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PART I

VISUALIZING THE LAND SURFACE

1

RECOGNIZING THE LAND SURFACE

Terra Firma, a Latin phrase for solid earth, is used to differentiate land from sea – thus connoting the land surface of the Earth. It is used specifically in the Amazon floral region where vegetation above flood level is called terra firma and that below igapo or varzea. Terra firma in a search engine produces more than 11 million results, referring to tiles, travel firms, landscapes, rug company and many others but only one book (Orban, 2006). It is surprising that the land surface of the Earth has not received more explicit attention – perhaps because with hindsight it seems to have been hijacked by disciplines whose prime purpose lies elsewhere: a reason for what Tooth (2009) has described as invisible geomorphology where geomorphological awareness still needs to be raised by stressing the discipline's relevance and contribution to a host of environmental issues. For over a century, museums have been one way to inform about the surface of the Earth, but they emphasized geology, natural history and archaeology. In recent decades public awareness of the surface of the Earth has increased through press and media news reports and documentaries, cinema and the internet. It is ironic that the land surface of the Earth has not received more explicit attention but thought of geologically in terms of rock and tectonic control; biologically in terms of the vegetation types and ecosystems spread across the surface; economically and archaeologically in terms of the environments provided. This chapter introduces terra firma, what it is, how we think of it, and how we have divided it up.

1.1 What is the land surface?

Over the last five decades data collected by **remote sensing** from orbital satellites has revolutionized our valuation of the land surface of the blue planet, by enabling definitive measures of its characteristics. Complementary recent progress has been provided by computer analysis and **Geographical Information Systems** (**GIS**), by satellite navigation, and by advances in dating techniques. It is salutary to recall that the shape of the continents were not known until the eighteenth and nineteenth centuries when national topographic surveys were undertaken. Although we should now expect little variance in dimensions of the land surface (see Table 1.1), it is surprising how much variation occurs in published estimates – some because of conversions to the **International System of Units** (**SI**), or because they have not been verified or definitions have varied, but some because changes of the land surface have occurred.

Table 1.1 DIMENSIONS FOR THE LAND SURFACE

Dimension	Value (based on several sources)	Notes
Spatial extent	148.847×10^6 km^2 representing 29.18% of the earth's surface.	Much more land area in the northern hemisphere than in the southern.
Relief	Highest point Mount Everest at 8848 m, lowest at –418m in the floor of the Dead Sea.	Hypsographic curve – see Figure 1.1.
Mean height of land above sea level	686 m.	Average depth of the oceans at 3795 m is much greater.
Ice extent	Area of 14,898,320 km^2 represents more than 10% of the land surface.	South polar region including Antarctica represents 84.6% and Greenland accounts for 11.6% of the ice surface area, together locking up more than 90% of the 33 million km^3 of glacier ice in the world. Water equivalent of ice caps and glaciers is 26,000,000 km^3 (Nace, 1969) equivalent to water needed to supply world rivers for nearly 900 years.
Freshwater, lakes	Lakes, described as wide places in rivers, together with inland seas have a surface area of 1,525,000 km^2, more than 1% of the earth's surface. Lakes store 90,000 km^3 of world's freshwater, 0.27% of world's water, about 80% in 40 large lakes.	Fresh water bodies in all continents, but majority occur in the northern hemisphere. World's 145 largest lakes estimated to contain over 95% of all lake freshwater. Lake Baikal, the world's largest, deepest and oldest lake, contains 27% of all lake freshwater.
Rivers	Contain 0.0064% of world's water. The total volume of water stored in rivers and streams is estimated at about 2,120 km^3.	Because of their role in the hydrological cycle have a major influence on the land surface. An estimated 263 international river

