Shrub removal and grazing alter the spatial distribution of infiltrability in a shrub – encroached woodland

Daryanto, S.[1] and Eldridge, D.J.[2]

[1]School of Biological, Earth and Environmental Science, UNSW

[2]Department of Environment, Climate Change and Water, c/- School of Biological, Earth and Environmental Science, University of NSW, Sydney, NSW, 2052

Keywords*:* Infiltration; spatial pattern; disturbance

Abstract

The tendency of water to infiltrate (infiltrability) determines the productivity of rangelands. However, how patterns of infiltrability change in response to gradients of disturbance remains largely unexplored. To address this, we examined changes in the pattern of infiltrability across a disturbance gradient in a semi–arid Australian woodland. We measured the spatial distribution of infiltrability in relation to distance from the canopy of trees and shrubs at long ungrazed sites to ploughed and grazed sites. Infiltrability on long ungrazed sites was relatively homogenous throughout the landscape and up to distances of four metres from plant canopies. In contrast, at either grazed or grazed and ploughed sites, infiltrablilty was demonstrated a heterogeneous pattern across the plot. Infiltrability was also greatest only around vegetated patches but very low at distance of more than 2 m from woody plant canopies. Factors such as increased bulk density and removal of cryptogamic soil crusts as a result of livestock trampling are probably responsible for the heterogeneous patterns of infiltrability. Our results highlight the importance of maintaining woody plants for maximising infiltration of water in the semi–arid woodland. Removal of woody shrubs by ploughing with and without grazing appears to have a deleterious effect on infiltrability.

Introduction

It has been well documented that infiltration is greatest under vegetated patches and that grazing reduces infiltration rates, mainly as a result of trampling–induced soil disturbance (Castellano *et al*. 2007). By contrast, soil accumulating under shrubs has different properties to that of the surrounding interspaces. It is usually sandier in texture, has more macropores, due to invertebrate activity, and has lower bulk density (Dunkerley 2000; Stavi *et al*. 2008), which contribute to the increased ability of shrub mounds to absorb water.

Previous research has documented marked changes in the spatial distribution of soil nutrients, solar radiation and soil moisture due to grazing in semi-arid woodlands (Breshears *et al*. 1997; Stavi *et al*. 2008). As infiltration is a key determinant of production in semi–arid woodlands, rangeland managers are particularly interested in the long–term effects of ploughing and grazing on the spatial distribution of infiltration. We examined soil infiltrability (the ability of soil to accept water) as an indicator of infiltration, at sites in a shrub–encroached woodland, and hypothesized that grazing and shrub removal by ploughing would alter the spatial distribution of soil infiltration.

Methods

The study was conducted near Bourke in north–western New South Wales, Australia (29º 16'S, 145º 26'E). In 1990, one block (200 m x 400 m) was established and divided into four equal plots of 100 m wide by 200 m long. The two central plots were then enclosed in a 6 m high, herbivore–proof fence. Half of both the fenced and unfenced plots were then ploughed leaving the remaining half unploughed. This design resulted in four combinations: ploughed-grazed, ploughed-ungrazed, unploughed-grazed and unploughed-ungrazed. Here we report the results for three of these combinations, as the ploughed-ungrazed treatment is unlikely to be applied by land managers. The treatments represent a gradient in impact from the most (ploughed-grazed) to least (unploughed-ungrazed) impacted.

Within each treatment we established one 10 m x 10 m plot and sampled the surface on a coarse 2 m grid (*n*=36) as well as a finer grid of points that were spaced at distances of 25 cm apart (*n*=72) across the plot. For each sampling point, we recorded its position in relation to the canopy (canopy or open), and distance to the canopy. Soil, sampled to 7 cm depth, was collected at each of the 108 points, and a derived index of infiltrability determined using the laboratory–based syringe method of Mills *et al*. (2006). We used the GS+ geostatistical package to examine the nature of the spatial scaling of the infiltrability index at spatial scales ranging from 0.25 to 14 m. Semi-variograms were examined to look for trends in spatial patterning in relation to the disturbance gradient.

