13

FORCINGS

Forces external to systems that result in system responses are known as forcing functions or drivers. These are responsible for environmental change that can occur over a range of timescales. Relief sets available energy, and tectonic mobility can alter systems whilst exogenetic processes are in operation. Surface forces can be natural or human-induced and can cause change directly or indirectly. Whereas a direct forcing function or driver unequivocally influences system processes, an indirect driver will operate more diffusely by altering one or more direct drivers.

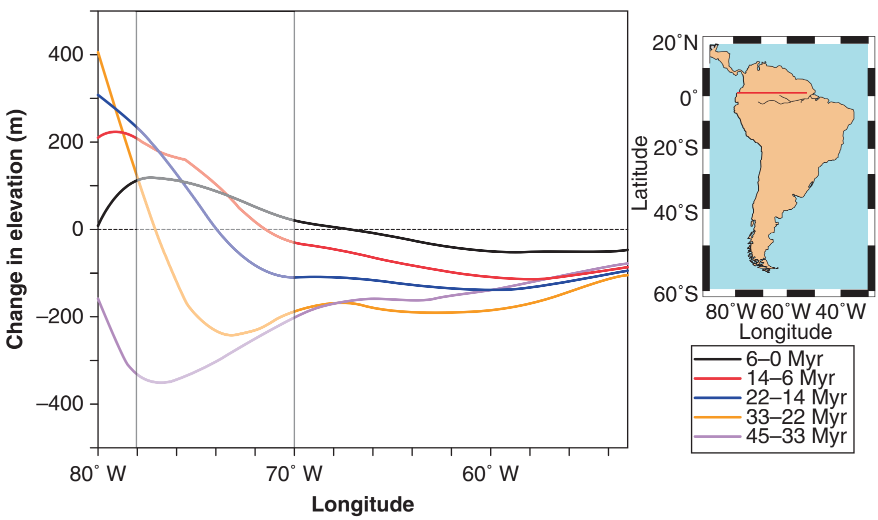

Figure 13.1 Tectonic activity and elevation change across South America (after Shepherd et al. 2010)

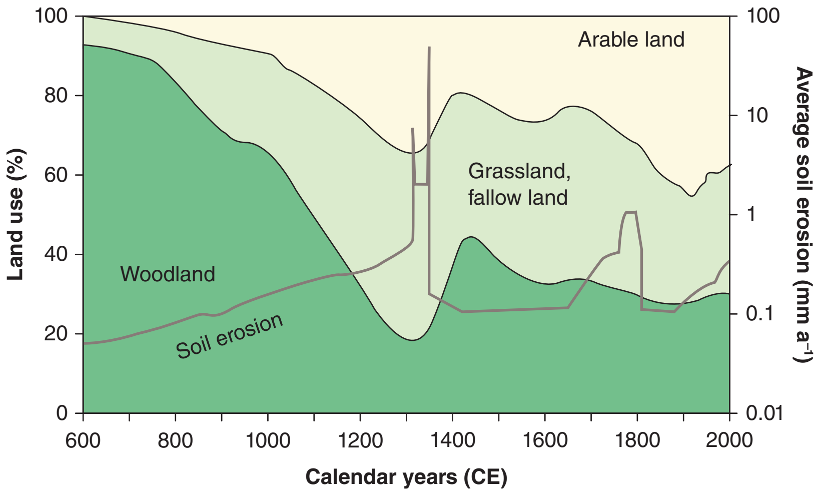

Figure 13.5 Land cover changes in Germany with estimated soil erosion (after Lang et al., 2003)

RELEVANT ARTICLES IN *PROGRESS IN PHYSICAL GEOGRAPHY:*

Brocklehurst, S.H. (2010) Tectonics and geomorphology, *Progress in Physical Geography,* 34: 357–83.

Glasser, N.F. and Bennett, M.R. (2004) Glacial erosional landforms: origins and significance for palaeoglaciology, *Progress in Physical Geography,* 28: 43–75.

