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Using gypsum to ameliorate a highly-saline, scalded claypan

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Abstract

Scalds are common on degraded soils in the rangelands of western NSW. Scalds restrict plant growth and biological activity. Scalds form due to dispersive (sodic) sealing surfaces and high salinity. Sodic soils can be stabilised by the addition of gypsum which flocculates the soil in the short term and decreases the propensity to disperse in the medium to longer term while facilitating leaching of problematic chloride salts. This study examined the use of gypsum to remediate a scald that was sodic (exchangeable sodium percentage (ESP) >10%) and had high salinity (electrical conductivity (ECe) ~45 dS/m) to at least 60 cm soil depth. Mechanical disturbance (ripping with a single mouldboard plough) previously trialled resulted in only minimal establishment of halophytes with shallow roots but with no survival. A replicated trial was established to examine the response of soil and pasture to four rates of gypsum: nil (Control), 1 t/ha (Low), 2.5 t/ha (Moderate), and 6.5 t/ha (High). The design allowed remote monitoring via Sentinel imagery.

After 12 months there was greater volunteer plant establishment and decreased surface salinity (to ~5 dS/m) in the High treatment areas. Satellite imagery indicated greater cover of green vegetation (NDVI) during the growing season, but only in the High treatments. While the timing of rainfall and leaching of salts will influence the persistence of the improvements, the results so far show the amelioration of an extreme scald with appropriate techniques.

Introduction

Scalded soils present problematic conditions for water infiltration and for plant establishment and growth. Scalds are areas that have lost their topsoil, leaving a clay subsoil as the new surface layer which is commonly hard, saline or sodic. Scalded country is common on alluvial and residual soils in the rangelands of western NSW and in dry regions globally. Researchers since the 1940s have demonstrated remediation of scalded land in the NSW rangelands by natural regeneration, and intervention by ripping, ponding, and managing grazing pressure. Successful remediation is the restoration of functioning soils and productive systems. Because salinity is a common feature of soils in dry areas and is close to the surface on scalded sites, flushing salts deeper into the profile is key to scald remediation.

Gypsum applied to dispersive soils can act to flocculate the soil surface in the near term while infiltration leaches undesirable salts deeper. In the longer term, calcium in the gypsum can exchange with sodium on clay surfaces to decrease their propensity to disperse. When vegetation establishes, infiltration can be enhanced and wicking of salts to the surface decreased; all these processes reinforce the amelioration of the scald.

The objective of this study was to assess remediation of a scald on an alluvial soil in north-west NSW, using different rates of gypsum, and to compare the soil conditions between the treated site and a nearby area that is recovering naturally.

Methods

The trial was located on 'Gurrawarra', approximately 80 km north-east of Bourke, NSW Australia (29º46'41"S, 146º23'19") on a scald situated on an alluvial meander plain west of the current Culgoa River. The climate is semi-arid, with an average annual rainfall of 370 mm, with a summer dominant rainfall pattern. Preliminary assessment of the scald identified high salinity, a dispersive surface and highly aggregated subsurface. The scald has persisted despite previous mechanical disturbance (ripping with a single mouldboard plough). The site was devoid of vegetation except for some small dead halophytes present in the old rip lines.

The application of gypsum was chosen because the landowners had noted the long-term (>10 years) effect of established vegetation at isolated spots where gypsum tailings had been dumped on the property. Prior to the application of the gypsum, soils were analysed at 0-10 cm, 10-20 cm, 20-30 cm and 30-60 cm for salinity (Shaw, 1999) and sodicity profiles (electrical conductivity, soluble chloride, exchangeable sodium percentage). Exchangeable cations were measured by the Tucker method with pre-wash to minimise any artefact of soluble salts or dissolution of sparingly soluble salts (15C1, Rayment and Lyons, 2011). Satellite data to calculate NDVI (normalised difference vegetation index; no units) for each plot was downloaded from the Sentinel portal (Copernicus; https://sentinel.esa.int/web/sentinel/home) from the first available date (2-11-2016) to November 2024. Laboratory analyses of samples collected in July 2023 from inside and outside the old gypsum dump and a separate self-ameliorating scald were also made for comparison with the trial.

