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LANDSCAPE SENSITIVITY, ENVIRONMENTAL CHANGE AND GEODIVERSITY

SENSIBILIDADE DAS PAISAGENS, MUDANÇAS AMBIENTAIS E GEODIVERSIDADE

SENSIBILITÉ DES PAYSAGES, CHANGEMENTS ENVIRONNEMENTAUX ET GÉODIVERSITÉ

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PRESENTATION

This article is a synthesis based on an online lecture given by Professor Michael Thomas to the research group Geolands (Science, Technology in Evolution of Landscape, Soils and Planning), from the State University of Feira de Santana (UEFS, Bahia, Brazil), coordinated by Professor Jémison Mattos. The lecture took place on October 29, 2020, and was translated into Portuguese by Professor Vanda de Claudino-Sales. It also had the participation, as a mediator, of Professor Jémison Mattos (UEFS). It was translated int English by Milena Araujo, master's student in geography at the State University of Acarau Valley (UVA).

LECTURE

Bom dia from Escócia, obrigado por me convidar para sua conferência. Thank you very much for the invitation, it´s a great pleasure to be at your conference. I´ve been to Brazil maybe 5 or 6 times and I always enjoyed my visits; people being very hospitable and I´ve seen many exciting landscapes.

The title of my presentation is, 'Landscape sensitivity, environmental change and geodiversity', and I want to try to see these different terms in a tropical environment, and how we should discuss the concept of "Geodiversity" in the wider contexts of geography and geomorphology. Geodiversity has become much more widely discussed during the last two decades, but exploration of the question "How do we apply geodiversity from a geographical and geomorphological point of view?" has not always been clearly focused, and it has not always been widely accepted that geodiversity is important to the study of biodiversity and the protection of the geoheritage. The context of much of this work has been to promote sustainable development in both resilient and unstable environments. Geomorphology has an important role to play in researching the whole range of spatial and time scales, where destabilization of the landscape can occur rapidly or slowly especially in river valleys and due to extreme events.

One of the key publications about geodiversity was a book by Murray Gray at London University, first published in 2004 (Figure 1) and now in its second edition. The author argues that geodiversity be considered as a central idea (even a paradigm) in the study of physical geography and geomorphology. Similar ideas have been developed in Brazil, illustrated in a recent paper by Pãmella Moura et al. (2017).

