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Research article

Global effectiveness of group decision-making strategies in coping with forage and price variabilities in commercial rangelands: A modelling assessment

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ABSTRACT

This paper presents a modelling study that evaluated the global effectiveness of a range of group decision-making strategies for commercial farming areas in rangelands affected by temporal variations in forage production. The assessment utilised an integrated system dynamics model (86 equations) to examine the broad and long-term group decision outcomes. This model considers aspects usually neglected in related studies, such as the dynamics of the main local prices, the dynamics of the number of active farmers, the supplementary feeding of livestock, and certain behavioural traits of farmers and traders. The assessment procedure was based on an analysis of the outcomes of the model under 330,000 simulation scenarios.

The results indicated that only if all the farmers in an area are either opportunistic or conservative that is, are either responsive or unresponsive to expected profits, the exploitation of the grazing resources were optimal in some senses. A widespread opportunism proved optimal only from an economic viewpoint. However, it is very unlikely that most of the farmers would agree to be opportunistic in practice. By contrast, a widespread conservatism, which in principle is perfectly feasible, proved optimal from economic, social, and ecological perspectives. Notably, it was found that the presence of a relatively small number of opportunistic farmers would suffice to considerably reduce the economic results of widespread conservatism.

1. Introduction

Savannas, grasslands, and shrublands—biomes within the group with the highest climatic variability—support 72% of the world's grazing area (Asner et al., 2004). Consequently, forage is the most critical source of risk to many grazing systems worldwide, and a number of management strategies have been found to manage this problem, namely, adapting livestock numbers, purchasing feed, moving livestock to another location, leasing forage, resting pastures, incorporating store animals, or diversifying income sources (Kachergis et al., 2014; Torell et al., 2010).

Adapting livestock numbers and purchasing feed are the strategies most commonly adopted by extensive commercial farms in some regions, especially in developed countries. This has been observed to be the case in the Mediterranean area, after transhumance has almost disappeared (Martínez-Valderrama et al., 2017; Iglesias et al., 2016; Müller et al., 2015; Pulido and Picardo, 2010; Jouven et al., 2010; Lorent et al., 2009), and in parts of the United States (Kachergis et al., 2014). Thus, in these areas, to contend with the temporal variability in forage resources, farmers must cope with the variabilities in the prices of two factors of production (i.e. breeding animals and supplementary feed), which are often interrelated with forage variability. If, for example, many farmers decide to destock or purchase supplementary feed when drought occurs, they may cause major price fluctuations. Hence, the economic effectiveness of both management strategies depends on the aggregate behaviour of many farmers.

However, other factors in addition to the economy of the farms

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can be affected by the aggregate use of these strategies. Livestock grazing pressure is, by itself, a factor in rangeland degradation (Gillson and Hoffman, 2007; Vetter, 2005), and the provision of supplementary feed allows livestock numbers to be maintained above the carrying capacity (Martínez-Valderrama et al., 2017). Thus, depending on how both strategies are implemented across the farms in a rangeland, there may be a decline in the ecosystem services provided by the rangeland to society, such as forage, fresh water, medicinal products, nutrient cycling, biodiversity, carbon sequestration, hunting, traditional lifestyles, or tourist experiences (Sala et al., 2017).

We hypothesise that one farmer may adopt a more or less responsive decision-making strategy when implementing the two management strategies in question. Thus, a farmer may be more or less conservative (i.e. unresponsive) or opportunistic (i.e. responsive), when making decisions based on expected profits. Nevertheless, for the reasons aforementioned, we are not concerned with the responsiveness of a single farmer but with the average responsiveness across all the farmers in an area, which can affect the distribution over time of their aggregate response (i.e. the trade in breeding animals and demand for supplementary fodder), and thus prices. For example, a high average responsiveness across farmers means that opportunistic farmers predominate in the area, so that their quick responses coincide in time, whereas a low average responsiveness means that conservative farmers predominate, so that their slower responses spread out over time.

Thus, the work presented here aimed to address the following research questions: To efficiently cope with the temporal variability in forage resources from economic, social and ecological perspectives, should all the farmers in a rangeland adopt the same decision-making strategy (i.e. conservative or opportunistic), that is, should the average responsiveness across farmers take an extreme value (i.e. low or high)? If so, what is such an optimal group decision-making strategy? Is it a widespread conservatism or a widespread opportunism? Or is there a distribution of conservative and opportunistic farmers, that is, a nonextreme average responsiveness across farmers, which is the most effective?