Table 1.1 *(Continued)*

Dimension	Value (based on several sources)	Notes
		basins have drainage areas that cover about 45% (231 million km^2) of the Earth's land surface (excluding polar regions). The world's 20 largest river basins have catchment areas ranging from 1 to 6 million km^2. The Amazon carries 15% of all the water returning to the world's oceans.
Coastline	356,000 km including 94 nations and other entities that are islands according to https://www.cia.gov/library/publications/the-world-factbook/fields/2060.html.	Allowing for the many inlets and estuaries total length may approximate 1 million km (Bird, 2000).
Mountains	Approximately 20% represented by mountains. Mountains, highlands and hills, collectively cover 36% of the land surface of the earth (Fairbridge, 1968). See Figure 6.1.	No agreed definition of mountains but can be where relief greater than 1500 m, and according to Wikipedia >2500 m high or 1500–2499 m if their slope is >2°, or 1000–1499 m if their slope is >5°. On this basis 24% of earth's land surface could be regarded as mountainous with 64% of Asia mountainous.
Land cover	20% is dry land (desert, rock, ice and sand 42.0×10^6 km^2), with 10% that doesn't have topsoil. Forests (48.5×10^6 km^2) and woodland and scrubland (8.0×10^6 km^2) account for 27%. 2% urban area. Irrigated 2,770,980 km^2 (CIA World Factbook, 2003, accessed 5 March 2009.	Forest is now c. 27% of land area. Since 1700, nearly 20% of the world's forests and woodlands have disappeared. Forest 39.52×10^6 km^2 in 2005 (was 40.77×10^6 km^2 in 1990 and 39.89×10^6 km^2 in 2000) according to www.fao.org/forestry/site/32038/en (accessed 17 March 2009). In 2005, arable land accounted for 10.57%; permanent crops for 1.04%; and other 88.38% of land cover.
Human impact	Between one-third and one-half of the land surface has been transformed by human action. See Table 3.10.	13.31% of the land surface is arable with 4.71% covered by permanent crops whereas approximately 40% is used for crops or for pasture (13×10^6 km^2 cropland; 34×10^6 km^2 pastureland). 45,000 big dams now block the world's rivers, trapping 15% of all the water that used to flow from the land to the sea. Reservoirs now cover almost 1% of land surface.

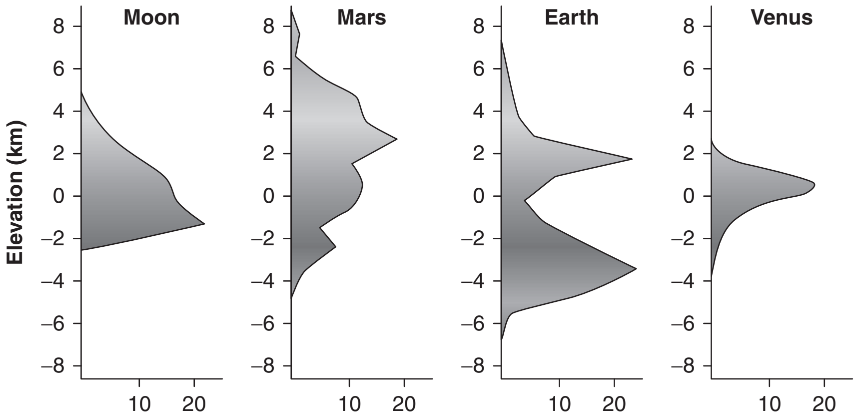

Figure 1.1 Comparative hypsometries (elevation is plotted against percentage of the Earth's surface area; based on http://comp.uark.edu/-sboss).

A way of demonstrating the overall distribution of the land surface is according to elevation above sea level. Such a hypsometric or hypsographic curve is a graph showing the proportion of the land mass occurring above a given level; it can be constructed for Earth as a whole or a part such as a drainage basin or glacier. Unlike the hypsometric curve for the moon or Venus that for the earth (see Figure 1.1) is bimodal with one peak for the continents and one for the ocean basins, revealing more of the earth's surface beneath the sea than above it.

