"…the task we have now to undertake, in attempting to estimate the long-term effects of our actions both on the biosphere and on human societies, is so immense that in relation to it our ignorance is almost total."

John Passmore (1974)

LEARNING FROM THE PAST

When it comes to managing the environment, we rarely look beyond the past few years to inform decisions. **John Dearing** says this needs to change.

We have advanced quite a bit since John Passmore, writing more than 35 years ago, considered our lack of understanding about human impacts on nature. Earth-system science has revolutionised the way we think about the interconnectedness of the world's ecosystems and human activities. Computing power has driven the development of global climate models and produced future scenarios of environmental change that affect global politics and policy. Models can now help assess impacts at the global and regional levels. And new theories and concepts about ecological services, resilience, tipping points and adaptation have emerged.

But Passmore's focus on the *long-term effects* of our actions on the biosphere and on human societies is still valid. In contemporary parlance, we want to assess how socio-ecological systems will respond to the mix of climate and the economic and social stresses likely to be experienced. Only then will we have sufficient information to determine the optimum strategy for managing landscapes and ecosystems for the next decades.

Social and ecological processes operate over different timescales.

Complexity science suggests that we might benefit from treating human activities and ecological systems as evolving systems for which the present is the latest point in a time continuum (Dearing *et al.* 2010). A key element is the idea that social and ecological processes operate over different timescales (Figure 1). For example, major shifts in social structure may reflect changes in culture and technology taking place over centuries. At shorter timescales, accelerated soil erosion observed over a decade might be coupled to the introduction of new agricultural technologies. And at even shorter timescales, fire and flooding may be a direct consequence of seasonal climate. Identifying these individual timescales is important enough, but knowing how these different processes interact with each other at any point in time lies right at the heart of improving predictability. If we can reconstruct, and even model, interactions in the past we increase the chance to anticipate the future with more certainty. It follows that we need to emphasise more the longer, historical changes in many social and ecological processes and not to rely so much on short-term information for a few. This is exemplified by two case studies from Australia.

Links between systems

Mark Stafford Smith and colleagues, in their 2007 study, show how a historical perspective of ecological and social change offers rich insights into the interlinkages between society and ecosystems. The researchers focused on a period from the 1890s to the beginning of this century. During the 20th century, some Australian rangelands repeatedly turned to deserts. The reason was a complex interplay of environmental and social factors including, for example, long-term climate variability (the El Nino-Southern Oscillation variability), grazing, the local and global economies, local environmental knowledge and local decisions.

