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Figure 2.27 A monument in the botanic gardens in Mauritius, drawing attention to the value of introduced plants. Figure 2.28 Number of nonindigenous plant species by date as reported in botanical treatments of the California flora (from Schwartz et al., 1996, figure 47.1).

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Progressive habitat fragmentation in the rainforest environments of (a) Sumatra and (b) Costa Rica (modified after Whitten et al., 1987 and Terborgh, 1992).

The Fynbos of the Cape Region of South Africa is a biodiversity hot spot that has a great diversity of flora and fauna. It is a habitat that is under a number of threats, including the invasion of competitive species from Australia, which smother the native heathland.

Forest and heathland hot-spot areas. Hot spots are habitats with many species found nowhere else and in greatest danger of extinction from human activity (after Wilson, 1992: 262–3).
Figure 4.1 An irrigated field in southern Morocco. The application of large amounts of irrigation of water causes groundwater levels to rise and high air temperatures lead to rapid evaporation of the water. This leads to the eventual build up of salts in the soil.

Figure 4.2 The extension of irrigation in the Indus valley of Pakistan by means of large canals has caused widespread salination of the soils. Waterlogging is also prevalent. The white efflorescence of salt in the fields has been termed ‘a satanic mockery of snow’.

Figure 4.3 Comparison of hydrographs recorded from the boreholes in Wights (——) and Salmon (-----) catchments in Western Australia. Both catchments were forested until late in 1976 when Wights was cleared (modified after Peck, 1983, figure 1).

Figure 4.4 Dust plumes caused by the deflation of salty sediments from the drying floor of the Aral Sea as revealed by a satellite image (153/Metero-Priroda, 18 May 1975) (modified after Mainguet, 1995, figure 4).

Figure 4.5 Changes in the chloride concentration of the Llobregat Delta aquifer, Barcelona, Spain as a result of seawater incursion caused by the overpumping of groundwater (modified from Custodio et al., 1986).

Figure 4.6 (a) The Ghyben–Herzberg relationship between fresh and saline groundwater. (b) The effect of excessive pumping from the well. The diagonal hatching represents the increasing incursion of saline water (after Goudie and Wilkinson, 1977, figure 63).

Figure 4.7 Impact of sea-level rise on an island water table. Note: the freshwater table extends below sea level 40 cm for every 1 cm by which it extends above sea level. (a) For islands with substantial elevation a 1-m rise in sea level simply shifts the entire water table up 1 m, and the only problem is that a few wells will have to be replaced with shallower wells (b). For very low islands, however, the water table cannot rise due to runoff, evaporation, and transpiration. A rise in sea level would thus narrow the water table by 40 cm for every 1 cm that the sea level rises (c), effectively eliminating groundwater supplies for the lowest islands (modified after Broadus, 1990).

Figure 4.8 Percentage of drained agricultural land in Europe. There are no data for the blank areas (after Green, 1978, figure 1).

Figure 4.9 Global consumption of nitrogen fertilizer over the past five decades.

Figure 4.10 Soil erosion near Baringo in Kenya has exposed the roots of a tree, thereby indicating the speed at which soil can be lost.

Figure 4.11 The removal of vegetation in Swaziland creates spectacular gully systems, which in southern Africa are called dongas. The smelting of local iron ores in the early nineteenth century required the use of a great deal of firewood, which may have contributed to the formation of this example.

Figure 4.12 Rates of erosion in Papua New Guinea in the Holocene derived from rates of sedimentation in Kuk Swamp (after Hughes et al., 1991, figure 5, with modifications).

Figure 4.13 Soil erosion on a bare field in Oxfordshire, central England.

Figure 4.14 The concentration of dust storms (number of days per month) in the USA in 1939, illustrating the extreme localization over the High Plains of Texas, Colorado, Oklahoma, and Kansas: (a) March, (b) April, and (c) May (after Goudie, 1983).

Figure 4.15 In the High Plains near Lubbock in Texas the effect of soil erosion and drifting was very evident in 1977. Note the vast fields and absence of windbreaks.

Figure 4.16 The spread of contour-strip soil conservation methods in Wisconsin, USA, between 1939 and 1967. One dot represents one adopter (after H. E. Johansen, in Trimble and Lund, 1982, figure 22).

Figure 5.1 The Kariba Dam on the Zambezi River between Zambia and Zimbabwe. Such large dams can provide protection against floods and water shortages, and generate a great deal of electricity. However, they can have a whole suite of environmental consequences.

Figure 5.2 Generalized representation of the possible effects of dam construction on human life and various components of the environment.

Figure 5.3 Historical (a) sediment and (b) water discharge trends for the Colorado River, USA (after the US Geological Survey, in Schwarz et al., 1991).

Figure 5.4 (a) Suspended sediment discharge on the Mississippi and Missouri rivers between 1939 and 1982 (after Meade and Parker, 1985, with modifications). (b) Long-term average discharges of suspended sediment in the lower Mississippi River c. 1700 and c. 1980.