Ice covers more than 10%, of the land surface and frequent references to rates of melting of glaciers and ice sheets reflect the changes taking place so that regular auditing and monitoring of glacier and ice cap extent is necessary (see Table 1.2). Whereas ice-covered areas dominantly occur in high latitudes and high mountains, fresh water bodies are distributed over approximately 1% of the land surface in all continents. The largest closed basin lake is the Caspian Sea with a coastline approximately 7,000 km long and a drainage basin covering 3.1 million km^2. Lake Baikal is the deepest single body of water with a volume of 22,000 km^3 – nearly equivalent to the total volume in all five Great Lakes of North America. Some countries are particularly proud of their lakes. Finland, known as the Land of the Thousand Lakes, actually has more than 180,000, Manitoba claimed 100,000 lakes to beat Minnesota which proclaimed Land of 10,000 lakes on its license plates. Lake Huron, the second largest lake in the world according to its surface area of 117,702 km^2, is one of the five Great Lakes of North America which are part of a system collectively containing some 22% of the world's freshwater – enough to cover the 48 contiguous states of the USA to a depth of 2.9m, with a surface area nearly the same as that of the United Kingdom.

When seen from space, the surface of the blue planet, in addition to land, water and ice, shows the green of forest, and broad categories of land use (see Table 1.1). As much of the land surface has been substantially affected by human

Table 1.2 GLACIER INVENTORY: EXAMPLES OF PROGRESS

1	Plans for an inventory of global glacier features were included in the International Hydrological Decade (1965–1974), with the intention of repeating the survey every 50 years to detect changes in glaciers. By 2008 about 37% of the estimated total glacier surface had been inventoried, available through the World Glacier Monitoring Service (WGMS) in Zürich and National Snow and Ice Data Center (NSIDC) in Boulder.
2	A simplified inventory method was developed in the early 1980s mainly based on satellite images, as outlined in Global Land Ice Measurements from Space (GLIMS) which covers 34% of the estimated glacier surface outside Greenland and Antarctica. See http://www.glims.org/ (accessed 17 March 2009).

action, dramatically increased since the nineteenth century, a new geological period, the Anthropocene, was suggested in 2000 by Paul Crutzen, a Nobel prize winner, because he regarded human impact on the Earth as so significant that it justified a new geological era to succeed the Pleistocene and Holocene of the Quaternary in the Geological timescale (see Figure 5.1). A 2008 article (Zalasiewicz et al., 2008) was aptly entitled 'Are we now living in the Anthropocene?'.

The Earth's land surface is not static because change is, and always has been, a characteristic feature. Each year sees changes in detail – in ice extent for example. In addition to seasonal changes there are also changes from year to year, as drought years follow wetter years, and there are also evolutionary changes, for example as some coastlines progressively advance, complemented by others which are submerged. Some of the most dramatic changes arise from human impact, and most recently from global change on a scale which is substantial and potentially very serious. The level of the Caspian Sea fell over the last century so that, between 1927 and 1977, many economic activities, including oil exploration, oil field development, and pipeline construction, developed on the exposed lake floor. The lake level reached a record low of 29.0 m below mean sea level (Rodionov, 1990) in 1977, prompting an engineering solution response to bring water to the Sea from wetter parts of the Soviet Union (Glantz, 1995). After 1977 therefore the level of the Caspian began to rise rapidly (Rodionov, 1990) with consequential environmental problems including coastal inundation because of sea level rise; water pollution by raw sewage and oil production; fishing pressure and its impacts on fish populations (Glantz, 1995). The fall in level of the Aral Sea has also been dramatically affected by human activity: by 1989 the sea level had fallen by 14.3 m and the surface area had shrunk from 68,000 km^2 to 37,000 km^2. In the twenty-first century, as a result of conservation measures, the Sea level is rising again.

Interpreting the land surface requires a range of time scales analogous to the different resolutions of a microscope. A perceptive way of envisaging time scales (Schumm and Lichty, 1965) distinguished steady, graded and cyclic time (see Table 1.3). Any point on the land surface of the earth can be thought of as a location in space and time so that to understand its characteristics we have to refer to changes occurring over time: some of the actual surface characteristics are the

