



Moderating soil surface temperature via restoration hollows and its implication for restoration strategies in arid rangelands

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Abstract

Arid regions worldwide, including the drier areas of the Western Cape of South Africa, often suffer from rangeland degradation resulting from poor management, mining activities or other anthropogenic sources of disturbance. Without active restoration intervention, these areas may take a considerable amount of time to recover. Digging hollows as a form of active restoration has been successfully applied to restore vegetation to denuded areas in arid regions around the world. However, the effect of these hollows on soil surface temperature has yet to be determined.

To determine the role of restoration hollows in providing suitable micro-climates for plant growth, soil surface temperature measurements were compared between bare ground and hollows during both summer and winter at three sites in the arid region of the Western Cape. Soil temperatures within the hollows were lower than that of bare ground during the warmest part of the day, and higher than bare ground during the coolest part of the day. Hollows have a moderating effect on soil surface temperature, which creates a more suitable micro-climate for seed germination. Restoration hollows may offer a cost-effective alternative to other restoration methods, such as brush packing and tilling. This research contributes to the broader understanding of land restoration strategies in arid environments, potentially reducing restoration costs and improving ecosystem resilience in the face of environmental challenges, including climate change.

Introduction

Much of the arid rangelands of the world is degraded and denuded of vegetation, often due to disturbances such as overgrazing and mining activities, amongst others (Carrick 2022). Rangelands cover over 70% of the land surface of South Africa and most of these are degraded to some extent (Carrick 2022). Degraded rangelands have reduced plant productivity and are prone to soil erosion (Snyman 2003).

Restoration of degraded rangelands improves productivity by re-establishing plant cover to denuded areas and improves their capacity support grazing animals (Snyman 1999). Restoration can be expensive, time consuming, labour intensive and often prone to failure due to adverse weather conditions or inadequate

rainfall (Saayman et al. 2017). Brush packing, digging soil hollows, and other forms of soil treatments have been promoted by many restoration practitioners to provide suitable seed germination sites (Coetzee 2005; Bothma and Van Rooyen 2006; Carrick et al. 2022). Soil hollows create a more favourable environment for seedling germination and establishment (Milton and Coetzee 2022). Soil hollows can be dug by hand or with the use of a specialized “dyker plough” that operates on a cam wheel and digs hollows at set distances and depths (Snyman, 2003).

The rationale being that these hollows will capture runoff rainwater, organic matter and seeds, and in addition, brush packing within the hollows will provide protection to seedlings (Bothma and Van Rooyen 2006).

There is a significant difference in temperature and in diurnal temperature fluctuations between bare ground, restored vegetation and intact vegetation, with bare ground reaching higher temperatures and temperature fluctuations (Drezner 2007; Hamberg et al. 2020). Snyman (2003) found that the soil temperature on bare ground in the grassland biome could reach temperatures as high as 65 °C. Large temperature fluctuations on bare ground are detrimental to seedling germination (Milton and Dean 1990; Saayman and Botha 2010). Nurse plants provide seeds with protection against severe temperature fluctuations (Esler et al. 2006). Brush packing is typically used in restoration of bare areas to simulate nurse plants (Ren et al. 2008).

The aim of this paper is to determine if the creation of hollows in bare patches may provide a moderating effect to soil temperature which creates a suitable microclimate for seeds to germinate and for seedlings to survive.

Methods

The trial was conducted at three sites in the Western Cape province of South Africa: the Worcester Veld Reserve, the Wolwekraal Nature Reserve at Prince Albert and at the Nortier Research Farm near Lambert’s Bay. All three sites have a Mediterranean climate. The Worcester and Prince Albert sites both have shallow, poorly developed soils with Mispah and Glenrosa soil forms prevailing. These soils are generally shallow and rocky with a high clay content. The soils of Nortier Research Farm consist of fine aeolian (regic) sands of the Namib soil form (Western Cape Department of Agriculture 2024).

January is the warmest month of the year for the Prince Albert site, with an average temperature of 22.2°C, while February is the warmest month for the Worcester and Nortier sites with average temperatures of 22.3°C and 19.7 °C respectively (Western Cape Department of Agriculture 2024). July is the coldest month for all three sites, with average temperatures of 10.8°C, 11°C and 12.9 °C for Prince Albert, Worcester and Nortier respectively (Western Cape Department of Agriculture 2024).