Figure 5.5 The Madurai–Ramanathapuram tank country in south India (after Spate and Learmonth, 1967, figure 25.12).

Figure 5.6 A large irrigation canal taking water across the Indus Plain from the Sukkur Barrage in Sind, Pakistan.

Figure 5.7 The irrigated areas in Sind (Pakistan) along the Indus Valley (after Manshard, 1974, figure 5.7).

Figure 5.8 Comparison of the natural channel morphology and hydrology with that of a channelized stream, suggesting some possible ecological consequences (after Keller, 1976, figure 4).
Figure 5.9 (left) Some major schemes proposed for large-scale interbasin water transfers: (a) projected water transfer systems in the Commonwealth of Independent States: 1, from the Ongera River and in future from Ongera Bay; 2, from the Sukhona and Northern Dvina rivers; 3, from the Svir River and Lake Onega; 4, from the Pechora River; 5, from the Ob River; 6, from the Danube delta. (b) Projected systems for water transfers in India: 1, scheme of the national water network; 2, scheme of the Grand Water Garland. (c) Some major projects for water transfers in North America: 1, North American Water and Power Alliance (NAWAPA); 2, Grand Canal; 3, Texas River basins (after Shiklomanov, 1985, figs 12.6, 12.9 and 12.11, in Facets of hydrology II, ed. J. C. Rodda, by permission of John Wiley and Sons Ltd).

Figure 5.10 Changes in annual runoff in the Commonwealth of Independent States due to human activity during 1936–2000 (from Shiklomanov, 1985, figure 12.7, in Facets of hydrology II, ed. J. C. Rodda, by permission of John Wiley and Sons Ltd).

Figure 5.11 Some hydrological consequences of urbanization. (a) Effect of urban development on flood hydrographs. Peak discharges (Q) are higher and occur sooner after runoff starts (T) in basins that have been developed or sewered (after Fox, 1976, figure 3). (b) Flood frequency curves for a 1 mile² basin in various states of urbanization (after US Geological Survey, in Viessman et al., 1977, figure 11.33). (c) Effects of flood magnitude with paving 20% of a basin (after Hollis, 1975).

Figure 5.12 The increase of water yield after clear-felling a forest: a unique confirmation from the Coweeta catchment in North Carolina, USA.

Figure 5.13 Variations in the level of Lake Valencia, Venezuela, to 1968 (after Böckh, 1973, figure 18.2).

Figure 5.14 Annual fluctuations in the level of the Caspian Sea, for the period 1880–1993. Curve (a) shows the changes in level which would have occurred but for anthropogenic influences, while curve (b) shows the actual observed levels (modified from World Meteorological Organization, 1995, figure 15.3).

Figure 5.15 Changes in the Aral Sea: (a) 1960–1989 (from data in Kotlyakov, 1991) and (b) 1960 to after 2000 (after Hollis, 1978, p. 63).

Figure 5.16 The level of the Dead Sea since 1850. Notice the 20-m fall since the 1960s.

Figure 5.17 Construction of wells tapping the confined aquifer below London, 1850–1965.

Figure 5.18 Groundwater levels in the London area (a) prior to major development and (b) in 1985 (from Wilkinson and Brassington, 1991, figures 4.5, 4.6, 4.7).

Figure 5.19 In the High Plains of the USA, fields are irrigated by center-pivot irrigation schemes which use groundwater. Groundwater levels have fallen rapidly in many areas because of the adoption of this type of irrigation technology. Beneath Trafalgar Square, central London, shows the sharp decline until the 1950s and the 1960s, and the substantial rise since then (from Environment Agency (UK) data).

Figure 5.21 Urban effects on groundwater recharge (after Lerner, 1990, figure 2).

Figure 5.22 Diffuse and point sources of pollution into river systems (after Newson, 1992, figure 7.7).

Figure 5.23 Recent trends of nitrate concentrations in some rivers: A, Mississippi at mouth; B, Danube at Budapest; C, Rhine at the Dutch–German border; D, Seine at mouth; E, Thames at mouth (from Meybeck, 2001b, figure 17.6).

Figure 5.24 Nitrate levels in surface and groundwater in the UK: (a) the trends in annual fertilizer usage in the UK during the period 1928–1980; (b) trends in mean annual nitrate concentration in five rivers for which long-term data are available – WHO, World Health Organization; (c) nitrate concentrations in selected public water supply abstraction boreholes in the Cretaceous Chalk and Triassic sandstone aquifers of the UK (Royal Society Study Group, 1983, figures 4, 18, 31); (d) changing nitrate concentrations in five UK rivers. The averages are five-year means (from Department of the Environment statistics, in Conway and Pretty, 1991, figure 4.8).

Figure 5.25 Biological concentration occurs when relatively indestructible substances (dichlorodiphenyltrichloroethane (DDT), for example) are ingested by lesser organisms at the base of the food pyramid. An estimated 1000 kg of plant plankton are needed to produce 100 kg of animal plankton. These in turn are consumed by 10 kg of fish, the amount needed by one person to gain 1 kg. The ultimate consumer (man or woman) then takes in the DDT taken in by the fish.

