Disintegration of cattle hoof prints in cracking-clay soils of the arid South Australian Stony Plains region during a wet period

HELEN P. WAUDBY and SOPHIE PETIT

Helen Waudby PhD is a member of the Sustainable Environments Research Group, (SERG) School of Natural and Built Environments, University of South Australia, Mawson Lakes. She is presently an adjunct researcher at the Institute for Land, Water and Society, Charles Sturt University, Albury, New South Wales. Sophie Petit is a member of the SERG. The corresponding author's email is hpwaudby@gmail.com

Abstract

Recovery of clay-soil microtopography from trampling by cattle was assessed over 247 days in the Stony Plains region of South Australia during La Niña conditions. Hoof prints took 96 to 247 days to disintegrate. Several prints were still visible nearly seven months after initial measurement. Print volume and area declined more-or-less uniformly over time, but were still considerable for prints present at the end of the study. Rain may facilitate the surface recovery of cracking-clay soils from trampling via shrink-swell processes. In dry years, microtopography might take longer to recover. Considering the threatened and endemic species that these soils support, and their value to the pastoral industry, land managers should consider recovery time from trampling when implementing grazing management strategies.

Introduction

Stony tableland soils of the South Australian Stony Plains region are fine-textured, gypseous, saline, and characterised by numerous stones (gibbers) in the upper soil profile and surface. Gibber plains in this region often show pronounced microrelief in the form of gilgais (Jessup, 1960). 'Gilgai' is an indigenous term for the depressions that form in these soils (Paton, 1974). Cracking-clay soils are a common feature of gilgaied gibber plains of the Stony Plains region. They support nationally-threatened species such as plains rats (*Pseudomys australis*) (Brandle and Moseby, 1999). These soils are also habitat to a diversity of other small animal species, including endemic reptiles such as gibber dragons (*Ctenophorus gibba*), and little-known species such as Woomera sliders (*Lerista elongata*) (Waudby, 2013; Petit et al., 2012; Waudby and Petit, 2011). Pastoralists in the region consider these soils to be important opportunistic sources of stock fodder following sufficient rainfall (Waudby et al., 2013b). The integrity of these soil cracks is likely to be of critical importance to biodiversity conservation in the region (Waudby, 2013). Cracking-clay soils may be relatively resilient to trampling by stock since shrink-swell processes (caused by wetting and drying cycles) peculiar to these soil types may allow them to regenerate from mechanical disturbance (Taddese et al., 2002; Drewry, 2006) and since clay soils typically have a greater supporting capacity than other soil types (Lull, 1959). Few studies have examined the physical recovery of these soils from trampling over time. We aimed to quantify the surface recovery of these soils from trampling by cattle during a period of high rainfall, when recovery is expected to be most rapid.

Methods

Study site characteristics

The study was undertaken on a 4915 square km cattle lease (Billa Kalina Station; 29º55'01.66" S, 136º11'14.45" E) in the arid South Australian rangelands (north-west pastoral district; Figure 1), during La Niña conditions. Billa Kalina is located in the South Australian Stony Plains region. Stony tableland soils of the Stony Plains region are saline and gypseous with a clay profile, and covered by gibbers (Jessup, 1960), which sometimes form a desert pavement (Bourman and Milnes, 1985).
Billa Kalina consists of several land systems—groups of areas with similar patterns of geology, topography, soils, and vegetation. This research took place in the northern section of the property, within the Oodnadatta land system, which is characterised by gibber plains with gilgai microrelief.

