A comparison of rehabilitated coal mine soil and unmined soil supporting grazed pastures in south-east Queensland

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Abstract

Land that is disturbed by mining activities is required to undergo suitable rehabilitation. This study compared soils supporting grazed pasture on land that was rehabilitated after coal mining activity with that on unmined land. Pasture biomass, and soil physical and chemical properties important for pasture production and sustainability were intensively monitored on three sites that had completed rehabilitation at different times over the last 10 years, and one unmined control site. A further 18 unmined grazing sites were monitored for benchmarking purposes. Analysis of soil properties of plant available phosphorus and nitrogen, salinity and sodicity in the first year of the study suggested little difference in terms of benefits or constraints to pasture production between the rehabilitated and control sites. Plant-available phosphorus was sufficiently high in the two oldest rehabilitated sites that a fertiliser response would not be expected. Soil depth and the pasture rooting depth at the rehabilitated sites were at the shallow end of the wide range observed across the benchmark and control sites. Higher pasture biomass at the rehabilitated sites compared with the control at the initiation of the trial was attributed more to differences in grazing history than differences in soil attributes.

Introduction

Land that is disturbed by mining activities in Australia is legally required to be suitably rehabilitated. The New Acland coal mine in south-east Queensland is undertaking a program to rehabilitate most of its mined land to support pastures and scattered native trees and shrubs suitable for grazing (SKM, 2013). To rehabilitate land, stockpiled soil is spread to a target depth of 30 cm onto deep ripped and profiled interburden (mine spoil) material before sowing pasture species. Pasture species sown can include the exotics Katambora Rhodes grass (*Chloris gayana*) and both green and Gatton Panic (*Panicum maximum*) grasses as well as native Queensland Bluegrass (*Dicanthium sericeum*). Once established and considered stable, the rehabilitated land is used for cattle grazing. Conditions of the rehabilitated soils, monitored in April 2013, were found to be generally favourable for plant growth and good soil aggregate stability was observed (SKM, 2013).

The mining company is conducting a five-year trial to compare the livestock production performance of rehabilitated land with that of unmined land. The trial includes livestock, pasture and soil monitoring over five years. Data from the first year of soil sampling, and initial pasture biomass data, are presented here. The soil monitoring component of the study compared soil chemical and physical properties of the rehabilitated soils with an unmined soil recently sown to similar pasture species (the control site) and analysed the relative benefits and constraints to pasture production. Properties and profile characteristics of the control site and 18 nearby grazed soils (benchmark sites) were also compared to identify how representative the control site was of surrounding grazed land.

Methods

The mine is located in south-east Queensland which has summer-dominant rainfall (70% of annual rainfall) of 630 mm annually on average. Four trial site paddocks were fenced for cattle grazing. The sites represent pasture on land rehabilitated seven to ten years ago (R1, 22 ha), five years ago (R2, 32 ha) and three years ago (R3, 22 ha) and a control site (C, 21 ha) on a Brown Dermosol which had not been mined, and was sown at the same time and with the same pasture mix as R3. Eighteen benchmark sites were chosen to represent the main soil types (Vertosols and Dermosols) mapped by SKM (2013) and used for grazing within a surrounding unmined area of approximately 10,000 ha. In November-December 2013 (time zero, T0), composite samples from at least 5 – 7 soil cores were collected for depths of 0 – 10 cm, 10 – 20 cm and 40 –60 cm at each trial site to measure the potentially mineralisable soil N content at the beginning of the growing season and before cattle started grazing the sites. Potentially mineralisable N was measured as hot KCl-extractable mineral N (Method 7D1, Rayment and Lyons, 2011) on samples that were dried at 40°C and sieved to 2 mm. During February-March 2014 (T1), five soil cores were collected along transects within five subsample areas in each trial site. Subsample areas were stratified to represent the topographic and vegetative variation in the landscape. Sampling was avoided in parts of the landscape considered to be atypical. Three cores were also collected during T1 at each benchmark site. Soil properties measured for T1 samples using methods from Rayment and Lyons (2011) were exchangeable cations (Ca^{2+}, M^{2+}, Na^+ and K^+, method 15C1 without alcohol and using an ICPMS analytical finish), pH (method 4A1), electrical conductivity (method 3A1), plant-available P (Colwell P, method 9B), and mineral N (KCl-extractable, method 7C2) on samples that were dried at 40°C and sieved to 2 mm. Field soil water content was measured gravimetrically. All P and N analyses were conducted by staff at the Agricultural Chemistry Ltd laboratory in Ipswich, Queensland. Soil profiles were characterised in one soil pit at benchmark sites, one pit in rehabilitated soil (R2) and three pits in the control. During soil pit characterisation and during soil coring, observations of soil depth to B, BC or interburden (mine spoil) layer, and maximum depth of pasture rooting were made. Pasture yields were visually assessed immediately prior to T0 and assessed using the Botanal technique (Tothill *et al*., 1992) prior to the introduction of cattle in January 2014. Statistical comparisons between treatments and depths were analysed using analysis of variance in Genstat 16th edition. Differences between means were considered significant at the 95th percent confidence level.