Figure 1

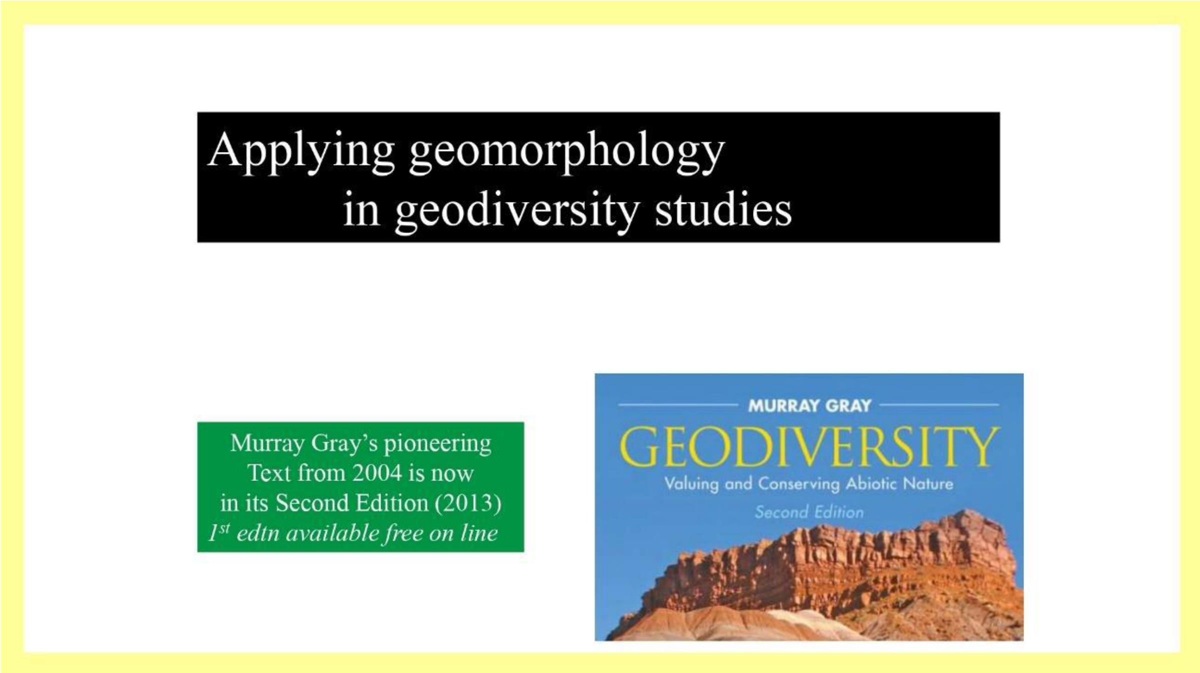
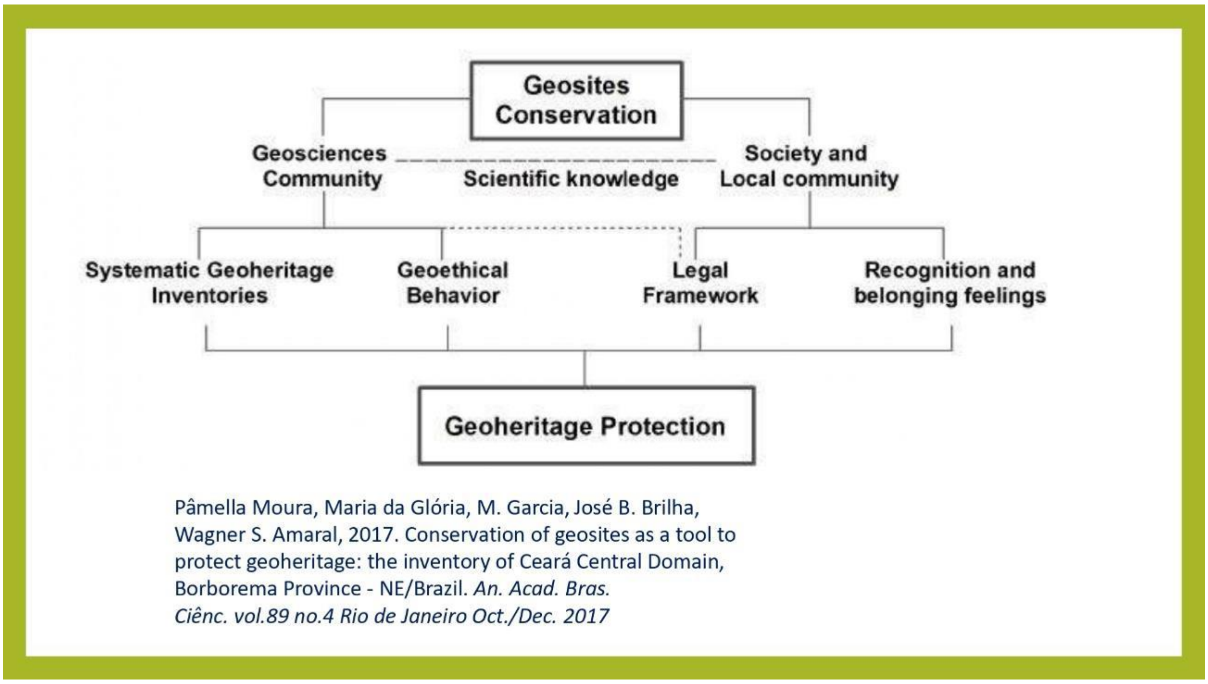
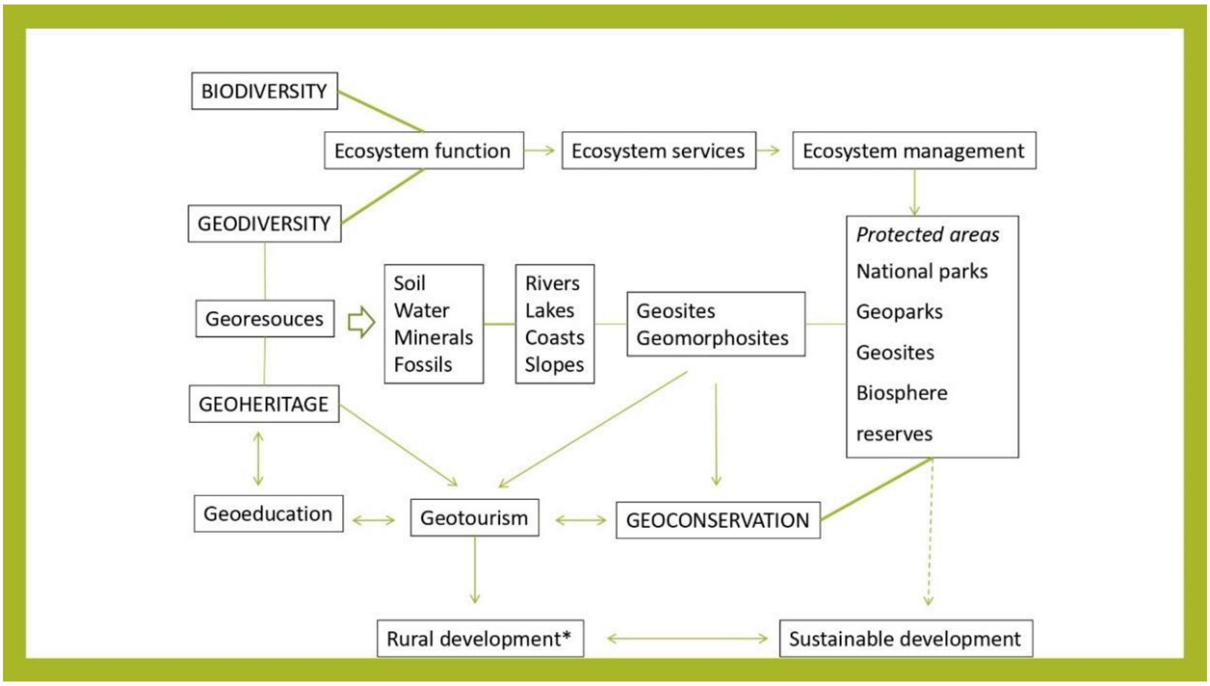


