16

THE 'ANTHROPOCENE'

Whereas geomorphology (landform science) gave insufficient attention to human impact until the second half of the 20th century, subsequent studies of the impact of human agency on the Earth's surface and its processes are now known to be substantial. This has produced a range of overarching concepts and terms. For geomorphologists it has involved measuring the consequences, deciding what is 'natural', and reviewing their research agenda. The degree of human impact has encouraged the proposal that the Anthropocene should be defined as a new era in the geological time scale.

Table 16.1 Examples of contributions indicative of the appreciation of the nature and significance of human impact on the Earth's surface and its pertinence to geomorphology

Date	Contribution	Significance
First contributions – the foundation		
1864	Marsh, G.P. *Man and Nature.* Subtitle was *Physical Geography as Modified by Human Action*	He characterized it as a '… little volume showing that whereas others think that the earth made man, man in fact made the earth …'. Illustrated that man is 'a power of a higher order than any of the other forms of animated life'. Provided a foundation for the conservation movement.
1872	Kingsley, C. *Town Geology.*	
1893	Kropotkin, P.	In an article on the teaching of physiography (*Geographical Journal,* 2: 350–59) objected to the trend to exclude man from physiography.
1922	Sherlock., R.L. *Man as a Geological Agent*	Emphasized the contrasts between natural and human denudation and concluded that in a densely populated country 'Man is many more times more powerful, as an agent of denudation, than all the atmospheric denuding forces combined'.
1923	Barrows, H.	Presidential address to the Association of American Geographers proposed that human ecology should be the central theme for the discipline.
1956	Thomas, W.L. (ed.) *Man's Role in Changing the Face of the Earth*	52 chapters organized in three parts: the first elaborating the way in which man has changed the face of the earth; the second reviewing the many ways in which processes had been modified; and the third concerned with the prospect raised by limits on the role of man.
Second contributions – establishing the implications		
1967	Wolman, M.G.	Article in *Geografiska Annaler* (49A: 385–95) suggested how sediment yield varied at the present time between urban and non-urban areas, providing a model of change of sediment yield in the northeast of the USA since 1700, which was capable of application to other developed areas and was a brilliant paper which changed the ways of geomorphological thinking (Gregory, 2011).

Date	Contribution	Significance
1969	Vita-Finzi, C. *The Mediterranean Valleys*	Showed that the evolution of valleys around the Mediterranean basin could be understood only by reference to human activity.
1970	Brown, E.H.	Article in *Geographical Journal* (136: 74–85) characterized man as both a geomorphological process in relation to his direct, purposeful modifications of landforms, and also as indirectly effective through the human influence upon geomorphological processes. Other inaugural lectures took a similar theme.
1971	Detwyler, T.R. (ed.) *Man's Impact on Environment*	Collected previously published papers to produce edited volume.
1971	Chorley, R.J.	Article in *Progress in Physical Geography* proposed that control systems offered an approach whereby human activity acts as a regulator in natural systems; this was elaborated in Chorley, R.J. and Kennedy, B.A., *Physical Geography: A Systems Approach.*
1973	Chorley, R.J.	In a chapter on Geography as Human Ecology, echoing Barrows's 1923 thesis, concluded that the control system could be an appropriate focus, that it would clearly incorporate human activity and focus upon the links between human and physical environment, and that: 'It is clear, however, that social man is, for better or worse, seizing control of his terrestrial environment and any geographical methodology which does not acknowledge this fact is doomed to in-built obsolescence'.
1979	Gregory, K.J. and Walling, D.E. (eds) *Man and Environmental Processes*	Edited collection reviewing aspects of human impacts upon processes, was later revised as *Human Activity and Environmental Processes* (Gregory and Walling, 1987).
1981	Goudie, A.S. *The Human Impact, Man's Role in Environmental Change*	Book 'seeks to find out whether, and to what degree, humans have during their long tenure of the earth changed it from its hypothetical pristine condition'. Dealt with human impact on the major components of environment, namely vegetation, soil, waters, geomorphology, climate and the atmosphere. Subsequent editions of book published in 1986, 1990 and 1993.