Results

At T0, pasture yields were estimated to be up to 15,000 kg/ha of dry matter (DM) in the R2 and R3 sites, consisting of old growth accumulated from recent years of above average rainfall and a small proportion of new growth from the current season. To make green pasture more readily accessible for grazing stock, R1, R2 and R3 paddocks were slashed to a height of approximately 30 cm at T0. The control site had been "crash" grazed and at T0 had very low pasture yields (< 300 kg/ha DM) and low ground cover. In January 2014, the rehabilitated sites R1, R2 and R3 yielded 3300, 5300, and 5000 kg/ha DM, respectively, and the control site yielded 1300 kg/ha DM.

In early summer (T0), there were similar amounts of potentially mineralisable N in the control and R3 sites, which were sown to pasture at the same time, and higher potentially mineralisable N particularly at 40-60 cm depth in the two older rehabilitated sites (R1 and R2, Figure 1). Similarly, at the end of summer (T1), mineral N was significantly higher in R1 and R2 compared with the control site (Figure 2). Colwell P was significantly higher in all three rehabilitated sites than in the control, and pasture in the two oldest (R1 and R2) rehabilitated sites was not likely to respond to P fertiliser. The exchangeable sodium percentage (ESP) of the soil was significantly higher at all depths in the control site compared with the R2 site (Figure 2) but most control and rehabilitated sites and depths were considered non-sodic (<6% ESP). Average salinity was low (EC<50 mS/m) across all sites. Most of the measured soil chemical properties were similar (ie. not significantly different) between the control and benchmark sites. Exceptions were Colwell P, which was significantly lower at the control site at all three depth intervals, and soil water content in the topsoil (0-10 cm), which was also significantly lower at the control site at the time of sampling.

Due to the soil rehabilitation process, the depth to interburden was shallow in comparison to the depth to BC or C horizons in the control and in most nearby unmined benchmark soils (Figure 3). Variation (expressed as the standard error or the mean) in the depth to the interburden across the rehabilitated sites was fairly uniform (40 ± 21.4 cm, 50 ± 21.5 cm and 44 ± 21.3 cm at sites R1, R2 and R3 respectively). Forty percent of the sampled cores displayed soil profiles shallower than the 30 cm target in the oldest rehabilitated site (R1) and 12% and 16% of observed soil depths were shallower than 30 cm in the more recently rehabilitated sites (R2 and R3, respectively). At five of the six sites with shallow soil profiles (<0.6 m), pasture roots explored the deeper horizons or layers, including the interburden material in the rehabilitated sites. The rehabilitated soil (a Spolic Anthroposol) A1 and B2 layers were both massive with 20% weak 5 to 10 mm angular blocky peds and the interburden layer, below 0.35 m depth, was structureless with 40-80% predominantly sandstone fragments. Of note was that darkening of the A1 horizon was observed.