Figure 5.26 Estimates of the total quantity of de-icing salt purchased annually in mainland Britain during the period 1960–1991. Arrows highlight severe winters. Data provided by ICI (in Dobson, 1991, figure 1.1).

Figure 5.27 The average dissolved oxygen content of the River Thames at half-tide in the July–September quarter since 1890: (a) 79 km below Teddington Weir; (b) 95 km below Teddington Weir (after Gameson and Wheeler, 1977, figure 4).

Figure 5.28 Changes in the state of Lake Washington, USA, associated with levels of untreated sewage from 1933 to 1973. The relative amount of treated sewage entering the lake is shown as a percentage of the maximum rated capacity of the treatment plants, 76 × 10⁶ L per day (after Edmonson, 1975, figure 3).

Figure 5.29 Changes in water pollution in the Great Lakes of North America: (a) estimated phosphorus loadings; (b) dichlorodiphenyltrichloroethane (DDT) levels; (c) polychlorinated biphenyl (PCB) levels (after Council on Environmental Quality, 17th (1986) and 22nd (1992) Annual Reports).
Figure 5.30 Changes in the chemical composition of stream water from clear-cut and forested catchments in mid-Wales, 1983–1990: (a) nitrate ($\text{NO}_3^-$); (b) aluminium ($\text{Al}$); (c) dissolved organic carbon (DOC) (modified after Institute of Hydrology, 1991, figure 20).

Figure 5.31 Maximum temperatures for the spawning and growth of fish. Heated waste water may be up to 5 to 10°C warmer than receiving waters and consequently the local fish populations cannot reproduce or grow properly. (After J. C. Giddings, Chemistry, man and environmental change, Harper and Row; from Encounter with the Earth by Leo F. Laporte, figure 15-2. Copyright © by permission of Harper & Row Publishers, Inc.)

Figure 6.1 Strip lynches (terraces) in Dorset, southern England, produced by plowing on steep slopes.

Figure 6.2 A limestone pavement at Hutton Roof Crags in northwest England. Such bare rock surfaces may result in part from accelerated erosion induced by the first farmers in prehistoric times. Many of them are now being damaged by quarrying and removal of stone for garden ornamentation.

Figure 6.3 The Rössing uranium mine near Swakopmund in Namibia, southern Africa. The excavation of such mines involves the movement of prodigious amounts of material.

Figure 6.4 Some shapes produced by shale tipping: (a) conical, resulting from MacClaine tipping; (b) multiple cones tipped from aerial ropeways; (c) high fan-ridge by tramway tipping over slopes; (d) high plateau mounds topped with cones; (e) low multiple fan ridges by tramway tipping; (f) lower ridge by tramway tipping (after Haigh, 1978, figure 2.1).

Figure 6.5 Map of Hong Kong showing main urban reclamation areas shaded black (reprinted from Hudson, 1979, figure 1, in Reclamation review, 2, 3–16, permission of Pergamon Press Ltd © Pergamon Press Ltd).

Figure 6.6 The distribution of pits and ponds in a portion of northwestern England: (a) in the mid-nineteenth century; (b) in the mid-twentieth century (after Watson, 1976).

Figure 6.7 The human and environmental history of the Peten Lakes, Guatemala. The shaded areas indicate a phase of local population decline (modified after Binford et al., 1987).

Figure 6.8 Subsidence in the salt area of mid-Cheshire, England, in 1954 (after Wallwork, 1956, figure 3).

Figure 6.9 The subsidence of the English Fenlands peat at Holme Fen Post from 1842 to 1960 following drainage (from data in Fillenham, 1963).

Figure 6.10 Diagram illustrating how the disturbance of high ice-content terrain can lead to permanent ground subsidence. 1–3 indicate stages before, immediately after, and subsequent to disturbance (after Mackay in French, 1976, figure 6.1).

Figure 6.11 The city of Mexico has subsided by many meters as a result of groundwater abstraction. Many of the ancient buildings in the city center have been severely damaged, and have been cracked and deformed.

Figure 6.12 A model for the formation of arroyos (gullies) in southwestern USA (after Cooke and Reeves, 1976, figure 1.2).

Figure 6.13 Chronology of Holocene alluviation in Greece and the Aegean. Broken bars are dated uncertainly or represent inferred deposition (from various sources in Van Andel et al., 1990, figure 10).

Figure 6.14 The ancient city of Mohenjo-Daro in Pakistan was excavated in the 1920s. Irrigation has been introduced into the area, causing groundwater levels to be raised. This has brought salt into the bricks of the ancient city, producing severe disintegration.

Figure 6.15 Slope instability produced by road construction.

Figure 6.16 Principal types of adjustment in straightened river changes (after Brookes, 1987, figure 4). For an explanation of the different types see text.