(Continued)

Table 16.1 (Continued)

Date	Contribution	Significance
1990	Turner et. al. (eds) *The Earth as Transformed by Human Action*	A volume with four sets of chapters: • The first dealing with global changes over the past three centuries in major aspects of human activity relative to environment transformation, namely population, technology, institutions and social organization, trade, urbanization and awareness of human impact. • The second concerned with the long-term assessment of natural change in the biosphere, involving 18 chapters in five sets dealing with the last 300 years of impacts on major states and flows of the globe, including land transformation, water flows, marine, climate and atmosphere, fauna and flora, flows of carbon, sulphur etc. • Thirdly, studies of historical and contemporary human impact on environment in 12 regions of the world. • Fourthly, three chapters addressing the contribution that different perspectives in social science could make to human-induced environmental transformation. This volume succeeded Thomas (ed.) 1956.
1997	Goudie, A.S. and Viles, H. *The Earth Transformed: An Introduction to Human Impacts on the Environment*	Explored 'the many ways in which humans have transformed the face of the Earth' and placed the transformations into an historical context, seeing how humans have changed through time by focusing upon the biosphere, atmosphere, waters, land surface, oceans, seas and coasts, with a conclusion directed towards a sustainable future.
Third group of contributions – the present position		
1999	Hooke, R.L.	Paper in *Earth Surface Processes and Landforms* (24: 687–92) showed how the role of human activity was now greater than that of any other geomorphic agent in certain areas of the United States where he compared rates of movement by humans and by rivers.
1999	Harbor, J.	Review in *Geomorphology* (31: 247–63) shows that for urban areas erosion rates can be up to 40,000 times greater than pre-disturbance rates.
2000	Douglas, I. and Lawson, N.	Article in *Journal of Industrial Ecology* (4: 9–33) suggested that globally deliberate movement of 57,000Mt.yr-1 of material through mineral extraction processes exceeded the annual transport of sediment to the oceans by rivers by almost a factor of 3, and in Britain the deliberate materials shift is nearly 14 times larger than the shift caused by natural processes.

Date	Contribution	Significance
2001	Phillips, J.D.	Article in *Physical Geography* (22: 321–32) argues that the unpredictability of human environmental agency is ubiquitous.
2003	Haff, P.K.	AGU Monograph Series (135: 15–26) states that 'the surface of the earth is undergoing profound change due to human impact … comparable to the effects of major classical geomorphic processes such as fluvial sediment transport. This change is occurring rapidly, has no geologic precedent, and may represent an irreversible transition to a new and novel landscape with which we have no experience. The combination of physical and social forces that drive modern landscape change represents the Anthropic Force'. Neogeomorphology is the study of the Anthropic Force and its present and likely future effects on the landscape. Unique properties associated with the Anthropic Force include consciousness, intention and design.
2006	Rivas, V. et al.	Article in *Geomorphology* (73: 185–206) reports study of four areas in Spain and Argentina, indicating that mobilization rates due to construction and mining seem to be 2–4 orders of magnitude greater than natural denudation rates.
2008	Walling, D.E.	Although variations in effects of human activity increase in pre-human flux global sediment budget due to human activity is 160%.
2010	Haff, P.K.	Paper in *Earth Surface Processes and Landforms* (35:1157–66) compares technological and natural mass transport mechanisms.

Table 16.3 Impact of human agency

Stages of human development		
Age		**Major innovation**
Hunting-gathering		Beginning of tool production
Agricultural	Early agriculture up to 5000BC	Cultivation, domestication
	Riverine civilizations up to 500BC	Irrigation, use of metals, spread of plough and wheel
	Agricultural empires up to 1750s	Terracing, road network, utilization of wind and water power
Industrial	First industrial revolution up to 1870s	Steam engines, industrialization
	Second industrial revolution up to 1950s	Steel making, railway network, utilization of electricity, combustion engine
	Third industrial revolution since 1950s	Plastics, electronics, nuclear power, computerization
Impacts		
Direct	**On Processes**	**On Influencing Spheres**
Land cultivation – soil erosion, sedimentation Mining – excavation including quarrying, accumulation Coastal development – Water management Industrial impact Urbanization	Exogenic: • Weathering • Mass movement • Fluvial processes • Coastal processes • Aeolian processes • Glacial • Periglacial, nival and cryonival • Subsidence • Soil processes and soil erosion • Ecosystem processes	Atmosphere Hydrosphere Pedosphere Geosphere Biosphere
Military activities	Endogenic:	
Tourism and sports activities	• Earthquakes • Volcanic activity	