Figure 1. Location of the study site on Billa Kalina Station, South Australia

Common plant species include Oodnadatta saltbush (*Atriplex nummularia* ssp. *omissa*), bladder saltbush (*Atriplex vesicaria*), samphires, native millet (*Panicum decompositum*), Mitchell grass (*Astrebla pectinata*), Flinders grass (*Iseilema membranaceum*), and annual herbs (DWLBC, 2008). Creeks and stony tablelands are dominant landscape features (Figure 2), with coolabah (*Eucalyptus coolabah*) and river cooba (*Acacia stenophylla*) common in and along the creeks. The Stony Plains region is located in the most arid part of Australia, with a median annual rainfall of 150 mm (Smyth et al., 2009). During this study, rainfall (0.2 mm increments) and

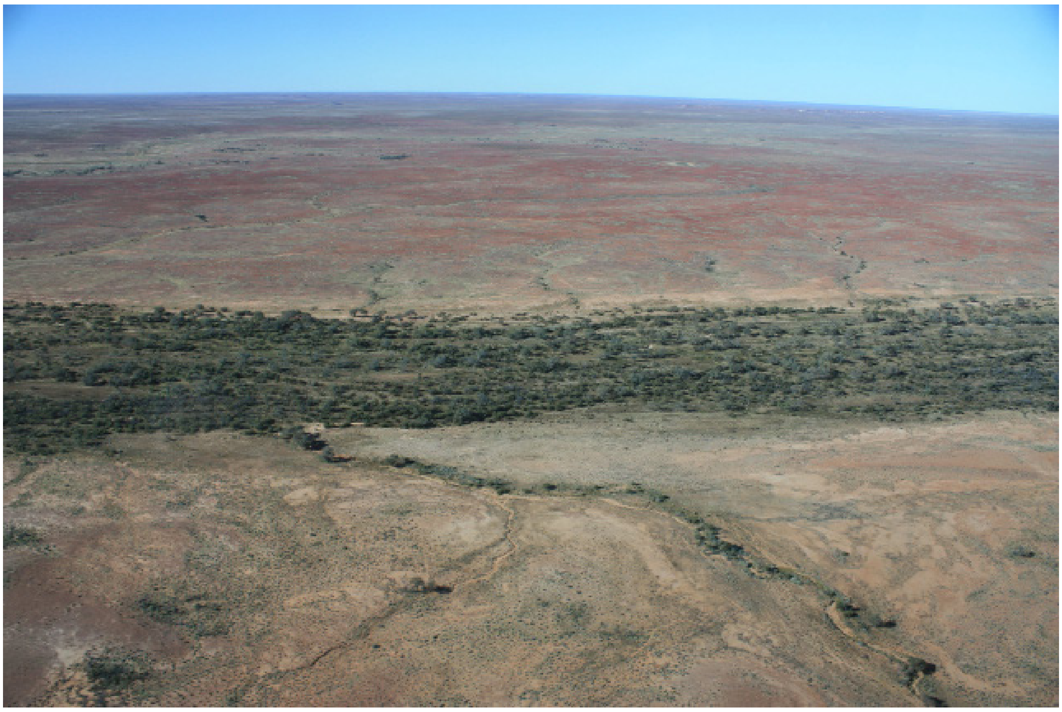


Figure 2. Aerial view of a large creek system, Mudla Wantamaran Creek, and the stony plains typical of the study area, on Billa Kalina Station

hourly temperature data as degrees centigrade were collected using a weather station (Vantage Pro2; Davis Weather Stations, South Windsor, New South Wales) located approximately two kilometres away from the study site.

Disintegration of hoof prints

Thirteen cattle hoof prints were marked with pin flags and measured. These prints were not part of a cattle pad (trails that cattle form as they travel the same path to water-points). They had been made in the seven days prior to the first measuring period and either during or immediately after a rainfall event. Some had been made by adult cattle and others by calves; some may have been created by the same individuals. Maximum width (diameter) and depth of the print were measured to the nearest 0.5 cm on six occasions, starting on 28 April 2010 and ending on 3 December 2010. The mean area (for a circle: πr^2) and volume (for a cylinder: $\pi r^2 h$) of soil disturbed in all prints were calculated for all measuring periods. Means were plotted with rainfall, which was measured from the first monitoring session. The approximate number of days until complete disintegration (when the print was no longer visible) was determined for all prints that disappeared during the sampling period.

Results

Climate
Over 150.0 mm fell from April 2010 to December 2010. Mean temperatures ranged from 10.8°C (± 0.20) in July 2010 to 26.7°C (± 0.26) in December 2010 as shown in Figure 3.