To gain insights into these questions, a modelling assessment was performed by means of a generic integrated dynamic model (Kelly et al., 2013; Jakeman and Letcher, 2003) of a commercial farming area within a rangeland affected by temporal variability in forage production. The use of a model was inevitable because our research involved multiple factors and large spatial and temporal scales; thus, traditional experimentation on management practices was not possible.

Other modelling assessments of the merits of conservatism and opportunism to manage forage variability exist in the literature: Iglesias et al. (2016), Jakoby et al. (2014), Torell et al. (2010), Quaas et al. (2007), Müller et al. (2007), Higgins et al. (2007), Janssen et al. (2004), Sandford and Scoones (2006) or Campbell et al. (2000). However, we have not found any study addressing the two issues which are key to ours: first, the evaluation of the merits of conservatism and opportunism when implementing two management strategies (and not only when varying livestock numbers); and second, the examination of the broad and long-term group decision outcomes, that is, of the implications of group decision-making strategies from a global perspective.

Our model integrates a representation of the interactions between livestock and its biophysical environment with a representation of the interactions between livestock production and prices. The former interactions are directly involved in the dynamics, and thus in the sustainability, of the ecological system, so they are commonly represented in rangeland models. This is the case, for example, for the models utilised in the first seven aforementioned studies. By contrast, the interactions between livestock production and prices, which are also related to the ecological system, albeit indirectly, have been generally neglected, or greatly simplified. Thus, among the previous studies, only the latter two use models including a representation of such interactions, though overly simplified (however, these two studies neglect any consideration of ecological issues).

The assessment procedure was based on analysing the outcomes (i.e. time trajectories) of 330,000 model simulations conducted under the same number of scenarios. Because each scenario combined the values of numerous parameters which have a real-world counterpart (Section 2), it can be said that the assessment was based on analysing 330,000 case studies.

This paper is structured as follows. Section 2 provides an outline of the model. Section 3 presents the results of some simulations which are intended to illustrate the functioning of the model. In Section 4, the assessment procedure is outlined, and its results are presented and discussed. The main conclusions drawn from the study are presented in Section 5. Because of space constraints, a detailed description of the model, and the particulars of the assessment procedure, are given in a Supplementary Document.

2. The integrated dynamic model

2.1. Modelling approach

The model was created by following the system dynamics approach (Elsawah et al., 2017; Kelly et al., 2013; Sterman, 2000; Forrester, 1961). This well-known methodology is suitable when the aim is to represent the causal relationships, feedback loops, delays, and decision-making rules thought to underlie the behaviour of a complex system. A system dynamics model is a stocks-and-flows structure of ordinary differential equations which is commonly deterministic and used to generate the time trajectories of the model variables under different simulation scenarios. This was our case, as indicated in Section 1. System dynamics models usually serve to answer 'what if' questions and not to optimise any objective function. However, if the trajectories linked to a sufficiently great number of scenarios are analysed, it is possible to gain insights into the best way to manage the system. This is how our model was utilised, as shown in Section 4.

2.2. Brief outline of the model

As aforementioned, readers interested in entirely understanding the model should examine the complete description given in the Supplementary Document. An outline is provided here.

The model comprises 86 equations. It is lumped spatial (Kelly et al., 2013); thus, its variables represent either totals or averages across the entire area modelled, which is a commercial farming area (not a communal rangeland). The total area of the rangeland and potential number of active farmers, namely, the people who own a piece of land in the rangeland, are model parameters. Hence, the average size of one farm throughout a model run is determined by the parametric scenario.

The model represents a generic rangeland where climate is characterised by the alternation of dry and wet seasons as well as the regular occurrence of droughts. The annual succession of aboveground green and dry herbage masses, and their shortage during droughts, is related to the availability of soil water (Fig. 1).

In this rangeland, farms produce weaned animals for sale (hereafter, the output). Thus, the grazing herds consist of breeding females and young females (the number of breeding males is taken to be negligible). The model also assumes that farmers only rear those young females required to replace the old females that leave production; thus, they always increase their herds by purchasing