Figure 6.17 The configuration of the channel of the South Platte River at Brule, Nebraska, USA: (a) in 1897 and (b) in 1959. Such changes in channel form result from discharge diminution (c) caused by flood-control works and diversions for irrigation (after Schumm, 1977, figure 5.32 and Williams, 1978).

Figure 6.18 Diagrammatic long profile of a river showing the upstream aggradation and the downstream erosion caused by dam and reservoir construction.

Figure 6.19 Changes in the evolution of fluvial landscapes in the Piedmont of Georgia, USA, in response to land-use change between 1700 and 1970 (after Trimble, 1974, p. 117, in S. W. Trimble, Man-induced soil erosion on the southern Piedmont, Soil Conservation Society of America. © Soil Conservation Society of America).

Figure 6.20 Techniques to control dune movement: (a) a sand fence on a dune that threatens part of the town of Walvis Bay in Namibia; (b) a patchwork of palm frond fences being used at Erfoud on the edge of the Sahara in Morocco; (c) vegetation growth on coastal sand dunes at Hout Bay in South Africa being encouraged by irrigation.

Figure 6.21 Sand accumulation using the method of multiple fences in North Carolina, USA. This raised the dune height approximately 4 m over a period of 6 years (after Savage and Woodhouse, in Goldsmith, 1978, figure 36).

Figure 6.22 Coastal defense: (a) at Weymouth, southern England; (b) at Arica, northern Chile. The piezometric emplacement of expensive sea walls and cliff protection structures is often only of short-term effectiveness and can cause accelerated erosion downdrift.
Figure 6.23 A selection of ‘hard engineering’ structures designed to afford coastal protection (modified from A. H. Brampton, ‘Cliff conservation and protection: methods and practices to resolve conflicts’, in J. Hooke (ed.), Coastal and earth science conservation (Geological Society Publishing House, 1998), figures 3.1, 3.2, 3.4, 3.5, 3.6, and 3.7).

Figure 6.24 Diagrammatic illustration of the effects of groyne construction on sedimentation on a beach.

Figure 6.25 Examples of the effects of shoreline installations on beach and shoreline morphology. (a) Erosion of Bayocean Spit, Tillamook Bay, Oregon, after construction of a north jetty in 1914–17. The heavy dashed line shows the position of the new south jetty under construction. (b) The deposition–erosion pattern around the Santa Barbara breakwater in California. (c) Sand deposition in the protected lee of Santa Monica breakwater in California. (d) Madras Harbor, India, showing accretion on updrift side of the harbor and erosion on the downdrift side (after Komar, Beach processes and sedimentation, p. 334, © 1976. Reprinted by permission of Prentice-Hall Inc.).

Figure 6.26 A jetty was built at West Bay, Dorset, to facilitate entry to the harbor. Top: in 1860 it had had little effect on the coastline. Center: by 1900 sediment accumulation had taken place in the foreground but there was less sediment in front of the cliff behind the town. Bottom: by 1976 the process had gone even further and the cliff had to be protected by a sea-wall. Even this has since been severely damaged by winter storms.

Figure 6.27 Sea-walls and erosion: (a) a broad, high beach prevents storm waves breaking against a sea-wall and will persist, or erode only slowly; but where the waves are reflected by the wall (b) scour is accelerated, and the beach is quickly removed and lowered (c) (modified after Bird, 1979, figure 6.3).

Figure 6.28 The decline in suspended sediment discharge to the eastern seaboard of the USA between 1910 and 1970 as a result of soil conservation measures, dam construction and land-use changes (after Meade and Trimble, 1974).

Figure 6.29 Comparison of the outlines of the Mississippi birdfoot delta from the 1950s to 1990 gives a clear indication of the transformation from marsh to open water. Artificial controls upriver have decreased the amount of sediment carried by the river; artificial levees along much of the lower course have kept flood-borne sediment from replenishing the wetlands; and in the active delta itself rock barriers installed across breaks similarly confine the river. The Gulf of Mexico is intruding as the marshland sinks or is washed away.

Figure 6.30 Cross-sections of two barrier islands in North Carolina, USA. The upper diagram (a) is typical of the natural systems and the lower (b) illustrates the stabilized systems (after Dolan et al., 1973, figure 4).

Figure 6.31 Correlation between quantity of waste water pumped into a deep well and the number of earthquakes near Denver, Colorado (after Birkeland and Larson, 1978, p. 573).

Figure 6.32 Worldwide distribution of reservoir-triggered changes in seismicity (after Gupta, 2002, figure 1).

Figure 6.33 Relationship between reservoir levels and earthquake frequencies for: (a) Vaiont Dam, Italy; (b) Koyna, India (these curves show the 3-monthly average of water level and the total number of earthquakes for the same months from 1964 to 1968); (c) The Nurek Dam, Tajikistan (after Judd, 1974 and Tajikistan Academy of Sciences, 1975).

Figure 7.1 A schematic representation of some of the possible influences causing climatic change (after Goudie, 1992, figure 1).

