10 Soil and change

KEY QUESTIONS

- What are the causes of soil degradation?
- What are the environmental and socio-economic consequences of soil degradation?
- What management strategies can be used to combat soil degradation?

Lower than average rainfalls can make soils more vulnerable to degradation.

The extent of soil degradation

Soil plays a vital role in the functioning of the planet. It supports agriculture, wildlife and the built environment. It also filters water, stores carbon and preserves records of the ecological and cultural past. Soil scientists have asked for more targeted research and strict guidelines to stop what they say is the massive degradation of land and soil around the world, which is contributing to climate change and food insecurity.

Soil degradation is a global process. It involves both the physical loss (erosion) and the reduction in quality of topsoil associated with nutrient decline and contamination. It has a significant impact on agriculture and also has implications for the urban environment, pollution and flooding. The loss of the upper soil horizons containing organic matter and nutrients and the thinning of **soil profiles** reduces crop yields on degraded soils. Soil degradation can cancel out gains from improved crop yields. The statistics on soil degradation make worrying reading:

- Globally it is estimated that 2 billion hectares of soil resources have been degraded. This is equivalent to about 15% of the Earth's land area. Such a scale of soil degradation has resulted in the loss of 15% of world agricultural supply in the last 50 years.
- For three centuries ending in 2000, topsoil had been lost at the rate of 300 million tonnes a year. Between 1950 and 2000 topsoil was lost at the much higher rate of 760 million tonnes a year.
- During the past 40 years nearly one-third of the world's cropland has been abandoned because of soil erosion and degradation.
- In Sub-Saharan Africa, nearly one million square miles of cropland has shown a 'consistent significant decline' according to a March 2008 report by a consortium of agricultural institutions. Some scientists consider this to be a 'slow-motion disaster'.
- In the UK, 2.2 million tonnes of topsoil is eroded annually and over 17% of arable land shows signs of erosion.
- It takes natural processes about 500 years to replace 25 mm of topsoil lost to erosion. The minimum soil depth for agricultural production is 150 mm. Thus, from this perspective, productive fertile soil can be considered a non-renewable, endangered ecosystem.

A recent study has highlighted the severity of human-induced soil change (Figure 1, page 162), stating that soils around the world are being transformed by human activities in ways that we poorly understand. The loss of the ability of degraded soils to store carbon is given particular attention. Over the last 50 years or so global soils have lost about a hundred billion tonnes of carbon to the atmosphere in the form of carbon dioxide, due to the depletion of soil structure. The idea that the extent of human impacts on the environment could represent a new geological age was first put forward in 2002 by Nobel Prize-winning chemist Paul Crutzen.

Human activities triggering 'Global Soil Change'

Earth's climate and biodiversity aren't the only things being dramatically affected by humans – the world's soils are also shifting beneath our feet, a new report says.

'Global soil change' due to human activities is a major component of what some experts say should be recognised as a new period of geologic time: the Anthropocene, or human-made age.

This new era will be defined by the pervasiveness of human environmental impacts, including changes to Earth's soils and surface geology, proponents of the theory say.

'Unquestionably we are entering the Anthropocene,' said Daniel Richter of Duke University, who authored the new study of Earth's changing soils.

In the December 2007 issue of the journal *Soil Science*, Richter warns that Earth's soils already show a reduced capacity to support biodiversity and agricultural production.

As the amount of depleted and damaged soils increases, global cycles of water, carbon, nitrogen, and other materials are also being affected.

Richter's report supports an independent proposal in the current issue of the journal *GSA Today* that calls for official recognition of the Anthropocene epoch.

In that paper, Jan Zalaseiwicz of the University of Leicester in England and colleagues argue that the fossil and geologic record of our time will leave distinct signatures that will be apparent far into the future.

To future geologists, Zalaseiwicz said, 'the Anthropocene will appear about as suddenly as [the transition] triggered by the meteorite impact at the end of the Cretaceous 65.5 million years ago, when the dinosaurs became extinct'.

Figure 1 *Human activities triggering global soil change.*

The Global Assessment of Human-induced Soil Degradation (GLASOD) is the only global survey of soil degradation to have been undertaken. Figure 2 is a generalised map of the findings of this survey. It shows that substantial parts of all continents have been affected by various types of soil degradation. The GLASOD calculation is that damage has occurred on 15% of the world's total land area – 13% light and moderate with 2% severe and very severe.