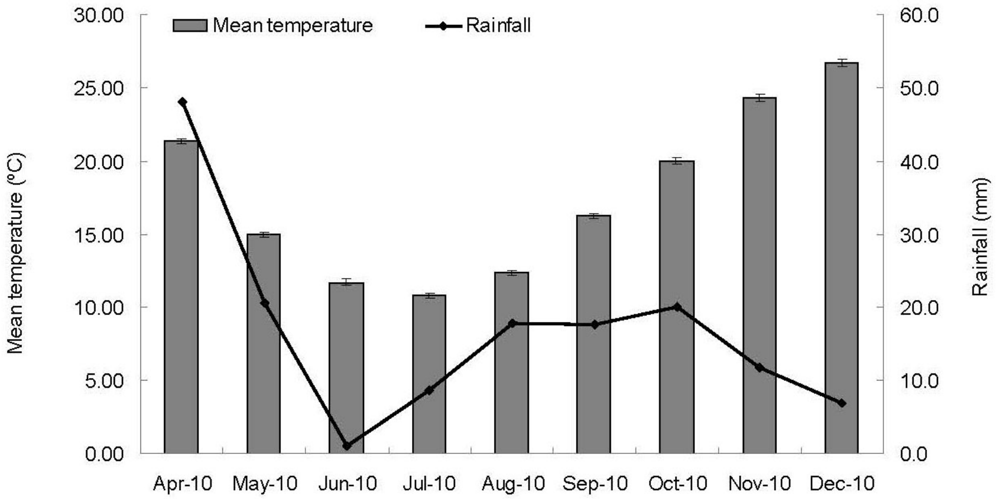


Figure 3. Mean temperature (± s. e.) and rainfall during the study period

Disintegration of hoof prints
The hoof print study period spanned 247 days. The maximum number of days until disintegration ranged from 96 to 247 days. Five hoof prints were still clearly visible approximately seven months after their initial measurement, remaining considerable in volume and area. Eight prints had either disappeared or were only a faint imprint that could not be measured by the final (sixth) measuring period. Standard error at each measuring session was smaller for surface area than for volume; mean surface area decreased considerably only at the last sampling date (Figures 4 and 5).

Discussion
Rainfall during the study period exceeded the yearly average for the region. Wetting and drying cycles cause cracking-clay soils to swell and shrink, which may facilitate the recovery of soil microtopography from mechanical disturbance such as trampling (Taddese *et al.* 2002; Drewry 2006). However, the extent of the influence of rainfall (for example timing, amount, rate, and evaporation) on shrink-swell processes is unclear and warrants further investigation. This study indicates that during rainy

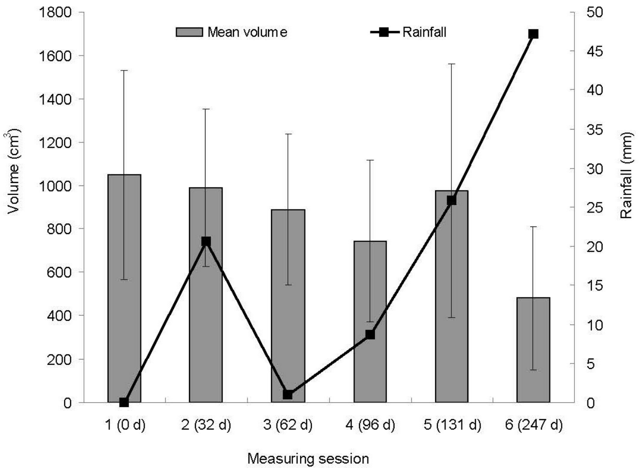


Figure 4. Mean volume (cm^3 ± s. e.) of disturbance for each measuring session (cumulative number of days) and rainfall (mm) beginning from the first session. Prints disintegrated over time and could not be measured; n = 13 for sessions 1-3, n = 12 for the fourth session, n = 7 for the fifth session, and n = 5 for the sixth session. The increase in volume during session five occurred because two prints collapsed inwards and subsided

