Soil-water utilisation and sustainability in a semi-arid grassland

HA Snyman

Department of Grassland Science, University of the Orange Free State, PO Box 339, Bloemfontein 9300, South Africa

Abstract

The impact of different botanical composition classes, viz. poor, moderate and good, on soil-water balance, water-use efficiency (WUE: crude protein produced per unit of evapotranspiration), productivity and soil temperature were determined in a semi-arid grassland during four growing seasons (1995/96 to 1998/99). In addition, the same measurements were also made on an undisturbed bare soil surface and soil cultivated twice per annum, only for the last four years. Evapotranspiration was determined by quantifying the soil-water balance equation with the aid of runoff plots and soil-water content measurements. Crude protein content calculated from N-content (Kjeldahl-method) of the leaves, stems and seed was determined. Though the percentage crude protein content of grassland in good condition was generally lower ($P<0.01$) than that of grassland in poor condition, crude protein production was still significantly ($P<0.01$) higher when expressed as total quantity of above-ground phytomass produced. Water-use efficiency declined significantly ($P\leq0.01$) with grassland degradation. Grassland in good condition averaged a WUE of 0.29 kg crude protein·ha^{-1}·mm^{-1} during four growing seasons. Higher surface runoff occurring in grassland in poor condition due to less vegetation cover, caused soil-water content to be much lower than that of grassland in good condition. Soil-water storage increased by 31% due to cultivation. Veld degradation resulted in soil temperature increasing up to 8.5 °C at a depth of 50 mm during December. An important requirement for sustainable grassland production in semi-arid climates, is effective soil-water management, which is only possible when the veld is in good condition.

Introduction

It is estimated that 82% of the land available in South Africa for agricultural purposes or 68 million ha veld (native pasture), can only be effectively utilised by grazing ruminants (Snyman, 1998). The South African veld types are extremely diverse in terms of botanical composition (Acocks, 1988), productivity in terms of nutritive value (O'Connor and Bredenkamp, 1997), and therefore the ability to sustain animal production. Furthermore, large variations in grassland production, primarily due to differences in annual rainfall as well as its distribution, occur at any specific site between years and are invariably reflected in animal performance (De Waal, 1990).

The cyclic nature of the annual precipitation and the unreliable distribution of the seasonal rainfall of Southern Africa, result in long extensive droughts and shorter seasonal droughts (O'Connor and Bredenkamp, 1997). Greater incidence of drought is relevant to the risks associated with ranching activities. Accurate balancing of the stored soil water with the expected water deficit for grasslands in different conditions is a means of lowering risk in fodder flow planning (Snyman, 1999b). This requires a sound knowledge of the soil-water balance and the quantification of each component thereof.

In South Africa, grasslands and forestry together utilise approximately 62%, and dryland crop production 12%, of the rainfall (Bennie et al., 1997). As rainfall is the limiting environmental factor that determines grassland production in the arid and semi-arid areas (Snyman, 1998), sustainable utilisation of the grassland ecosystem must emphasise the capturing and efficient use of water. Community composition has a decisive influence on the productivity and eventually on the grazing capacity expected from grasslands (Snyman, 1997a). Although the farmer cannot control the rainfall on his farm, he can directly and/or indirectly influence its effectiveness, since grassland condition is influenced by management practices (Snyman, 1999a).

Water-use efficiency (WUE) (expressed in kg above-ground phytomass production or kg crude protein for each mm of evapotranspiration) is a convenient and suitable tool to evaluate the productivity of a grassland ecosystem. In calculating WUE, most researchers (Le Houérou, 1984; Snyman, 1988; 1998; 1999b; Snyman and Fouché, 1991) only express it in terms of the quantity of dry matter (DM) produced per unit water consumed, while its calculation in terms of crude protein produced per unit of water consumed, receives little attention at present. The latter calculation can make a large contribution to the estimation of short-term nutritive value of grassland in a specific condition, given the quantity of rainfall received or water consumed.

The purpose of this study was to investigate the ability of veld to efficiently utilise limited soil-water in the semi-arid Central grassland and to identify the influence of veld degradation on water-use efficiency and productivity. This study identified the seasonal soil-water withdrawal pattern generally occurring under different compositional states, as well as the extent of water loss from bare soil.

Procedure

Site description

The study was conducted in Bloemfontein (28°50'S; 26°15'E, altitude 1 350 m), which is situated in the semi-arid summer rainfall (annual average 560 mm) region of the Republic of South Africa. Rain falls almost exclusively during summer (October to April), with an average of 78 rainy days per year. Mean maximum monthly temperatures range from 17°C in July to 33°C in January, with an

* To whom all corresponde nce should be addressed.
☎(051) 401-2221; fax (051) 448-0692; e-mail: hennie@landbou.uovs.ac.za
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