The trial was established in July 2023. Three replicates of four treatments (including a Control) were established in 50 x 50 m plots. Gypsum was spread evenly at rates to reflect the approximate amount of gypsum dissolved through 10 cm at field capacity (1 t/ha, Low), a standard rate to allow for some leaching (2.5 t/ha, Moderate), and a rate to allow additional time for leaching and adequate for replacement of Na with Ca on the clay exchange sites (6.5 t/ha, High; Loveday 1976). The soil surface was tilled to approximately 10 cm after spreading to minimise wind drift. Banks were mounded around the site to minimise run-on.

Soil sampling and assessment of vegetation cover was undertaken in July 2024. 20 soil samples in each plot were composited at depths 0-5, 5-10, 10-20, 20-30cm for the same laboratory analysis as the 2023 samples. Additional samples were collected from the general plot area and the pre-existing rip lines (Control and High plots only), and under patches of newly established vegetation (High plots only) to assess effects of ripping and vegetation. Ground cover (percent cover of plant, litter, cryptogam, coarse woody debris, dung, rock or bare ground) was monitored in twenty 0.5 x 0.5 m quadrats located along four transects in each plot. Standard errors (se) were calculated for each measure.

Results

No differences in soil properties between treatment plots were found in the initial measurements. Drought conditions persisted following establishment of the trial until early 2024 after which 300 mm fell through the winter and spring. A visible response of improved infiltration in the High treatment compared to surface ponding in other plots was borne out with increased vegetation cover in July 2024. Vegetation cover did not differ significantly between the Control, Low and Medium treatments (averaging 4.2-7.2%) but was higher on the High gypsum treatment (average 18.0%, Figure 1). Despite the response of vegetation to the High rate of gypsum, there was no significant difference between the treatments in salinity down the soil profile (Figure 2). However, there was an overall decrease in salinity at the surface, and translocation to below 20 cm, compared to 2023 following good rainfall (Figure 2). The soil under vegetation in the High plots had lower salinity through to 20 cm depth than the bare Control and the bare patches within the High plots (Figure 3). The existing rip lines also affected salinity: within the High plots the salinity in the rip lines was lower than the bare areas in the 0-5 cm and 20-30 cm increments; and in the Control plots the salinity was lower in the Rip lines than away from the rip lines through the to 20 cm. After just one year there was no change in sodicity with any rate of gypsum (data not shown).

The salinity levels of the upper profile in the gypsum dump and under vegetation of the self-ameliorating area were low, while outside the dump the salinity was high and in bare areas of the self-ameliorating area the salinity was half that of the trial site. The sodicity inside the gypsum dump was lower compared to outside (5% and 15%, respectively, data not shown).

The relatively good 2024 season was reflected in the greater NDVI in the Control, Low and Moderate plots compared to the period preceding the trial (Figure 4). The apparent increase in NDVI immediately following installation was likely due to the surface disturbance. The greater plant cover observed in the High treatment compared to the other plots was consistent with the NDVI (up to 0.21), while there was no difference in NDVI between the Control, Low and Moderate plots.

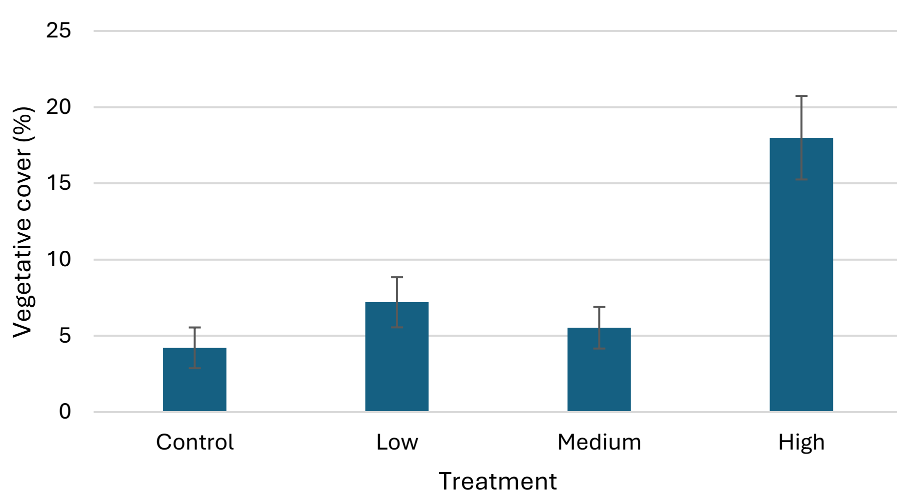

Figure 1. Average vegetative (plant + litter) cover within the different gypsum treatment plots in July 2024 (+/- 1 se).