Table 1.3 SOME CLASSIFICATIONS OF TIME

Authors	**Subdivisions proposed**			
Schumm and Lichty, 1965	*Steady state time*, typically of the order of a year or less when a true steady state situation may exist.		*Graded time*, may be hundreds of years during which a river develops a graded profile condition or a dynamic equilibrium exists involving progressive evolution of landform in relation to erosion and deposition.	*Cyclic or geological time*, encompasses millions of years as needed to complete an erosion cycle.
Udvardy, 1981	*Secular scale* spatial dimensions of about 100 km and time dimensions of about 100 years.		*Millennial scale* covering at least the last 10,000 years and spatial scales of up to 1000 km where climate and sea level change are the major factors operating.	*Evolutionary time or the phylogenetic scale* may be up to 500 million years and spatial extent may reach 40,000 km so that continental displacement may be important.
Driver and Chapman, 1996	'*Now time*'	*Generational time scale*, 10–100 years for sustainable development.	*Century time scale*, 100–1000 years.	*Late Quaternary time*, 1000–10,000 years.

result of relatively recent changes, some parts of the earth retain characteristics developed over millions of years (see **Quaternary chronology**, Glossary p. xxx). Where human impact is substantial then the surface characteristics may be just years or decades old. Time scales are inextricably combined with spatial scales so that one of the greatest challenges in studying the land surface of the earth is to apply results gained from study at one time and spatial scale to one of the other time scales. Relating process measurements made over years or decades to development over centuries or millennia requires reconciling timeless and timebound scales.

1.2 Envisaging the land surface

How do we describe the land surface of the Earth? Language descriptions of characteristics of the surface are the obvious way, applying words to particular earth surface features. In English the nouns mountains, plains, valleys, plateaux have equivalents in other languages. Inevitably some languages include words for earth surface characteristics according to the environment in their particular country, so that a language of place (Mead, 1953) reflects the fact that some vocabularies have words for particular features which do not have direct counterparts in other languages. In Russian there are words for types of valley, like balki, which cannot easily be translated into English because no comparable features occur as extensively in England or in America. Many descriptive words have now evolved to describe landforms – landform refers to the morphology and character of the land surface resulting from the interaction of physical processes with the surface materials in the land surface environment. Words for particular types or shapes of feature have become adopted as scientific terms so that words such as corrie or the Welsh word cwm for armchair-shaped hollows, became accepted as features of glacially eroded landscapes. Words gradually became adopted in this way so that it is not easy to discern when landform first became basic for the science of geomorphology (see pp. 00, Chapter 2).

Scientists in the nineteenth century included Baron Ferdinand von Richthofen (1833–1905) who had trained in geology and geography at Breslau (now Wroclaw) and published a book, arising from his travels, on regional geology and geography in 1886 which may be the first systematic textbook of modern geomorphology (Fairbridge, 1999). Ways in which landforms gradually became assimilated into the scientific literature of studies of the land surface of the Earth are illustrated in Table 1.4, showing the importance of exploration of the American West and the contributions of William Morris Davis which may have

Table 1.4 ILLUSTRATIONS OF THE EMERGENCE OF LANDFORMS AS THE SCIENTIFIC BASIS FOR STUDY (SEE ALSO CHORLEY ET AL., 1964)

Individual contributor	Contribution	Indicative references
Oscar Peschel (1826–75) Professor of Geography, Leipzig	Compared the nature of similar landforms throughout the world, involving classification of surface features and comparison of their morphology.	Peschel, 1870
Ludwig Rutimeyer (1825–95) Professor of Zoology, Basle	In a book on valley and lake formation showed that the largest Alpine valleys had been produced by stream erosion over long periods of geologic time and that different sections of a river course can be marked by distinct types of erosional forms including waterfalls, meanders and floodplains.	Rutimeyer, 1869
J.W. Powell (1834–1902) US Geological Survey	In a study of the Colorado in 1875 identified 3 types of river valleys (antecedent, consequent, superimposed) and referred to landforms.	Powell, 1875
G.K. Gilbert (1843–1918) US Geological Survey	In 1875 discussed formation of alluvial fans. In 1914 produced a masterpiece on fluvial processes.	Gilbert, 1875
Baron Ferdinand von Richthofen (1833–1905)	A Guidebook for scientific travellers in 1886 was largely descriptive of landforms, included a classification of mountains.	Von Richthofen, 1886

