Gully development is normally associated with river activity. However, there are different reasons for their development:

- Some are related to increased discharge due to climate change.
- Others are caused by the removal of vegetation by people exposing the surface to accelerated rates of erosion.
- Some develop where concrete structures have been built to improve runoff.
- Tectonic disturbances can initiate gully development, especially uplift.
- Catastrophic flooding may be responsible for some gully development.

10.3 Soils and vegetation

An ecosystem is the interrelationship between plants and animals and their living and non-living environments. A biome is a global ecosystem, such as the tropical rainforest, savanna or hot desert ecosystem.

Deserts have low rates of biomass productivity – on average, net primary productivity of 90 g/m²/year. This is due to the limited amount of organic matter caused by extremes of heat and lack of moisture. Productivity can generally be positively correlated with water availability. Despite the diversity of life forms found in deserts, desert flora and fauna are relatively species poor. At the continental scale, species diversity of lizards and rodents has been correlated with increasing precipitation. Desert vegetation is simple in that its structure is poorly developed and its cover becomes increasingly open and discontinuous with increasing aridity. Given the extreme conditions, it is not surprising that the biodiversity is limited.

Energy flow in deserts is controlled by water, which can be very irregular. The impact of herbivores in deserts is similar to that in other ecosystems, with about 2–10 per cent of the primary production being directly consumed. Some studies have indicated that 90 per cent or more of seed production may be eaten by seed-eaters such as ants and rodents. Energy flow in hot deserts is less than in semi-arid areas due to the lack of rainfall, and less biomass.

Owing to the low and irregular rainfall, inputs to the nutrient cycle (dissolved in rain and as a result of chemical weathering) are low (Figure 10.15). Most of the nutrients are stored in the soil, and there are very limited stores in the biomass and litter. This is due to the limited amount of biomass and litter in the desert environment. In some deserts, nutrient deficiency (especially of nitrogen and/or phosphorus) may become critical. The rapid growth of annuals following a rain event rapidly depletes the store of available nutrients, while their return in decomposition is relatively slow. Desert ecosystems are characterised by smaller stores of nutrients in the soil (due to low rates of chemical weathering), and low amounts of nutrients in

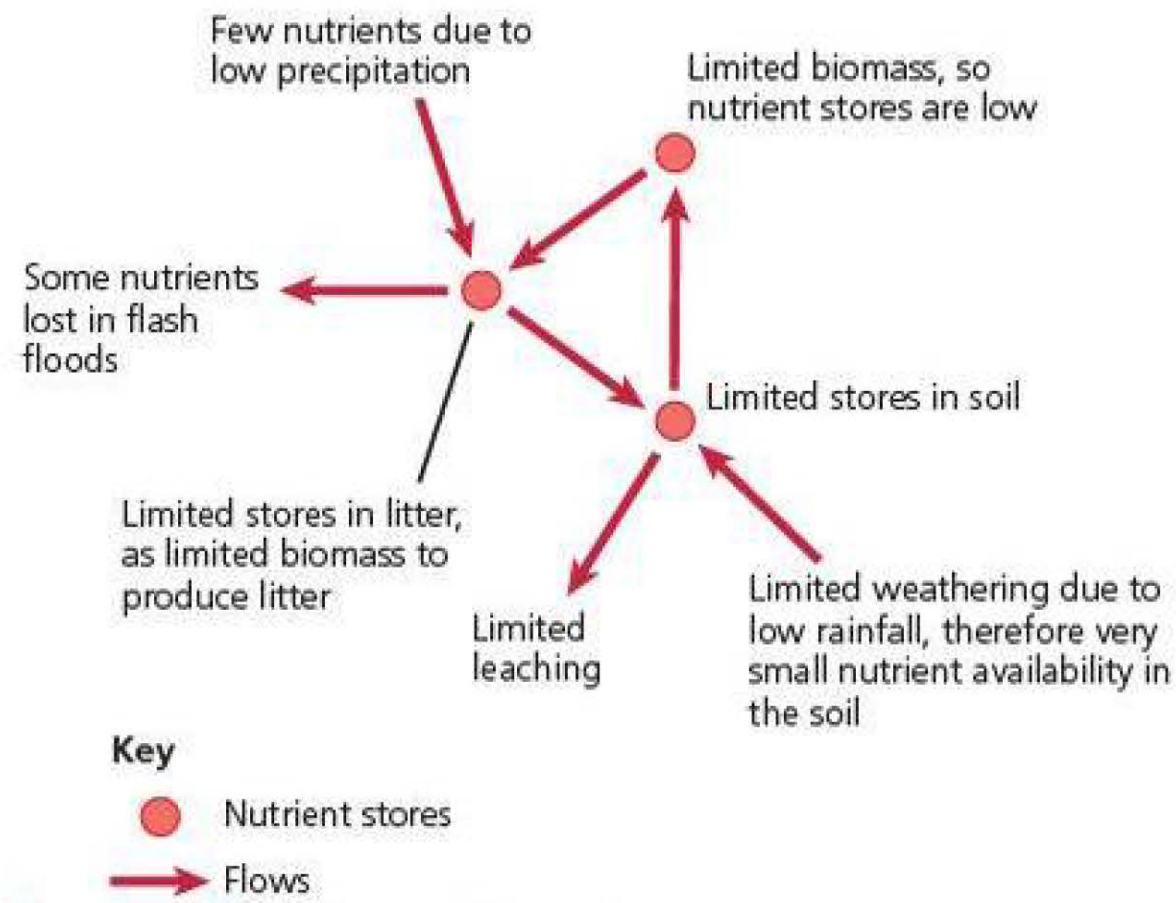

Figure 10.15 Nutrient cycle in a desert

the biomass, due to the dry conditions. In semi-arid areas the amount of nutrients available increases with rainfall and chemical weathering.

Decomposition, like growth, is slow. Microbial decomposers are limited. Two important processes are involved in nutrient cycling:

- the fragmentation, erosion and transport of dead organic matter (DOM) by wind and runoff
- consumption of DOM by detritivores such as termites, ants and mites, which are relatively abundant in deserts.

In the absence of leaching, nutrients may accumulate in the upper layers of the soil. A large proportion of the nutrients is held either in young tissue or in the fertile islands surrounding large plants where, as a result of slightly lower temperatures and higher humidity, decomposition is lower and DOM accumulates.