Table 16.4 Anthropocene concepts and terms

Concept	Originator	Accepted Meaning
Anthropozoic era	Antonio Stoppani (1824–1891)	Resulted from the increasing power and impact of humanity on the Earth's systems.
Noosphere	Vernadsky, 1924	The realm of human consciousness in nature or the 'thinking' layer arising from the transformation of the biosphere under the influence of human activity. May be regarded as synonymous with the anthroposphere.
Anthropogeomorphology	Golomb and Eder, 1964	The study of humans as geomorphological agents.
Anthroposphere		Includes human activity and constructions by the human population such as cities, bridges, dams, and roads. Synonymous with noosphere? Part of the environment that is made or modified by humans for use in human activities and human habitats. Aspen Global Change Institute: encompasses the total human presence throughout the Earth system including our culture, technology, built environment, and activities associated with these. The anthroposphere complements the term anthropocene – the age within which the anthroposphere developed.
Technosphere		The part of the physical environment affected through building or modification by humans. An online digital environment launched on 1 September 1995 and hosted on a computer at a UK university.
Noöcene epoch	Samson and Pitt, 1999	How we manage and adapt to the immense amount of knowledge we've created.
Homosphere	Svoboda, 1999	Biosphere modified by *homo sapiens*, one from which the noosphere or 'thinking layer' emanates.

(Continued)

Table 16.4 (Continued)

Concept	Originator	Accepted Meaning
Anthropocene	Crutzen, 2000	New geological era to succeed the Pleistocene and the Holocene.
Anthropic Force	Haff, 2003	The combination of physical and social forces that drive modern landscape change
Neogeomorphology	Haff, 2003	The study of the Anthropic Force and its present and likely future effects on the landscape. Unique properties associated with the Anthropic Force include consciousness, intention and design.
Polyanthroponemia	Lovelock, 2009	What Gaia's illness could be called, where humans overpopulate until they do more harm than good.

BOX 16.1

Background to the study of impact of human activity (see Table 16.1)

The texts in section 2 of Table 16.1 provide summaries of human impacts throughout the environments of the Earth's surface; some global effects are included in the third section. Because so many impacts have now been recognized it is not easy to classify the myriad of influences and impacts on the Earth's surface: these happen at different times in different places. Although 'human impact' was the description preferred for many years, it has been suggested that this should be succeeded by 'human agency' (Urban, 2002). The traditional assumption that human activities are somehow external to the biophysical environment has also been questioned (Abram, 1996, in Loczy and Suto, 2011). One way of demonstrating the magnitude of human agency is via data documenting the transformations of natural processes, although these depend upon approximate estimates of various kinds (Table 16.2). Results indicate that rates of erosion and amounts of material moved by human agency are now greater than natural rates (Hooke,1999). In summarizing the character of human agency it is first necessary to show the change that has occurred, and the first part of Table 16.3 identifies seven stages of human development (after Simmons, 1993; Goudie and Viles,1997; Rozsa, 2006) with progression from hunting and gathering, through three stages of agricultural activity and then to three revolutions in industry, with major innovations indicated in each case. This sequence applies at particular dates in different parts of the world, and individual impacts may have peaked at different times (see Figures 13.6 and 13.7), but the culmination of human agency effectiveness is now so great that the possibility of a new geological epoch is ripe for debate (see Table 16.4).

The impacts of human agency can be thought of as arising in three principal ways: direct ones are those which impact intentionally and immediately on the Earth's land surface (for example by excavation or construction); indirect ones are effective in changing processes producing particular process responses (such as increased sediment yields); and there are also effects on the other spheres which then influence surface processes (such as climates or plants) (see Table 16.3). This human impact model (Loczy, 2008, 2011) offers a way of rationalizing the range of impacts. Direct impacts listed in Table 16.3 each have many potential consequences but a range of others exists (Goudie, 2006; Szabo et al., 2010; Loczy, 2011; Lewin, 2012). It is possible to construct a genetic classification of man-made landforms (Szabo, 2010) with each of the direct categories in Table 16.3 having such landforms: terraces and

(Continued)

(Continued)

lynchets for agriculture, open cast mining or spoil heaps for mining, sea walls and groynes along the coast, polders and dams affecting floods, industrial parks, urban runoff drainage systems, moats, bomb craters reflecting military impacts, and recreation lakes or sports fields for tourism.

