Eco-hydrological changes following grassland degradation in a semi-arid climate

HA SNYMAN
Department of Animal, Wildlife and Grassland Sciences, University of the Free State
Email: Snymanha@ufs.ac.za

Introduction

A new discipline called eco-hydrology has received increasing interest by ecologists over the last few years. Eco-hydrology may be defined as “the science that seeks to explain the hydrologic mechanisms that underlie ecological patterns and processes” (Snyman 2005). Although some efforts have been made to evaluate the eco-hydrological implications of arid and semi-arid grassland degradation, many authors argued that we are far from a complete understanding of the issue. For sound grassland management it is essential to develop a better understanding of patterns of plant growth, production (above- and belowground) and how they relate to the driving influences of water and ecosystem degradation (Swemmer et al. 2007).

Aboveground observations of plants are often used to make inferences about mechanisms that influence interactions among plants within communities and between seasons. However, ecological interactions in arid ecosystems, such as competition and other factors that control plant distributions, primarily occur belowground (Busso and Bolletta 2007). Thus, extrapolating from aboveground observations to belowground functions can be misleading especially with grassland degradation. This study aimed at quantifying the effects of grassland degradation over an 8-year period (2000/01 to 2007/08 growing seasons) on different plant (above- and belowground) characteristics in a semi-arid climate.

Material and methods

The research was conducted in a semi-arid summer rainfall (annual average 530 mm) region of South Africa (28°50’ S, 26°15’ E, altitude 1 350 m). The study area is situated in the moist, cool Highveld grassland. Soils are dominant fine, sandy loams. Grasslands in three condition classes (good, moderate and poor) was studied (Snyman 2005). The three sites chosen reflect distinct species composition and basal cover arising from different grazing histories in this grassland type. Each experimental unit was 2 m x 15 m, with three replications per composition state (condition class).

The aboveground phytomass production for each grassland condition class were collected every second month at the end of October (spring), December (summer), February (summer) and April (autumn) over the 2000/01 to 2007/08 growing seasons. Aboveground production was obtained by defoliating grasses to a height of 30 mm (the effective stubble height) in eight (0.25 m^{-2}) quadrates randomly placed in each plot. Root mass was estimated to a depth of 1 200 mm from a sample of 10 soil cores systematically distributed throughout each plot. Soil cores were collected with an auger (70 mm diameter) at the same time as aboveground samples were taken every second month. Most roots were extracted via successive washings of soil cores through a 2 mm mesh sieve. The remainder of the soil was spread in a shallow tray and fine roots were collected by flotation. The outflow from the tray passed through a 0.5 mm-mesh sieve.

Soil-water content was measured every 15 days (Snyman 2005). Detailed methods, as well as the calculation of above- and belowground rates of production and water-use efficiency are given in Snyman (2005). Water-use efficiency (WUE) is defined as the quantity of above- and belowground phytomass produced per unit of water evapotranspired. It was attempted to emphasize root growth increase in mass over a specific period rather than the accumulation of existing root mass over a season. Evapotranspiration was determined by quantifying the soil-water balance equation (Snyman 2005). Data were analyzed using a repeated-measure ANOVA. The Number Cruncher Statistical System (2000) software package (Hintze 1997) was used for all statistical analysis.

Results and conclusions

Peak aboveground phytomass at the end of each growing season was on average 1 466, 1 233 and 654 kg ha^{-1} for grasslands in good, moderate and poor conditions, respectively. The growing seasonal (October to March) average root mass to a depth of 900 mm was 3 433, 2 343 and 1 220 kg ha^{-1}, respectively, for grassland in good, moderate and poor condition. Water-use efficiency over 2 months periods expressed as either the total phytomass or aboveground phytomass only, is presented in Figure 1. Grassland degradation significantly (P<0.01) lowered water-use efficiency over all months. The mean WUE (root production included) were 4.75, 3.23 and 2.11 kg ha^{-1} mm^{-1} for grasslands in good, moderate and poor conditions, respectively.