Desert ecosystems are sometimes considered to be fragile, due to the extreme climatic conditions and the relative lack of biodiversity. Nevertheless, despite the extreme short-term variability of the desert environment, the desert ecosystem is considered, in the long term, to be both stable and resilient. This is due to the adaptations of desert organisms to survive water stress – in some cases for years. The hogweed (*Boerhavia repens*) plant in the Sahara takes just 8–10 days from seed germination to seed production. It therefore produces seeds before the water runs out, and flowers at a time when insect pollinators are abundant. Desert ecosystems may appear fragile, but in fact they are very resilient.

Plant and animal adaptations

Desert vegetation is generally ephemeral (it appears or flowers after rain). Some desert vegetation has a very short life cycle, some less than eight weeks. Vegetation is generally shallow-rooted, small in size and with small leaves. In contrast, vegetation in semi-arid areas is succulent (able to store water), and more vegetation is located near to water sources.

Desert plants and animals have acquired similar morphological, physiological and behavioural strategies that, although not unique to desert organisms, are often more highly developed and effectively utilised than their moist counterparts.

The two main strategies are avoidance and tolerance of heat and water stress (Table 10.5). The *evaders* comprise the majority of the flora of most deserts. They can survive periods of stress in an inactive state or by living permanently or temporarily in cooler and/or moister environments, such as below shrubs or stone, in rock fissures or below ground. Of desert animals, about 75 per cent are subterranean, nocturnal or active when the surface is wet. In such ways, plants and animals can control their temperature and water loss.

Section 10.3 Activities

1 Describe the typical nutrient cycle of a desert as shown in Figure 10.15.
2 Explain why deserts have low values for NPP (net primary productivity).

Table 10.5 Adaptations of plants and animals to hot desert environments

Strategy	Plants	Animals
Stress-evading strategies		
	Inactivity of whole plants Cryptobiosis* of whole plant Dormancy of seeds	Dormancy in time (diurnal and seasonal) and space (take refuge in burrows) Cryptobiosis of mature animals (aestivation of snails, hibernation) Cryptobiosis of eggs, shelled embryos, larvae: permanent habitation or temporary use of stress-protected microhabitats
Structural and physiological stress-controlling strategies		
Strategies reducing water expenditure	Small surface : volume ratio Regulation of water loss by stomatal movements Xeromorphic features Postural adjustments	Small surface : volume ratio Regulation and restriction of water loss by concentrated urine, dry faeces, reduction of urine flow rate Structures reducing water Postural adjustment
Strategies to prevent death by overheating	Transpiration cooling High heat tolerance Mechanisms decreasing and/or dissipating heat load	Evaporative cooling High heat tolerance Mechanisms decreasing and/or dissipating heat load
Strategies optimising water uptake	Direct uptake of dew, condensed fog and water vapour Fast formation of water roots after first rain Halophytes: uptake of saline water, high salt tolerance, salt-excreting glands	Direct and indirect uptake of dew, condensed fog and water vapour (e.g. arthropods, water enrichment of stored food) Fast drinking of large quantities of water (large mammals), uptake of water from wet soil (e.g. snails) Uptake of highly saline water, high salt tolerance, salt-excreting glands
Strategies to control reproduction in relation to environmental conditions	'Water clocks' of seed dispersal and germination Suppression of flowering and sprouting in extreme years	Sexual maturity, mating and birth synchronised with favourable conditions Sterility in extreme drought years
* Cryptobiosis: an ametabolic state of life in response to adverse environmental stress; when the environment becomes hospitable again, the organism returns to its metabolic state.		

Temperature adaptations

Desert plants and animals are able to function at higher temperatures than their mesis (moist environment) counterparts. Some cacti such as the prickly pear can survive up to 65 °C, while crustose lichens can survive up to 70 °C. The upper lethal levels for animals are lower, although arthropods, particularly beetles and scorpions, can tolerate 50 °C. Plants and animals are able to modify the heat of the desert environment in a number of ways:

- Changing the orientation of the whole body enables the organism to minimise the areas and/or time they are exposed to maximum heat – many gazelle, for example, are long and thin.
- Light colours maximise reflection of solar radiation.
- Surface growth (spines and hairs) can absorb or reflect heat, which **a** keeps the undersurface cooler and **b** creates an effective boundary layer of air, which insulates the underlying surface.
- Body size is especially important in controlling the amount of heat loss – evaporation and metabolism

are proportional to the surface area of the plant or animal. The smaller the organism, the larger the surface area to volume ratio and the greater the heat loss.

- Large desert animals such as the camel and the oryx can control heating by means of evaporative cooling. Cooling by transpiration is also thought to be most effective in cacti and small-leaved desert shrubs because of their surface-area-to-volume ratio.

Water loss

Physical droughts refer to water shortages over an extended period of time. **Physiological drought** occurs when drought conditions are experienced by plants despite there being sufficient soil moisture. In hot arid areas, this is associated with high rates of evapotranspiration. To reduce water loss, desert plants and animals have many adaptations. Again, a small surface-area-to-volume ratio is an advantage (Figure 10.16b). Water regulation by plants can be controlled by diurnal closure of stomata, and xerophytic plants have a mix of thick, waxy cuticles, sunken stomata and leaf hairs (Figure 10.16e). The most drought-resistant plants are the **succulents**, including cacti, which possess well-developed storage tissues (Figure 10.16a); small surface-to-volume ratios and rapid stomatal closure especially during the daytime; deep tap roots (Figure 10.16b and 10.16c); and very small leaves (Figure 10.16d).