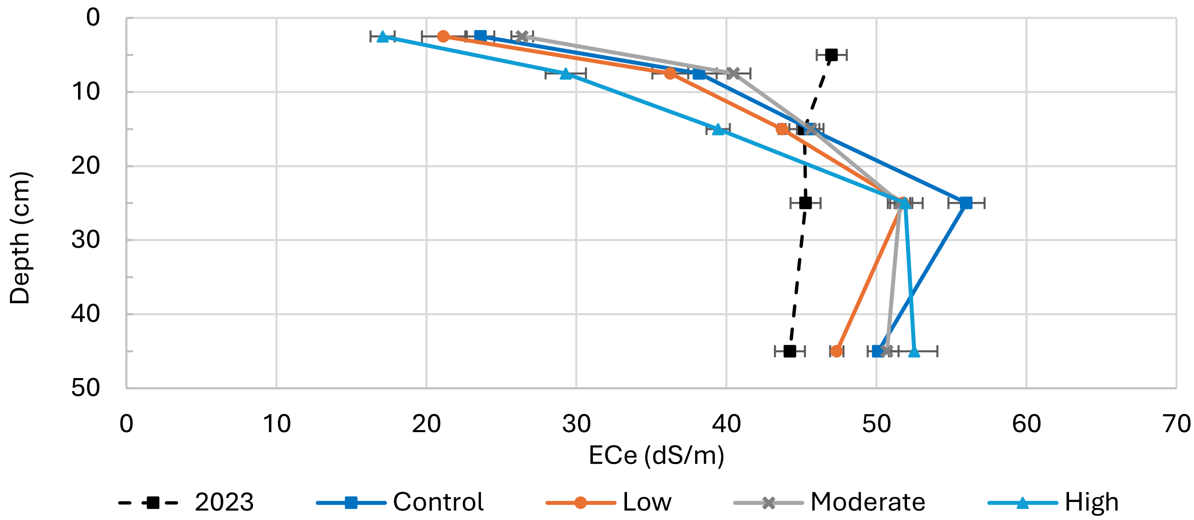

Figure 2. Average salinity (electrical conductivity, ECe) down the soil profile of the Control and Low, Moderate and High gypsum application plots in July 2024 and the site average in July 2023 (+/- 1 se).

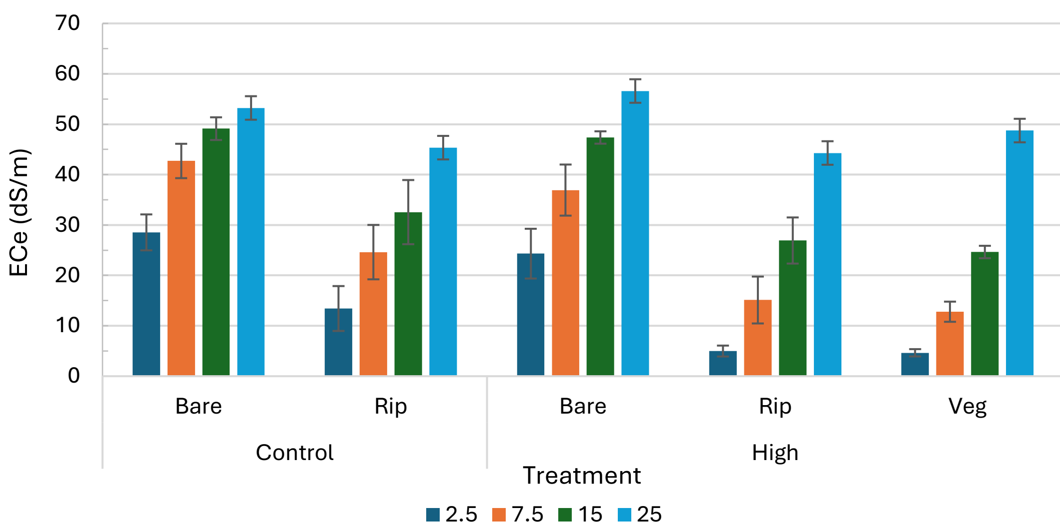

Figure 3. Salinity (electrical conductivity, ECe) within the Control and High treatments in July 2024 (+/- 1 se). Insufficient (~no) vegetation was present for sampling outside of rip lines in control plots.

