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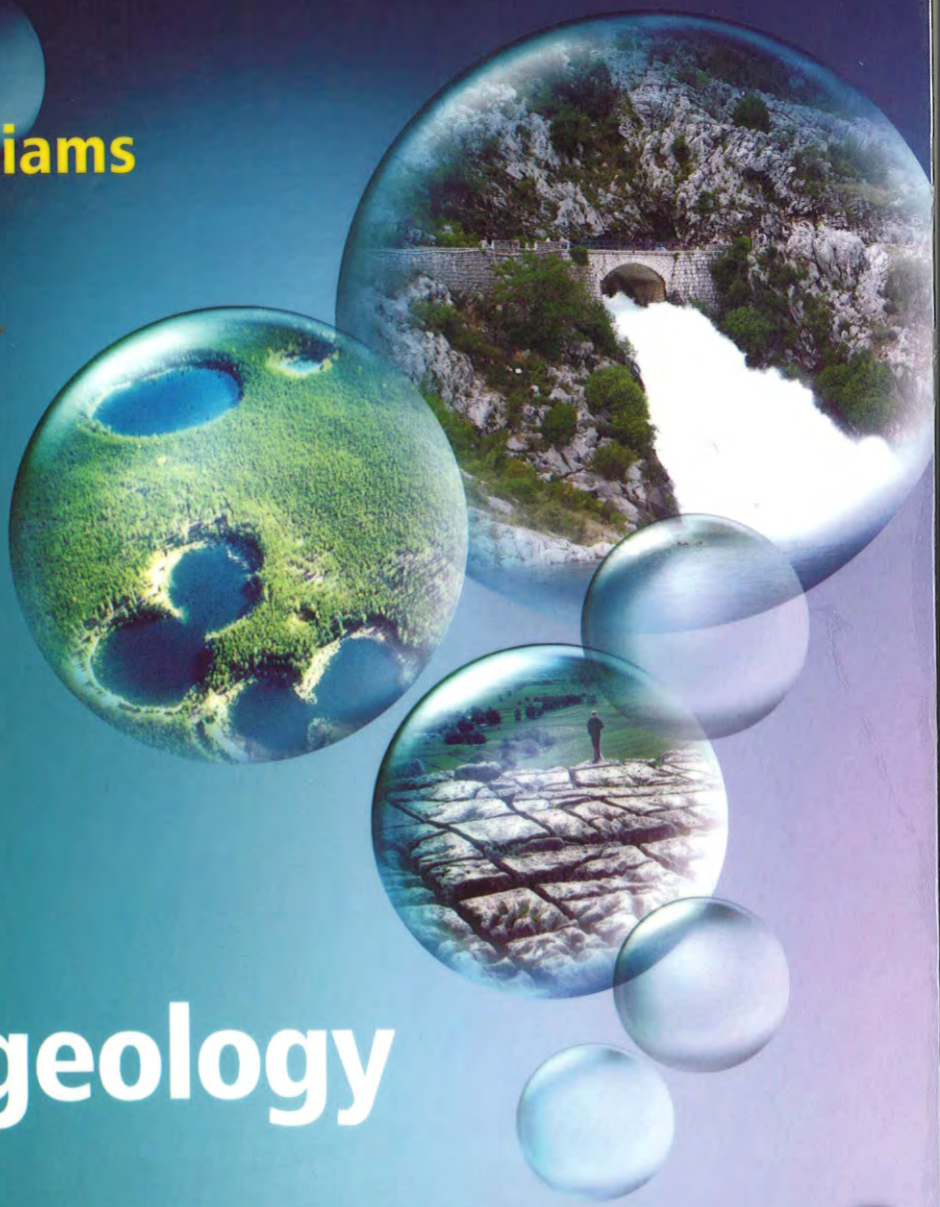

Karst Hydrogeology and Geomorphology

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12

Human Impacts and Environmental Rehabilitation

'Nature to be commanded must be obeyed'

Francis Bacon, *Novum Organum* (1620)

12.1 THE INHERENT VULNERABILITY OF KARST SYSTEMS

Natural environmental change and human impacts on the environment have occurred concurrently since the Last Interglacial about 125 000 years ago. *Homo sapiens* is an integral part of the ecosystem, at first minor because our earliest impacts were sustainable hunter–gatherer activities. The earliest cultivators began to change that. Nicod *et al.* (1996) provide a detailed historical review of human–karst relationships, and consider uses of karst and associated impacts from classical Greek and Roman times until present. It was only when there was extensive deforestation and widespread use of fire that our impacts began to leave a permanent imprint. In the past 8000 years, with the rise of settled agriculture and the building of towns, such activities started to have significant effect on natural ecosystems. Many of the impacts on karst are reviewed in special issues of *Catena* (Williams 1993) and *Environmental Geology* (1993, Vol. 21) and in an increasing number of international conference proceedings.

We can distinguish human-induced environmental change from natural environmental change by the rate of change (e.g. of water-table lowering) and the type of change (e.g. landform modification by quarrying), which is often more rapid and different to that encountered in natural systems. Human-induced environmental change is transmitted through karst, often far from the initial point of impact, by hydrological processes that largely operate underground and out of sight; thus their impact often is not obvious until it is well advanced. For example, water extraction via boreholes may cause springs to dry up (Figure 11.2). Activities on adjacent non-karst terrains also often impinge on karst, because allogenic runoff transmits polluting and clogging effects. Figure 12.1 illustrates this point and shows the particularly complex ramifications of such activities as urbanization and quarrying. Sets of human activities whether undertaken on karst or on non-karst terrains upstream can lead to major effects that result in karst ecosystem degradation. Dam building has particularly large impacts as noted in section 11.6, and even when built beyond the outflow boundary of karst can still affect it as a result of backflooding.