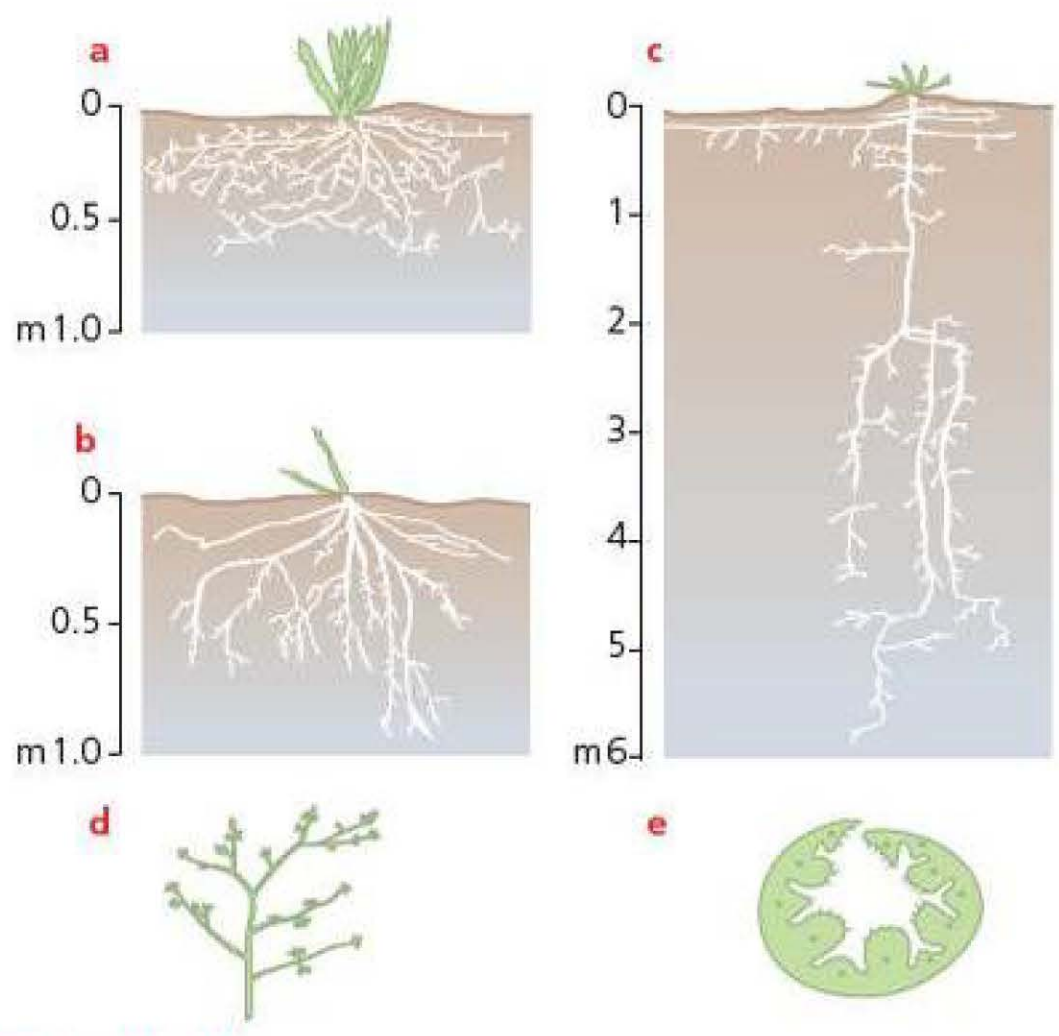

Figure 10.16 Plant adaptations to drought

Some plants and many arthropods are drought-resistant. The creosote bush can survive up to a year without rain. Rapid uptake of water is also a characteristic of many desert organisms, including lichen, algae and camels. Animals can rapidly imbibe, and salt-tolerant plants have a high cell osmotic pressure that allows the efficient uptake of alkaline water. The roots of many desert plants can exert a greater suction pressure so they can extract water from fine water-retentive soils.

Reproduction

Desert survival is also dependent on an organism's ability to reproduce itself. Desert fauna and flora have developed several different strategies. High seed production and efficient dispersal are more essential than in humid environments. Some seeds have built-in 'water clocks' and will not germinate until a certain amount of water becomes available. Some arid-zone shrubs, such as the ironwood and the smokewood, have seeds with coats so tough that germination can only take place after severe mechanical abrasion during torrential flash floods. In both plants and animals, reproduction is suppressed during periods of drought.

Desert soils

Desert soils, called **aridisols**, have a low organic content and are only affected by limited amounts of leaching. Soluble salts tend to accumulate in the soil either near the water table or around the depth of moisture percolation. As precipitation declines, this horizon occurs nearer to the surface. Desert soils also have a limited clay content. In semi-arid areas, there is a deeper soil, more chemical weathering and more biomass in the soil, due to the higher rainfall.

The accumulation of salt in desert soils is important. Salt concentrations may be toxic to plants. This is more likely in areas where there is a high water table or in the vicinity of salt lakes. Soils with a saline horizon of NaCl (sodium chloride) are called **solonchaks** and those with a horizon of Na_2CO_3 (sodium carbonate) are termed **solonetz**. Solonchaks are white alkali soils, whereas solonetz are black alkali soils. A high concentration of salt can cause the breakdown of soil structure, increase water stress and affect the health of plants.

Sometimes the concentration of salts becomes so great that crusts are formed on the surface or sub-surface. There are different types of hard crust (duricrusts). Calcrete or caliche is formed of calcium carbonate and is the most common crust in warm desert environments. It can be up to 40 metres, comprising boulders, gravels, silt and calcareous materials. It predominates in areas of between 200 and 500 millimetres.

Silcrete is a crust cemented by silica. It may produce an impermeable hard pan in a soil. Silcretes are found in areas that have more than 50 millimetres but less than 200 millimetres of rain, such as southern Africa and Australia.

Section 10.3 Activities

1 Describe the ways in which plants have adapted to drought, as shown in Figure 10.16.
2 Describe and explain the main characteristics of desert soils.

Case Study: Salinisation in Pakistan

Irrigation has been practised in Pakistan since at least the eighth century CE. Much of the irrigation takes place along the Indus and Punjab rivers. The irrigation system here is among one of the most complex in the world, and provides Pakistan with most of its food and commercial crops, such as wheat, cotton, rice, oil seed, sugar cane and tobacco. Hence the health of the irrigated area is essential to the health of the national economy.

Many of the drainage canals are in a poor state. Many are unlined and seepage is a major problem. Consequently, there has been a steady rise in the water table, which has caused widespread waterlogging and **salinisation**. Up to 40 000 hectares of irrigated land are lost annually.

There have been attempts to rectify the problem. Two main methods are used: pumping water from aquifers (to reduce the water table) and vertical and horizontal drainage of saline water. These have met with some success. In parts of the lower Indus plain, water tables have been reduced by as much as 7 metres, and up to 45 per cent of saline soils have been reclaimed. However, the use of reclaimed land for agriculture only results in salinisation again.

