Rangeland ecology: Key global research issues & questions

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This paper discusses developments in our understanding about rangeland ecology and rangeland dynamics in the last 20 years. Before the late 1980's, the mainstream view in range ecology was that livestock and vegetation were in equilibrium, and too much grazing (overstocking) caused the range to lose productivity. This, in turn, meant fewer livestock could be supported on those pastures in the future. Thus our management practices and policy focused on making sure that livestock numbers stayed below the *carrying capacity* of the range to prevent overstocking. Carrying capacity is the upper limit of forage (grass, shrubs) that livestock can graze and still sustain the productivity of the range for the subsequent seasons.

In the last two decades, our thinking about rangeland ecology and the dynamics of pastoral ecosystems has undergone a major intellectual change (Sandford 1983, Ellis and Swift 1988, Westoby et al. 1989). From work in arid rangelands with highly variable rainfall, research in the 1980's and 1990's showed that rainfall has more impact on rangeland productivity than livestock grazing does. In these dry rangelands, frequent drought and long dry / cold seasons mean that livestock populations rarely become so high to exceed the ability of the vegetation to support them. If herders have no access to external sources of feed and water, they either move their livestock to wetter pastures or, if this is not possible, livestock die and herds are smaller after drought for a period of time. This movement or smaller herds allows the vegetation to recover. Here, there is no fixed carrying capacity; instead, the maximum number of animals a pasture can support fluctuates with rainfall. These are termed 'non-equilibrium systems'. Researchers contrast them to 'equilibrium systems' where herders can overstock the range, livestock can damage the production of vegetation, and where carrying capacity can be a useful concept.

This distinction is important. If rainfall is more important than grazing and livestock do not damage vegetation, then it does not matter how many livestock graze a rangeland, because livestock cannot degrade rangelands (Ellis and Swift 1988). Thus policy and management should support pastoral families during drought to move to new pastures, but there should be no limitation on animal numbers. On the other hand, if livestock can damage vegetation by grazing, it is critically important that policy and management focus on the numbers of animals that graze a rangeland, as well as supporting families during dry times.

Subsequent research shows that both equilibrium and non-equilibrium rangelands exist (Briske et al 2003), and sometimes they are mixed in the same landscape or change by season (Vetter 2005). Generally, arid rangelands are non-equilibrium and semi-arid rangelands follow equilibrium patterns. But even in arid rangelands, areas like wetlands and river-edge vegetation, often called key resources, can be in equilibrium with livestock populations, while the wider rangeland is not (Illius and

O'Connor 1999, 2000). In conclusion drier rangelands tend to have non-equilibrium dynamics, wetter ones have more equilibrial dynamics with significant mixing of these dynamics. There is evidence that heavy grazing can degrade arid rangelands (Todd and Hoffman 1999), so it is important to not assume that livestock have no impact on arid, non-equilibrium rangelands (Fernandez-Gimenez and Allen-Diaz 1999). Rather, it is important to monitor and assess the health of all rangelands over time. And as we measure change, we need to distinguish among the effects of livestock, land use and climate and find out how reversible that change is.

There has also been a shift in the way we think about how rangelands change over time. Previous to 1989, the traditional range model, following principles of equilibrium dynamics, described rangeland change as a linear (or straight line) process along one predictable pathway that could be reversed. Since then, significant research shows that any particular rangeland can follow several different pathways of change to different vegetation states[1] (like grassland compared to bushland), depending on the amount of grazing or other disturbances (like fire). And these changes may not be linear; there may be abrupt changes that occur as the system passes over a *threshold* (Friedel 1991, Bestelmeyer et al. 2006, Briske et al. 2006). These thresholds may make the change from one vegetation state to another hard to reverse or irreversible, unless there is significant labor and capital to restore the vegetation to the original state. Non-linear change happens, for example, when livestock grazing pushes vegetation structure or productivity over a threshold, with a major change from a grassland (the first 'state') to a bushland (the second 'state').

These ideas led to the development of *state-and-transition models* that help us describe changes in rangeland vegetation and estimate future changes. These models (Westoby et al. 1989, Bestelmeyer et al. 2003, Stringham et al. 2003, Briske et al. 2006) describe these non-linear changes across thresholds from one state (like stable soil) through a transition to another state (like eroded soil). These models are particularly useful because they can integrate local, traditional and scientific knowledge together to describe alternative states of rangelands. Rangeland managers find these models useful in describing change in rangelands and there is much attention on identifying thresholds, these periods of 'hard-to-reverse' change. These models can be applied to non-equilibrium or equilibrium rangelands. There are other ways of modelling rangelands, through models using difference / differential equations or rules but these will not be covered here.

Finally, as land tenure changes and use of rangelands intensifies, herders often settle and convert into other uses or fragment the rangeland, often with fences (Reid et al. 2008). This was common in US and Australian rangelands in the last century, and in Africa and Asia in this century (Galvin et al 2008). Fragmented rangelands can support fewer livestock per hectare because herders and their livestock can no longer move freely and thus do not have easy access to different types of vegetation

[1] A recognizable, resistant and resilient complex of soil and vegetation structure that is distinguished from other states by relatively large differences in plant functional groups and ecosystem processes, and therefore in veg. structure, biodiversity & management requirements.

that are important for grazing in different seasons and during drought (Hobbs et al. in press). This may be a future issue in Mongolian rangelands.

From this overview of rangeland dynamics, we propose that the following are important research questions to ask in any rangeland:

- What are the management objectives of users of the rangelands?
- Does livestock grazing cause undesirable changes in rangelands (like lower vegetation productivity, fewer native plants, reduced stream flow)?
- Do these changes feedback on the livestock? In other words, does livestock grazing affect rangeland productivity to the extent that future livestock grazing suffers?
- At what level of grazing do these changes begin to occur?
- If grazers are removed, does the rangeland recover to the pre-grazed state? How long does this take?
- How does livestock grazing interact with climate and land use to influence the state of rangelands?
- What mix of local, traditional and scientific indicators of change are most useful to measure the health of the rangeland?
- At broader scales, what are the forces driving fragmentation in rangelands and what policies can slow down this process?

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