Results

The spatial distribution of the infiltrability index changed in relation to ploughing and grazing (Fig.1). The semi–variogram for the least disturbed site (unploughed–ungrazed) had a high nugget to sill ratio (± 40%), suggesting that 40% of the variability in infiltrability under this treatment occurred at a scale smaller than our smallest sampling interval of 25 cm. However, it was auto correlated at approximately 4 m, which indicates that infiltration under low levels of disturbance is almost random or independent of the presence of woody perennial vegetation such as shrubs and trees and it was relatively constant with distance from the shrub up to 4 m. This result is supported by the results for changes in infiltrability with increasing distance from shrub or tree canopy (Fig.1), which shows relatively high rates of the index with distance, and only weak declines out to 4 m from the trunk. In contrast, infiltrability under grazing, with or without ploughing was auto correlated at distances of about 1 m, which corresponds to the zone of maximum biological activity of the shrubs. Under the ploughing and/or grazing treatments however, there was a relatively rapid decline in infiltrability from with distance from the canopy, with very low levels at distances of 1.5 to 2 m. Thus under the grazed and/or ploughed treatments, infiltration was restricted to the area in the immediate vicinity of the canopy i.e. < 2m (Fig. 1).

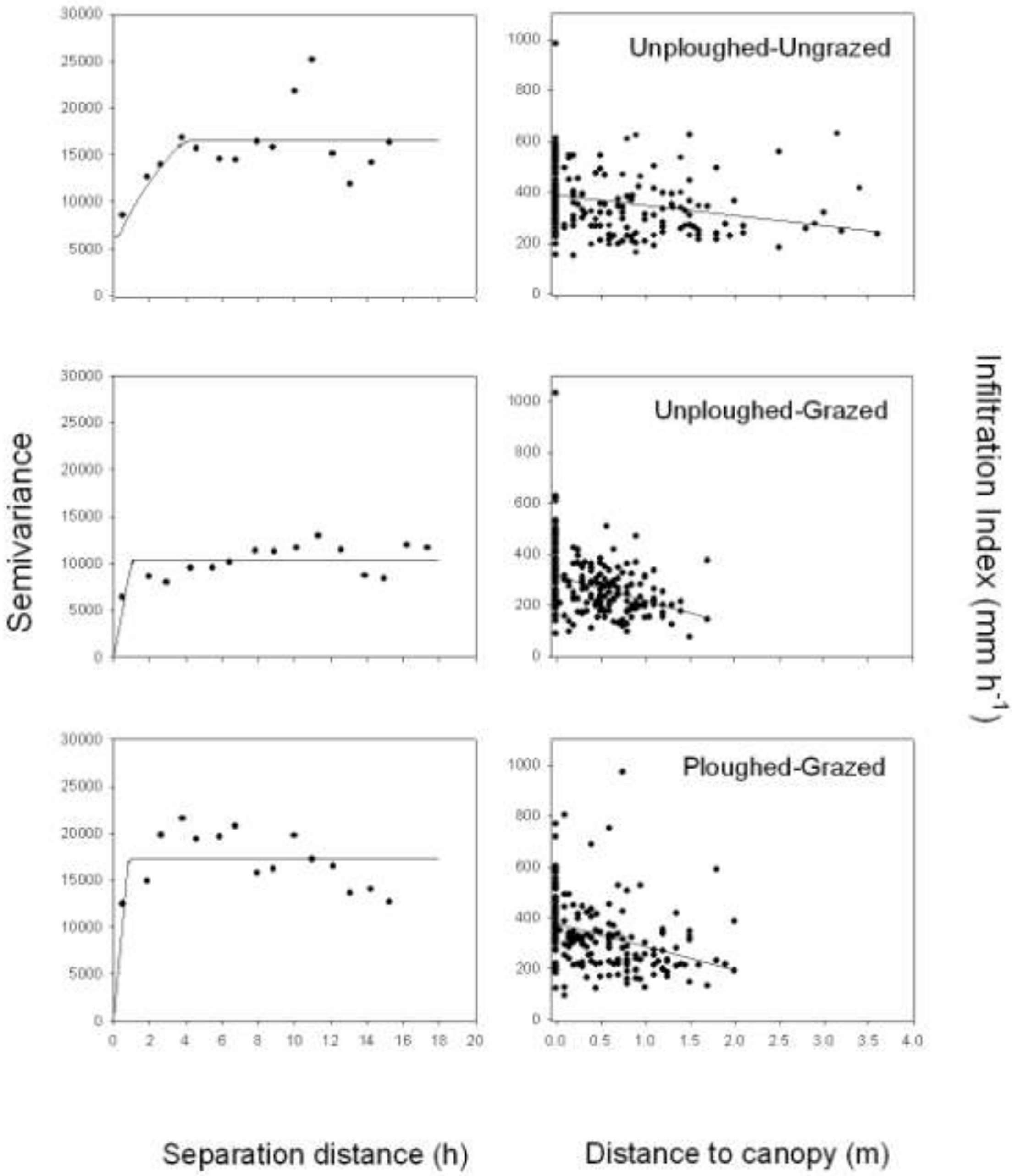

Fig. 1. Semi-variogram of infiltrability as well as relationship between distance to canopy and infiltration at three different sites

Discussion

The major difference between the two semi–variogram forms, i.e. those auto correlated at distances of 1 m (ungrazed) or 4 m (grazed), was likely due to grazing and trampling.