Desertification

Desertification is defined as land degradation in humid and semi-arid areas; that is, not including non-desert (arid) areas. It involves the loss of biological and economic productivity and it occurs where climatic variability (especially rainfall) coincides with unsustainable human activities (Figure 10.17). For example, if the surface cover is removed and the surface colour becomes lighter, its reflectivity (albedo) changes. It reflects more heat, absorbs less, and so there will be less convectional heating, less rain and possibly more drought. Desertification occurs in discontinuous and isolated patches – it is not the general extension of deserts as a consequence of natural events like prolonged droughts, as in China in the 2000s.

Desertification leads to a reduction in vegetation cover and accelerated soil erosion by wind and water, lowering the carrying capacity of the area affected. Desertification is one of the major environmental issues in the world today. At present, 25 per cent of the global land territory and nearly 16 per cent of the world's population are threatened by desertification.

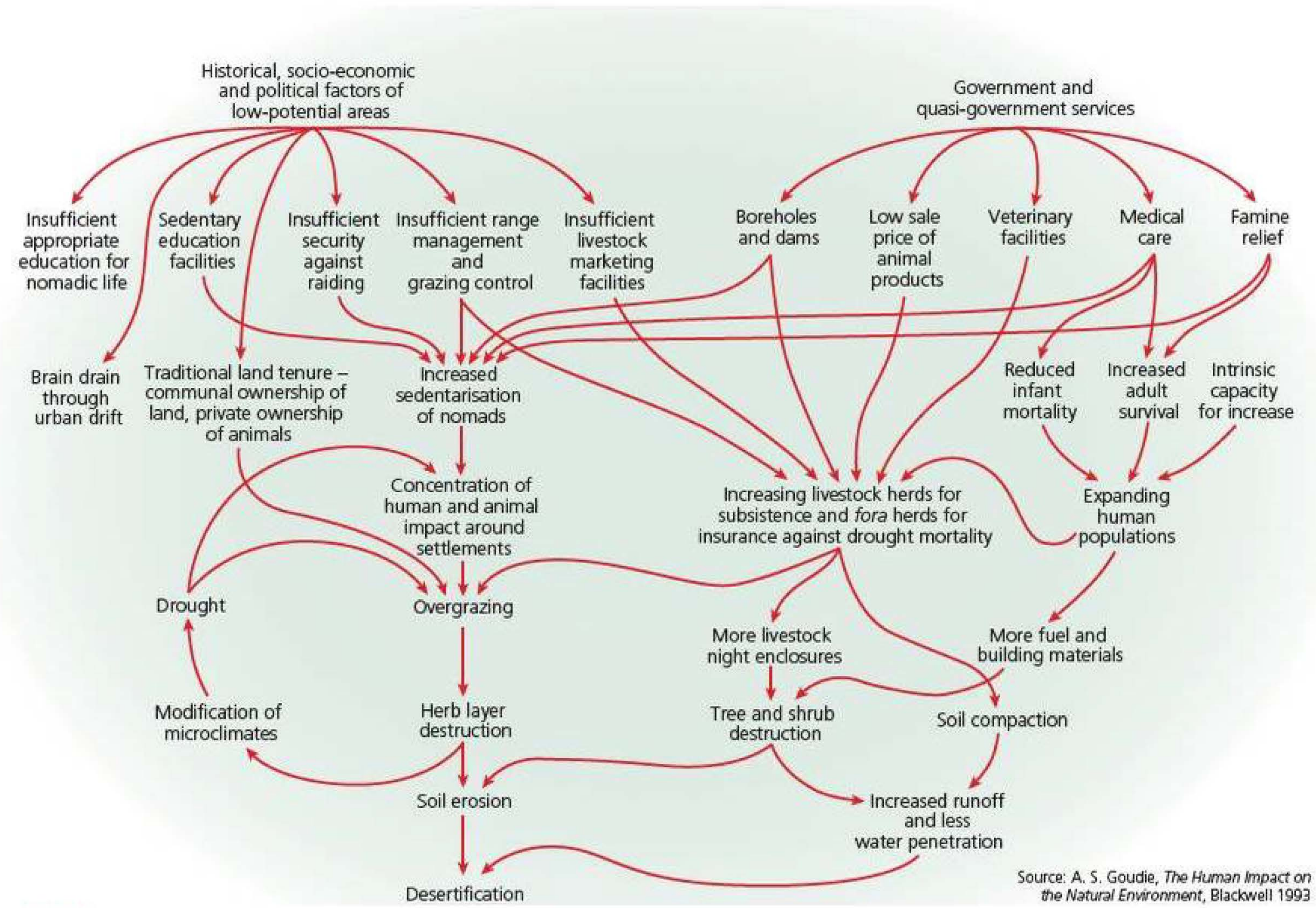

Figure 10.17 A model of desertification

Causes of desertification

Desertification can be a natural process intensified by human activities. All the areas affected by desertification are marginal and characterised by highly variable rainfall. An exception to this are the parts of the rainforest desertified following inappropriate farming techniques.

Natural causes of desertification include temporary drought periods of high magnitude and long-term climate change towards aridity. Many people believe that it is a combination of increasing animal and human population numbers, which causes the effects of drought to become more severe. Desertification occurs when already fragile land in arid and semi-arid areas is over-exploited. This overuse can be caused by overgrazing, when pastoralists allow too many animals to graze on a fixed area of land; overcultivation, where the growing of crops exhausts soil nutrients; and deforestation, when too few trees are left standing after use as firewood, to act as windbreaks or to prevent soil erosion.

- **Overgrazing** is the major cause of desertification worldwide. Vegetation is lost both in the grazing itself and in being trampled by large numbers of livestock. Overgrazed lands then become more vulnerable to erosion as compaction of the soils reduces infiltration, leading to greater runoff, while trampling increases wind erosion. Fencing, which confines animals to specific locations, and the provision of water points and wells, have led to severe localised overgrazing. Boreholes and wells also lower the water table, causing soil salinisation.
- **Overcultivation** leads to diminishing returns, where the yield decreases season by season, requiring an expansion of the areas to be cultivated simply to maintain the same return on the agricultural investment. Reducing fallow periods and introducing irrigation are also used to maintain output, but all these contribute to further **soil degradation** and erosion by lowering soil fertility and promoting salinisation.
- **Deforestation** is most obvious where land has been cleared to extend the area under cultivation and in the surrounds of urban areas where trees are stripped for firewood. The loss of vegetation cover increases rainsplash erosion, and the absence of root systems allows easy removal of the soil by wind and water.