Figure 7.2 Air pollution in Cape Town, South Africa. The combustion of fossil fuels, including coal, to generate electricity and to power vehicles, is a major cause not only of local air pollution but also of the increase in greenhouse gas loadings in the atmosphere.

Figure 7.3 The greenhouse effect: shortwave radiation from the sun is absorbed at Earth’s surface, which in turn radiates heat at far longer wavelengths because of its temperature of around 280 K, compared with 6000 K for the sun.

Figure 7.4 Carbon dioxide concentrations at Mauna Loa, Hawaii.

Figure 7.5 The net annual flux of carbon from deforestation in tropical and temperate zones globally, 1850–1980 (after Houghton and Skole, 1990, figure 23.2, and Woodwell, 1992, figure 5.2).

Figure 7.6 The changing concentrations of accessory greenhouse gases in the atmosphere: (a) nitrous oxide – note these remained fairly constant between 23,000 years ago and 1850 at approximately 285 parts per billion (after Khalil and Rasmussen, 1987); (b) methane (after Khalil and Rasmussen, 1987); (c) the changing production and release of two CFC gases (CFC-11 and CFC-12) between 1931 and 1992.

Figure 7.7 Global average temperature at Earth’s surface, 1880–2002.

Figure 7.8 The Gulf War of 1991 led to the deliberate release and burning of oil in Kuwait. Fears were expressed at the time that smoke plumes might have regional and global climate effects. In general, subsequent research has suggested that such fears may have been exaggerated.

Figure 7.9 Relations between the maximum heat island intensity and (a) urban population for Japanese, Korean, North American, and European cities; (b) the sky view factor for Japanese, Korean, North American, and European cities; (c) the ratio of impermeable surface coverage for Japanese and Korean cities (after Nakagawa, 1996, figures 2, 3, and 4).

Figure 7.10 Thunder in southeast England: (a) total thunder rain in southeast England, 1951–60, expressed in inches (after Atkinson, 1968, figure 6); (b) number of days with thunder overhead in southeast England, 1951–60 (after Atkinson, 1968, figure 5); (c) thunderstorms per year in London (decadal means for whole year) (after Brimblecombe, 1977, figure 2).
Figure 7.11 In December 1952 the city of London was affected by severe smog. Visibility was reduced and smog-masks had to be worn out of doors. Many people with weak chests died. Since then, because of legislation, the incidence of smog has declined markedly.

Figure 7.12 (a) The range of annual averages of total particulate matter concentrations measured at multiple sites within 41 cities, 1980–1984. The shading indicates the concentration range recommended by the United Nations Environment Program as a reasonable target for preserving human health. Each numbered bar represents a city, as follows: 1, Frankfurt; 2, Copenhagen; 3, Cali; 4, Osaka; 5, Tokyo; 6, New York; 7, Vancouver; 8, Montreal; 9, Fairfield; 10, Chattanooga; 11, Medellin; 12, Melbourne; 13, Toronto; 14, Craiova; 15, Houston; 16, Sydney; 17, Hamilton; 18, Helsinki; 19, Birmingham; 20, Caracas; 21, Chicago; 22, Manila; 23, Lisbon; 24, Accra; 25, Bucharest; 26, Rio de Janeiro; 27, Zagreb; 28, Kuala Lumpur; 29, Bombay; 30, Bangkok; 31, Illigan City; 32, Guangzhou; 33, Shanghai; 34, Jakarta; 35, Tehran; 36, Calcutta; 37, Beijing; 38, New Delhi; 39, Xi’an; 40, Shenyang; 41, Kuwait City; (b) The range of annual averages of sulfur dioxide concentrations measured at multiple sites within 54 cities, 1980–1984. Each numbered bar represents a city, as follows: 1, Craiova; 2, Melbourne; 3, Auckland; 4, Cali; 5, Tel Aviv; 6, Bucharest; 7, Vancouver; 8, Toronto; 9, Bangkok; 10, Chicago; 11, Houston; 12, Kuala Lumpur; 13, Munich; 14, Helsinki; 15, Lisbon; 16, Sydney; 17, Christchurch; 18, Bombay; 19, Copenhagen; 20, Amsterdam; 21, Hamilton; 22, Osaka; 23, Caracas; 24, Tokyo; 25, Wroclaw; 26, Athens; 27, Warsaw; 28, New Delhi; 29, Montreal; 30, Medellin; 31, St Louis; 32, Dublin; 33, Hong Kong; 34, Shanghai; 35, New York; 36, London; 37, Calcutta; 38, Brussels; 39, Santiago; 40, Zagreb; 41, Frankfurt; 42, Glasgow; 43, Guangzhou; 44, Manila; 45, Madrid; 46, Beijing; 47, Paris; 48, Xi’an; 49, São Paulo; 50, Rio de Janeiro; 51, Seoul; 52, Tehran; 53, Shenyang; 54, Milan. (Source: Graedel and Crutzen, 1993.)