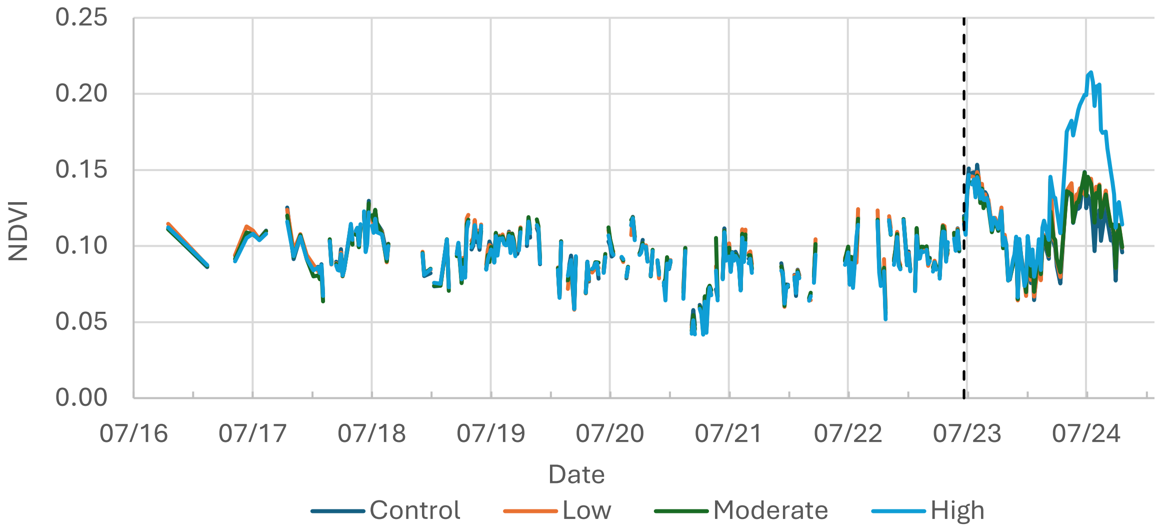

Figure 4. Remotely sensed NDVI over time at the gypsum demonstration site by treatment (vertical dashed line indicated date in installation).

Discussion

The overall response of both soil and vegetation to the gypsum application and earlier ripping on the scald has been an improvement in soil properties and a subsequent increase in plant establishment. The earlier ripping appeared to allow better infiltration and flushing of salts. However, these rip lines are narrow (~30 cm), and particularly in the Control areas the vegetation is still sparse. By comparison, the effect of the gypsum was promising but only at the High rate. While patchy, establishment of substantial patches of vegetation beyond the rip lines in vegetation the High treatment is likely to more effectively leach salts (Jones 1967). While senesced at the time of reporting (late spring 2024), the surface cover remains and serves to enhance infiltration.

The long-term success of the amelioration will depend on the persistence of the changes in the coming season and through drier periods. Persistent vegetation cover (even if senesced) would minimise wicking and re-occurrence of surface salinity, while ongoing exchange of Na for Ca would improve the inherent dispersibility. The marked change in salinity between 2023 and 2024, and between the treatments in 2024 compared to no significant change in sodicity indicates how much more dynamic fluctuations in salinity are compared to exchange processes. By comparison, the decrease in sodicity at the gypsum dump has occurred over 10 years at an unknown rate but likely very high rate of gypsum (Loveday 1976). Rather, landscape characteristics and the extent of the limiting factors guide the appropriate remediation technique and suitable rate of gypsum application. As is well understood (e.g. Jones 1967, Eldridge 1988), it is the leaching of salts that is often key to improving the rootzone for plant establishment and initiating positive feedback, and subsequent management and conditions determine the ongoing success of scald amelioration.

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