The suite of environmental processes (see Table 16.3) have all been affected to some extent by human agency, sometimes with disastrous consequences. The character and rates of geomorphological processes have been changed, sometimes leading to changed morphological consequences. Hazards may be exacerbated and there are cases where landscapes owe many, if not all, their characteristics to human agency. To indicate the scope of changes identified, Table 16.4 summarizes exogenous (land surface) and endogenous (geological) processes, and their human agency effects. It is not easy to determine whether some landforms or landscapes have been produced by human agency – for example, gullying can be triggered by human activity in some areas but in others reflects variations in climate. The genetic classification of man-made landforms (Szabo, 2010) acknowledges the indirect effects on landscapes such as gullying triggered by agricultural practices or avalanches triggered by explosions.

Surprisingly, the book on *Anthropogenic Geomorphology* (Szabo, David and Loczy, 2010) gives no elaboration of thermokarst landscape changes that are among the most dramatic. Permafrost regions which occupy nearly a quarter of Earth's land surface have ground in which a temperature lower than 0° C has existed continuously for two or more years, whether water is present or not. Permafrost has existed in Arctic areas for large parts of the Quaternary and it is estimated that it takes 100,000 years for permafrost to develop to depths greater than 500m. In Siberia a surface melt sequence was suggested (Czudek and Demek, 1970) progressing from small depressions, linear and polygonal troughs, to elongated thaw lakes and oriented lakes, and thence to much larger features called alases which are thermokarst depressions with steep sides and a flat grass-covered floor, ranging in depth from 3–40m and in diameter from100–15,000m in Yakutia. In the central Yakutian lowland up to 50% of the Pleistocene surface (originating 9000–250,000 years ago) has been destroyed, but notably more recently as a result of human activity (Czudek and Demek, 1970). Global warming initiated widespread thermokarst during glacial-to-interglacial transitions and, to a smaller degree, during the last 100–150 years. Projected warming during the next century will generally cause thermokarst to intensify and spread (Murton, 2008).

The production of thermokarst is an example of the way in which changes in processes by human agency can create whole landscapes that are dominantly the result of human impact, far exceeding those arising seasonally or through fluctuations in natural climates. In Table 16.3, the third component of impacts is the ways in which other spheres are influential. Global warming of the atmosphere, especially through increases in carbon dioxide concentrations, leads to rising world temperatures, and such changes have implications for the land surface of the earth, not least because they are often implemented through short-term and often dramatic events. Although global warming is not new, as shown by the IGPCC review of the history of the last 900,000 years, there are geomorphological impacts, involving for example glacier retreat and increased flood discharges on rivers. Gregory and Goudie (2011) suggested broad groups of issues to which geomorphologists can contribute:

- Evaluating the dynamic consequence of outputs from GCMs for earth surface processes.
- How such consequences translate into environmental hazards, with additional risks and uncertainties.
- What consequences will change land surface processes, including alterations in the frequency of land-forming events, as well as new consequences from changing events.
- How new process domains will be created, and how landscapes will have different degrees of sensitivity and resilience.
- How to contribute to future design for the Anthropocene under new conditions.

In other spheres equally significant changes can influence geomorphological processes: for the hydrosphere there are changes to river processes arising from the number of dams constructed, now with 39,000 higher than 15m so that few of the rivers of the world remain unregulated. Sediment yields have been grossly affected (Vörösmarty et al., 2003) and many flows are depleted so that the Colorado and the Yellow River have a small fraction of their original flows when they reach the sea. Saline intrusions in coastal areas caused by over-pumping of fresh groundwater from aquifers allow seawater to penetrate inland. Lake levels have declined due to water use for irrigation; the level of the Aral Sea had fallen by 14.3m by 1989, and its surface area had shrunk from 68,000km^3 to 37,000km^{3,} although in the 21st century conservation measures have enabled the level to start rising again.

Soil erosion occurs naturally in all landscapes to some degree, but 20% of the world's cultivated topsoil was lost between 1950 and 1990; so that

(Continued)

(Continued)

soil erosion is second only to population growth in world problems. Soils on average develop at rates of 1t.ha per year whereas estimated losses from agricultural lands can be 30t.ha.year in Africa, Asia and South America and 17t.ha.year in Europe and the USA (Ashman and Puri, 2002). Global estimates of annual soil loss range from 7 to 9 billion tonnes per year with Asia and Africa contributing some 60% of this (Garland, 1999). The United States may be losing soil 10 times faster than the natural replenishment rate, while China and India are losing soil 30–40 times faster and, as a result of erosion over the past 40 years, 30% of the world's arable land has become unproductive (Pimentel, 2006). Reasons for the acceleration of normal rates of erosion include deforestation and agriculture, aggravated by the ploughing of very steep slopes, greater use of machinery, removal of hedgerows and increase of field size, reduced levels of organic matter and cultivation throughout more of the year (Goudie and Viles, 1997). The consequences of soil erosion by water on the surface can be to produce bare areas that have been denuded by sheetwash erosion, or deep gullies produced by concentrated water flow; one can grade into the other but gullies tend to be defined as those channels that cannot be obliterated by normal ploughing operations. Down-channel, sedimentation can lead to a transformation of alluvial landforms and floodplains.