At the undisturbed site, infiltration was auto correlated at distances extending far beyond that of the zone of maximum biological activity of the shrubs, and was randomly scattered across the site. High rates of infiltrability at 2–4 m from the plant canopy are possible because there is little difference in bulk density (and therefore porosity) between soil under shrubs and soil in the interspaces. This is probably due to the fact that interspace soils in our study are relatively well–vegetated with other smaller perennial plants such as grasses and forbs, which would also create zones of higher infiltration. Furthermore, the presence of well–developed cryptogamic crusts within the interspaces in the undisturbed site (Daryanto and Eldridge, in review) would be expected to lead to relatively higher rates of infiltration, less than that near the canopy, but certainly greater than that found at distances of > 2 m in the grazed or ploughed treatments. Cryptogam cover is known to increase infiltration by forming micro-catchments on the surface that eventually infiltrate. Our study demonstrates that, in the undisturbed state, infiltration occurred throughout the plot irrespective of the presence of shrubs. In contrast, infiltration on the two disturbed treatments was autocorrelated at about 1 m and therefore highly localized around the shrubs. Clearly grazing–induced trampling has a substantial impact on water flow by localizing infiltration to the immediate area around shrubs, where bulk density is generally low and the macroporosity is high (Bhark and Small 2003). Grazing created patches of bare soil and compaction of the surface, which is mediated by the destruction of cryptogamic soil crusts (Neff *et al*. 2005). In terms of the maximization of infiltrability in woodland soils, existing patches of perennial vegetation are critically important loci for high levels of infiltration in semi–arid woodlands (Hartley *et al*. 2007). Our results suggest that shrubs are important for maintaining ecosystem services such as infiltration and that removal of shrubs will results in lower rates of infiltration and therefore higher runoff and resource loss.

References

Bhark, E.W. and Small, E.E. (2003). Association between plant canopies and the spatial patterns of infiltration in shrubland and grassland of the Chihuahuan Desert, New Mexico. *Ecosystems* **6**, 185-196.

Breshears, D.D., Rich, P.M., Barnes, F.J. and Campbell, K. (1997). Overstory-imposed heterogeneity in solar radiation and soil moisture in a semiarid woodland. *Ecological Application* **7**, 1201-1215.

Castellano, M. J. and Valone, T. J. (2007). Livestock, soil compaction and water infiltration rate: evaluating a potential desertification recovery mechanism. *Journal of Arid Environments* **71**, 97-108.

Dunkerley, D.L. (2000). Assessing the influence of shrubs and their interspaces on enhancing infiltration in arid Australian shrubland. *The Rangeland Journal* **22**, 58-71.

Hartley, A., Barger, N., Belnap, J. and Okin, G.S. (2007). Dryland ecosystems. *In*: Nutrient Cycling in Terrestrial Ecosystems (Eds. P. Marschner and Z. Rengel) pp. 271-307. (Springer-Verlag, Berlin).

Mills, A.J., Fey, M.V., Grongroft, A., Petersen, A. and Medinski, T.V. (2006). Unraveling the effects of soil properties on water infiltration: segmented quantile regression on a large data set from arid south-west Africa. *Australian Journal of Soil Research* **44**, 783-797.

Neff, J.C., Reynolds, R.L., Belnap, J. and Lamothe, P. (2005). Multi-decadal impacts of grazing on soil physical and biogeochemical properties in southeast Utah. *Ecological Applications* **15**, 87-95.

Stavi, I., Ungar, E.D., Lavee, H. and Sarah, P. (2008). Grazing-induced spatial variability of soil bulk density and content of moisture, organic carbon and calcium carbonate in a semi-arid rangeland. *Catena* **75**, 288-296.

Daryanto, S. and Eldridge, D.J. Shrub removal and grazing after the spatial distribution of infiltrability in a shrub-encroached woodland (2010). In: *Proceedings of the 16th Biennial Conference of the Australian Rangeland Society*, Bourke (Eds D.J. Eldridge and C. Waters) (Australian Rangeland Society: Perth).