ELSEVIER

Journal of Arid Environments 64 (2006) 488–504

Journal of Arid Environments

www.elsevier.com/locate/jnlabr/yjare

The impacts of grazing and rainfall variability on the dynamics of a Sahelian rangeland

L. Hein*

Environmental Systems Analysis Group, Wageningen University, P.O. Box 47, 6700 AA, Wageningen, The Netherlands

Received 25 August 2004; received in revised form 13 June 2005; accepted 13 June 2005
Available online 27 July 2005

Abstract

The impacts of grazing pressure and rainfall variability on rangeland dynamics have been the topic of much debate. Understanding the combined impact of these two factors is crucial for the development of efficient management strategies for rangelands. In this paper, the impacts of grazing and rainfall variability on the dynamics of a Sahelian rangeland in Northern Senegal are examined. Specifically, the paper assesses their combined impact on species composition, above-ground phytomass production and rain-use efficiency (RUE), on the basis of a 10-year (1981–1990) grazing experiment conducted in the Widou-Thiengoly catchment in the Ferlo, Northern Senegal. The experiment included both a high (0.15–0.20 TLU ha^{-1}, corresponding to current grazing) and a medium (0.10 TLU ha^{-1}) grazing pressure. It is shown that species composition, above-ground phytomass production and RUE markedly differ for these two grazing regimes—and that the differences are most pronounced in years with low rainfall. In dry years, both above-ground phytomass production and RUE are significantly reduced in the plots subject to a high grazing pressure. Consequently, the impacts of high grazing pressures on the productivity of the Ferlo are hardly noticed during years with normal or above normal rainfall, but the rangeland's productivity is strongly affected during a drought. The findings have important implications for the management of rangelands; they indicate that high grazing pressures may increase the vulnerability of rangeland ecosystems and local people to droughts.

Keywords: Rangeland; Sahel; Rain-use efficiency; Productivity; Livestock; Grazing

*Tel.: +31 317 482993; fax: +31 317 484839.
E-mail address: lars.hein@wur.nl.

0140-1963/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jaridenv.2005.06.014

1. Introduction

Rangelands are the large areas between deserts and agricultural zones where rainfall is generally too low or unreliable for cropping and where livestock keeping is the most important source of income (Walker, 1993; Walker and Abel, 2002). Early models of rangeland dynamics were based upon the Clementsian theory of ecological succession (Clements, 1916; Weaver and Clements, 1938; Tobey, 1981). These models assumed that succession to a climax is a steady process that can be reversed by grazing, drought, fire or other disturbances. A given stocking rate will result in an equilibrium state of the vegetation (Walker, 1993). In recent years, new insights in rangeland dynamics have emerged (Westoby et al., 1989; Friedel, 1991; Laycock, 1991; Walker, 1993; Walker and Abel, 2002). This was initiated by the increased recognition that the early models were not capable of adequately predicting rangeland development following changes in management (Walker, 1993). These new models encompassed such concepts as multiple steady states, stochasticity in ecosystem dynamics and irreversible responses to stress (Westoby et al., 1989; Friedel, 1991).

Whereas the understanding of rangeland dynamics has greatly increased in recent years (Westoby et al., 1989; Walker, 1993; Mortimore, 1998; Van de Koppel et al., 2002), the impact of high grazing pressures on rangelands is still strongly debated (Briske et al., 2003). A number of authors state that plant and animal dynamics are largely independent of one another and that high grazing pressures do not have a significant long-term impact on the composition and functioning of the rangeland. In their view, rangeland development is largely driven by year-to-year variation in abiotic drivers, primarily rainfall (Ellis and Swift, 1988; Scoones, 1994; Sullivan and Rohde, 2002). However, others stress that high grazing pressures do have an impact on the ecosystem, in particular in the medium and long term, and may affect composition, functioning and productivity of the ecosystem (Le Houérou, 1984; Sinclair and Fryxell, 1985; Illius and O'Connor, 1999; Fynn and O'Connor, 2000). It has also been shown that the impacts of a high grazing pressure can strongly vary between different rangelands (Fernandez-Gimenez and Allen-Diaz, 1999). The two approaches to rangeland dynamics relate to, respectively, the 'non-equilibrium' and 'equilibrium' paradigms in ecology (Wiens, 1984; Sullivan and Rohde, 2002; Briske et al., 2003). Clearly, they have very different implications for the optimal management of rangeland ecosystems.

The goal of this paper is to analyse the combined impacts of grazing and rainfall variability on the Ferlo semi-arid rangeland in the Sahel zone of Northern Senegal. The Ferlo has been selected as case study area because it provides a representative case of the larger Sahelian zone and because there were sufficient data available to analyse the impact of different management strategies on the dynamics and productivity of the system. These data come from a 10 years (1981–1990) grazing experiment conducted in the Widou-Thiengoly site in the Ferlo, as reported in Klug (1982), Miehe (1992, 1997) and Andre (1998). In the Sahel, there are few data series that stretch over a time period of 10 years, and that cover years of extreme drought (1983–1984) as well as years with normal