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Reorganizing resource use in a communal livestock production socio-ecological system in South Africa

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ABSTRACT

Livestock production on South Africa's commons contributes significantly to the livelihoods of communal households, offering status, food, income and savings. Management innovations are generally top-down and informed by commercial practices such as rotational grazing in combination with conservative stocking. Implementations often ignore how the specific socio-ecological context affects outcomes and the impact on equity. Science now acknowledges that rangeland management must be context specific and that a universally agreed-upon recommendation for managing semi-arid rangelands does not exist. We present a socio-ecological simulation model derived from a case study in South Africa and use it to assess the socio-ecological effects of rotational vs. continuous grazing under conservative and opportunistic stocking rates. We find that continuous grazing under conservative stocking rates leads to the most favourable outcomes from the social and the ecological perspectives. However, the past legacy under apartheid and participants' expectations renders its successful application unlikely because enforceability is not ensured.

1. Introduction

Livestock husbandry plays a vital role for livelihoods in southern Africa because it constitutes either a means of subsistence or a financial buffer in unfavorable times (Dovie et al., 2006; Shackleton et al., 2001). In the case of South Africa, livestock are the most important agricultural capital good in the crowded areas of the former homelands, where it is predominantly managed on common pool resources (Adams 2013; Vetter, 2013). Considering the high population density and poverty in the former homelands, the South African government has emphasized the need to increase the economic benefits generated by those rangeland systems (Department of Agriculture and Forestry, 2007). However, projects in the communal rangelands are often implemented top-down and ignore stakeholder participation and their expectations (Jakoby et al., 2014; Atkinson, 2013); they are guided by the persistent assumption that rangeland commons are generally overstocked and degraded (Adams 2013; Naumann, 2014; Harrison and Shackleton, 1999). This assertion is, however, challenged by the notion of non-equilibrium dynamics in semi-arid rangelands (Sullivan and Rhode, 2002; Oba et al., 2002). Improvements are thought to be achievable by imposing rotational grazing and conservative stocking rates as practiced in the commercial sector (Campbell et al., 2006). However, commercial beef cattle production maximizes the profitability from livestock sales, whereas the safety-net function is more important in the communal setting (Dovie et al., 2006). Thus, measures of system performance ignoring the intrinsic value of herd sizes fail to quantify an important goal of stakeholders. Large fluctuations in herd size reduce their inherent capacity to buffer against unforeseeable adverse circumstances. Moreover, there is little concern regarding how measures affect equity (Vetter, 2013). Inequality in household off-farm income translates into comparative advantages of richer households regarding supplementary feeding and restocking. Quantifying the differences in distributional effects from management alterations necessitates accounting for heterogeneity in endowments and interaction of production decisions via the common resource. A third concern is the enforcement of new management rules because cooperation is based on the willingness of stakeholders to invest in the institutional process. Benefits from management alternatives should match participant's expectations to be sustainable, and past legacies impact the likelihood for success (Frey and Jegen, 2001). In short, the human dimension of grazing systems is not yet adequately considered in management policies targeted at communal grazing systems in South Africa (Vetter,

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2005). According to Vetter (2013), the policy for the development and management of the rangeland commons should achieve

- better resource management for sustainable land-use activities,
- greater contribution of rangelands to livelihoods and
- greater equity in distributing benefits from the rangeland.

Using a simulation model for a communal rangeland case in South Africa, we investigate if the introduction of rotational grazing and conservative stocking satisfies the outlined development goals and discuss the constraints for a successful change in management. A contribution of the model is to allow for disaggregated equity dynamics by means of agent-based modelling. Agents who are heterogeneous in their ability to provide supplementary feeding and to restock are modelled explicitly and parameterized with household survey data. This allows for the emergence of interaction effects between household competition and management intervention, which is impossible for aggregate modelling approaches. The model presented in this paper constitutes a simplified version of the model presented by Rasch et al. (2016).

Management paradigms in South Africa focus on the notion of a fixed carrying capacity being an "institutionalized fact" (Benjaminsen 2006, p.524). The original rationale for that notion traces back to the succession model of rangeland science, which was subject to considerable debate. Section 2 highlights some key concepts surrounding this discourse. Section 3 presents the case. We omit a full model description here and refer to Rasch et al. (2016) for a condensed model description. An extended description is available in the supplementary material for this paper (ODD + D[1] protocol). The scenarios and measures of performance are outlined in Section 4, followed by the model results Section 5. Section 6 relates results to theoretical concepts of rangeland dynamics and investigates their applicability in managing the South African grassland biome, highlights the important role of social competition for equity dynamics and outlines institutional issues.