The study found that

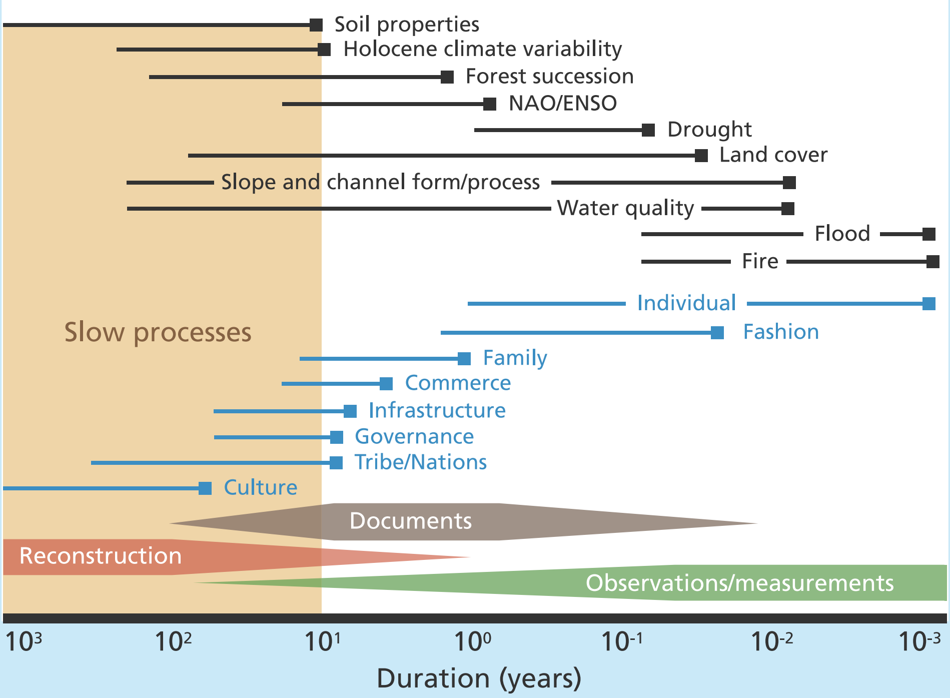

Figure 1. Slow and fast processes. Timescales for a range of biophysical and socioeconomic phenomena range from 'fast' sub-annual events (e.g. floods, fire) to 'slow' multi-decadal and centennial changes (e.g. culture). Understanding contemporary socio-ecological systems may require information from a similar range of timescales, but sources of information become more limited for longer timescales. The sources of information available for each segment of timescale with respect to the present is depicted by the lower horizontal bars. Observations and measurements (for example, instruments, remote sensing, censuses and economic statistics), and documents (for example, diaries, gazetteers and land-use descriptions) may be available for only relatively short timescales. Changes over longer timescales that are essential for assessing the role of 'slow' processes (tan vertical bar) may need to be reconstructed. Reconstruction covers all the palaeoenvironmental fields including archaeology, palaeoecology, palaeoclimatology and palaeohydrology, which interpret artefacts and natural sediment archives (e.g. lake sediments, stalagmites, peat) in terms of past environment and society (Dearing *et al.* 2010).

Saline water body from the Murray Basin.

Peter Gell

Australian farmers apparently responded to declining rainfall and pasture in similar ways throughout the 20th century: in some ways, history repeated itself (Figure 2). A number of self-reinforcing steps seem to have played a part. Hindsight allows us to see that in these event sequences there was invariably a decade or so before the drought when both commodity prices and weather conditions were favourable

Communities understood climate variability but on relatively short timescales.

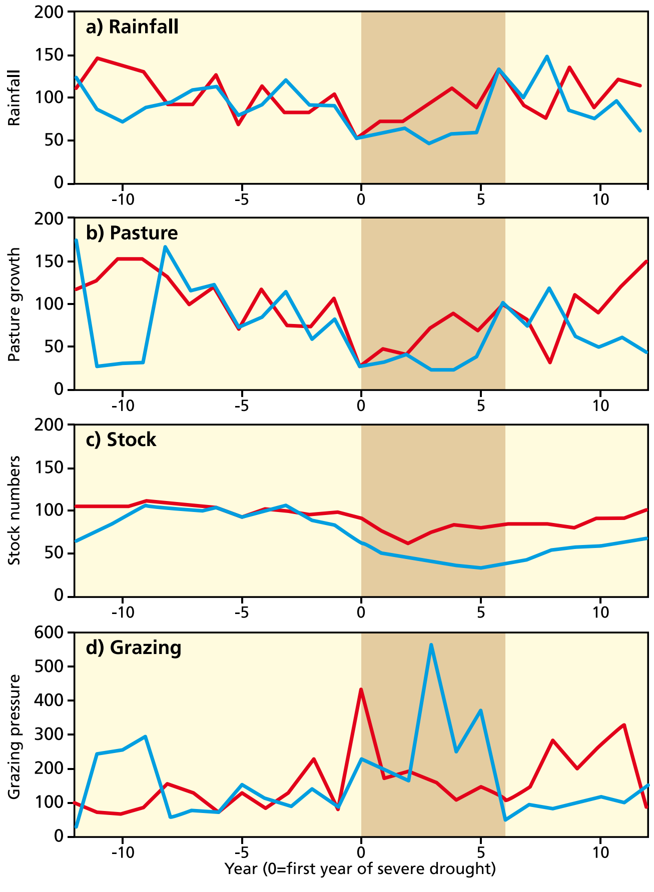

Figure 2. History repeats itself. The history of desertification in Australia since the late 19th century is characterised by a sequence of devastating desertification events. The figure shows normalised curves of a) rainfall, b) simulated pasture growth, c) livestock numbers and d) grazing pressure over more than 20 years that cover the time before, during and following a drought period (brown vertical bar).

Red line: means of relatively short droughts in 1925-29, 1941-44, 1964-67 and 1984-87.

Blue line: means of relatively long droughts in 1898-1902, 1935-40 and 1958-66.

The similarly shaped red and blue curves suggest broadly uniform trajectories for the pastoral socio-ecological system, irrespective of the length of drought or historical period. Farmers responded to declining rainfall and pasture in similar ways, which repeatedly led to unsustainable grazing pressure in the middle years of a drought. They did not heed the lessons from the past. After Stafford Smith *et al.* (2007). Copyright (2007) National Academy of Sciences, USA.

by chance. This encouraged high livestock numbers and thus heavier grazing, habits that did not change much even after the drought was under way. Grazing pressure led to a loss of pasture quality as each drought developed, and each successive drought accelerated soil degradation.

The study found that the communities understood climate variability but on relatively short timescales. Longer-term variability – changes that encompass most of the working lives of individuals – was overlooked. As a result, the expectations of the farmers and communities regarding, for example, the number of livestock that the local environment could support, were based on their experience of environmental conditions during their lifetimes. Managers were most likely to be affected by rare events that they experienced early on in their careers. Similarly, slow patterns of changes in commodity prices were also overlooked. Once a drought had developed, the government offered fodder and subsidies in some events, limiting the incentives farmers had for reducing livestock numbers. This simply heightened the grazing pressure on a declining resource, locking the system in a cycle of degradation.