A row-column treatment design with two treatments and 20 replicates was followed at each study site. The two treatments are hollows dug and a control - an area of cleared ground adjacent to each hollow. At each study site the trial consisted of 20 hollows, placed 10 meters apart. The hollows were dug in a grid pattern of 5 columns and 4 rows. Each hollow is one meter in diameter with a concave bottom, 20 cm deep at the centre. The hollows were dug by hand and the removed soil was used to build a berm on the downslope side of the hollow, to retain runoff water (Coetzee 2005).

An Infrared thermometer was used to measure the soil surface temperatures within the centre of each hollow and in the centre of the control. These measurements were made at dawn and at 14:00, on one day during summer and winter. The timing of the measurements was intended to capture the temperature during the

coldest and warmest time of day. Measurements were only taken on days with little or no cloud cover or strong wind.

Data were analysed separately by time and were subjected to analysis of variance (ANOVA) using the General Linear Models Procedure (PROC GLM) of SAS software (Version 9.4; SAS Institute Inc, Cary, USA). The Shapiro–Wilk test on the standardized residuals from the model verified normality (Shapiro and Wilk, 1965). Levene’s test verified homogeneity of treatment variances (Levene, 1960). Fisher’s Least Significant Difference (LSD) was calculated at the 5% significance level to compare interaction means (site*treatments, site*season, treatment*season, site*treatment*season) and main effects, treatment, site and season means (Ott and Longnecker, 2010). Box and whisker plots for temperature for site*treatment*season were constructed using XLSTAT (Addinsoft,2024).

Results

Temperatures within hollows were significantly higher at dawn compared to bare ground in each site (Figure 1). Afternoon temperatures were lower within hollows compared to bare ground, though not all were significantly different. The winter afternoon temperatures at the Worcester site were the exception, with temperatures within the hollows being significantly higher than the control (Figure 2). It should be noted that there was a gentle wind present during this part of the data collection. The temperature difference between hollows and bare ground for each site, time and season is displayed in table 1.

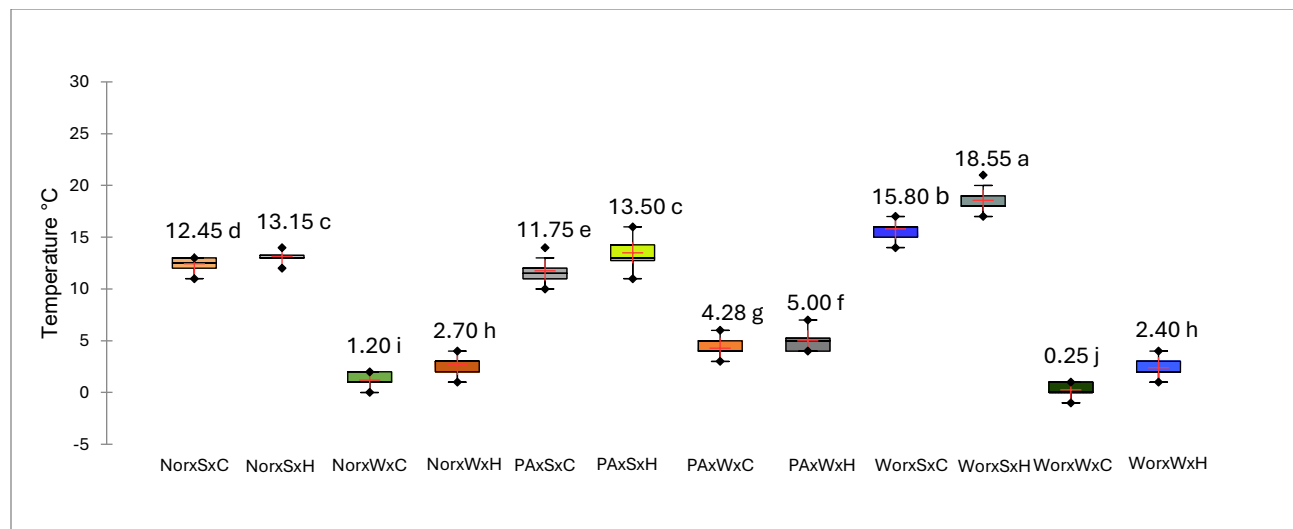


Figure 1. Soil surface temperatures within hollows and controls taken at dawn for three sites during summer and winter. Mean values with significant differences (p<0.05) are displayed with a different adjacent letter. Nor = Nortier, PA = Prince Albert, Wor = Worcester, S = Summer, W = Winter, C = Control, H = Hollow.

