Formation of clay pans in South-West Queensland, Australia

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Abstract
Clay pans are hard, bare, unproductive areas found throughout south-west Queensland. While anecdotal evidence suggested various mechanisms for how clay pans form, no detailed investigations had been done to identify the causal processes leading to the formation of clay pans. This study assessed 11 clay pans in an area west of Roma, examining the morphological, physical and chemical properties of the soils in the clay pans and in nearby grassed areas. The driving factor causing clay pans to form was a loss of cover which exposed the soil surface to raindrop impact and erosion, leading to surface sealing/crusting. The particle size distribution of the soil surface is a key contributing factor, with clay pans being dominated by fine sand.

Key Words
Vegetative cover, surface seal, particle size distribution, scalded area

Introduction
The area west of Roma, in south-west Queensland, is known to have many bare, "scalded" areas (Figure 1), which are locally referred to as clay pans. They are found in footslopes and in depressions, particularly on alluvial plains. The clay pans have been in the region for many years—local landholders remember seeing them at least since the 1940s. It is likely that clay pans have increased in area over time, due to continuous grazing and/or drought, but they are currently relatively stable in size.

Figure 1. Typical clay pans in the area west of Roma.

In early 2007, a project assessing salinity risk was being carried out in the region by the Department of Environment and Resource Management on behalf of the Queensland Murray-Darling Committee (QMDC). QMDC identified several areas where additional information was needed to guide decisions about where their salinity management efforts should be focused—the clay pans in the Roma region were included in the list.

Historically, salinity had been considered as a causal factor leading to the development of the clay pans. Sodicity had also been identified as a major contributor. However, the causal processes have never been thoroughly investigated, though some management trials have been conducted over the past 15 years at one clay pan in the area. These include saltbush plantings, constructing shallow banks to pond water, tree plantings, installing bores to monitor groundwater levels and fencing off the area to exclude stock. Unfortunately the trials have not been regularly maintained or monitored over time and detailed records have been lost. Some of these trials were more aimed at managing salinity, rather than reclaiming the clay pan itself, as it was thought that salinity was the main reason the area was scalded. Koch *et al.* (1994) conducted a study tour of scalded sites in far-west Queensland, assessing the success of management options such as shallow ponding.

In August and November 2007, soil investigations were undertaken to better understand the nature of the clay pans, and their possible causal processes—how were these clay pans forming? Was salinity the main contributing factor? Understanding how clay pans form, together with information about their physical and chemical properties could then be used to inform management activities for the clay pans. In July 2008, a field day was held to communicate the results to local landholders and community groups. A series of information sheets about clay pan formation and management were produced and distributed in August 2008.

Methods

A combination of aerial photography, satellite imagery, historical information and local expert knowledge were used to identify a number of clay pans to be investigated in the region. Eleven sites, across six properties, were assessed (Figure 2, Table 1). Soil profiles were taken with 50 mm hydraulic driven soil cores (~1.8 m length) to depths ranging from 0.9 to 1.7 m. Profiles were described using methods outlined in McDonald *et al*. (1990), field pH and electrical conductivity tests were carried out down the profile, and 57 soil samples were collected (from the soil surface, and then generally from 10 cm sections at 30 cm intervals) and analysed at the Department of Environment and Resource Management laboratories for pH, electrical conductivity, chloride, cations and exchange capacity, moisture content and particle size analysis, using standard methods outlined in Rayment and Higginson (1992).

