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How to avoid unsustainable side effects of managing climate risk in drylands — The supplementary feeding controversy

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ABSTRACT

The increase in climate risk is of great concern in drylands. Providing livestock with supplementary fodder has become a widely used strategy for coping with this risk. However, its application is controversial. On the one hand, this form of supplementation allows smallholders to avoid a breakdown in animal numbers in times of drought. On the other hand, it keeps herd sizes high and may thus result in rangeland degradation in the long term.

This study aims to tackle the question: can supplementary feeding strategies be designed in such a way that they help to reduce livestock asset risk, but avoid or at least reduce unsustainable side effects on pastures?

We constructed a stylized ecological–economic simulation model parameterized to a Moroccan case study which incorporates feedbacks between management and vegetation–livestock dynamics under stochastic rainfall. Three supplementation strategies are compared. Furthermore, the impact of socio-economic and climatic change processes, such as price increases for supplementary fodder or rising fluctuations in rainfall, is investigated.

Our results show that the conventional supplementation strategy, which supplements in years of forage shortage, reduces livestock asset risk in the short term. However, it can lead to lower pasture productivity and lower yields from pastoralism in the long run. In contrast, a hypothetical strategy which additionally supplements in the year after a drought in order to rest the pasture reduces livestock asset risk and maintains pastures in a better condition without increasing the amount of supplementation.

On the methodological level, this study shows the potential of ecological–economic models to assess new management strategies under different processes of global change.

1. Introduction

1.1. Potential of new technologies to cope with climate risk

Drought-induced economic losses are seen as a major threat to global food security, particularly in drylands (e.g., Haile, 2005; Fraser et al., 2011; Sietz et al., 2011). The extent of this problem is predicted to increase with future climate change (Reynolds et al., 2010; Freier et al., 2011; Rufino et al., 2013). Livestock systems are of particular concern in this regard (FAO, 2009). They make an important contribution to total food availability in places where crops cannot be easily grown, which is true for most parts of the world's drylands (FAO, 2011). Furthermore, they represent an important global asset with an estimated value of at least $1.4 trillion and take up about 30% of the planet's ice-free terrestrial surface area (Steinfeld et al., 2006; Thornton, 2010). Specific livestock management systems have been developed to deal with droughts and with variable resource availability, such as temporally and spatially adapted management of livestock, including livestock mobility and resting of pasture (Müller et al., 2007b; Davies, 2008; Hobbs et al., 2008; McAllister, 2010).

Recently, both commercial and subsistence pastoralists have turned to new technologies in an attempt to manage climate risk. For a few decades, trucks have been used for long-distance transportation of livestock to areas with temporally more favorable rainfall conditions (Rössler et al., 2010; Linstädter et al., 2013). Improved weather forecasting, the use of remote sensing techniques, and the widespread availability of mobile phones have given pastoralists better access to information on weather and rangeland conditions, thus enabling timely management decisions (Patt et al., 2005; Marshall, 2010; Nardone et al., 2010). One of the most important strategies for coping with climate uncertainty has been the supplementary feeding of livestock during times of scarcity and, nowadays, even in average and good years (Thornton et al., 2009; Linstädter et al., 2013). In southern Tunisia, for instance, pasture covers only 40% of the total feed requirements in dry years

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and 80% in humid years (Bourbouze, 2006). The remaining nutritional needs are provided through supplementary fodder consisting of self-produced or, increasingly, imported cereals. In a case study from southern Morocco, approx. 20% of pastoral-nomadic households had bought supplementary fodder for their herds in a year with good rainfall, and more than 50% had done so in a drought year (Linstädter et al., 2013). In our study area (see Section 2.1 below), two thirds of the wealthier livestock producers and about half of the poorer ones routinely recur to supplementary feeding (Breuer and Kreuer, 2011). The FAO (2012) states that 33% of the earth's croplands are used for livestock feed production. Nevertheless, this new form of risk management is controversial.

1.2. Supplementary feeding — pros and cons of a popular management strategy

1.2.1. Benefits

The relevance of supplementary feeding as a strategy for keeping livestock numbers relatively constant under fluctuating environmental conditions is well recognized among scientists and practitioners (Horn et al., 2003). It can be used to protect the key livestock asset (Rota and Sperandini, 2009) and to homogenize the use of forage that is unevenly distributed in space and time (see Bailey and Welling, 1999, for an experimental study in Montana, USA). Rota and Sperandini (2009) state that supplementary feeding reduces environmental degradation because it feeds animals from areas outside of the normal foraging area. Hence, policymakers and development agencies include the supplementation of livestock in their emergency programs, for instance in North Africa and West Asia (Hazell, 2000) or as part of development projects (cf. the Pastoral and Livestock Development Project in Eastern Morocco PDPEO, Mahdi, 2007).