Geographical skills

Describe the distribution of soil degradation types shown in Figure 2. Refer to all elements of the key and make reference to all continental areas.

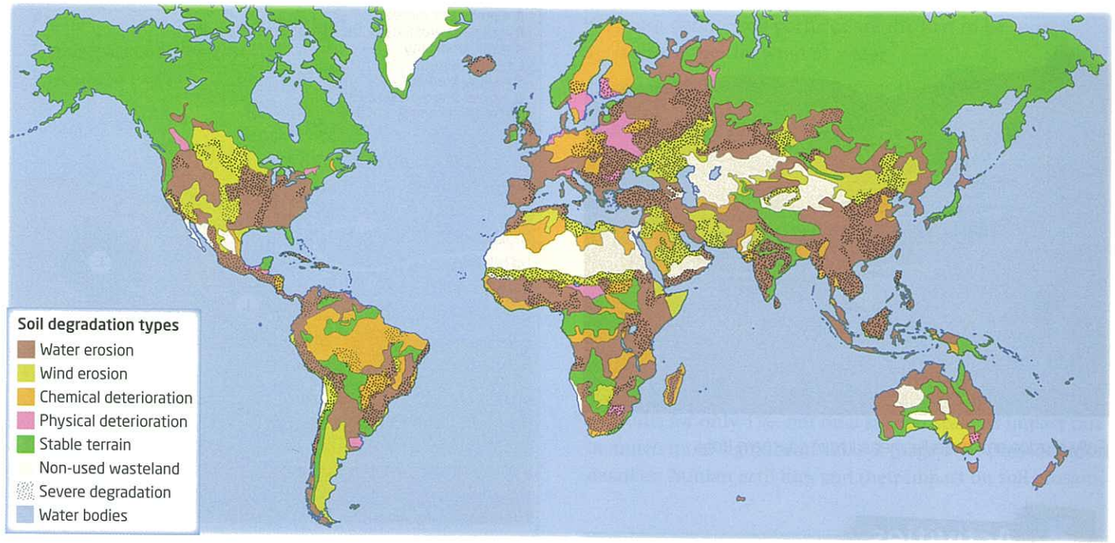

Figure 2 *Human-induced soil degradation.*

The International Forum of Soils, Society and Global Change in September 2007 referred to 'the massive degradation of land and soil around the world which is contributing to climate change and threatening food security'. The Forum noted that:

- At least a quarter of the excess carbon dioxide in the atmosphere has come from changes in land use, such as deforestation, in the last century.
- Without the cover of vegetation, land becomes more reflective. It also loses fertility and the capacity to support vegetation and agricultural crops.
- The Intergovernmental Panel on Climate Change should develop a special report on the link between land degradation and climate change. By addressing soils and protecting the land cover and vegetation we can obtain high value in terms of mitigating climate change.
- A better understanding of the capacity for carbon sequestration in soil is needed.
- Degradation of soil and land in already marginally productive land is a significant issue for many developing countries, particularly in northern Africa, the Sahara region and parts of Asia, including China. Many of these regions have fragile ecosystems where any human interventions can lead to serious degradation.

Research idea

For the country in which you live, find out where the problem of soil degradation is most severe. What is the extent of the problem?

Developed and developing world contrasts

In temperate areas much soil degradation is a result of market forces and the attitudes adopted by commercial farmers and governments. In contrast, in the tropics much degradation results from high population pressure, land shortages and lack of awareness. The greater climate extremes and poorer soil structures in tropical areas give greater potential for degradation in such areas compared with temperate latitudes. This difference has been a significant factor in development or the lack of it.

Gully erosion and remedial measures in southern Italy.

Activities

1. Define soil degradation.
2. What is the evidence in the photo above that soil degradation has occurred?
3. Write a 60-word summary of Figure 1 (page 162).
4. Briefly state the different reasons for soil degradation in the developed and developing worlds.

The causes of soil degradation

The **universal soil loss equation** A = R K LS C P is an attempt to predict the degree of erosion that will occur in an area on the basis of certain factors which increase susceptibility to erosion. Figure 3 and Table 1 illustrate the equation. The universal soil loss equation predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. It only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. Although it has limitations, it is a useful model to consider when beginning to investigate this globally important topic.