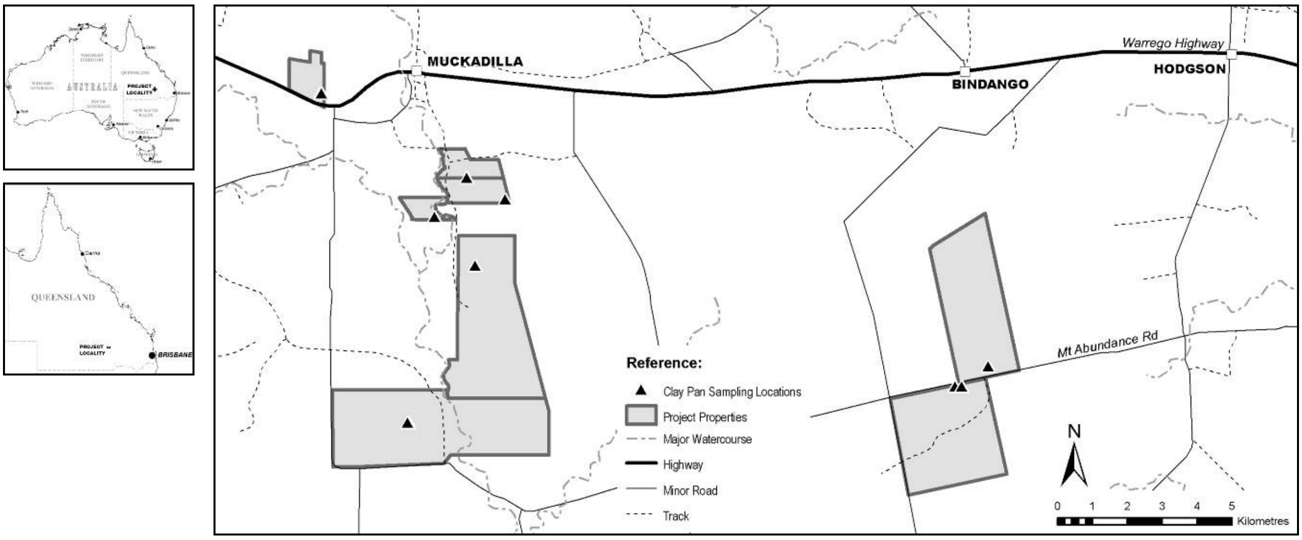


Figure 2. Location of clay pan sampling sites and properties.

Table 1. Summary of clay pan sites.

Date sampled	Site number	Property number	Comments
2/08/07	136	1	Site located in clay pan; 0–1.7 m; 11 samples analysed; previous management trials conducted at this clay pan
8/11/07	136	1	Re-visited clay pan; collected 0–0.02 m surface sample for analysis
8/11/07	143	2	Paired site 1; site located in clay pan; 0–0.9 m, five samples analysed
8/11/07	144	2	Paired site 1; site located in Mitchell grass area, about five metres from site 143; 0–1.2 m; six samples analysed
8/11/07	145	3	Site located in clay pan, about 10 metres away from an area of the clay pan that had previously been ripped; 0–1.3 m; field pH and EC tests only
8/11/07	146	4	Paired site 2; site located in clay pan; 0–1.1 m; five samples analysed
8/11/07	147	4	Paired site 2; site located in vegetated area within the same clay pan, about 20 m from site 146; 0–1.5 m; six samples analysed
9/11/07	148	5	Site located in a bare patch within a partially remediated clay pan; 0–1.2 m ; six samples analysed
9/11/07	149	5	Site located in clay pan, adjacent to creek; 0–0.9 m; five samples analysed
9/11/07	150	5	Paired site 3; site located in a wheat crop which had been a bare clay pan prior to ploughing and planting; 0–1.2 m; five samples analysed
9/11/07	150b	5	Paired site 3; site located in a wheat crop (not a prior clay pan area), about 300 m from site 150; field pH and EC tests only to 1.4 m
9/11/07	151	6	Site located in clay pan; 0–1.2 m; six samples analysed

Results and Discussion

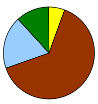
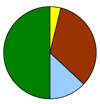
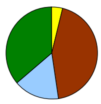
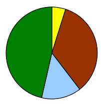
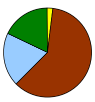
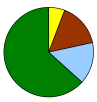
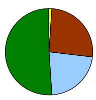
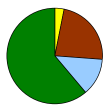
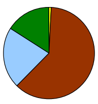
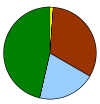
This study found that the formation of clay pans is driven by a lack of ground cover and that the particle size distribution of the soil surface is a key contributing factor. Most clay pan sites are non-saline at the surface (0–0.05 m), but are usually saline at depth (site 136 had the highest EC of 5.4 dS/m at 0.5 m).

Vegetative cover is lost mainly through overgrazing and/or drought. Grass and herb growth is usually better in parts of the landscape which receive more water, i.e. in footslope areas, depressions etc. This can lead to preferential grazing (or patch grazing) by stock in these areas. Even though the overall paddock stocking rate may be suitable, stock will overgraze these areas as they stay greener for longer and have sweeter feed, especially during dry times. Overgrazing and loss of cover is the start of the clay pan formation process. Many areas in the region may have been overgrazed by sheep and rabbits in the early 1900s during the Great Drought, leading to a loss of cover.