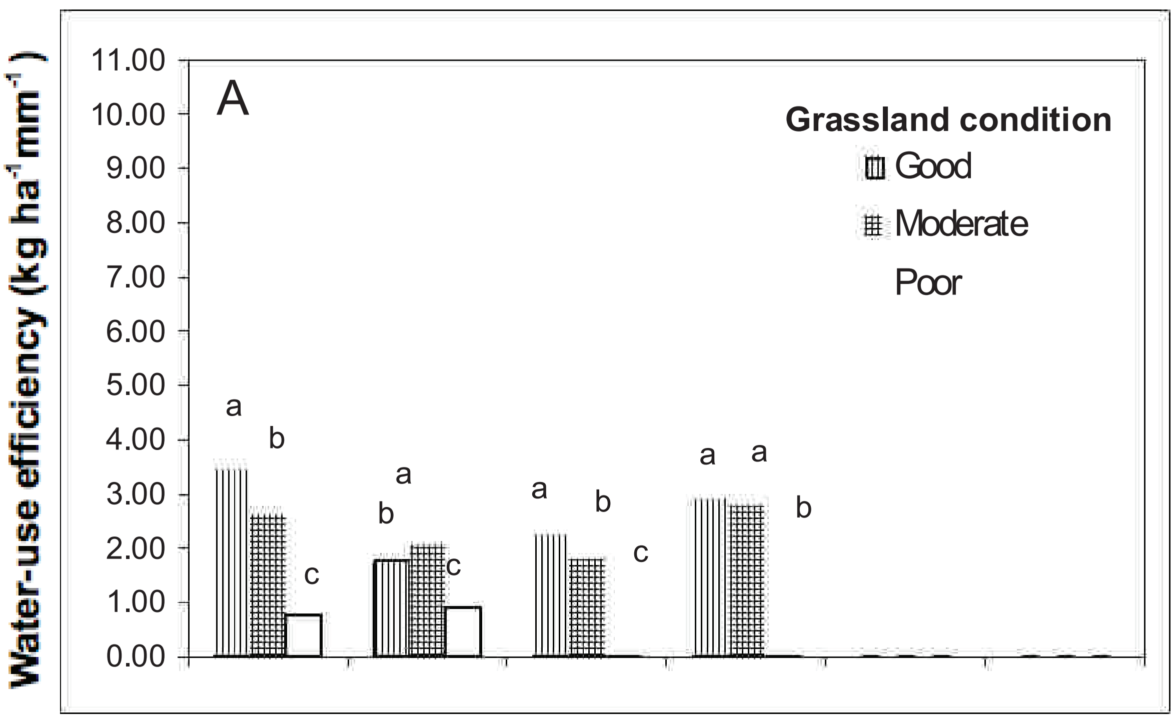
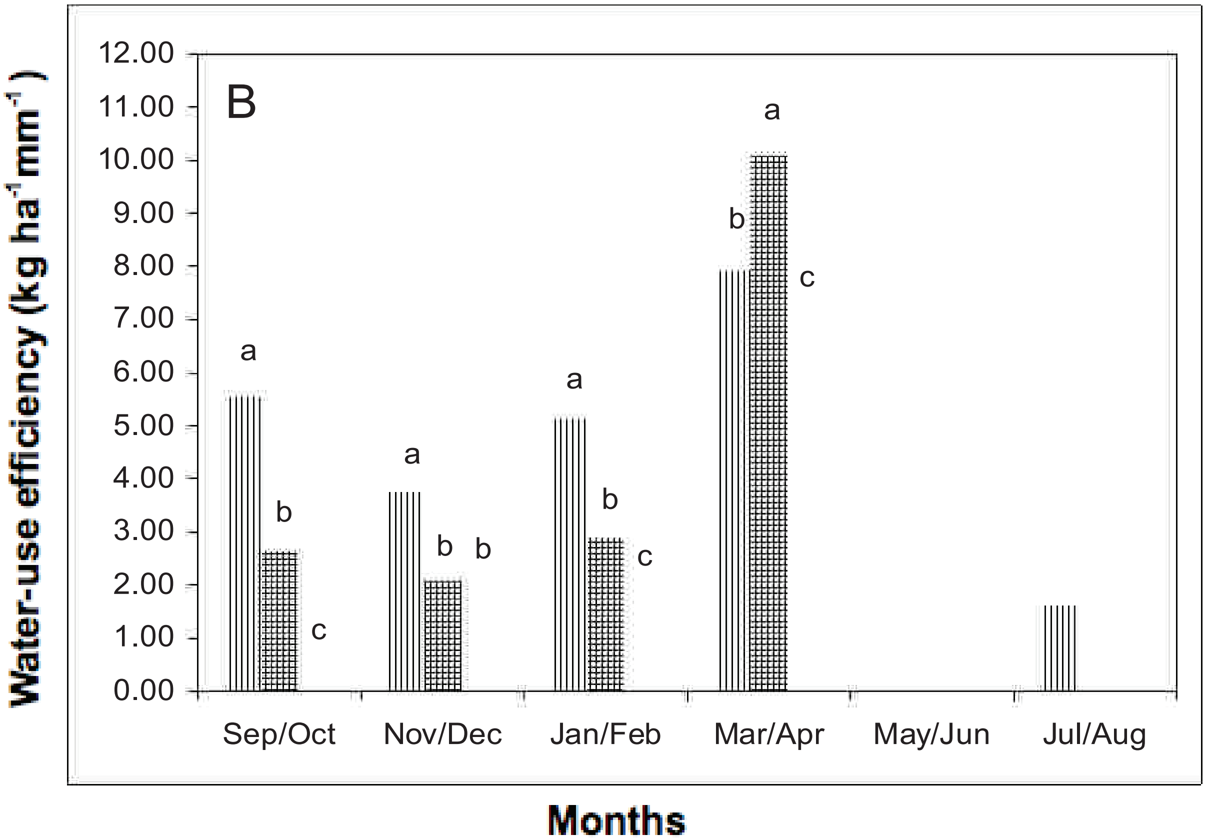


Figure 1. Mean (±SE) water-use efficiency (kg ha^{-1} mm^{-1}) (A = expressed in terms of only aboveground phytomass and B = expressed in terms of both aboveground phytomass plus root production increase over a 2-month period) for the different grassland conditions, averaged over 8-seasons (2000/01 to 2007/08). Means within a month with different superscripts differ significantly (P<0.01).



These WUE observations are among the few also including root production in its calculation. In the past, researchers only included aboveground production of grassland in estimating the water-use efficiency and therefore this study is unique with regards to roots produced for a certain quantity of water-use, also considered in WUE estimations. As the absence of knowledge limits our ability to prevent degradation and develop restoration strategies, this study identified the pursuit of eco-hydrological feedbacks in grassland degradation processes as one of the emerging issues of grassland ecohydrology.

References

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