RELEVANT ARTICLES IN *PROGRESS IN PHYSICAL GEOGRAPHY:*

Butler, D.R. (2001) Geomorphic process-disturbance corridors: a variation on a principle of landscape ecology, *Progress in Physical Geography*, 25: 237–8.

Castree, N. (2012) Progressing physical geography, *Progress in Physical Geography*, 36: 298–304.

Chorley, R.J. (1971) The role and relations of physical geography, *Progress in Physical Geography*, 3: 87–109.

Clifford, N.J. (2009) Globalization: a Physical Geography perspective, *Progress in Physical Geography*, 33: 5–16.

Meadows, M.E. (2012) Quaternary environments: going forward, looking backwards?, *Progress in Physical Geography*, 36: 539–47.

Trimble, S.W. (2008) The use of historical data and artifacts in geomorphology, *Progress in Physical Geography*, 32: 3–29.

Viles, H.A. (1988) Coastal landforms: human activity, geomorphology and ecology in the coastal zone, *Progress in Physical Geography*, 12: 293–301.

UPDATES

The Anthropocene (Section 16.4, p.176) continues to foster debate and three papers in *Geography Compass* review the development, current contributions and future directions for geography as a whole but provide a broad context for the way in which geomorphology reacts to the Anthropocene debate:

Castree, N. (2014) The Anthropocene and Geography I: The back story, *Geography Compass*, 8: 436–49.

Castree, N. (2014) Geography and the Anthropocene II: Current contributons, *Geography Compass*, 8, 450–63.

Castree, N. (2014) The Anthropocene and Geography III: Future directions, *Geography Compass*, 8, 464–76.

Debate also continues apace as to just where a start-date for the Anthropocene should be set; Lewis and Maslin (2015) list nine potential dates. These range from the megafaunal extinction in the Palaeolithic even before the Holocene began, to the persistence of industrial chemicals after c.1950 CE. The range of opinions can be seen in:

Lewis, S.L. and Maslin, M.A. (2015) Defining the Anthropocene, *Nature*, 519: 171–80.

Smith, B.D.and Zander, M.A. (2013) The onset of the Anthropocene, *Anthropocene*, Doi: 10.1016/j.ancene.2013.05.001.

Zalasiewicz, J. and 25 others (2015) When did the Anthropocene begin? A mid-twentieth century boundary level is stratigraphically optimal, *Quaternary International*, available online, Doi: 10.1016/j.quaint.2014.11.045.

Underlying such technical debates are adaptation and conservation issues: how should a changing environment be managed given intentional or inadvertent human factors that have become as strong as 'physical' processes? These issues are discussed in:

Harden, C.P. and 12 others (2014) Understanding human–landscape interactions in the 'Anthropocene', *Environmental Management*, 53: 4–13.

The Updates for Chapter 3 included:

Knight, J. and Harrison, S. (2014) Limitations of uniformitarianism in the Anthropocene, *Anthropocene*, 5: 71–5.

Defining the start of the ‘Anthropocene’, which is not as yet a formal geological term, continues to arouse considerable debate. A flavour of this may be gained from Malm and Hornborg (2014) who argue that uneven global distribution and diachronic temporal impacts are central to the modern fossil-fueled economy; Baker (2014) who advocates the study of analogues from Earth’s past, especially given the unpredictability of complex Earth systems; and the previously cited Zalasiewicz et al. (2015) who are convinced that the scale of change in the mid-twentieth century justifies designation of a new geological Epoch. Graphs for the ‘great accleration’ in Earth System trends in the last few centuries are usefully given by Steffen et al. (2015).

Ruddiman et al. (2015) and Certini and Scalenghe (2015) are less convinced about such a start date, especially in light of the long history of profound human effects on the planet. Tarolli and Sofia (2016) specifically explore geomorphological impacts, whilst Fuller et al. (2015) document the variable impacts of anthropogenic impacts on New Zealand river systems. Many such geomorphological impacts predate the mid-twentieth Century, whilst others, responding to the global climate changes now underway, have yet to come.