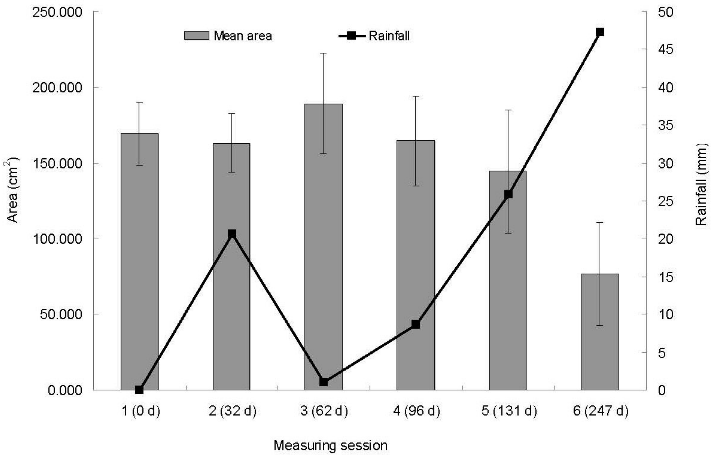
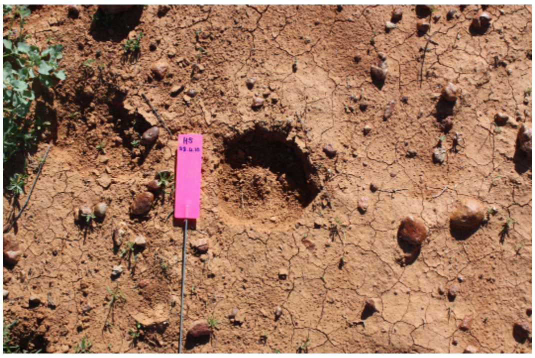


Figure 5. Mean area (cm^2 ± s. e.) of disturbance (cumulative number of days) and rainfall (mm) beginning from the first session Prints disintegrated over time and could not be measured; n = 13 for sessions 1-3, n = 12 for the fourth session, n = 7 for the fifth session, and n = 5 for the sixth session. An increase in mean hoof print area during the third session occurred because one print had become a 'pit' and another had seedlings growing inside it (the seedlings may have disturbed the print)



Gilgais hold water after rainfalls and are used as natural watering points by cattle

Typical cracking-clay soils with Helen Waudby's boot for scale

*Gibber dragons (*Ctenophorus gibba*) are an agamid species endemic to the southern Lake Eyre Basin*

*Plains rats (*Pseudomys australis*) likely rely on cracking-clay soils as critical habitat; this juvenile is eating fruit from red spinach (*Trianthema triquetra*)*

conditions in the Stony Plains region, clay-soil recovery can take at least 96 days. Five of the 13 monitored hoof prints were still clearly visible seven months after they were made, and were still large, such as 480.5 cubic cm. Under drier conditions, the rate of recovery may be much longer, particularly at intensively-grazed areas. Hoof prints could have long-term effects on the availability of cracking-clay shelters to wildlife (Waudby, 2013) and on plants for which compaction affects processes important for growth, for example water infiltration (Taddese et al., 2002). Hoof prints may collect moisture (Winkel and Roundy, 1991) and trap seed (Isselin-Nondedeu and Bédécarrats, 2007), facilitating the germination of some plant species.

Land managers seeking to rehabilitate paddocks after grazing or who 'spell' their stock should also consider the time needed for soil to recover. Potential for damage will be influenced by other factors than rainfall, including management regimes and stocking rates, herding behaviour, the tendency to follow well-used trails ('pads') to water, soil type, and topographic features, including slope. The mechanisms of soil recovery from trampling in the study area are not well understood as indicated by the paucity of published research. Considering that grazing dominates Australian rangelands (Waudby et al., 2012 and references therein; Waudby et al., 2013a), and that soil properties influence ecological processes (Yates et al., 2000) and rehabilitation efforts, further research is needed on the recovery of soil structure from trampling.