2. The ecological debate and management implications

Two areas of theoretical dichotomy in rangeland science have been the discourses of equilibrium vs. non-equilibrium systems (Briske et al., 2003) and of engineering vs. ecological resilience (Peterson et al., 1998; Vetter, 2009). These theoretical debates relate to diverging management paradigms on stocking rates and spatio-temporal grazing strategies.

The equilibrium system understanding assumes that herbivore-resource dynamics are in equilibrium. Above a supposed optimal stocking rate, increased competition for forage causes a decrease in animal performance (Oba et al., 2000). Livestock survival is density-dependent, and degradation occurs due to overstocking. Equilibrium theory is criticized for neglecting the impact of climatic variability predominant in arid and semi-arid areas (Briske et al., 2003). Proponents of the non-equilibrium theory argue that abiotic factors, particularly rainfall variability in our case, are the primary cause for livestock mortality. Population crashes are inevitable and solely induced by droughts. That is, mortality is density-independent. Likewise, degradation is not a result of grazing but induced by abiotic factors (Vetter, 2005). Consequently, non-equilibrium theory is criticized for neglecting any potential negative effect of intensive grazing (Wessels et al., 2007).

Management implications derived from equilibrium and non-equilibrium theory are conservative and opportunistic stocking, respectively (Sandford and Scoones, 2006). Conservative stocking tries to avoid crossing the (fixed) carrying capacity of rangelands by employing relatively low and constant stocking rates (Holechek et al., 1999). In contrast, opportunism maximizes resource utilization in favourable years and assumes that the rangeland will recover under light stocking after an ecological crisis. Recovery is possible because livestock are either sold in drought years or due to unintended resting caused by events of high mortality (Müller et al., 2007). However, opportunism requires the absence of significant supplementary feeding or restocking in drought years (Campbell et al., 2006; Vetter, 2005; Briske et al., 2003). There is a stark controversy regarding which of the two grazing practices is more suitable in semi-arid rangeland systems. See, for example, the dispute between Campbell et al. (2000) and Sandford and Scoones (2006). From an economic perspective, temporally high opportunity costs of conservative stocking trades off against reduced average productivity under opportunistic stocking (Campbell et al., 2006).

A second pair of management strategies related to the discussion is rotational vs. continuous grazing. The rationale of rotational grazing is to allow the vegetation to rest to recover and was introduced in South Africa to mimic evolutionary grazing patterns of traditional transhumance, later restricted by settlements in the early 20th century (Vetter, 2005). However, non-equilibrium theory argues that rest times are not necessary because the resource will eventually recover after droughts under light grazing (Müller et al., 2007). Briske et al. (2008) found that empirical evidence from the past 60 years could not support the superiority of rotational grazing. According to the authors, a key management dilemma with rotational grazing is the goal of simultaneously optimizing residual leaf area and utilization by livestock for production. This is especially relevant for semi-arid areas where high quality forage of under-utilized pastures rapidly decomposes. Research on the intersection between human ecology and political ecology suggests that fencing camps is nevertheless dominant on the political agenda and that this persistence is rooted in the theory of equilibrium dynamics (Benjaminsen et al., 2006). However, the proponents of continuous grazing also acknowledge that longer-term rests ("rest-rotation") might be ecologically beneficial (Briske et al., 2008; Bennett et al., 2010; Snyman, 1998).

The notion of single and multiple stable states associated with equilibrium and non-equilibrium systems is reflected in the discourse on resilience (Vetter, 2009). A classical ecosystem understanding of resilience is known as engineering resilience (Peterson et al., 1998). It assumes a single equilibrium and views resilience as the "speed of recovery" and resistance as the ability to withstand disturbances (Adger, 2000). Engineering resilience is criticized for ignoring sudden shifts in system states if system inherent thresholds are crossed (Peterson et al., 1998). In this case, examples of lake eutrophication (Carpenter et al., 1999) and, more relevant for rangeland systems, transitions from grassland to shrub-dominated systems are described and illustrated by simple ball-and-cup metaphors (Jeltsch et al., 1997; Anderies et al., 2002; Vetter, 2009; Briske et al., 2003). A system is considered resilient in this context if it does not change its fundamental functions when facing external shocks (Walker et al., 2006). The latter notion is termed ecological resilience. From an economics perspective, this definition does not consider the costs of being resilient in the first place (Béné, 2013). Even in the absence of alternative states, grazing pressure and resting time of the vegetation might determine the costs for withstanding disturbance and enduring recovery time for stakeholders. However, the management implications of the resilience discourse are not as clear-cut as for the non-/equilibrium discourse. At least for Harrison and Shackleton (1999), conservative stocking rates and rotational grazing are not needed for resilient rangelands.

The comparative simplicity of the non-/equilibrium debate is somewhat battered by a more differentiated view entailing the

[1] ODD + D—Overview, design concepts and details + decision making - Standard protocol for describing agent-based models—Grimm et al. (2010).