Other factors are involved, including the following:

- The mobility of some people has been limited by governments, especially where their migratory routes crossed international boundaries. Attempts to provide permanent settlements have led to the concentration of population and animals, with undesirable consequences.
- Weak or non-existent laws have failed to provide environmental protection for marginal land by preventing or controlling its use.
- Irrational use of water resources has caused water shortages or salinisation of soil.
- International trade has promoted short-term exploitation of land by encouraging cash crops for export. This has disrupted local markets and created a shortage of staple foods.
- Civil strife and war diverts resources away from environmental issues.
- Ignorance of the consequences of some human actions, and the use of inappropriate techniques and equipment, have contributed to the problem.

Consequences of desertification

There are some serious consequences of desertification (Table 10.6).

Table 10.6 Consequences of desertification

Environmental	Economic	Social and cultural
• Loss of soil nutrients through wind and water erosion • Changes in composition of vegetation and loss of biodiversity as vegetation is removed • Reduction in land available for cropping and pasture • Increased sedimentation of streams because of soil erosion and sediment accumulations in reservoirs • Expansion of area under sand dunes	• Reduced income from traditional economy (pastoralism and cultivation of food crops) • Decreased availability of fuelwood, necessitating purchase of oil/kerosene • Increased dependence on food aid • Increased rural poverty	• Loss of traditional knowledge and skills • Forced migration due to food scarcity • Social tensions in reception areas for migrants

Combating desertification

There are many ways of combating desertification, which depend on the perceived causes (Table 10.7).

Table 10.7 The strategies for preventing desertification, and their disadvantages

Cause of desertification	Strategies for prevention	Problems and drawbacks
Overgrazing	• Improved stock quality: through vaccination programmes and the introduction of better breeds, yields of meat, wool and milk can be increased without increasing the herd size. • Better management: reducing herd sizes and grazing over wider areas would both reduce soil damage.	• Vaccination programmes improve survival rates, leading to bigger herds. • Population pressure often prevents these measures.
Overcultivation	• Use of fertilisers: these can double yields of grain crops, reducing the need to open up new land for farming. • New or improved crops: many new crops or new varieties of traditional crops with high-yielding and drought-resistant qualities could be introduced. • Improved farming methods: use of crop rotation, irrigation and grain storage can all increase and reduce pressure on land.	• Cost to farmers. • Artificial fertilisers may damage the soil. • Some crops need expensive fertiliser. • Risk of crop failure. • Some methods require expensive technology and special skills.
Deforestation	• Agroforestry: combines agriculture with forestry, allowing the farmer to continue cropping while using trees for fodder, fuel and building timber. Trees protect, shade and fertilise the soil. • Social forestry: village-based tree-planting schemes involve all members of a community. • Alternative fuels: oil, gas and kerosene can be substituted for wood as sources of fuel.	• Long growth time before benefits of trees are realised. • Expensive irrigation and maintenance may be needed. • Expensive. Special equipment may be needed.

Section 10.3 Activities

1 Suggest a definition for the term *desertification*.
2 Outline the main natural causes of desertification.
3 Briefly explain two examples of desertification caused by people.
4 Comment on the effects of desertification.
5 To what extent is it possible to manage desertification?

Case Study: Desertification in China

Parts of China are among the most seriously desertified areas in the world. More than 27 per cent, or 2.5 million km², of the country comprises desert (whereas just 7 per cent of Chinese land feeds about a quarter of the world's population). China's phenomenal economic growth over the last ten years has been at a serious environmental cost. According to the China State Forestry Administration, the desert areas are still expanding by between 2460 and 10400 km² per year. Up to 400 million people are at risk of desertification in China – the affected area could cover as much as 3.317 million km² or 34.6 per cent of the total land area. Much of it is happening on the edge of the settled area – which suggests that human activities are largely to blame.

Causes of desertification

Desertification is widely distributed in the arid, semi-arid and dry sub-humid areas of north-west and northern China and western parts of the north-east of the country (Figure 10.18). Much of the country is affected by a semi-permanent high-pressure belt, which causes aridity. In addition, continental areas experience intensive thunderstorms, which can cause accelerated soil erosion. Drought plagues large parts of northern China. In addition to dry weather, human activities such as livestock overgrazing, cultivation of steep slopes, rampant logging and excessive cutting of branches for firewood are at the root of the crisis.