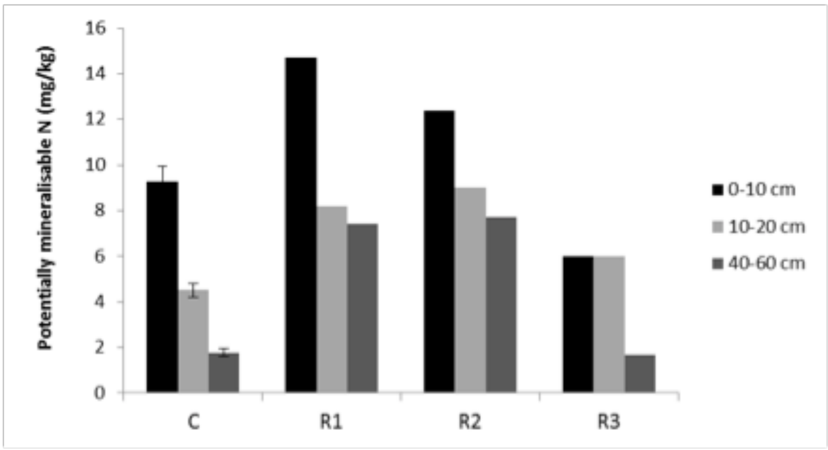

Figure 1. Potentially mineralisable soil N (mg/kg) at 0-10, 10-20 and 40-60 cm depth intervals in November - December 2013. Standard error of the mean of five subareas of the control (C) site presented as error bars. Data for the rehabilitated sites (R1, R2 and R3) represented composite multi-core samples from a single subarea per site.

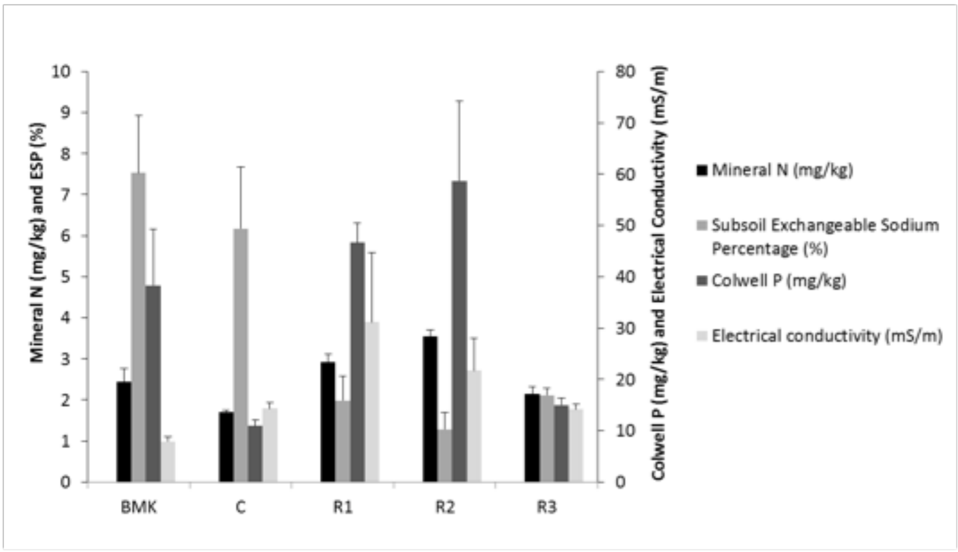

Figure 2. Soil plant available mineral N (combined average for depths 0-10, 10-20 and 40-60 cm, mg/kg), Colwell P (0-10 cm, mg/kg), exchangeable sodium percentage (40-60 cm, %) and electrical conductivity (0-10 cm, mS/m) across sites in February-March 2014

