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APPLYING RESILIENCE THEORY IN RANGELAND MANAGEMENT

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ABSTRACT

Resilience is a concept that is intuitively understood by most rangeland managers. Indeed it is a characteristic required of those who live in the rangelands. In essence it refers to the ability of a system to recover from a disturbance and persist in its pre-disturbance state, rather than moving to a new degraded state. Therefore managing for resilience in the variable and highly unpredictable rangelands is a desirable goal.

Managing for resilience should prevent a desirable rangelands agro-ecosystem from changing to an undesirable state in the face of a disturbance, by maintaining the underlying ecological, economic and management components of the system that allow it to recover from disturbance. A significant body of scientific theory about resilience exists. However, making the step from scientific theory to managing for resilience is hampered by the fact that resilience in complex agro-ecosystems has not been adequately quantified nor have the key elements that confer resilience been identified.

This paper reports on a developing research program to operationalise and test resilience theory in Australian agro-ecosystems using dynamic systems models that capture the feedbacks within and between the social, economic and ecological components.

INTRODUCTION

The rangelands of Australia are a highly variable and often extreme environment. They are typically semi-arid to arid regions, with rainfall < 600 mm per annum, although they also include the tropical savannas. The occurrence of rainfall in the rangelands is either seasonally restricted or unpredictable over periods of years, with summer dominant monsoons in the north, annually unpredictable but largely summer dominant rain in the centre, and winter dominant rain in the south.

Rangeland ecosystems and their fauna and flora are strongly influenced by water availability, soil type and soil fertility. The contemporary rangelands, particularly those dominated by grasses, appear to have come into existence less than 2 million years ago, with a climate trend to increasing aridity. During this time the fauna and flora have evolved behavioural and physiological responses for coping with an extreme and variable environment of low nutrient availability, uncertain water supply, and temperature extremes.

Humans have lived and survived in the rangelands for some 50,000 years, adopting a largely migratory lifestyle to live within the environmental variability. In the modern era, however, management practices and human interactions with the rangeland environment have changed rapidly under the influence of external social, economic and environmental drivers. Permanent urban and rural communities have established, extensive pastoralism is now the dominant land use, and enterprises such as ecotourism are gaining prominence.

Living and thriving in the rangelands is a challenge. In recent times, there has been an increasing recognition of the importance of "sustainable" land management. Until now, the science of sustainability has been about harvesting natural resources to: a) maximise their growth rate, while simultaneously b) avoiding over-harvest. We claim that in highly variable rangeland systems this idea is too simplistic; we need to foster the health of our systems to *respond* to the effects of climatic variability, such as drought. We also claim that this is not purely a question of ecology; maintaining the economics of on-farm practice and the social structures that tie rangeland communities together are also critical to the long-term viability of our rangeland systems. The solution, which we discuss below, involves learning from experience, adapting to change, fostering community links and information flows, and incorporating new ways of looking at rangeland systems scientifically.

WHAT IS RESILIENCE?

Many human-modified and managed ecosystems and the communities and industries that depend on them are failing, degrading or collapsing (Millennium Ecosystem Assessment 2005). This even includes ecosystems that are ostensibly being managed sustainably. There is increasing evidence that collapse is often triggered by an unusual environmental, social or economic "shock". However, research suggests that is often not the shock itself that destroys human-managed ecosystems, but the inability of the system-at-large to adapt to conditions after the shock that drive the system to ruin (e.g. Walker *et al.* 2004). As a whole, these coupled social-economic-ecological systems are not *resilient* to change.

Resilience is the ability of a system to return to its previous desirable condition following a disturbance. It is a *dynamic*, *whole-of-system* property, based on the ability of social, economic and ecological sub-systems to temporarily reorganize following a disturbance to absorb the effects and recover. To really embrace the ideas behind resilience, we have to acknowledge that dealing with "average" production and economic figures is useful, but does not provide *all* the answers for managing our systems. We must recognize that systems can collapse both temporarily and irretrievably following even small shocks to the system. We also need to avoid attributing collapse to the shock itself, and instead ask "what can we do to enhance the ability of our system to deal with such a shock next time?"