(Continued)

Table 1.4 *(Continued)*

Individual contributor	Contribution	Indicative references
W.J. McGee (1853–1912) US Geological Survey	Compiled a genetic classification of landforms similar to those used in subsequent textbooks.	McGee, 1888
W.M. Davis (1850–1934), Harvard?	Associated landforms with stages in the cycle of erosion and furnished over 150 terms and phrases, some relating to landforms, with probably at least 100 generated by his students.	Davis, 1884, 1900
The position achieved by 2008 is perhaps reflected by Wikipedia which defines a landform as: a geomorphological unit, largely defined by its surface form and location in the landscape, as part of the terrain, and ... typically an element of topography.		Wikipedia 2008 provides a list of 169 named landforms in 7 categories

formalized the recognition of the importance of landform (Davis, 1900: 158). Characteristics of the land surface of the Earth and its processes are not only reflected in language but also perceived through cultures, in art and music.

A second way of considering the surface of the Earth involves its contribution to environment or to nature. Einstein is reputed to have described environment as 'everything that isn't me' but usually it is thought of as the set of characteristics or conditions surrounding an individual human being, an organism, a group of organisms or a community. Of the several types of defined environment, the natural environment is a theoretical concept, which includes all living and non-living things occurring naturally on earth, whereas the physical environment or biophysical environment refers to phenomena excluding humans. Nature comprises the essential qualities of environment: it can be seen as a group of interrelated objects that objectively exist in the world independent from humans, together with the biophysical processes that create and maintain the objects; or as a concept that is socially created and maintained by the human imagination (Soper, 1995: 136; Urban and Rhoads, 2003: 213). Nature, like environment, is therefore seen as a human construct existing only when there are individuals to recognize it, albeit variously perceived by different cultures. Natural history as the study of the physical and biological environment was popular in the nineteenth century but was displaced as environmental sciences became more specialized. Now human impact is so great that one book has been titled *The End of Nature* (McKibben, 1989).

Thirdly, the land surface of the Earth can be thought of as physical places, landscapes or regions. Every country has its well-known places – for example, the Rockies, Himalayas, Sahara Desert, or Amazon basin – each conjuring up a specific picture of the land surface. Place is the word used to refer to that particular part of space occupied by organisms or possessing physical environmental characteristics (Gregory, 2009). Landscape comprises the visible features of an area of land, including physical elements such as landforms, soils, plants and animals, the weather conditions, and also any human components, such as the presence of agriculture or the built environment. Physical places, as enshrined in place names or types of landscape, are not easy to define but progress has been made by recognizing physical or natural regions. Such regions provided a way of dividing up and studying the land surface of the earth, illustrated by approaches to the regional geomorphology of the USA (Fenneman, 1931, 1938) and North America (Graf, 1987).

Early attempts to describe the land surface of the earth in terms of physical regions were very detailed but often lacked the necessary understanding of the way in which processes worked; they often relied upon an assumed historical interpretation of physical landscape. One development in the mid-twentieth century recognized the **land system** as a subdivision of a region in which there is a recurring pattern of topography, soils, and vegetation reflecting the underlying rock types and climate of the area and affecting the erosional and depositional surface processes. This idea may have originated in early attempts at land classification associated with national surveys, for example from soil maps, but it was the resource surveys in undeveloped parts of Australia and Papua New Guinea, initiated in 1946 by the Australian Commonwealth Scientific Industrial Research Organization (CSIRO), that initiated the land system approach. By collating information on the geology, climate, geomorphology, soils, vegetation and land use of areas, these surveys designated land systems which could be divided into units or land facets composed of individual slopes or land elements. After the 1960s the advent of Geographic Information Systems (GIS), as the collection, analysis, storage and display of data spatially referenced to the surface of the Earth, enabled identification of patterns and relationships between phenomena and processes (Oguchi and Wasklewicz, 2010). Numerical land classifications based on 1 km grid squares have the advantage of combining many aspects of environmental character without being use-specific.