1.2.2. Ecological implications

However, negative consequences of supplementary feeding on the ecological state of rangelands in dry areas are emphasized to the same extent. Maintaining the livestock number at high levels may decouple vegetation–livestock dynamics and lead to rangeland degradation (Illius and O'Connor, 1999; van de Koppel and Rietkerk, 2000; Le Houerou, 2000; Richardson et al., 2005; Vetter et al., 2005; Bourbouze, 2006; Teague et al., 2009; Diaz-Solis et al., 2006). It may prevent the natural seeding of annual pasture species (Hazell, 2000) and minimize the (unintended but beneficial) rest periods which usually occur directly after a drought due to a collapse in animal numbers and help to prevent pasture degradation (Horn et al., 2003; Müller et al., 2007a; Martin et al., 2014).

To what extent the cultivation of supplementary feed sources for livestock competes with food production for humans is the subject of an ongoing debate (Hirata et al., 1998; Steinfeld et al., 2006; FAO, 2009; Pelletier and Tyedmers, 2010; Erb et al., 2012). Rota and Sperandini (2009) argue that “feed security is more important to pastoralists than food security, since keeping animals alive ensures that their families will be able to survive beyond the drought”. On a global level, the FAO estimates that enough cropland would be available to feed 9 billion humans by 2050 if the crops produced today for animal feed were used for direct human consumption and grasslands were used more efficiently (cf. FAO, 2012).

1.2.3. Costs

Another disadvantage of feed supplementation is its high cost which places a substantial fiscal burden on individual pastoralists — or on governments in the case of subsidies. Examples include the 1988/89 drought which cost Tunisia $82 million in feed supplementation, and the 1990–1992 drought which cost Morocco $30 million (cf. Hazell, 2000). As a result of their high budgetary costs and negative environmental impacts, countries like Jordan have reconsidered their drought emergency plans and abolished feed subsidy programs (Hazell, 2000). Despite these controversial views, supplementary feeding is widely and increasingly applied by pastoralists and subsidized by governments all over the world (Nordblom and Shomo, 1995).

1.2.4. Research questions

This gives rise to a crucial question that has not been thoroughly investigated so far: do supplementation strategies exist — or can they be designed — that help to reduce livestock asset risk, but avoid or at least reduce unsustainable side effects on pastures? Livestock asset risk, in this paper, denotes the threat that the productive capital (i.e., livestock) falls below a critical threshold (as discussed by Chantarat et al., 2013).

To address this question, we examine and compare three different supplementation strategies with respect to their long-term ecological and economic effects. For control, we compare all three strategies to a fourth scenario where no supplementary fodder is used at all. The first strategy is a widespread conventional strategy that is characterized by the purchase of supplementary fodder in years of forage shortage. The second, hypothetical strategy supplements in the year directly after a forage shortage to facilitate pasture regeneration (cf. Müller et al., 2007a,b). The third (equally hypothetical) strategy combines both aspects: supplementation is practiced not only to keep livestock numbers at a constant level, but also to allow the pasture to rest in the year following a forage shortage.

To assess the impact of these strategies, we use a dynamic ecological–economic model to evaluate different supplementation strategies on a stylized dryland farm in a “virtual lab” (Seppelt et al., 2009). Ecological–economic modeling allows for an analysis of the long-term consequences of different resource management strategies, where field experiments are not implementable because they are too risky or too costly. This approach takes feedbacks between ecological and economic processes explicitly into account and helps to detect underlying key factors and mechanisms for specific system behavior (Schlüter et al., 2012). It has previously been shown to be a valuable tool in land-use research (Matthews et al., 2007; Rounsevell et al., 2012; Vang Rasmussen et al., 2012).

In order to ensure that the stylized model adequately represents the ecological–economic dynamics and interrelations in a dryland grazing system, we used quantitative and qualitative data from a Moroccan case study to parameterize the model. In order to gauge to what extent the results hold for ecological and socio-economic parameters of dryland systems in general, we performed a comprehensive sensitivity analysis. With the help of our model, we aim to address the following research questions:

(1) What effect does the conventional supplementary feeding strategy have on a pasture's ecological state (productivity) and on a livestock breeder's economic state (long-term income and livestock asset risk)?
(2) Can supplementary feeding strategies be designed in such a way that negative long-term effects on pasture productivity are avoided?
(3) What is the impact of climate change (decreasing mean annual rainfall, increasing variability) and socio-economic change (rising livestock prices and fodder prices correlated to rainfall, rising living costs for the producer) both on the ecological state of the pasture and on the economic state of the livestock breeder?

2. Material and methods

In this section, we introduce our Moroccan case study which helped us find a plausible parameterization for our stylized simulation model. Afterwards, the model is described according to the ODD protocol (Grimm et al., 2006, 2010). This protocol is commonly used to describe individual-based and agent-based models in a structured way. The first