Figure 7.13 Trends in atmospheric quality in the UK: (a) sulfur dioxide emissions from coal combustion and average urban concentrations; (b) smoke emissions from coal combustion and average urban concentrations of oil smoke; (c) increase in winter sunshine (10-year moving average) for London and Edinburgh city centers and for Kew, outer London; (d) annual fog frequency at 0900 GMT in Oxford, central England, 1926–80 (after Department of the Environment data, and Gomez and Smith, 1984, figure 3).

Figure 7.14 (a) Schematic presentation of a typical development of urban air pollution levels (after Fenger, 1999, figure 3): WHO – World Health Organization. (b) Lead concentration (annual means) in air at UK sites (Kirby, 1995, figure 1). (c) Annual average values for the total Danish lead emissions 1969–1993, the lead pollution in Copenhagen since 1976, and the average lead content in petrol sold in Denmark (Jensen and Fenger, 1994). The dates of tightening of restrictions on lead content are indicated with bars. Lead concentrations for the recent years can be found in Kemp et al. (1998). (Source: Feng, 1999, figure 12.)

Figure 7.15 Possible reactions involving primary and secondary pollutants (after Haagen-Smit, in Bryson and Kutzbach, 1968, figure 4. Reprinted by permission of the Association of American Geographers).

Figure 7.16 Air pollution in the Los Angeles area, 1970s to 1990s (after Lents and Kelly, 1993, p. 22).

Figure 7.17 Trends in atmospheric quality. (a) Lead content of the Greenland ice-cap due to atmospheric fallout of the mineral lead, or the snow surface. A dramatic upturn in worldwide atmospheric levels of lead occurred at the beginning of the industrial revolution in the nineteenth century and again after the more recent spread of the automobile (after Murozumi et al., 1969, p. 1247). (b) The sulfate concentration on a sea-salt-free basis in northwest Greenland glacier ice samples as a function of year. The curve represents the world production of thermal energy from coal, lignite, and crude oil (modified after Koide and Goldberg, 1971, figure 1). (c) Lead concentrations in Greenland snow (after Boutron et al., 1991. Reprinted with permission from Nature. Copyright 1991. Macmillan Magazines Limited).

Figure 7.18 Isopleths showing average pH for precipitation in North America. Note the low values for eastern North America and the relatively higher values to the west of the Mississippi. (Combined from Likens et al., 1979 and Graedel and Crutzen, 1993, with modifications.)

Figure 7.19 Global SO2 emissions from anthropogenic sources, including the burning of coal, lignite, and oil, and copper smelting.

Figure 7.20 Annual mean concentration of sulfate in precipitation in Europe (mg S L−1) (after Wallen in Holdgate et al., 1982, figure 2.3).

Figure 7.21 Pathways and effects of acid precipitation through different components of the ecosystem, showing some of the adverse and beneficial consequences.

Figure 7.22 (a) Trends in sulfate emissions in Europe 1880–1990, based on data in Mylona (1996). (b) Estimates of historical total global sulfur dioxide (TgS) emissions from anthropogenic sources. From Smith et al. (2001, figure 1) with modifications.

Figure 7.23 World production of major chlorofluorocarbons (t year−1). World production of the three major CFCs peaked in about 1988 and has since declined to very low values.

Figure 7.24 In the 1980s ground observations and satellite monitoring of atmospheric ozone levels indicated that a ‘hole’ had developed in the stratospheric ozone layer above Antarctica. These Nimbus satellite images show the ozone concentrations (in Dobson units) for the month of October between 1984 and 1988. Source: NASA.
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Figure 9.7 Total subsidence (in cm), 1978–87 (left) and ground elevation of Bangkok, 1987 (right). (Modified from Nutalaya et al., 1996, figures 3 and 9.)

Figure 9.6 Examples of hot spots that are especially sensitive to sea-level change. They may, therefore, be a consequence of changes in: (a) the rate of uplift (e.g. mountain building); (b) the rate of subsidence; (c) sea level. (Modified from Bird, 1993, figure 45.)

Figure 9.5 Sea-level changes are also the result of the re-equilibration of the ocean basins. Initially, all basins were at sea level. If the land regrows, the basins will be reoccupied by the ocean. This process may be short term, such as the opening of a new ocean basin, or long term, such as the gradual change from one ocean plate to another.

Figure 9.4 The changes in sea level reflect the changes in the volume of the ocean basins. The changes in the volume of the ocean basins are a function of the changes in the volume of the earth's crust. The changes in the volume of the earth's crust are a function of the changes in the volume of the earth's mantle. The changes in the volume of the earth's mantle are a function of the changes in the volume of the earth's core. The changes in the volume of the earth's core are a function of the changes in the volume of the earth's atmosphere. The changes in the volume of the earth's atmosphere are a function of the changes in the volume of the earth's biosphere.

Figure 9.3 The effects of global warming on the glacial cycle are complex and depend on a number of factors, including: (a) the rate of warming, (b) the extent of the warming, (c) the distribution of the warming, (d) the duration of the warming, (e) the seasonality of the warming, (f) the scale of the warming, (g) the nature of the warming, (h) the timing of the warming, (i) the spatial pattern of the warming, (j) the temporal pattern of the warming.