Fourthly, the surface of the Earth is perceived scientifically in different ways by particular disciplines. A meteorologist may see it in terms of its albedo, pedologists see soil landscapes, whereas ecologists recognize habitats. An overall view of the land surface is as part of Gaia, named after the Greek goddess of the Earth, first explicitly formulated by James Lovelock (see Box 1.1) who suggested that the whole planet acts as a self-regulating, living entity, requiring the interaction of the totality of physical, chemical and biological processes to retain the conditions vital for the survival of all life on earth, in turn controlling the atmospheric conditions required for the biosphere.

1.3 Components of the land surface

Gaia, the whole planet earth, is at one extreme, but what are the components that make up the land surface? Analogous to the building blocks of atomic structure, has been the search for the building blocks of land surface. It was suggested (Linton, 1951) that the ultimate units of relief are the undivided flat or slope – all land surfaces are composed of a jigsaw of these morphological units. Combinations of these units have been modelled in particular ways (e.g. Figure 4.2, pp. 00). There is a hierarchy of combinations of the smallest elements right up to the undivided continent (see Table 1.5), with, in between, physical regions such as the Rockies, the Loess plateau of China or the Deccan plateau of India. All environmental disciplines identify a basic environmental unit: in soil investigations the site was the place at which soil profiles were investigated, and the basic unit for soil study was the vertical section through all the constituent horizons of a soil, recognized as the soil profile since the time of Dokuchaev (see Box 6.1) and other Russian soil scientists in the late nineteenth century. As the profile is two dimensional, the pedon was introduced as the smallest unit or volume of soil that represents, or exemplifies, all the horizons of the soil profile: it is a vertical slice of soil profile of sufficient thickness and width to include all the features that characterize each horizon (Wild, 1993), is usually a horizontal, more or less hexagonal area of $1m^2$ but may be larger (Bates and Jackson, 1980), and is an integral part of many soil survey classification systems. Soil profiles, pedons and sites are then grouped, or classified, into the fundamental soil mapping unit which might be a series, defined as groups of soils with similar profiles formed on lithologically similar parent materials.

In ecology, habitat has come to signify description of where an organism is found, whereas niche is a complete description of how the organism relates to its physical and biological environment. A fundamental niche is that which an individual occupies in the absence of competition with other species; a realized niche is the niche occupied when competition is in progress (Watts,

Table 1.5 HIERARCHICAL CLASSIFICATION OF GEOMORPHOLOGICAL FEATURES (TIME AND SPACE SCALES ARE APPROXIMATE)

Typical units	Spatial scale km²	Time scale years
Continents	10^7	10^8–10^9
Physiographic provinces, mountain ranges	10^6	10^8
Medium and small-scale units, domes, volcanoes, troughs	10^2–10^4	10^7–10^8
Erosional/depositional units:		
Large scale, large valleys, deltas, beaches	10–10^2	10^6
Medium scale, floodplains, alluvial fans, cirques, moraines	10^{-1}–10	10^5–10^6
Small scale, offshore bars, sand dunes, terraces	10^{-2}	10^4–10^5
Geomorphic process units:		
Large scale, hillslopes, channel reaches, small drainage basins	10^{-4}	10^3
Medium scale, slope facets, pools, riffles	10^{-6}	10^2
Small scale, sand ripples, pebbles, sand grains, striations	10^{-8}	

Sources: developed from Chorley et al. (1984) and Baker (1986; http://geoinfo.amu.edu.pl/wpk/geos/geo_1/GEO_CHAPTER_1.HTML).

1971). The niche has subsequently been defined as the habitat in which the organism lives, but also the periods of time during which it occurs and is active, and the resources it obtains there. Other terms developed include microhabitat which is a precise location within a habitat where an individual species is normally found; a biotope is the smallest space occupied by a single life form, as when fungi grow on biotopes found in the hollows of uneven tree trunks. Habitat can also designate the living place of an organism or a community, applying to a range of scales from the microscale, relating to organisms of microscopic or submicroscopic size, through to the macroscale at continental or subcontinental levels.