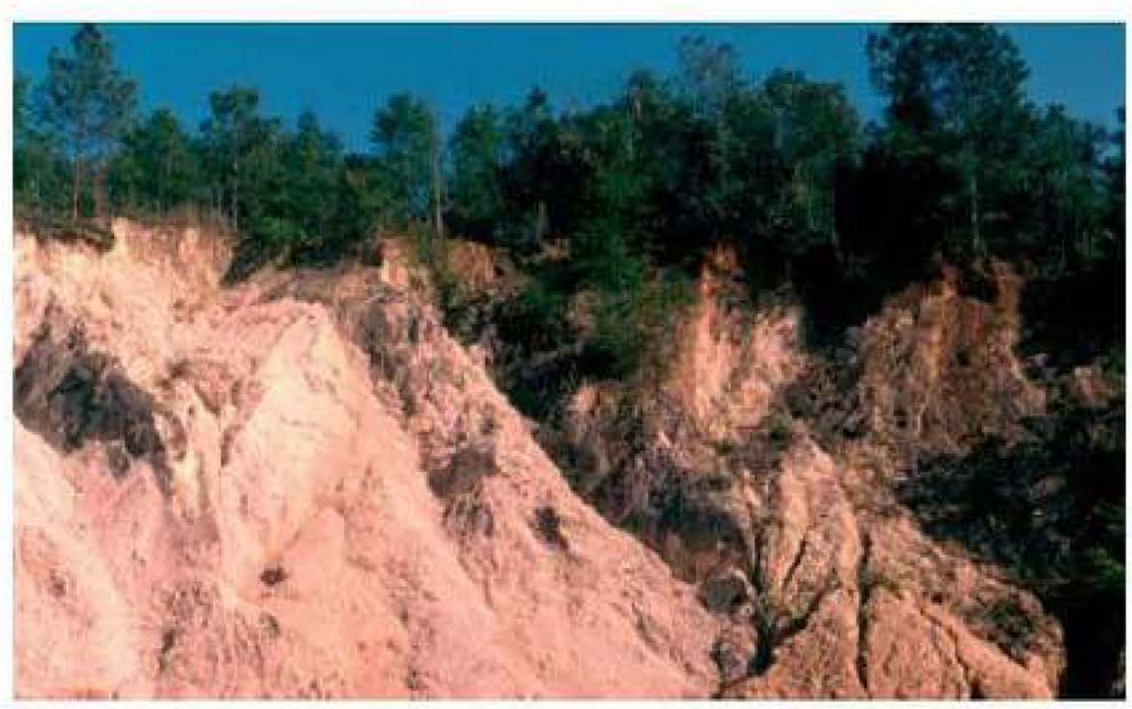

Figure 10.18 Desertification in China

- In the Inner Mongolia Autonomous Region, over 133 000 hectares of rangeland has been seriously degraded by overgrazing. The density of animals now exceeds the carrying capacity of the land.
- On the loess plateau, cultivation of steep slopes is the main cause of desertification. On slopes of less than 5°, the loss of topsoil per annum is about 15 tonnes/hectare. In contrast, on slopes of over 25° it rises to 120–150 tonnes/hectare. However, there is very little loss of soil on terraced slopes.
- Illegal collection of fuelwood and herbal medicines has removed more than one-third of vegetation in the Qaibam basin since the 1980s.

Rates and types of desertification

In China, the main types of desertification include sandy desertification caused by wind erosion; land degradation by water erosion; soil salinisation; and other land degradation caused by engineering construction of residential areas and communications, and industrial activities such as coal mining and oil extraction (Tables 10.8 and 10.9).

Table 10.8 Land in China desertified by different processes

Types of desertification	Area (km^2)	% of total
Wind erosion	379 600	44.1
Water erosion	394 000	45.7
Salinisation	69 000	8.3
Engineering construction	19 000	1.9
Total	**861 600**	**100.0**

Table 10.9 Soil degradation in China (million hectares)

		Negligible	Light	Moderate	Strong	Extreme
Water erosion	Loss of topsoil	15.8	105.9	44.9	3.8	0.2
	Terrain deformation	0.5	7.9	5.9	24.0	–
	Off-site effects	0.2	0.2	0.2	–	–
Wind erosion	Loss of topsoil	1.7	65.9	2.5	+	+
	Terrain deformation	+	7.2	5.5	57.9	–
	Off-site effects	+	2.0	6.5	0.2	–
Chemical deterioration	Fertility decline	32.4	31.7	4.8	–	–
	Salinisation	0.5	6.8	2.6	–	–
	Desertification	–	+	–	–	–
Physical deterioration	Aridification	–	23.7	–	–	–
	Compaction and crusting	–	0.5	–	–	–
	Waterlogging	3.8	–	–	–	–
Total degradation	All types	**55.0**	**251.9**	**72.9**	**86.0**	**0.25**

Note: (–) no significant occurrence; (+) less than 0.1 but more than 0.01 million hectares; for calculation of the totals (+) is equivalent to 0.05 million hectares.

Sandy desertification through wind erosion

In northern China, the main land degradation is sandy desertification caused by wind erosion, an area that covers about 379 600 km^2 and is mainly distributed in the arid and semi-arid zones where the annual rainfall is below 500 millimetres.

Sandy desertification in northern China has been caused mainly by irrational human economic activities, and the growth rate of desertified land increased from 1560 km^2/year during the 1950s to 2100 km^2/year between the mid-1970s and the late 1980s, and since the late 1980s has increased to 2460 km^2/year.

Desertification through water erosion

Soil loss through water erosion is the most serious land degradation in China. By a rough estimate, annual soil loss caused by water erosion has reached about 5 billion tonnes, of which about two-fifths pours into the seas.

Salinisation

About 69 000 km^2 of China's farmland has been salinised, mainly in the arid and semi-arid regions of north-west China and the sub-humid regions of the North China Plain.

Desertification caused by engineering construction

A new type of desertification has spread very quickly, with some large-scale projects such as the development of oilfields and mining; construction of residential areas; and communications. These developments have led to increased wind and water erosion.

Some consequences of desertification

Desertification brings many adverse impacts. It causes a decrease in farmland availability, declining crop productivity, falling incomes, disruptions to communications and may eventually cause out-migration. Desertification also causes an increase in sandstorms, silting of rivers and reservoirs and increased soil erosion.

- Desertification causes annual direct economic losses valued at US$6.5 billion.
- In the north-west, where the problems are the biggest, desertification has escalated rapidly (see above).
- Each year, another 180 000 hectares of farmland in China is salinised, causing productivity to fall by 25–75 per cent, and about 200 000 hectares turns into desert; about 2 million hectares of pasturage are degraded each year.
- Erosion claims about 5 billion tonnes of China's topsoil each year, washing away nutrients equivalent to 54 million tonnes of chemical fertiliser – twice the amount China produces in a year.
- In the 1950s, dust storms affected Beijing once every seven or eight years, and only every two or three years in the 1970s. By the early 1990s, dust storms were an annual problem.

- Desertification has led to a heavy loss of land in pastoral, dry farming areas in northern China and in hilly areas in southern China.
- The government fears that encroaching sands will reach Beijing by the year 2035 as any serious drought turns farmlands into dunes in northern parts of the country, just 100 kilometres away. These dunes are advancing at a rate of 3.5 kilometres a year.

Possible solutions

The China National Research and Development Centre on Combating Desertification (RDCCD) was established to assist the government in implementing the UN Convention to Combat Desertification, which was established to enable China and other countries to combat desertification by developing profitable techniques and environmentally improved practices, and to meet the needs of poverty alleviation.

There are a number of effective measures that can be taken to combat desertification (Table 10.10).

Table 10.10 Methods of combating desertification

Method	Description
Fixing sand by planting	Effective; economic – source of additional fuel and forage
Fixing sand by engineering	Cover sand with straw, clay, pebbles, branches – used successfully along railways, motorways and near cities
Fixing sand using chemical methods	Create a protective layer over the sand – used in areas of high economic value such as airports and railways
Water-saving techniques	Spray irrigation, drip irrigation, prevention of seepage in channels, water transport in pipes
Integrated water management	Terraces, check dams, silt arresters

In 1978, China implemented a forest shelterbelt development programme in its northern, north-western and north-eastern regions, where 16 million hectares of plantations were established, which increased the forest cover from 5 per cent to 9 per cent. It also brought 10 per cent of the desertified land under control and protected 11 million hectares of farmland. In 1991, this was extended as a nationwide campaign.