This historical analysis helps uncover the reasons for changes in a socio-ecological system and provides a sounder basis for designing optimum strategies for sustainable land management. In the case of Australia, the study's authors suggest that while it is important to manage grazing and fires at the local level, it is not sufficient. This is because long-term processes and feedbacks are difficult for individual land managers to take into account based on experience gained during their lives. Alliances between the government, industry and research institutions at the regional levels need to step in. Such alliances can ensure that those charged with decision-making at the local scale have access to knowledge about long-term climate cycles and trends, and receive advance warning of potential environmental or economic disturbances. Stafford Smith and colleagues emphasise that both environmental and socio-economic variability were responsible for the desertification episodes. They suggest that it is important to monitor and understand such variability, and to use this understanding to inform policy.

Evolution of socio-ecological systems

As the study discussed above shows, many processes operate over timescales longer than we have direct information for. Instrumental, documentary, palaeo-environmental and archaeological records within regions can thus be helpful in providing "socio-ecological profiles". Such profiles can help in developing policies and strategies in regions where successful management of key environmental processes, ecological services and their interaction is critical (Dearing *et al*. 2010).

Peter Gell and colleagues, in their 2007 study, have done exactly this for the Murray-Darling basin. This basin is possibly Australia's most critical resource management issue, with 95 percent of its river length degraded. The Murray lakes and lagoons are under pressure from different stressors, with the Coorong lagoon system – a coastal wetland of international significance – being a particular concern. In the past, the Coorong used to be an open system and received clear water from the hinterland and the ocean with flows from the Murray River maintaining an active estuary mouth. In contrast, the modern Coorong is hypersaline, turbid, deficient in oxygen and effectively closed. What happened? To find out, Gell and colleagues integrated decadal reconstructions of water quality (as inferred from a study of diatoms) and land cover (as inferred from pollen analysis) at many sites with land-use histories and hydrological modelling. They were thus able to reconstruct interactions and feedback through space and time.

It turns out that historical land clearance that began two centuries ago triggered a cascade of linked but different biogeochemical changes (Figure 3). Clearance activities, livestock grazing and irrigation caused erosion and groundwater levels to rise, which increased salinity and sodicity levels (the amount of sodium in irrigation water), further increasing erosion. Eroded soils carried native phosphorus to low-lying lakes and coastal lagoons causing increased sedimentation, turbidity and depletion in oxygen levels. More elevated lakes continued to become more saline and eventually acidified.

Naturally the government wants to reverse this trend. It wants to restore the Coorong system by using 1985 as a baseline. Management options include prioritising the Murray's divertible flow to support wetland restoration. There are plans for afforestation in order to combat soil erosion and soil salinity. But these options may result in new problems. A baseline reference from 1985 overlooks the fact that the wetlands have been degraded for almost a century. Restoration efforts may need to be far more rigorous than anticipated if they are to be successful. Diverting river flows at a time when climate change is projected to drive down river flows by as much as 25 percent by 2030 would limit water for other uses, like irrigation. It seems that most development occurred during a flood-dominated regime, yet we may now be in a drought regime. Taking the short-term view seems to have given an unrealistically optimistic view of the available resource. To design more realistic management strategies, it would be beneficial to view the history of the present landscape in terms of an evolving set of interacting processes.

Lessons from the past

The 30-year update on *Limits to Growth* (Meadows *et al*. 2005) considers this problem in terms of how the global society may make the transition to sustainable systems. It rejects an emphasis on maintaining the status quo or finding new technological/economic fixes in favour of "changing the structure of the system". In other words, we need to be doing things differently. To do so, however, we need to be aware of the complexity of the system. Societies and ecosystems can change slowly over long periods of time before crossing thresholds and undergoing sudden changes. The timescales for societal change may be different from those for environmental change, leading to complex interactions and a diversity of states. This means that our ability to say when and where the changes will occur is always likely to be extremely limited, and there are no easy ways to remove the spectre of unpredictability. But a combination of a historical perspective and complexity science may help – especially as we focus more on designing adaptation strategies at regional scales. Managers everywhere should know that their options will be often constrained by the legacy of past decisions affecting the processes they seek to control. In the same vein, they need to be aware of the responsibility they have to future land managers who may operate in a time that lies well beyond their own planning horizon.

We need to be aware of the complexity of the system.

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MORE INFORMATION:

Leading the interdisciplinary integration of historical information are the PAGES Past Human-Climate-Ecosystem Interactions focus and the Integrated History and Future of People on Earth (IHOPE) project, co-sponsored by IGBP's AIMES and PAGES projects, and IHDP.

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