Figure 2



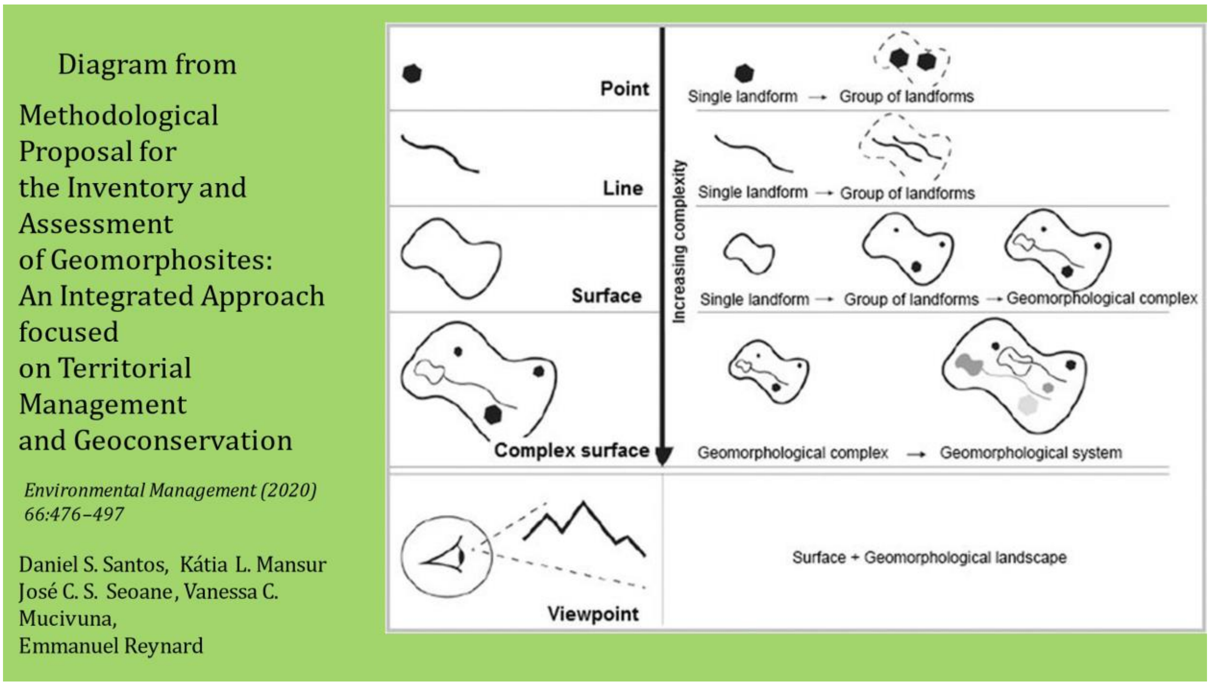
In this paper, the authors consider the study of geosite conservation in relation to a wide range of scientific, social, ethical and legal criteria, incorporating local knowledge within communities, and they show how the whole connects with the purpose of protecting our geoheritage (Figure 2).

Figure 3



Geosites (including geomorphosites) are presented in Figure 3 in terms of the physical environment, to describe the geology and geomorphology with reference to the range of different components of the landscape, and how geodiversity and biodiversity are interdependent in the delivery of ecosystem services and environmental management. Geodiversity is also essentially linked to the understanding and protection of the geoheritage and embraces geoarchaeology.