To protect Beijing, the government issued a ban on the foraging and distribution of three wild plants – facai, liquorice and ephydra – grown in the country's dry western regions. It also plans to build a second green belt of forest around Beijing to achieve a forest coverage of 49.5 per cent by 2020.

Major problems in combating desertification

China is a developing country, and as economic growth exerts great pressure on its funds, the state input to combat desertification is limited. In addition:

- Public awareness needs to be raised, and education regarding desertification improved.
- Legislation is incomplete and the legal enforcement system is imperfect.
- The speed at which desertification is being tackled lags behind the rate of development.
- There is a shortage of funds to combat desertification.

Conclusions

China suffers as a result of desertification. This is the result of a combination of natural reasons and human ones. Economic growth and population pressure are placing a great strain on China's environment. Nevertheless, there have been a number of strategies to tackle desertification, and some of these have had impressive results. However, despite these successes, the rate of desertification appears to be exceeding the rate of environmental restoration. Unless China can tackle its desertification problem, there will be an increase in problems related to its overall development and standards of living.

Section 10.3 Activities

1 Outline **a** the causes and **b** the impacts of desertification in China.
2 To what extent is it possible to manage desertification in China?

☐ Soil degradation

Soil degradation is the decline in quantity and quality of soil. It includes:

- erosion by wind and water
- biological degradation – for example, the loss of humus and plant/animal life
- physical degradation – loss of structure, changes in permeability
- chemical degradation – acidification, declining fertility, changes in pH
- salinisation
- chemical toxicity.

Causes of degradation

The universal soil loss equation (USLE) A = RKLSCP is an attempt to predict the amount of erosion that will take place in an area on the basis of certain factors that increase susceptibility to erosion (Table 10.11).

The complexity of soil degradation means that it is hard to make a single statement about its underlying causes. Soil degradation encompasses several issues at various spatial and time scales (Figure 10.19):

- **Water erosion** – water erosion accounts for about 60 per cent of soil degradation; there are many types of erosion, including surface, gully, rill and tunnel erosion.

Table 10.11 Factors relating to the universal soil loss equation

Factor	Description
Ecological conditions	
Erosivity of soil R	Rainfall totals, intensity and seasonal distribution. Maximum erosivity occurs when the rain falls as high-intensity storms. If such rain is received when the land has just been ploughed or full crop cover is not yet established, erosion will be greater than when falling on a full canopy. Minimal erosion occurs when rains are gentle, and fall onto frozen soil or land with natural vegetation or a full crop cover.
Erodibility K	The susceptibility of a soil to erosion. Depends on infiltration capacity and the structural stability of soil. Soils with a high infiltration capacity and high structural stability that allow the soil to resist the impact of rainsplash have the lowest erodibility values.
Length–slope factor LS	Slope length and steepness influence the movement and speed of water down the slope, and thus its ability to transport particles. The greater the slope, the greater the erosivity; the longer the slope, the more water is received on the surface.
Land-use type	
Crop management C	Most control can be exerted over the cover and management of the soil, and this factor relates to the type of crop and cultivation practices. Established grass and forest provide the best protection against erosion and, of agricultural crops, those with the greatest foliage and thus greatest ground cover are optimal. Fallow land or crops that expose the soil for long periods after planting or harvesting offer little protection.
Soil conservation P	Soil conservation measures can reduce erosion or slow the runoff of water, such as contour ploughing and use of bunds, strips and terraces.

Source: adapted from Hugget et al, Physical Geography – a Human Perspective, *Arnold 2004*

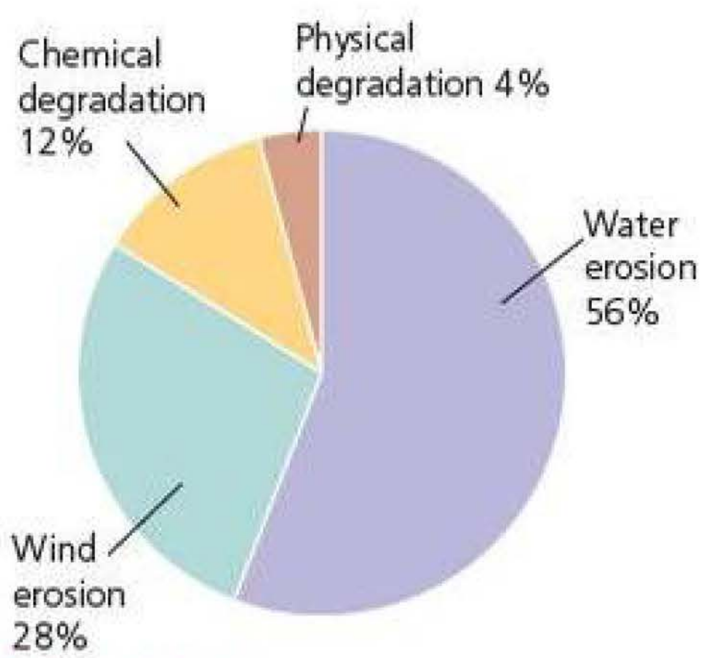

Figure 10.19 Types of soil degradation

- **Wind erosion** involves removal of material, especially of fine-grained loess and silt-sized materials or smaller.
- **Acidification** is the change in the chemical composition of the soil, which may trigger the circulation of toxic metals.
- **Eutrophication** (nutrient enrichment) may degrade the quality of groundwater; over-abstraction of groundwater may lead to dry soils.
- **Salt-affected soils** are typically found in marine-derived sediments, coastal locations and hot arid areas where capillary action brings salts to the upper part of the soil; soil salinity has been a major problem in Australia following the removal of vegetation for dryland farming.
- **Atmospheric deposition** of heavy metals and persistent organic pollutants may change soils so that they become less suitable to sustain the original land cover and land use.
- **Climate change** will probably intensify the problem; it is likely to affect hydrology and hence land use.

Climate change, higher average temperature and changing precipitation patterns may have three direct impacts on soil conditions. The higher temperatures cause higher decomposition rates of organic matter. Organic matter in soil is important as a source of nutrients and it improves moisture storage. More floods will cause more water erosion, while more droughts will cause more wind erosion.

Besides these direct effects, climate change may:

- create a need for more agricultural land to compensate for the loss of degraded land
- lead to higher yields for the major European grain crops due to the carbon dioxide fertilisation – the increase in carbon dioxide in the atmosphere leads to increased plant growth by allowing increased levels of photosynthesis.