Acknowledgements
We are indebted to the Greenfield family of Billa Kalina Station. Thanks to Robert Brandle, Brendan Lay, and John 'Max' Maconochie from the South Australian Department of Environment, Water and Natural Resources for their advice and provision of maps. Thank you also to our reviewers, and to sponsors: the Royal Geographical Society of South Australia, the Hermon Slade Foundation, the Holsworth Wildlife Research Endowment, The Nature Conservancy Applied Conservation Award and The Thomas Foundation, the South Australian chapter of the Australian Federation of University Women, the Nature Foundation of South Australia, the Australian Geographic Society, the Wildlife Preservation Society of Australia, and S. Kidman & Co Ltd. The University of South Australia and the Sustainable Environments Research Group (SERG) provided a post-graduate scholarship and in-kind support.

References
Bourman, RP & Milnes, AR 1985 Gibber plains, *Australian Geographer,* vol. 16: pp. 229-232.

Brandle, R & Moseby, KE 1999 Comparative ecology of two populations of *Pseudomys australis* in northern South Australia, *Wildlife Research,* vol. 26: pp. 541-564.

Drewry, JJ 2006 Natural recovery of soil physical properties from treading damage of pastoral soils in New Zealand and Australia: a review, *Agriculture, Ecosystems & Environment,* vol. 114: pp. 159-169.

DWLBC 2008 Billa Kalina Pastoral Lease Map. Adelaide: Department of Land, Water and Biodiversity Conservation.

Isselin-Nondedeu, F & Bédécarrats, A 2007 Soil microtopographies shaped by plants and cattle facilitate seed bank formation on alpine ski trails, *Ecological Engineering,* vol. 30: pp. 278-285.

Jessup, RW 1960 The stony tableland soils of the south-eastern portion of the Australian arid zone and their evolutionary history, *The Journal of Soil Science,* vol. 11: pp. 188-196.

Lull, HW 1959 *Soil compaction on forest and range lands,* Forest Service, United States Department of Agriculture, Washington.

Paton, TR 1974 Origin and terminology for gilgai in Australia, *Geoderma*, vol. 11: pp. 221-242.

Petit, S, Waudby, HP, Walker, AT, Zanker, R & Rau, G 2012 A non-mutilating method for marking small wild mammals and reptiles, *Australian Journal of Zoology,* vol. 60: pp. 64-71.

Smyth, AK, Brandle, R, Chewings, V, Read, J, Brook, A & Fleming, M 2009 A framework for assessing regional biodiversity condition under changing environments of the arid Australian rangelands, *The Rangeland Journal,* vol. 31: pp. 87-101.

Taddese, G, Mohamed Saleem, MA & Ayalneh, W 2002 Effect of livestock grazing on physical properties of a cracking and self-mulching vertisol, *Australian Journal of Experimental Agriculture,* vol. 42: pp. 129-133.

Waudby, HP 2013 *Effects of cattle grazing on the biodiversity of cracking-clay gibber-gilgai systems in the arid South Australian rangelands,* PhD thesis. Environmental Science, University of South Australia.

Waudby, HP, Petit, S & Brown, G 2013a Use of creeks and gilgaied stony plains by cattle in arid rangelands during a wet summer: a case study with GPS/VHF radio collars, *Range Management and Agroforestry,* vol. 34: pp. 101-107.

Waudby, HP, Petit, S & Robinson, G 2013b Pastoralists' knowledge of plant palatability and grazing indicators in an arid region of South Australia, *The Rangeland Journal,* vol. 35: pp. 445-454.

Waudby, HP, Petit, S. & Robinson, G. 2012 Pastoralists' perceptions of biodiversity and land management strategies in the arid Stony Plains region of South Australia: implications for policy-makers, *Journal of Environmental Management,* vol. 112: pp. 96-103.

Waudby, HP & Petit, S 2011 Comments on the efficacy and use of visible implant elastomer (VIE) for marking lizards, *The South Australian Naturalist,* vol. 85: pp. 7-13.

Winkel, VK & Roundy, BA 1991 Effects of cattle trampling and mechanical seedbed preparation on grass seedling emergence, *Journal of Range Management,* 44: pp. 176-180.

Yates, CJ, Norton, DA. & Hobbs, RJ 2000 Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia: implications for restoration, *Austral Ecology,* vol. 25: pp. 36-47.