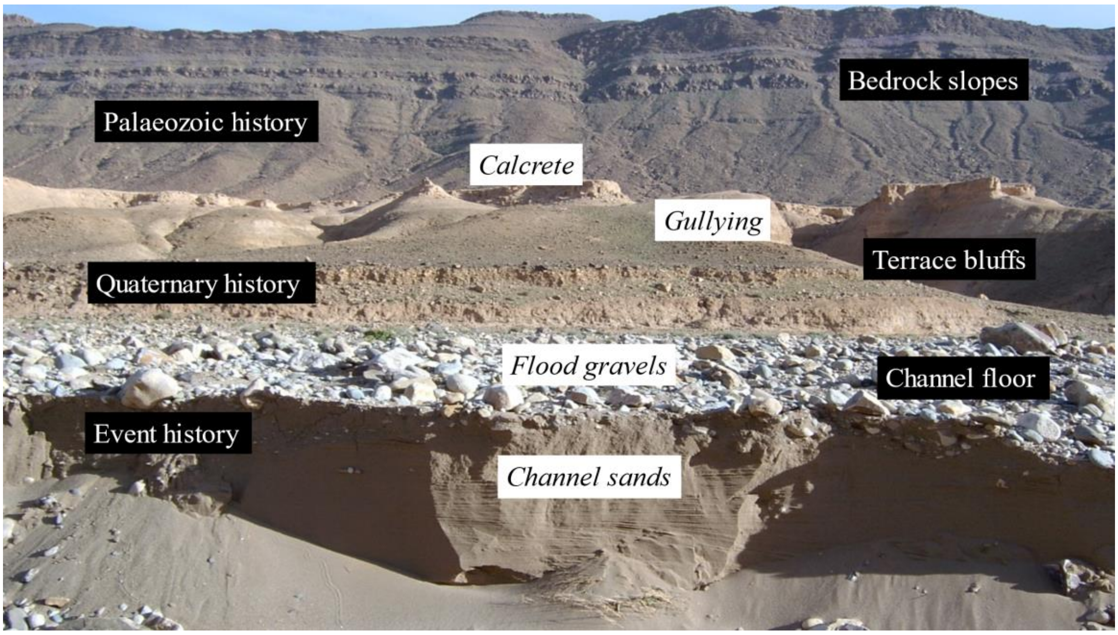
Figure 4



In Figure 4 Santos et al (2020). illustrate the different types and scales of geosites. What it shows is that we can view landscapes as complexes or systems containing individual landforms within linear and areal units or as landform complexes. The latter are often perceived as landscapes. Description of the landsurface according to scale has a long history: different schemes being published from the 1930s, expanding in the1940s with the military use of aerial photography. In the 1950s-1970s Land Systems mapping was developed in Australia and for soil surveys in Africa and many other examples including Brazil in the 1980s onward.

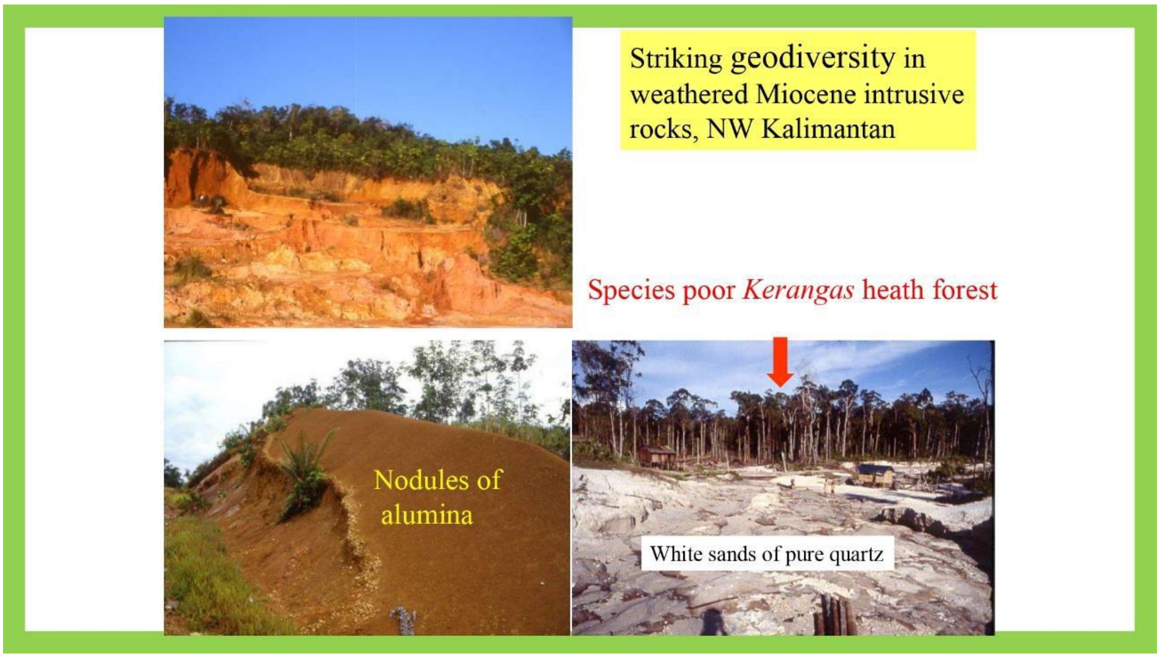
Every landscape has a geological history. It has a range of different surfaces or geosites that are formed sequentially over varied timescales and created by different processes. In Figure 5 a typical arid landscape of the Anti-Atlas in Morocco is illustrated, indicating landforms, geological history and materials formed by different processes. Development of calcrete for example, forms on the surface of a river terrace; gullying, flood gravels and channel sands reflect ongoing erosion and deposition; a history from the Palaeozoic history to the Quaternary 10^4 - 10^3 y, to what I call event history. This applies to the recent period, maybe $10^2 – 10^{-1}$ years, which we can measure and even see the changes happening.