Contrasting start-date views arise partly because of the different perspectives of traditional stratigraphy and the newer Earth-System Science that incorporates the totality of global systems. The latter includes the atmosphere and oceans that have been impacted especially in the later Twentieth Century because of accelerated fossil fuel consumption. Hamilton and Grinevald (2015) argue that the Anthropocene belongs to this Earth-System Science era: both understandings and the earth itself represent significant ruptures in the later Twentieth Century. But like it or not, the term Anthropocene has, in an undefined way, become widely used across both the sciences, social sciences and the arts.

The case for formal recognition of the Anthropocene has again been promoted by Zalasiewicz et al. (2017). They maintain, in spite of some criticisms for identification of a single formal start date (the most vigorously advanced being c.1950 CE), that this is both useful and can be identified geologically using materials novel to the period such as plastics. They recognise the now widespread use of the term in social and political contexts without as yet a formal definition. From a geomorphological point of view, and rather than getting drawn into the discussion about a formal boundary, Brown et al. (2017) point to the varying relevance of the concept in, for example, aeolian and urban environments. They summarise evidence from different branches within the discipine and the different responses to human activities in contrasting process domains, including artificial landscapes arising from excavations and building construction. They favour an informal stratigraphic status with a diachronous lower boundary. Variability in response to anthropogenic disturbance is similarly emphasised by Verstraeten et al. (2017). The case studies they summarise suggest that magnitudes of change are constrained by local catchment connectivities, thresholds and tipping points.

Baker, V.R. (2014) Uniformitatianism, easrth system science, and geology, *Anthropocene*, 5: 76–79.

Brown, A.G., Tooth, S., Bullard, J.E., Thomas, D.S.G, Chiverrell, R.C., Plater, A.J., Murton, J., Thorndycraft, V.R., Tarolli, P. , Rose, J., Wainwright, J., Downs, P. and Aalto, R. (2017) The geomorphology of the Anthropocene, *Earth Surface Processes and Landforms*, 42: 71–90.

Certini, G., Scalenghe, R. (2015) Is the Anthropocene really worthy of a formal geologic definition?, *The Anthropocene Review*, 2: 77–80.

Fuller, I.C., Macklin, M.G. and Richardson, J.M. (2015) The geography of the Anthropocene in New Zealand: Different river catchment response to human impact, *Geographical Research*, 53: 255–69.

Malm, A.and Hornborg, A. (2014) The geology of mankind? A critique of the Anthropocene narrative, *The Anthropocene Review*, 1: 62–9.

Ruddiman, W.F., Ellis, E.C., Kaplan, J.O. and Fuller, D.Q. (2015) Defining the epoch we live in, *Science*, 348: 38–9.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O. and Ludwig, C. (2015) The trajectory of the Anthropcene: The great Acceleration, *The Anthropocene Review*, 2: 81–98.

Tarolli, P., Sofia, G. (2016) Human topographic signatures and derived geomorphic processes across landscapes, *Geomorphology*, 255: 140–61.

Verstraeten, G., Broothaerts, N., Van Loo, M., Notebaert, B., D'Haen, K., Dusar, B. and De Brue, H. (2017) Variability in fluvial geomorphic response to anthropogenic disturbance, *Geomorphology* (in press, available online).

Zalasiewicz, J. et al.(2017) Making the case for a formal Anthropocene Epoch: an analysis of on-going critiques, *Newsletter on Stratigraphy*, 205–26 (open access online).

Demonstration of the importance of considering domestication in relation to the biogeographical implications of the Anthropocene is given in:

Young, K.R. (2016) Biogeography of the Anthropocene Domestication, *Progress in Physical Geography*, 40: 161–74.

An overview of recent literature on the role of humans as a geological agent is the basis for exploring different contexts that are significantly characterized by anthropogenic topographic signatures:

Tarolli, P. and Sofia, G. (2016) Human topographic signatures and derived geomorphic processes across landscapes, *Geomorphology*, 255: 140–61.

See also from Chapter 3 update: MacDonald, G. M. (2017) The new nature: Limitations and prospects of the paleoenvironmental tradition in biogeography in the 21st century, *The Canadian Geographer /Le Géographe canadien*, 61: 41–51.