These two indirect effects appear to balance out.

Human activities

Human activities have often led to degradation of the world's land resources (Figure 10.20 and Table 10.12). A global assessment of human-induced soil degradation has shown that damage has occurred on 15 per cent of the world's total land area (13 per cent light and moderate; 2 per cent severe and very severe). These impacts frequently lead to a reduction in yields. Land conservation and rehabilitation are essential parts of sustainable agricultural development. While severely degraded soil is found in most regions of the world, the negative economic impact of degraded soil may be most severe in countries that are most dependent on agriculture for their income.

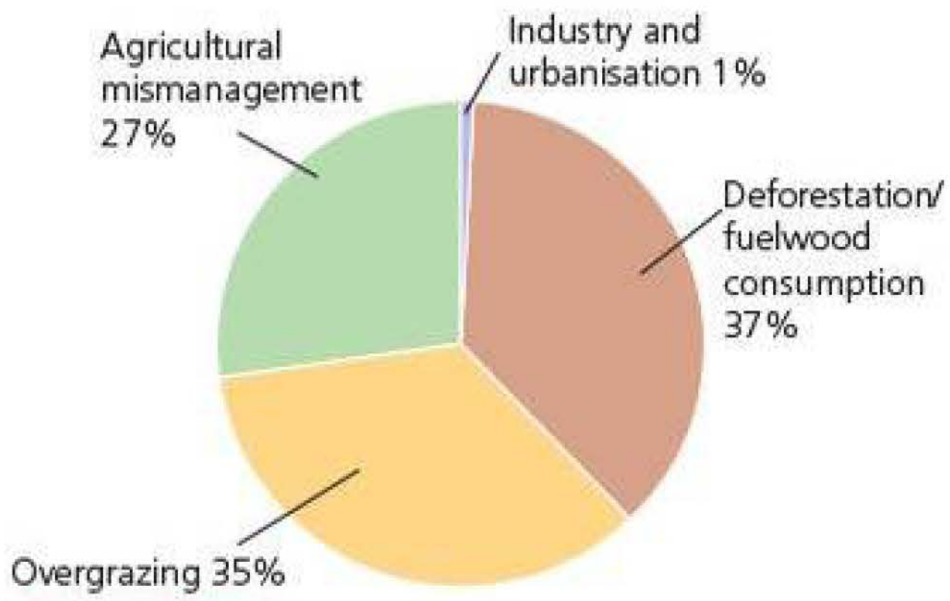

Figure 10.20 Causes of soil degradation

Table 10.12 Human activities and their impact on soil erosion

Action	Effect
Removal of woodland or ploughing established pasture	The vegetation cover is removed, roots binding the soil die and the soil is exposed to wind and water. Particularly susceptible to erosion if on slopes.
Cultivation	Exposure of bare soil surface before planting and after harvesting. Cultivation on slopes can generate large amounts of runoff and create rills and gullies.
Grazing	Overgrazing can severely reduce the vegetation cover and leave the surface vulnerable to erosion. Grouping of animals can lead to overtrampling and creation of bare patches. Dry regions are particularly susceptible to wind erosion.
Roads or tracks	They collect water due to reduced infiltration that can cause rills and gullies to form.
Mining	Exposure of the bare soil.

Managing soil degradation

Abatement strategies, such as afforestation, for combating accelerated soil erosion are lacking in many areas. To reduce the risk of soil erosion, farmers are encouraged towards more extensive management practices such as organic farming, afforestation, pasture extension and benign crop production. Nevertheless, there is a need for policy-makers and the public to intensify efforts to combat the pressures on and risks to the soil resource.

Methods to reduce or prevent erosion can be mechanical, for example physical barriers such as embankments and windbreaks, or they may focus on vegetation cover and soil husbandry. Overland flow of water can be reduced by increasing infiltration.

Mechanical methods include building bunds, terracing, contour ploughing and planting shelterbelts (trees or hedgerows). The key is to prevent or slow the movement of rainwater downslope. Contour ploughing takes advantage of the ridges formed at right-angles to the slope, which act to prevent or slow the downward accretion of soil and water. On steep slopes and those with heavy rainfall, such as areas in South East Asia that experience the monsoon, contour ploughing is insufficient and so terracing is practised. The slope is broken up into a series of level steps, with bunds (raised levees) at the edge. The use of terracing allows areas to be cultivated that would not otherwise be suitable. In areas where wind erosion is a problem, shelterbelts of trees or hedgerows are used. The trees act as a barrier to the wind and disturb its flow. Wind speed is reduced, which therefore reduces its ability to disturb the topsoil and erode particles.

Preventing erosion by different cropping techniques largely focuses on:

- maintaining a crop cover for as long as possible
- keeping in place the stubble and root structure of the crop after harvesting
- planting a grass crop.

A grass crop maintains the action of the roots in binding the soil, minimising the action of wind and rain on a bare soil surface. Increased organic content allows the soil to hold more water, thus preventing aerial erosion and stabilising the soil structure. In addition, care is taken over the use of heavy machinery on wet soils and ploughing on soils sensitive to erosion, to prevent damage to the soil structure.

There are three main approaches in the management of salt- and chemical-affected soils:

- flush the soil and leach the salt away
- apply chemicals, for example gypsum (calcium sulphate), to replace the sodium ions on the clay and colloids with calcium ones
- reduce evaporation losses in order to limit the upward movement of water in the soil.

Soil degradation is a complex issue. It is caused by the interaction of physical forces and human activities. Its impact is increasing and it is having a negative effect on food production. Some areas are more badly affected than others, but in a globalised world the impacts are felt worldwide. The methods of dealing with soil degradation depend on the cause of the problem, but also on the resources available to the host country. Degradation is a problem that is not going to go away and is likely to increase over the next decades as population continues to grow, and people use increasingly marginal areas.

Section 10.3 Activities

1 Explain the meaning of the term *soil degradation*.
2 Outline the natural causes of soil degradation.
3 a Comment on the human causes of soil degradation.
  b To what extent is it possible to manage soil degradation?
4 Study Table 10.13, which shows annual soil losses from a small catchment in the Lake Victoria basin.
  a Describe how the range of soil loss varies with the type of land cover.
  b Suggest reasons for the patterns you have identified in a.