Figure 5



A quite different landscape, greatly influenced by rock weathering and soil formation is illustrated from Kalimantan in Indonesia, where you can see typical weathering associated with the humid tropical climate (Figure 6). Northwest Kalimantan is underlain by crystalline rock, mainly granodiorite, the intense leaching of which produces an alumina-rich saprolite (bauxite) beneath low, rolling hills. More recent, silica-rich intrusions now form residual hills (top-right) underlain by ferrallitic saprolite. Rivers have deposited quartz-rich sand, extending into mangrove swamps around the coastline. The ‘white sands’, form in the lower part of the topography, leached by acid groundwater under waterlogged conditions. These have had almost all the minerals removed except quartz, and some clays mostly derived from volcanic ash. A species poor *kerangas* forest has become established. Similar environments are known, in South and Central America, and in many other parts of the world, where they usually support a very poor vegetation with a low biodiversity. Other tropical examples can be found in Thomas (2012).

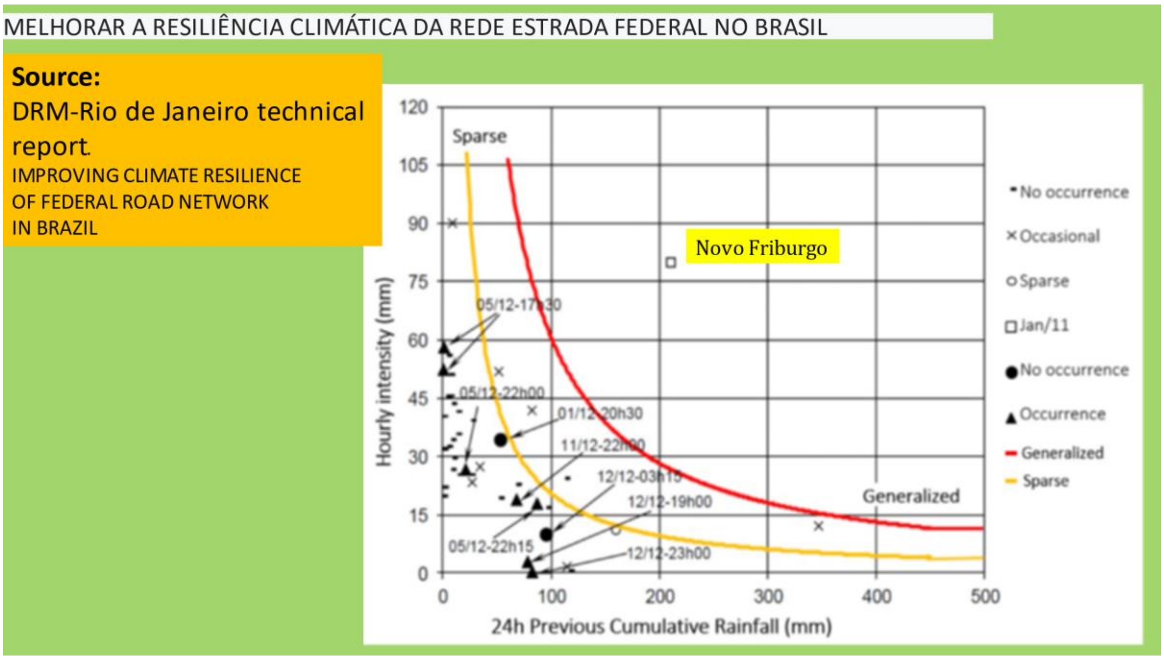
Figure 6



It is also important to consider geohazards in the context of geodiversity. For example, by determining the dynamic status of geosites. Are they *relics* from some former environment; *dormant* and sensitive to change or or are they *dynamic* and actively being modified and altered? Can we determine its resilience or sensitivity? How will they respond to extreme events? And can we understand the *connectivity* or linkages between geosites? Two of the most important and obvious ways in which landscapes are subject to geohazards are in the formation of very deep gullies, and of landslides.