The *science* of resilience is still developing. It is difficult to quantify precisely because it deals with uncertainty, variability and imprecise knowledge; it is fundamentally interdisciplinary (incorporating social science, economics and ecological and natural sciences); and it deals with subjective issues (e.g. one person's disaster is another's opportunity). Since the 1960s, an interdisciplinary field has developed that has provided a framework encompassing these issues. Today it is represented best by the Resilience Alliance (www.resalliance.org).

RESILIENCE OF WHAT AND TO WHAT?

One of the fundamental tenets of resilience science today is that both the system (of what) and the shock (to what) must always be defined clearly (Carpenter *et al.* 2001). Intuitively, we want our system to be resilient to *all* perturbations; but scientifically, we need to deal with well-defined sequences of events.

Our research is focussed on determining the resilience *of* Australian agro-ecosystems, including but not limited to rangelands, under a variety of management practices, *to* factors such as drought, rising fuel prices and changing social, economic and environmental policy. These issues are expected to become increasingly important under scenarios of global climate and climate variability change, globalisation of the world economy, and social and technological change of the human systems based on Australian agro-ecosystems.

HOW DO WE MEASURE RESILIENCE?

Modern social-ecological resilience, as promoted by the Resilience Alliance, is a system-wide property. It depends on social, economic and ecological factors, the interaction between these system components, and how the components and the interactions between them change through time and react to external forces or drivers. In addition, it allows for multiple system states, collapses between states, and total catastrophic collapse.

One measure of resilience is the time required for a system to return to its previous condition following disturbance (e.g. Pimm 1984, 1991; Orwin & Wardle 2004). However, this measure implicitly assumes that a system *will* recover following disturbance, even though there have been many examples of systems that collapsed to a less desirable condition. Modern resilience recognises that a disturbance may kick a desirable system (e.g. a grass dominated rangeland) across a threshold to a less desirable state (e.g. a shrub-dominated rangeland), from which it may not return unless significant energy is invested in it doing so (Westoby *et al.* 1989; Carpenter 2003; Gunderson & Holling 2001). Given that resilience in this approach is measured after a disturbance, it provides very little predictive ability, and cannot directly incorporate social or economic effects and interactions.

Ideally we want to be able to measure or assess the current resilience of a social-ecological system to a range of likely disturbances in order to manage it to avoid degradation or catastrophic change. This is a major scientific challenge (Carpenter *et al.* 2001). To embrace the social, economic and ecological components of the system, while incorporating predictive capacity, we measure the resilience of mathematical models that we construct to represent real systems. Specifically, we are pioneering the use of dynamical systems models that capture the dynamics of feedbacks within and between the social, economic and ecological components. This model structure is vital to describing the process whereby the action of one system component, say commodity prices on the global market, affects other components at various scales. For example, management practice on a farm here in Renmark leads to altered grass production, which integrates up to affect the regional economy of SA, the Australian markets, until eventually the affected component has an effect on the structure or function of the original component, i.e. the global commodity price.

Because the systems we deal with have a significant level of uncertainty, variability and unknowability, our predictive models exhibit some inaccuracy beyond their immediate scale of focus. Think of weather forecasting! However, instead of searching for incremental gains in production or environmental outcomes, we're looking for major thresholds to catastrophic collapse. Where we demonstrate the *potential* for a collapse, we can investigate in more detail while managing the system to minimise the risk of catastrophe. Our techniques are *complementary* to other management tools, such as on-farm experience and precise simulation models.

To date we have developed these techniques to model the resilience of generic landscape exploitation systems including early societies such as Easter Island, through to modern hunting-gathering societies, traditional nomadic grazing, modern extensive grazing and modern intensive agriculture (Fletcher & Hilbert, submitted). We have also started to investigate specific systems, such as the effect of the clover root weevil on New Zealand's dairy industry (Fletcher *et al.* in prep). We are currently seeking research funding to develop and test this approach in determining the resilience of intensive (dairying) and extensive (rangeland pastoralism) agriculture. One of the significant research challenges is to develop and test techniques for integrating multi-scale social, economic and/or ecological models, and their feedback loops.

CONCLUSION

The future of Australia's rangeland biological and human communities will depend on their capacity to learn and/or adapt to a dynamic global, regional and local environment. The emerging science of resilience, complemented with the mathematical modelling technique we discuss here, offers an opportunity to learn how social-ecological systems operate at multiple scales, how these systems can develop or maintain resilience, and how we can specifically manage for resilience.

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