Graf, W.L. (2013) James C. Knox (1977) Human impacts on Wisconsin stream channels. *Annals of the Association of American Geographers* 67: 224–44, *Progress in Physical Geography,* 37: 422–31.

Huggett, R.J. (1988) Terrestrial catastrophism: causes and effects, *Progress in Physical Geography,* 12: 509–32.

Huggett, R.J. (1994) Fluvialism or diluvialism? Changing views on superfloods and landscape change, *Progress in Physical Geography,* 18: 335–42.

Souness, C. and Hubbard, B. (2012) Mid-latitude glaciations on Mars, *Progress in Physical Geography,* 36: 238–61.

Summerfield, M.A. (1989) Tectonic geomorphology: convergent plate boundaries, passive continental margins and supercontinent cycles, *Progress in Physical Geography,* 13: 431–41.

UPDATES

Increasing attention is being given to the need for long-term records of floods to extend the relatively short periods for which measurements have been made. Lake sediments can provide such sedimentary records, and these have been reviewed by Schillereff et al. (2014):

Schillereff, D.N., Chiverrell, R.C., Macdonald, N. and Hooke, J.M. (2014) Flood stratigraphies in lake sediments: a review, *Earth-Science Reviews*, 135: 17–37.

Hydromorphic regimes affecting ancient civilizations, and their variability in time and from place to place, have been reviewed in:

Macklin, M.G.and Lewin, J. (2015) The rivers of civilization, *Quaternary Science Reviews*, 114: 228–44.

Tim Lenton (2016) provides a very useful introduction to Earth System Science. This doesn't deal specifically with geomorphology, but it does explain the forcing factors that have regulated the very long-term history of the earth overall, and thus in some form or other, landforms.

On a different scale, Phillips explores landforms as 'phenotypes', that is, reflecting biological control factors ranging from whole ecosystems to biological engineering accomplished by particular plant forms.

A third scale of forcing factor study comes from Italy (Rossato et al., 2015) where a series of flooding 'crises' affecting rivers over the past several thousand years of the Holocene have been documented.

A conceptual distinction (comparable to Macklin and Lewin (2015) previously cited for past Holocene river environments) in driving future change has been put forward by von Elverfeldt et al. (2016). They argue that self-organisation encompasses many intrinsic (autogenic in the terminology used in this volume) processes, and these are important as well as external (or allogenic) drivers.

Lenton, T. (2016) *Earth System Science: a Very Short Introduction*. Oxford: Oxford University Press.

Phillips, J.D. (2015) Landforms as extended composite phenotypes, *Earth Surface Processes and Landforms*, 41: 16–26.

Von Elverfeldt, K., Embleton-Hamann, C. and Slaymaker, O. (2016) Self-organizing change? On drivers, causes and global environmental change, *Geomorphology*, 253: 48–58.

Rossato, S., Fontana, A. and Mozzi, P. (2015) Meta-analysis of a Holocene 14C database for the detection of palaeohydrological crisis in the Venetian-Friulian Plain (NE Italy), *Catena*, 130: 34–45.

Extreme events have been viewed as crucial agents in the development of mountain landforms. Floods are susceptible to on-going climate changes leading to multiple phenomena including changes in bed material, river incision, and increasing hazards. These are being mitigated by human interventions such as channel restoration A special issue of Geomorphology was devoted to this theme:

Stoffel, M., Wyżga, B. and Marston, R.A. (eds) (2016) Floods in mountain environments, *Geomorphology*, 272: 1–150.

A case study of extreme flood event monitoring in SE Spain demonstrated that such exceptual 'drivers' may equally be instrumental in achieving striking change in other environments:

Hooke, J.M. (2016) Geomorphological impacts of an extreme flood in SE Spain, *Geomorphology*, 263: 19–38.

Given such research, extreme events are likely to be crucial for understanding future geomorphologies. This theme is taken up in:

Taylor, L.A., Spencer, T., Lane, S. N., Darby, S. E., Magilligan, F. J., Macklin, M. G. and Möller, I. (2017) Stormy geomorphology: geomorphic contributions in an age of climate extremes, *Earth Surface Processes and Landforms*, 42: 166–90.