Figure 9.2 The glacial cycle is characterized by a series of events, including: (a) the initiation of plate tectonics, (b) the formation of the ocean basins, (c) the formation of the continents, (d) the formation of the atmosphere, (e) the formation of the biosphere, (f) the formation of the hydrosphere, (g) the formation of the cryosphere, (h) the formation of the geosphere, (i) the formation of the lithosphere, (j) the formation of the mantle, (k) the formation of the core, (l) the formation of the crust, (m) the formation of the mantle, (n) the formation of the lithosphere, (o) the formation of the crust, (p) the formation of the mantle, (q) the formation of the lithosphere, (r) the formation of the crust, (s) the formation of the mantle, (t) the formation of the lithosphere, (u) the formation of the crust, (v) the formation of the mantle, (w) the formation of the lithosphere, (x) the formation of the crust, (y) the formation of the mantle, (z) the formation of the lithosphere.
Figure 9.8 Sea-level rise and coastline changes. The Bruun Rule states that a sea-level rise will lead to erosion of the beach and removal of a volume of sand (\(V_r\)) seaward to be deposited (\(V_d\)) in such a way as to restore the initial transverse profile landward of \(D\), the outer boundary of nearshore sand deposits. The coastline will retreat (\(R\)) until stability is restored after the sea-level rise comes to an end. The coastline thus recedes further than it would if submergence were not accompanied by erosion.

Figure 9.9 Overwash: natural response of undeveloped barrier islands to sea-level rise. (Source: Titus, 1990, figure 2.)

Figure 10.1 (a) The present frequency of cyclones crossing 500-km-long sections of the Australian coast, and an estimate of the frequency under conditions with a 2°C rise in temperature. (b) The area where July and August mean sea-surface temperatures around Australia are currently greater than 27°C (stippled) and the additional area with such temperatures with a 2°C rise in temperature (hatched) (modified after Gell, 1999, figures 1 and 2.)

Figure 10.2 (a) Scatter diagram of monthly mean sea-surface temperature and best-track maximum wind speeds (after removing storm motion) for a sample of North Atlantic tropical cyclones. The line indicates the 99th percentile and provides an empirical upper bound on intensity as a function of ocean temperature. (b) The derived relationship between sea-surface temperature and potential intensity of tropical cyclones. (Source: Holland et al., 1988, figures 5 and 6.)

Figure 10.3 Monthly runoff by the 2050s under two scenarios for six British catchments (modified from Arnell and Reynard, 2000, figure 7.19).

Figure 10.4 Effect of a climate change scenario on streamflow in two European snow-affected catchments by the 2050s (modified from Arnell, 2002, figure 7.20).

Figure 10.5 The Zambezi River at Victoria Falls.

Figure 10.6 Conceptual model of the impacts of effective precipitation, air temperature, and atmospheric CO₂ concentration on karst dissolution, hydrology, and other geomorphic processes. (Source: Viles, 2003, figure 1.)

Figure 10.7 Decadal means of the freeze–thaw cycles in central England. (Source: Brimblecombe and Camuffo, 2003, figure 3.)

Figure 10.8 Sea-level rise and coastline changes. The Bruun Rule states that a sea-level rise will lead to erosion of the beach and removal of a volume of sand (\(V_r\)) seaward to be deposited (\(V_d\)) in such a way as to restore the initial transverse profile landward of \(D\), the outer boundary of nearshore sand deposits. The coastline will retreat (\(R\)) until stability is restored after the sea-level rise comes to an end. The coastline thus recedes further than it would if submergence were not accompanied by erosion.

Figure 10.9 Overwash: natural response of undeveloped barrier islands to sea-level rise. (Source: Titus, 1990, figure 2.)

Figure 10.10 (a) The distribution of the main permafrost types in the Northern Hemisphere. (b) Vertical distribution of permafrost and active zones in longitudinal transects through (i) Eurasia and (ii) northern America.

Figure 10.11 Cross-section of an ice stream and ice shelf of a marine ice sheet, indicating location of grounding line, bedrock rise on the ocean floor, and possible extent of deformable till. The thickness of the till layer, actually a few meters, is exaggerated for clarity. Sea-level rise due to collapse of the West Antarctic Ice Sheet (WAIS) was estimated by T. Hughes. (Source: Oppenheimer, 1998, figure 2, p. 327 in *Nature*, volume 393, 28 May 1998 © Macmillan Publishers Ltd 1998.)

Figure 10.12 (a) Generalized curve of ablation and accumulation in relation to surface temperature. In warmer areas, such as Greenland, an increase in temperature may lead to rapid increases in ablation. (b) Generalized curve of the mass balance of ice sheets in relation to surface temperature. In the very cold environment of Antarctica, an increase in temperature may lead to increased accumulation of snow and ice and hence to a positive mass balance, whereas in the warmer environment of Greenland, increased rates of ablation may lead to a negative mass balance. (Source: Oerlemans, 1993, figure 9.4.)