Experience shows that karst environments are particularly fragile and vulnerable to damage compared with most other natural systems. The reason for this is the nature of the karst hydrological system. Efficient drainage of the surface down numerous widened joints, dolines and stream-sinks rapidly transmits surface pollution underground and readily evacuates soils stripped from the surface. Filtration of diffuse recharge is minimal because limestone soils are usually thin; transmission of recharge is essentially unfiltered because subterranean conduits have large dimensions and rapid transmission provides minimal opportunity for die-off of pathogenic

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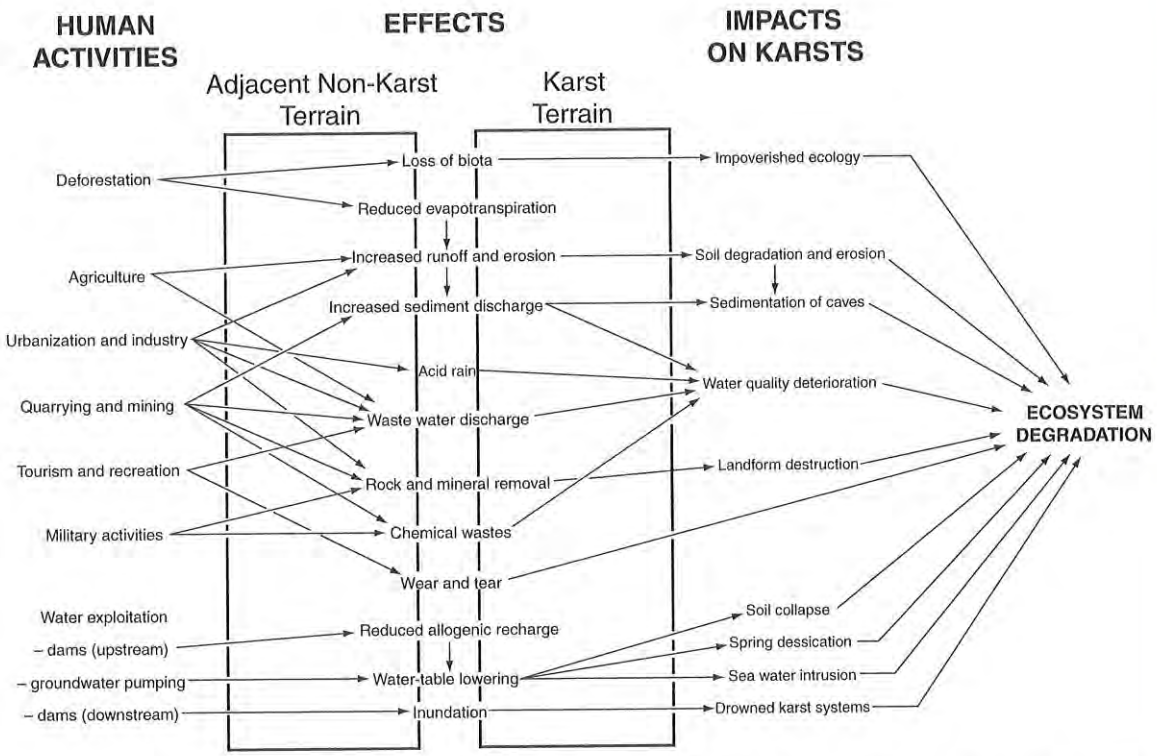

Figure 12.1 Human activities, their effects and impacts on karst terrains. Activities on adjacent, upstream non-karst areas often have an impact on karst as a result of transmission by allogenic drainage into karst. Less frequently an activity on the downstream side also has an impact, such as backflooding from dams. Reproduced from Williams, P.W. (Ed.), Karst terrains; environmental changes and human impacts. Cremlingen-Destedt, Catena Verlag, Catena Supplement 25, 268 pp. © 1993 Elsevier.

organisms. Once thin soils are lost, their replacement time is very long, because there are only small quantities of insoluble residues in karst rocks that might form the inorganic basis of a new soil cover. Whereas inorganic residues might be released at a rate of 50 t km^{-2} a^{-1}, soil erosion in deforested country can easily be one or two orders of magnitude greater. Soil losses have occurred for generations in some temperate and tropical karsts and have led to very severe environmental degradation, in the Gunung Sewu of Java for example. Even in karst lowlands where wet rice paddy field agriculture (supported by irrigation from karst springs) has operated sustainably for centuries, recent changes brought about by population increase, intensification in upland cultivation, deforestation, quarrying, agricultural chemicals and competition for water resources have resulted in severe stress on the resource base and threaten the continued viability of the system, e.g. Urich (1993), Urich and Reeder (1996) provide ample evidence for this from karst areas of the Philippines. Even relatively benign activities such as tourism and recreation can also have severe effects on karst. Tourist caves in particular are vulnerable because of the focused intensive nature of the visitation. The tourist impact of CO_2 exhalation and lighting was so severe on ancient cave art in Lascaux Cave in France, for example, that this World Heritage site was closed in order to preserve the paintings (section 12.8).

The message is clear: karsts are highly vulnerable to overuse and misuse, have a major subterranean component that requires specialist knowledge to manage properly, and once damaged can be extremely difficult to restore. As a consequence of recognizing this problem, considerable effort has recently been made by countries of the European Union to protect the quality and quantity of groundwater resources, especially karst water resources (COST Action 620 2004), as discussed in Chapter 11. The World Commission on Protected Areas of the International Union for the Conservation of Nature and Natural Resources (IUCN) has also drawn up guidelines for the protection of caves and karst (Watson *et al.* 1997) and for sustainable tourism in protected areas (Eagles *et al.* 2002).