Figure 7

Figure 8



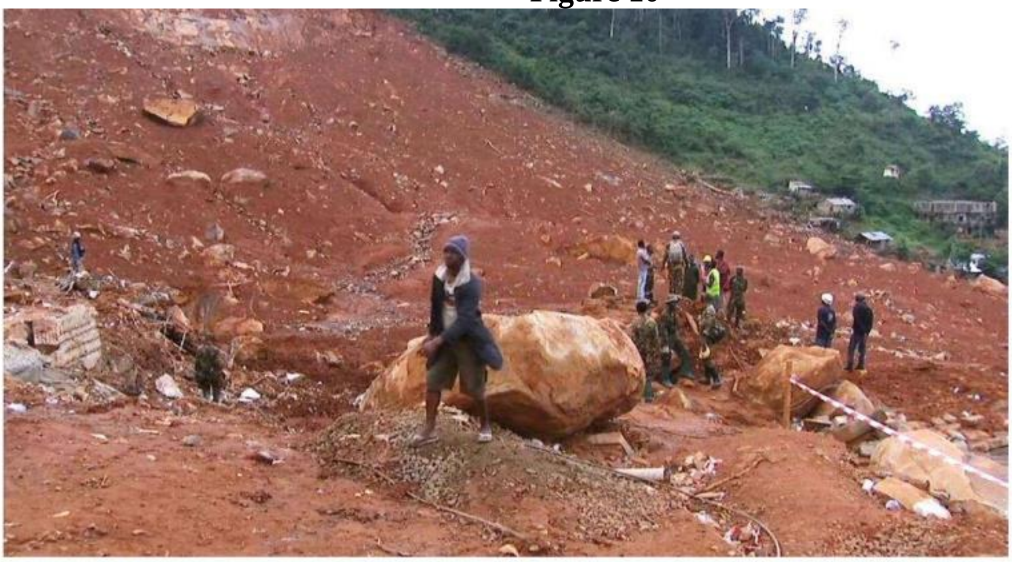
There are many examples of landslides in Brazil. One recent, devastating event occurred in 2011 in Nova Friburgo (Figures, 7, 8). When a large number of landslide events are compared, it can be seen that they are arranged in such a way that two different parameters are very important: the cumulative, rainfall, over 24 hours, and the maximum intensity of rainfall occurring. It is also clear that the Nova Friburgo event is exceptional, outside the curves in Figure 8, There are many such curves in the literature which broadly agree about the dominant controlling factors; others may relate to topography and geology. Devastating events in Brazil, such as Nova Friburgo disaster have occurred before, including the Serra des Araras disaster of 1967, in which 1,700 deaths were recorded (Jones, 1973).

I want to finish this section on landslides with a reference to the Freetown Peninsula in Sierra Leone. This area has hills rising to 900 meters, and the steep terrain has been largely modelled by landslides (Figures 9,10). During early fieldwork in Freetown, I took two photographs (1978, 1983) of the Charlotte landslide, which occurred in 1945 (Figure 9). It was not in a densely populated area, but the slide destroyed the village of Charlotte, killing 15 people. Using 1:10,000 aerial photographs and extensive field observation the landslide distribution for the entire peninsula was mapped. Detailed maps were prepared for the Charlotte and other previous landslide sites. During 2016-17 geologists and engineers from Arup engineering and the British Geological Survey were working on the potential for serious destructive landslides in the Freetown Peninsula for the World Bank, when in August 2017 a major landslide disaster occurred, killing 1000 people in Regent area of Freetown.. In their investigations they were able to use our work for a base line survey. This is just an illustration of the many ways in which research that we do now can become relevant decades later. Figure 10 shows some of the features of the landslide, with very large boulders detaching from the rock face and rolling down the slope, which then developed into a debris flow that continued a destructive path down valley. Factors involved in this slide included steep hillslopes (ca 28^0), rock fractures (sheeting) parallel to the hillslopes, deep weathering penetration, storm size, and probably clearing of rainforest. But there are problems arising from such work. First, we need to communicate risk to competent authorities, which proved difficult in 1980s Sierra Leone. Second, we can map risk for areas with common climate and topography, but efforts to give warnings for precise locations have proved very difficult. In Japan certain mountain roads are closed when storm rainfall reaches a threshold value.

Figure 9

Photo by Phileas Jusu, UMNS (UMC.org)
A view of Sugar Loaf Mountain in Regent area of Freetown, Sierra Leone, shows the breadth of the area that was devastated by flooding on Aug. 14.