The hierarchy of building blocks of the Earth's surface (see Table 1.5) subsequently developed in at least three ways. First, by involving organisms as well as the environment of the organisms, as reflected in biogeocoenosis, a Russian term equivalent to the western term ecosystem, and involving both the biocoenosis, a term introduced by Mobius in 1877 for a mixed community of plants and animals, together with its physical environment (ecotope). Biotope was defined as an area of uniform ecology and organic adaptation, although subsequently thought of as a habitat of a biocoenosis or a microhabitat within a biocoenosis. Ecological patches forming a mosaic connected by corridors in any scale of landscape can be employed in hydrology, analogous to a patchwork of geomorphological units nested at different scales (Bravard and Gilvear, 1996).

Secondly there has been the need to have an integrated unit for surface form, soil, and ecology and Russian studies recognized the urochischa as a basic physical–geographical unit of landscape with uniform bedrock, hydrological conditions, microclimate, soil and mesorelief (Ye Grishankov, 1973), reminiscent of the land system (Christian and Stewart, 1953).

Thirdly there has been recognition of sequences of units identified for climate (climosequences), relief (toposequences), lithology (lithosequences), ecology (biosequences), and time (chronosequences). In geomorphology a nine-unit hypothetical landsurface model (Dalrymple et al., 1969) showed how nine particular slope components could occur in landsurface slopes anywhere in the world (see Figure 4.2). Each component was associated with a particular assemblage of processes so that it was possible to predict how slopes could occur under different morphogenetic conditions. A similar approach was applied to pedogeomorphic research (Conacher and Dalrymple, 1977), although a simple 5-unit slope may be sufficient (e.g. Birkeland, 1984) and this scheme can be adapted for particular landscapes such as drylands (see Table 9.4).

The ecosystem is a good example of a functioning unit, a term invented by Tansley (1935) for a community of organisms plus its environment as one unit; therefore embodying the community in a place together with the environmental characteristics, relief, soil, rock type (the habitat) that influence the community. Ecosystems (see Chapter 3, pp. 00) can vary in size from 1 to thousands of hectares and could be a pond upstream of a debris dam or a large section of the Russian steppe. The drainage basin, also a functional unit, is the land area

Table 1.6 DRAINAGE BASIN COMPONENTS (DEVELOPED FROM DOWNS AND GREGORY, 2004)

Drainage basin component	Provisional definition
River channel	Linear feature along which surface water may flow, usually clearly differentiated from the adjacent flood plain or valley floor.
River reach	A homogeneous section of a river channel along which the controlling factors do not change significantly.
Channel pattern	Or channel planform, is the plan of the river channel from the air, may be either single thread or multithread, varying according to discharge.
Floodplain	Valley floor area adjacent to the river channel.
River corridor	Linear features of the landscape bordering the river channel.
Drainage network	Network of stream and river channels within a specific basin, may be perennial, intermittent or ephemeral.
Drainage basin or catchment	Delimited by a topographic divide or watershed as the land area which collects all the surface runoff flowing in a network of channels to exit at a particular point on a river.

delimited by a topographic divide or watershed which collects all the surface runoff flowing in a network of channels to exit at a particular point along a river. The subsurface phreatic divide (the underground watershed defined by the water table) may not correspond exactly to the topographic divide on the surface. In the USA the term 'watershed' is often applied to small and medium-sized drainage basins, 'river basin' is used for larger areas, and in some countries the term catchment is used to describe small drainage basins. The drainage basin is dynamic because the water and sediment-producing areas expand and contract depending upon the catchment characteristics, the antecedent conditions prior to any storm event, and the character of the storm input. The components of the drainage basin nested within each other (see Table 1.6) are all affected by the dynamic character of the basin. The functional significance of the drainage basin is the reason it has been used as a basis for collecting hydrological information, for the **modelling** of flows such as flood forecasting, and for the management of physical resources.