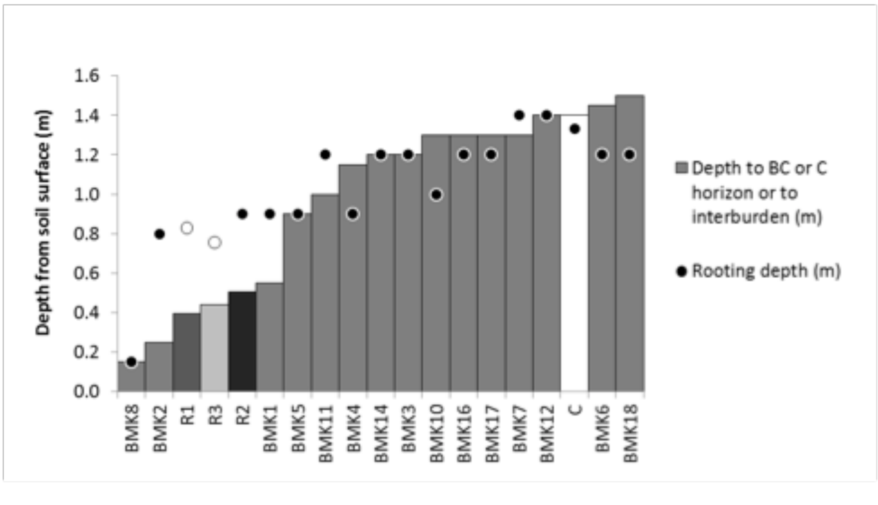

Figure 3. Average soil depth (bars) and rooting depth (circles) across benchmark (BMK) and treatment sites. Closed circles represent measurements from open pits. Open symbols represent depths at which roots were present in 20 soil cores per treatment.

Discussion

The soil properties measured suggest the control site was broadly representative of the surrounding unmined grazed soils. Lower plant-available P and soil water content may contribute to differences in pasture growth between the control and rehabilitated sites. Significantly higher plant-available P in R1 and R2, and also higher mineral N in R2 than the control and benchmark sites contrasted with findings by others where rehabilitated mine soils have had lower soil fertility than undisturbed soils (Schwenke *et al.* 2000; Vickers *et al*. 2012) but similar to Schwenke *et al.* (2000), mineralisable N appeared to increase with age of rehabilitation. The higher soil fertility may explain the high pasture biomass in the oldest rehabilitated sites compared with the control site. However, high biomass production in R3 was not reflected by higher plant available P or N. Evidence of pasture root exploration to at least 0.75 m across the control and rehabilitated sites suggested that pasture rooting depth was not a major factor limiting pasture growth. Grazing management was therefore likely to have been important in determining variation in initial biomass. Quantification of root vigour, soil water availability and nutrient cycling properties deserve further investigation in terms of the sustainability of soil conditions favourable for pasture production on these soils.

The mean depth to interburden in all rehabilitated sites (40-50 cm) was shallow compared with the control soil depth to saprolitic material, but exceeded the mining company's operational target depth of 30 cm. In both undisturbed and rehabilitated soils with shallow soil profiles (<0.6 m) pasture roots generally explored the deeper horizons or layers, including the interburden material in the rehabilitated sites. The interburden was considered structureless, much like naturally occurring saprolitic (partially weathered parent material) horizons, but the observations of roots suggested that this horizon was being utilised to some extent to satisfy plant demands. Two benchmark sites displayed similar features of shallow soil depth and root exploration beyond the maximum soil depth. Assuming the rehabilitated soil was a mixture of original A and B horizon material, darkening of the A1 horizon in the site that was rehabilitated five years ago (R2) suggested that there had been a significant level of organic matter breakdown and some degree of soil evolution.

Conclusion

With the exception of higher plant-available P and mineral N in two rehabilitated sites, there was little difference in the measured soil chemical properties at T1 between the control and rehabilitated sites with regard to benefits or constraints to pasture production. On average, none of the rehabilitated sites and depths would be considered sodic or saline. The rehabilitated soil depth was at the shallow end of the range measured across benchmark sites, however, root exploration into the interburden layer occurred in all rehabilitated sites suggesting pastures may also extract minerals and moisture from this layer. Information on soil hydraulic, porosity and nutrient cycling properties is required to inform the long term sustainability of the rehabilitated soils.

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