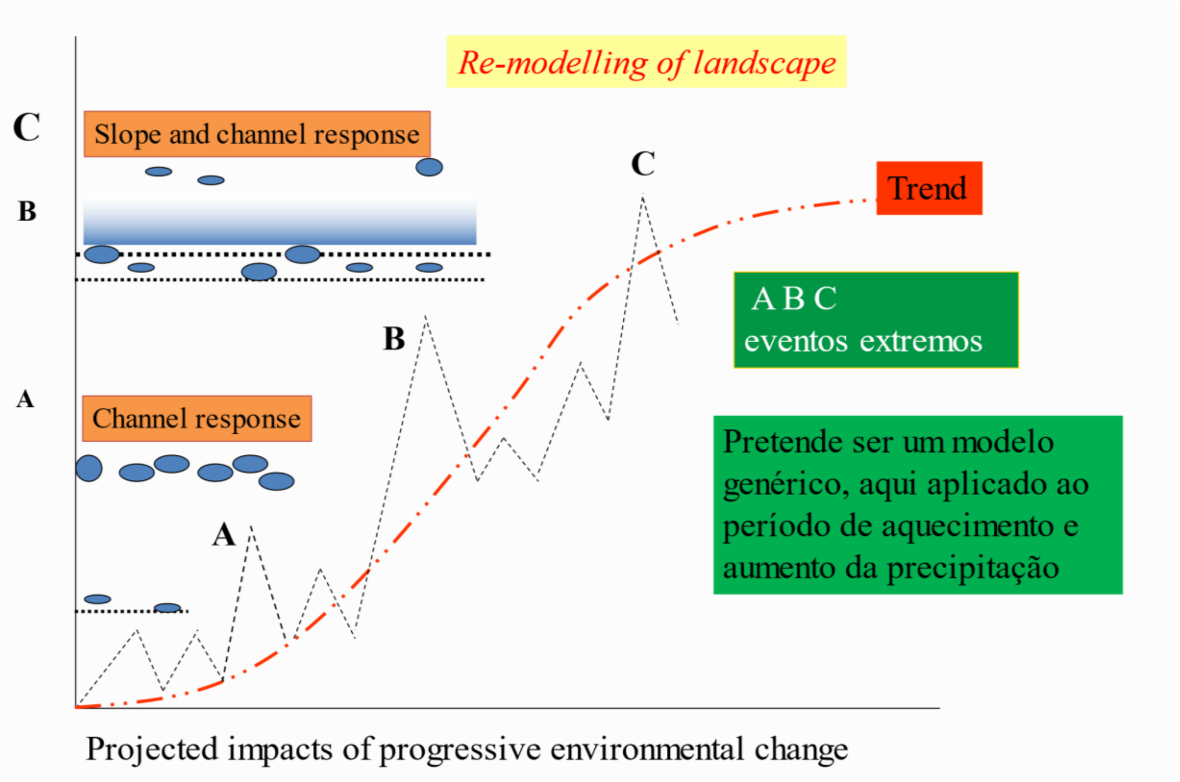
Figure 10



Large boulders involved in the slide (news.sky.com)

More recently I have worked in the Eastern Province of Zambia, where steep quartzite ridges are flanked by numerous landslides in weathered schists. But efforts to derive dates for these events were largely unsuccessful. OSL dates obtained from embedded sands proved to be at least 200,000 years old, suggesting that an event of greater magnitude than any subsequent events had been responsible, possibly an earthquake. The landslides are therefore probably relict (see Thomas, 2021).

Figure 11



In Figure 11, I present a concept of how landscapes can become remodelled by a combination of long-term environmental change and the magnitude of extreme events: the red curve shows the trend of a climate change involving increasing rainfall, from a relatively dry period towards a more humid tropical climate; the dotted line with peaks A, B, C represents the increasing magnitude of storm events. At each level the impact of extreme events is illustrated: coarse gravel-bed channels at A transform into more regular discharges with low flows able to deposit fine sediment at B. When very large storms occur, hillslopes can be destabilised with landslides taking place (C). In other climatic regimes the more extreme flood events may take place during otherwise dry conditions, as in Figure 5.

Figure 12 is based on data from a project I undertook in North East Queensland, which has a humid, tropical (monsoon) climate. We were interested in a series of depositional features along the escarpment facing the Coral Sea. These were mainly alluvial fans and landslide deposits, which we were able to date using Optically Stimulated Luminescence (OSL) of quartz sand grains (Thomas et al, 2007). The period of fan deposition from several rivers draining the escarpment commenced during the late Pleistocene (ca 30 ka) and terminated around 15-14 thousand years ago with fanhead trenching. This fits very well with the known recovery of the rainforest changing from seasonal savanna climate towards a humid forest climate, which is associated with deep soils and the development of wide floodplains. Landslides have also occurred in the intermediate period of rapidly changing climate, including major cyclone events. At the end of the last Northern Hemisphere glaciation climates in many areas of the tropics became warmer and wetter. Around circa 15ka climate change accelerated and landscapes were rapidly transformed.