The main cause of soil degradation is the removal of the natural vegetation cover, leaving the surface exposed to the elements. Figure 4 shows the human causes of

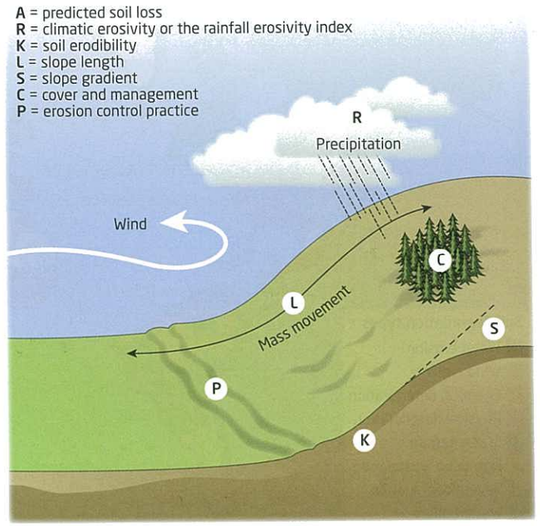

Figure 3 *The universal soil loss equation.*

degradation, with deforestation and overgrazing as the two main problems. The resulting loss of vegetation cover is a leading cause of wind and water erosion. **Deforestation** occurs for a number of reasons, including the clearing of land for agricultural use, for timber, and for other activities such as mining. Such activities tend to happen quickly whereas the loss of vegetation for fuelwood – a massive problem in many developing countries – is generally a more gradual process. Deforestation means that rain is no longer intercepted by vegetation, with rainsplash loosening the topsoil and leaving it vulnerable to removal by overland flow.

Overgrazing is the grazing of natural pastures at stocking intensities above the livestock carrying capacity. Population pressure in many areas and poor agricultural practices have resulted in serious overgrazing. This is a major problem in many parts of the world, particularly in marginal ecosystems. The process occurs in this way:

- trampling by animals (and humans) damages plant leaves
- some leaves die away, reducing the ability of plants to photosynthesise
- now there are fewer leaves to intercept rainfall and the ground is more exposed
- plant species sensitive to trampling quickly disappear
- soil begins to erode when bare patches appear and trampling will compact the soil and damage its structure

Factor	Description
Ecological conditions	
Erosivity of soil R	Rainfall totals, intensity and seasonal distribution. Maximum erosivity occurs when the rainfall occurs 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 upon infiltration capacity and the structural stability of soil. Soils with high infiltration capacity and high structural stability that allow the soil to resist the impact of rainsplash, have 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. This factor relates to the type of crop and cultivation practices. Established grass and forest provide the best protection against erosion. 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, such as contour ploughing, bunding (a wall or barrier designed to prevent leaks) and use of strips and terraces, can reduce erosion and slow runoff water.

Table 1 *Factors relating to the universal soil loss equation.*

- loose surface soil particles are the first to be carried away, either by wind or water
- the loss of soil structure means that less water can infiltrate to the lower soil horizons; the growth rate of plants is reduced and it is more difficult for damaged plants to recover.

Agricultural mismanagement is also a major problem due to a combination of a lack of knowledge and the pursuit of short-term gain against consideration of longer-term damage. Such activities include shifting cultivation without adequate fallow periods, absence of soil conservation measures, cultivation of fragile or marginal lands, unbalanced fertiliser use, and the use of poor irrigation techniques. On a global scale industrialisation/urbanisation accounts for only 1%, but on a smaller scale its impact can be much more significant. Table 2 (page 166) provides more detail on human activities and their impact on soil erosion.

Discussion point

Why do you think overgrazing continues to be a problem in many areas when the local population understand what is happening?

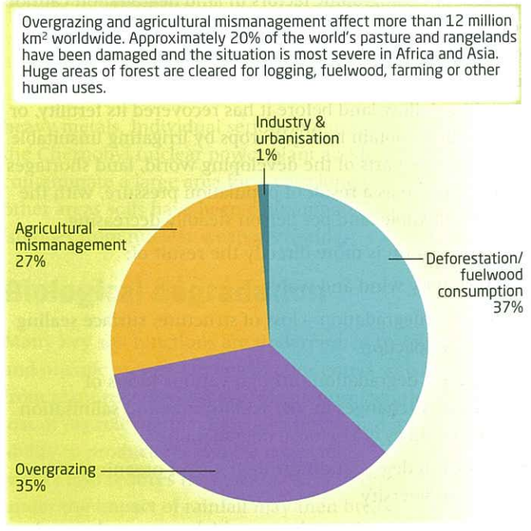

Figure 4 *Causes of land degradation.*