Figure 10.13 The Minapin Glacier snout in the Karakoram Mountains of Hunza, Pakistan. Behind the cultivated fields in the middle distance is a mass of moraine, which was deposited by the glacier in the Little Ice Age. The glacier has now retreated up its valley.

Figure 10.14 Cumulative mass balance for the Alps (top left), Scandinavia (top right), and western North America (bottom).

Figure 10.15 Changes in glacier volume 1980–2100 as modeled by Oerlemans et al. (1998) for 12 glaciers: Franz Josef Glacier (New Zealand), Glacier d'Argentière (France), Haut Glacier d’Arolla (Switzerland), Hintereisferner (Austria), Nigardsbreen (Norway), Pastorze (Austria), Rhonegletscher (Switzerland), Storglaciären (Sweden), Un. Grindelwaldgl., (Switzerland), Blondujökull (Iceland), Illulijajökull (Iceland), ice cap (Antarctica). (a) Ice-volume change with a warming rate of 0.02 K year⁻¹ without a change in precipitation. Volume is normalized with the 1990 volume. (b) Scaled ice-volume change for six climate change scenarios: + refers to an increase in precipitation of 10% per degree warming.
Figure 11.9 Permafrost in Siberia. The great quantity of ice in the permafrost is illustrated behind the figure standing in the foreground (photographed by the late Marjorie Sweeting).

Figure 11.10 Projection of changes in permafrost with global warming for (a) North America and (b) Siberia (after French, 1996, figure 17.5 and Anisimov, 1989).

Figure 11.11 Ground settlement in response to a thickening of the active layer in permafrost with an excess ice content of 50%. The active layer increases from 1.0 to 1.5 m and in so doing 1.0 m of permafrost is thawed and the surface settles by 0.5 m. (Source: Woo et al., 1992, figure 8.)

Figure 12.1 The flooding of Lake Eyre. (a) Extent of flooding in 1949–1952 (after Bonython and Mason in Mabbutt, 1977, figure 54). (b) Estimated annual inflows to Lake Eyre North for the period 1885–1989 (based on Kotwicki and Isdale, 1991, figure 2). Both 1949–1952 and 1974 were strong La Niña events. (Source: Viles and Goudie, Earth-science Reviews, 2003, volume 61: 105–131.)

Figure 12.2 Variation of sediment yield with climate as based on data from small watersheds in the USA (after Langbein and Schumm, 1958).

Figure 12.3 Relation between drainage density and mean annual precipitation. (After Gregory, 1976. Copyright © 1976. Reprinted by permission of John Wiley and Sons, Ltd.)

Figure 12.4 The potential responses of desert environments to increases of carbon dioxide in the atmosphere.

Figure 12.5 Comparison between two ‘Dust Bowl years’ (1934 and 1936) and the Geophysical Fluid Dynamic Laboratory (GFDL) model prediction for a × 2 CO₂ situation for the Great Plains (Kansas and Nebraska) (modified from Smith and Tirpak, 1990, figure 7.3).

Figure 12.6 The influence of decreased precipitation and increased temperatures on eolian activity.

Figure 12.7 Summary of dune field activity and associated loess deposition for the Great Plains, USA. The terrestrial eolian record is also compared with the eolian input record from Lake Ann and Elk Lake, Minnesota. Note that there is evidence for sustained aridity between 10,000 and 5000 years ago and numerous discrete events in the past 2000 years. Length of solid bar reflects duration of eolian events and inferred dating errors. (Source: S. L. Forman et al., 2001, figure 13.)

Figure 12.8 Dune mobility for stations across the Canadian Prairies for the 1988 drought year. Black dots represent values for 1961–1990 normals. Dune activity classes of Mubs and Holliday (1995) are also shown: (1) fully active; (2) largely active; (3) largely inactive. The names of the localities are Brandon (Ba), Broadview (Bv), Calgary (Ca), Coronation (Co), Estevan (Es), Lebbridge (L), Mayberries (Ma), Medicine Hat (MH), Moose Jaw (MJ), North Battleford (NB), Outlook (O), Red Deer (RD), Regina (R), Saskatoon (SK), Suffield (SU), Swift Current (SC), Yorkton (Y). Shaded stations are from drier, subhumid locations. (Source: Wolfe, 1997, figure 8.)

Figure 12.9 Land rotation and population density. The relationship of soil fertility cycles to cycles of slash-and-burn agriculture: (a) fertility levels are maintained under the long cycles characteristic of low-density populations; (b) fertility levels are declining under the shorter cycles characteristic of increasing population density. Notice that in both diagrams the curves of both depletion and recovery have the same slope (after Haggett, 1979, figure 8.4).

Figure 12.10 The impact of recreation pressures is well displayed at a prehistoric hill-fort, Badbury Rings, Dorset, England. Pedestrians and motorcyclists have caused severe erosion of the ramparts.

Figure 12.11 Some causes of anthropogenic stress on coral reef ecosystems.