Once ground cover is lost, two key factors come into play—raindrop impact and erosion. Without cover, the soil surface becomes more susceptible to raindrop impact—the physical action of raindrops hitting the soil surface is enough to 'sort' the soil so that the fine sand, silt and clay particles are re-arranged until they eventually pack together, filling the pore spaces at the surface, causing a surface seal and setting hard like concrete which limits infiltration of water. All of the clay pans investigated in the study area had a visible layer of silt/fine sand on the soil surface which set quite hard and appeared to be limiting infiltration of water. A number of the clay pans also had a vesicular layer (Figure 3). Particle size analysis showed that the clay pan surface is dominated by fine sand, while vegetated sites were dominated by clay in the surface (Table 2).

Figure 3. Surface clod from site 148 (a bare patch of soil within a fenced off clay pan). A firmly packed layer of fine sand/silt, approximately 10 mm thick is evident, with an underlying vesicular layer.

Table 2. Comparison of particle size analysis results between clay pans and grassed areas, at the soil surface and at 0.5–0.6 m. Clay pans were dominated by fine sand at the surface (>50%), though by 0.5 m, their particle size distribution was dominated by clay, more like the 'normal' grassed sites.

Clay pan sites	Depth (cm) 0–5	Depth (cm) 50–60	Grassed area sites	Depth (cm) 0–5	Depth (cm) 50–60
146			Vegetated area within a clay pan (147)		
143			Mitchell grass area (144)		
149			Coarse sand; Silt	Fine sand; Clay	

In some clay pans, it is also possible that the surface seal made up of fine sand, silt and clay particles has been deposited by surface wash over time. A key factor influencing this is slope and the management of the surrounding upslope areas. If there has been a loss of cover in the upslope areas (e.g. they have been cleared, grazed, cropped etc), then this is more likely to occur. The soil particles tend to be deposited in footslope areas and depressions, building up the surface crust.

As with the other clay pans in the study area, results from site 149 (clay pan located near a creek) showed that a surface seal was present. Sampling at this site also revealed that the soil underneath the seal had no obvious serious chemical limitations to vegetation growth. It therefore seems very likely that this area is bare simply due to the physical action of raindrop impact sealing the surface, leading to reduced infiltration and seedling emergence.

The creek clay pan area was re-visited in March 2008 and again in July 2008. At both times, sections of the former bare area had recovered quite well and had reasonable cover. The property received about 500 mm of rain in December 07/January 08. Given that the landholder had not touched the area since November 2007, this highlights that some clay pans (especially the ones with no serious underlying chemical limitations e.g. salinity or sodicity) can regenerate somewhat without human interference. It also highlights how clay pans can change from season to season, and the importance of good rain and a suitable seed source (in this case the Mitchell grass area upslope) for clay pan remediation.

Many soils in the region are naturally saline and sodic at depth (Macnish, 1987). With reduced infiltration and leaching under crusted/sealed soils, evaporative accumulation of salts at the surface can occur. Once cover is lost and a surface seal is in place, even light rainfalls will usually be lost as runoff. This means that over time, soil salt, chloride and sodium levels are all likely to increase in a clay pan, compared to vegetated areas. This can give the impression that salinity is causing the clay pan as testing will show elevated salts at the surface, but in effect, it is usually a symptom of the clay pan formation process, rather than a contributing factor.

A number of factors combine to restrict plant growth on clay pans:

- The soil is too hard for roots to penetrate or water to infiltrate;
- High levels of salts close to the surface inhibit plant growth;
- Surface temperatures on a dry bare area can exceed the shade air temperature by up to 11°C in winter and by up to 25°C in summer (since summer surface temperatures will regularly reach 65°C, this means bare areas can reach 90°C);
- Light falls of rain are ineffective (due to low infiltration, high runoff and high evaporation rates) while heavy rainfalls are lost as runoff;
- Loose wind-blown sand particles can develop sufficient velocity on bare areas to cut plant tissue, exposing the affected plant to desiccation; and
- In bigger clay pans there are usually low levels of seed supplies in the immediate surrounding area.

Conclusion

This study found that the majority of clay pans are likely to have formed from the following sequence of events:

1. Vegetative cover is lost through overgrazing and/or drought.
2. The soil surface becomes exposed and susceptible to raindrop impact.
3. This leads to 'sorting' of the soil surface, resulting in a surface seal or crust which limits infiltration and seedling emergence.
4. Evaporation brings any salts that may be present naturally at depth in the soil profile closer to the surface.
5. Eventually the salts accumulate due to evaporative concentration.
6. Any vegetation that tries to grow can't get established due to limited water and/or a hostile soil environment, so the area remains bare.

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