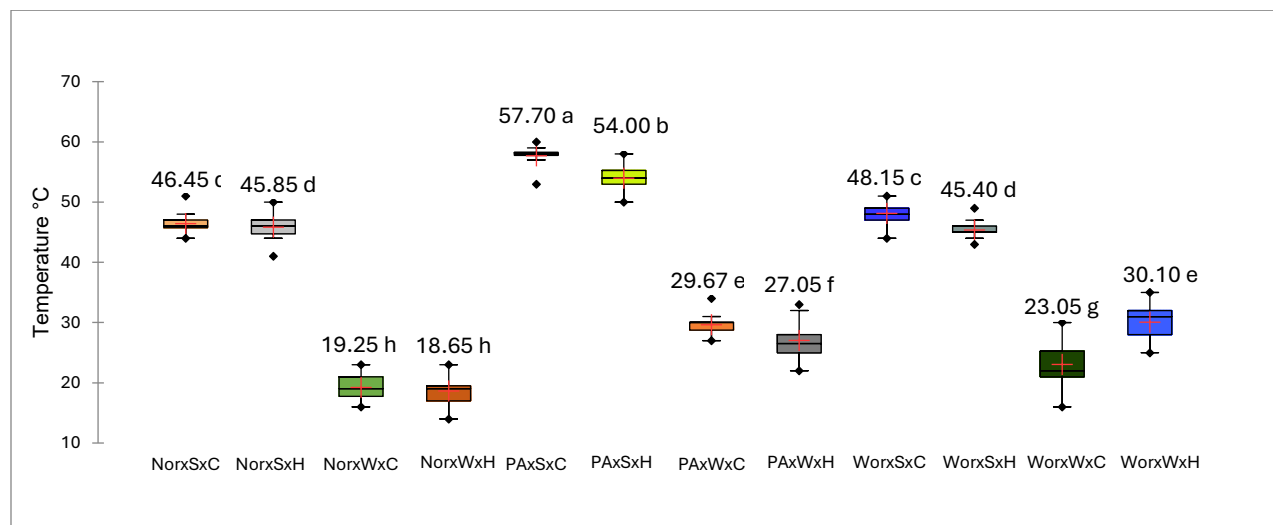


Figure 2. Soil surface temperatures within hollows and controls taken at 14:00 for three sites during summer and winter. Mean values with significant differences ($p < 0.05$) are displayed with a different adjacent letter. Nor = Nortier, PA = Prince Albert, Wor = Worcester, S = Summer, W = Winter, C = Control, H = Hollow.

Table1: Effect of hollows on soil surface temperature compared to bare ground in °C. *=significantly different, $p < 0.05$; ns= not significantly different.

	Worcester	Prince Albert	Nortier
Summer-Morning	+2,75*	+1,75*	+0,7 ns
Winter-Morning	+2,15*	+0,72 ns	+1,5*
Summer-Afternoon	-2,75*	-3,7*	-0,6 ns
Winter-Afternoon	+7,05*	-2,62*	-0,6 ns

Discussion

The soil surface temperature within the hollows were warmer during the coldest time of day, and cooler during the hottest time of day. This insulating effect protects seeds and seedlings from temperature extremes and contributes to creating the more stable micro-climate that seeds require to germinate and for seedlings to establish (Esler et al. 2006; Milton and Coetzee 2022).

Wind caused rapid soil surface temperature fluctuations, which impeded accurate measurements. These temperature fluctuations were especially evident at the Nortier site, which is adjacent to the coast and is particularly windy. It is likely that some of the temperature measurements taken during even slightly windy conditions, could have been affected by wind-chill (Ashcroft and Gollan 2013). Severe windy conditions may also decrease the efficacy of hollows, a problem that could be addressed by trapping air within the hollows with brush packing. Differences in soil composition and moisture content may also influence soil surface temperature in hollows (Ashcroft and Gollan 2013). Despite these confounding factors, it is clear that soil hollows provide a moderating effect on soil surface temperature.

Conclusions and Implications

Restoration hollows create a more favourable micro-climate for seed germination than bare ground. These hollows offer a simple way to improve the survival rate of seedlings and to allow revegetation of denuded arid rangelands.

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