be 0 per cent for 10,000 years ago (before the present=BP) and 100 per cent for 1985. They then estimated the dates by which each component had reached successive quartiles (that is, 25, 50 and 75 per cent) of its total change at 1985. They believe that about half of the components have changed more in the single generation since 1950 than in the whole of human history before that date.

Human activities are now causing environmental transformation on the local, regional, continental and planetary scales. The following examples both give an

indication of what is currently being achieved and provide a sample of some of the issues we cover in this book.

Large areas of **temperate** forest have been cleared in the past few centuries. Now farmers and foresters are removing forests from the humid tropics at rates of around 11 million hectares (ha) per year. This is exposing soils to intense and erosive rainfall and increasing rates of **sediment yield** by an average of six times. The world's rivers are being dammed by around 800 major new structures each year, transforming downstream **sediment loads.** Huge reservoirs held behind dams as high as 300 metres are generating seismic hazards and catastrophic slope failures. Some of the world's largest lakes, most notably the Aral Sea in the former Soviet Union, are becoming **desiccated** because the water is being taken for irrigation use and transferred to other water basins at a nearcontinental scale. Fluids, both water and **hydrocarbons** (e.g. oil and gas) are being withdrawn from beneath cities and farmlands, leading to subsidence of up to 8–9 metres. Recreational vehicles and trampling feet are damaging many popular tourist areas. Development on **tundra** areas is disturbing the thermal equilibrium of **permafrost,** leading to more and more instances of **thermokarst**. Coastlines are being 'protected' and 'reclaimed' by the use of large engineering structures, often without due thought for the possible consequences. We are pumping at least 500 million tonnes of dissolved material into rivers and oceans around the world each year. We are acidifying **precipitation** to the extent that some of it has the **pH** of vinegar or stomach fluid, thereby altering rates of mineral release and rock weathering.

Figure I.2 Percentage change (from assumed zero human impact at 10,000 BP**)** of selected human impacts on the environment



These human impacts are having great direct and indirect effects on vegetation: table I.4 shows the amounts of vegetation (in terms of **net primary production**) used, dominated or lost by humans.

We shall return to these and other issues in subsequent sections. In this book we have chosen to focus on specific environmental issues as they affect the **biosphere** (part II), atmosphere (part III), surface waters (part IV), land surface (part V), and oceans, seas and coasts (part VI). However, you will notice through all of these sections that a range of important human activities play key roles and can have a range of different impacts on many sectors of the environment.

Even in the modern world economy, hunting and gathering activities still have an important effect on the environment, largely through the biological impacts of fishing and the shooting of game. These activities are becoming increasingly large-scale and mechanized. Agriculture, **aquaculture** and other forms of food production now occupy vast areas of the Earth’s surface and have a wide variety of environmental effects, including soil erosion, nutrient depletion, changes in species divesity and genetic changes to crops and animals. Forestry and quarrying, as extractive industries, are creating whole new landscapes and releasing large amounts of sediment in parts of the

globe ranging from the humid tropics to the Arctic. Heavy industries (such as oil refining and chemical manufacture), power generation plants (from coal-fired to nuclear), and light and high-technology industries have many different environmental impacts and contribute to pollution of land, water and air on the local and regional scales.

Transport and urbanization have, perhaps, some of the most dramatic local impacts on the environment. They create whole new landscapes dominated by concrete, add to pollution, and affect plant and animal distributions and the circulation and distribution of water. Tourism, which is now a booming global industry, also has considerable impacts on the environment. In recent years there has been much interest in the notion of ‘ecotourism’, or tourism which attempts to minimize environmental damage.

One of the consequences of all these different human interactions with the environment is the production of waste. This itself has had major environmental effects. There are problems of waste disposal and waste management. Big issues like nuclear waste disposal have potentially long-term environmental implications. So do less contentious matters, such as disposing of domestic and industrial waste on **landfill** sites.

Table I.4 Terrestrial net primary production of vegetation used, dominated or lost through human activities

Source: Vitousek (1994).

Category	*Amount* (*Pg per year*)[a]
NPP used:	
consumed by humans	0.8
consumed by domestic animals	2.2
wood used by humans	2.4
Total	5.2 (4% of total global NPP)
NPP dominated:	
croplands	15
converted pastures	10
tree plantations	2.6
human-occupied lands	0.4
consumed from little-managed areas	3
land-clearing	10
Total	41 (31% of total global NPP)
NPP lost to human activities:	
decreased NPP of cropland	10
desertification	4.5
human-occupied areas	2.6
Total	17 (8% of total global NPP)
Total NPP dominated and lost	58 (39% of total global NPP)

[a] 1 Pg or Petagramme = 1×10^{15} g.

Human societies do not always run smoothly. War, civil strife and smaller-scale disruptions such as vandalism and crime have their own environmental consequences. Indeed, some wars are partly motivated by disputes over environmental resources, for example over water supplies. Recent conflicts in the Arabian Gulf, Bosnia and Afghanistan have had both short-term and long-term environmental consequences, including pollution and soil erosion. In the 1960s and 1970s the Vietnam War had widely publicized

effects on the **mangrove** vegetation of the Mekong Delta. The use of **defoliant** chemicals there has had long-term impacts on biodiversity from which the environment is only just recovering. Even without war, political systems can impose additional stress on the environment. The apartheid system in pre-1994 South Africa, for example, forcibly distributed population and wealth in a highly unfair way, leading to huge environmental pressures on **marginal land**. The planned socialist economics of the former Soviet Union and many East European states appear now to have had particularly damaging environmental impacts. And capitalist enterprise, which now dominates the global economy, has often had a tendency to plunder and despoil the environment.

These many negative environmental impacts have generated in response a longterm, and growing, focus on conservation and improving human management of the environment. Conservation and management themselves have environmental impacts, as in the creation of nature reserves; there may also be less desirable impacts where management schemes go wrong. The ideas of **sustainable development** are the most recent attempt to combine resource exploitation with conservation and a concern for the environmental future. As our scientific understanding of how the environment works has advanced, we have gained a better view of how serious our human impacts can be. On the other hand, we have also learnt that there is much reason for hope. The environmental future is not all doom and gloom, as we stress in part VII of this book.

6 UNDERSTANDING ENVIRONMENTAL TRANSFORMATIONS

We have already shown in this chapter that human impacts on environmental processes have had a long and complex history, and now take on many complex and interlinked forms. The environment itself is also not a static, simple entity, but has a complicated history of its own. We now realize that the environment changes naturally, over a range of different time-scales, as a response to a number of natural 'forcing factors', such as the varying position of the Earth within its orbit around the sun. On shorter time-spans, we know that the environment can work in abrupt and challenging ways, producing what are called 'natural hazards' such as volcanic eruptions, earthquakes, floods and hurricanes. So, putting together human and natural factors influencing the environment to explain any single environmental transformation can be a hugely difficult task. It is important to realize that there is still a lot of scientific uncertainty and debate over the causes and consequences of many of the environmental issues we look at in this book.

Understanding the role of human activities in environmental transformations is not a completely hopeless task, however. There are several useful concepts which we can adopt to help us untangle what is going on. First, it is useful to think of the environment (of which, of course, we are a part) as being a series of interlocked systems. These systems are affected by a whole series of stresses (which can be human or natural in origin). The stresses produce some changes in the system, or responses: these are what we see as environmental transformations or environmental issues. Because the systems are interlocked, stresses on