More than 200 river basins, accounting for about 60% of the earth's land area, extend over two or more countries. Fragmented planning and development of the associated trans-boundary river, lake, and coastal basins are the rule rather than the exception. Although more than 300 treaties have been signed by countries to deal with specific concerns about international water resources and more than 2000 treaties have provisions related to water, co-ordinated management of international river basins is still rare, resulting in economic losses, environmental degradation, and international conflict (World Bank, 1993). Many disciplines have an interest in the land surface, as considered in the next chapter.

Box 1.1

PROFESSOR JAMES LOVELOCK

Professor James Lovelock (1919–) trained in Chemistry (BSc Manchester, 1941), and Medicine (PhD 1948, London), is a pioneer in the development of outstanding environmental concepts, having been described as one of the great thinkers of our time. His ideas have created a context which can be considered when understanding the land surface of the earth. Working as an independent scientist since 1961, he has been associated with universities in the UK and the USA, was made FRS in 1974, and a Companion of Honour in 2005. He is renowned for the Gaia hypothesis, formulated in the 1960s, and although it was largely ignored until the 1970s, it has subsequently become generally accepted as the Gaia theory. His 1979 book launched the idea into both scientific and humanistic communities and was at first much derided by the former, although subsequent books (1988, 2006, 2009) have been taken much more seriously. In 2006 he argued that change is now so substantial that Gaia may no longer be able to adjust, drawing the analogy of an old lady sharing her house with a growing, destructive group of teenagers – Gaia grows angry and if they do not mend their ways she will evict them (2006: 47). Referring to the deadly 3Cs (combustion, cattle, and chainsaw – Lovelock, 2006: 132), he suggests that we could be past the tipping point – the threshold at which the characteristics of the land surface change dramatically, identifying the potential fragility of the land surface of the earth. His most recent book (Lovelock, 2009) argues that, although the planet will look after itself, humans need to be saved – and soon. Some hope is offered arising from geo-engineering.

Professor Lovelock is a scientist whose independent thought provides a context for analysing the land surface of the earth, giving a challenging framework within which to think holistically about the earth – present and future. His *Homage to GAIA – The Life of an Independent Scientist* was published in 2000. How should study of the land surface be conditioned by thinking of Gaia and the possibility that global change is inevitable (see Chapter 12, pp. 000) and requires action?

FURTHER READING

Many books provide an introduction to the surface of the earth including the oceans such as:

Skinner, B.J., Porter, S.C. and Botkin, D.B. (1999) *The Blue Planet: An Introduction to Earth System Science*. Wiley, New York, 2nd edn.

and with numerous illustrations:

Janson-Smith, D., Cressey, G. and Fleet, A. (2008) *Earth's Restless Surface*. Natural History Museum, London.

An excellent summary covering the context for spatial units is:

Kent, M. (2009) Space: Making room for space in physical geography. In N. Clifford, S.L. Holloway, S.P. Rice and G. Valentine *Key Concepts in Geography*. Sage, London, 2nd edn., pp. 97–118.

Throughout the following chapters it could be useful to refer to a dictionary such as:

Thomas, D. and Goudie, A. (eds) (2000) *The Dictionary of Physical Geography*. Blackwell, Oxford:

or a Companion:

Gregory, K.J., Simmons, I.G., Brazel, A.J., Day, J.W., Keller, E.A., Sylvester, A.G. and Yanez-Arancibia, Y. (2009) *Environmental Sciences. A Student's Companion*. Sage, London.

A stimulating read is:

Tooth, S. (2009) Invisible geomorphology? *Earth Surface Processes and Landforms* 34: 752–754.

TOPICS

1. As noted in the Preface all the individuals described in this and subsequent chapters are male. Many very significant contributions have been made by females in the subsequent generations – identify individuals and research their contributions (suggestions to consider: Cuchlaine A.M. King, Marie E. Morisawa, Angela M. Gurnell, Marjorie Sweeting).
2. Find values from the internet and other sources for a particular dimension (e.g. mean height, 10 highest mountains, 4 longest rivers) of the land surface, see how much variation occurs and suggest why.
3. For a specific area of the land surface consider how several time scales (see Table 1.3) might be applied – how easy is it to relate studies undertaken at different time scales?
4. Is nature possible without human beings?