Figure 12

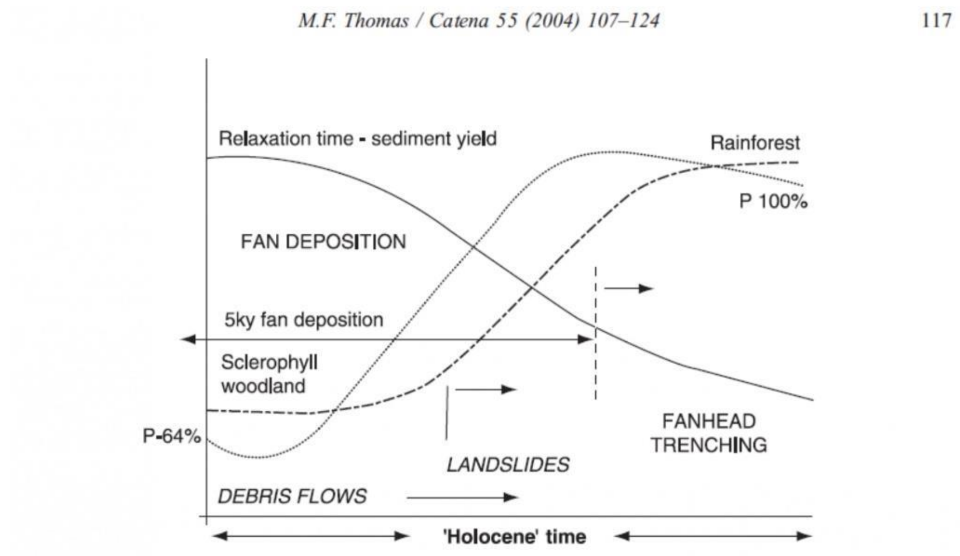
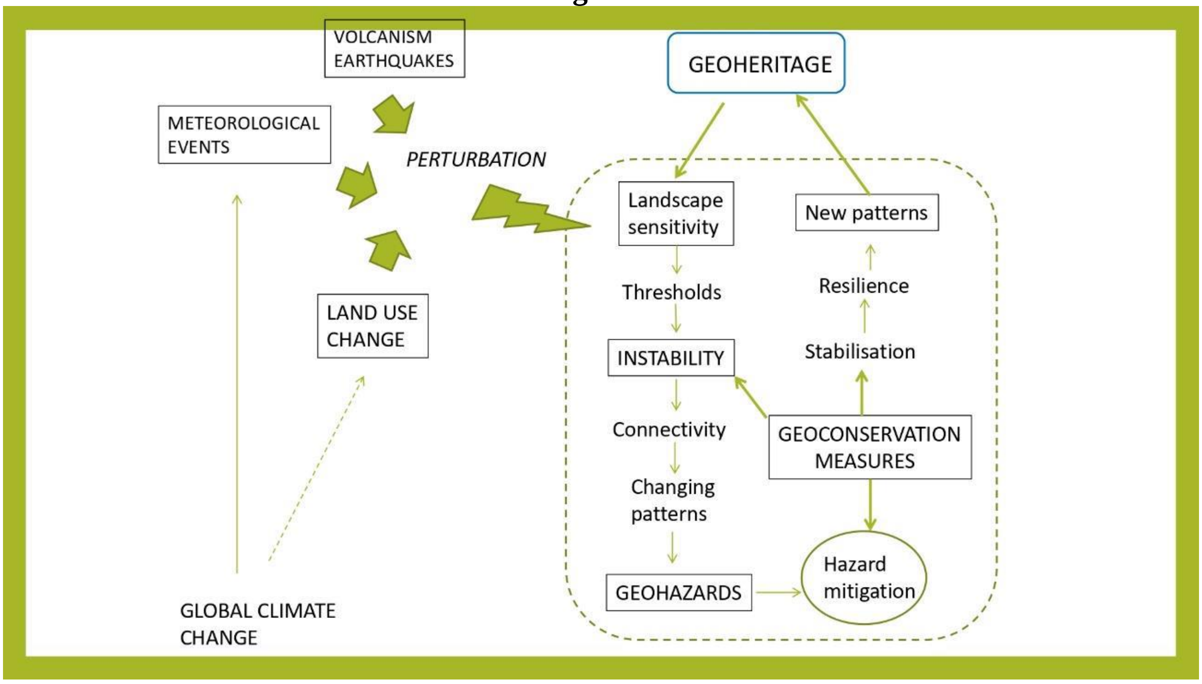


Fig. 3. Model of delayed or lagged response of the fan depositional systems in NE Queensland during postglacial climatic recovery after the last termination. 'Holocene' time refers to the 10^3 year involved in these transitions.

How we understand, landscape sensitivity, and the thresholds that lead to instability can inform the need for conservation measures. Understanding the factors leading to geohazards such as landslides and floods remains largely unquantified, but if we can trace how the present mosaic of slopes and valley floors has evolved, and where geosites of high sensitivity are to be found, then we can begin to search for thresholds of extreme meteorological events likely to trigger rapid and disastrous instability.

We must also consider other factors likely to destabilise the landscape. In this presentation some of these can only be indicated in general terms as shown in Figure 13.

Figure 13



I shall end at this point. It's been a very interesting experience, and very pleasant to be able to visit Brazil virtually. A virtual visit is not as good as a real visit, but it's been very stimulating to meet you all and to have the chance to share some ideas. And I thank you for your patience. Some papers by the author and others are listed below.

ACKNOWLEDGEMENTS

I should like to thank Professor Dr Vanda Claudino, Universidade Federal do Ceará, and Prof. Dr. Jémison Mattos, Universidade Estadual de Feira de Santana) for inviting me to address the Geolannds research group. Thanks are also due to Milena Araujo, master's student in geography at the State University of Acarau Valley (UVA) for transcribing the oral presentation. The author is solely responsible for this edited version.

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