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Water Infiltration Rates into Unponded and Ponded Soils in Central Australia

A. Wilkie, Rangeland Production Officer, Alice Springs

INTRODUCTION

Ponding banks in central Australia, are usually constructed on land where active gully erosion is occurring, or where the top layer of the soil surface has been removed producing large unvegetated scalds. The banks are used to collect and control the flow of rainfall, holding water on the soil surface, increasing soil moisture levels and generally improving the conditions for plant growth.

The changes in the soil physical properties of scalded country treated with ponding banks has been partially described in central Australia (Purvis, 1986, Purvis and Bastin, 1990; Bastin,1991) and more fully in other regions of Australia (Rhodes and Ringrose-Voase, 1987; Rhodes, 1987). Briefly, ponding allows water infiltration into the soil profile, providing soil moisture for plant establishment and growth. Over time, the wetting and drying of the soil causes small shrinkage cracks to develop on the soil surface. As ponding continues these surface cracks enlarge and extend into the subsoil. This has two benefits, increasing the roughness of the soil surface and greatly improving the rate and depth of water infiltration (Green, 1989). The roughness of the soil surface helps trap sand, silt and the organic matter, all of which further modifies the soil surface and increases infiltration (Purvis, 1990).

As part of a larger project, studying the economic effects of water ponding for pastoral production in central Australia, water infiltration rates into ponded (soils subjected to periodic water ponding due to ponding banks) and unponded soil profiles were measured. To demonstrate some of the soil physical changes which occur under water ponding, three important components of infiltration, the sorptivity of the soil, the flow rate of water at steady state and the total cumulative infiltration were studied.

Sorptivity

Water moves into a soil profile through pores and cracks in the soil surface. The rate of infiltration is dependent on the amount and intensity of rainfall and the number and size of the cracks and pores in the soil surface (Briggs, 1977). As water moves into the soil profile it is influenced by the matric forces of the soil (the force of attraction between soil and water molecules) and gravity. The initial infiltration of water into a soil profile is dominated by a period during which water is absorbed by the matric forces of the soil. The measure of this rate of absorption of water, a function of the forces of attraction, is expressed as the sorptivity of the soil. Gravitational forces drain water through a profile and become more important as water infiltrates deeper into a soil profile.

Steady State Flow

Water infiltrating into a soil profile from a ponded or saturated source, will reach a point where the rate of infiltration into the soil profile is constant and steady. At this point gravity and hydraulic conductivity has replaced the sorptivity as the dominant forces acting on the flow of water (Greacen, 1983). This period of constant infiltration is expressed as the steady state flow rate and gives an indication of sub soil structure, water holding capacity and the drainage properties of the soil.

Cumulative Infiltration

Cumulative infiltration is the measure of the total amount of water that enters the soil profile over a given time. It is used to demonstrate the amount of water that can enter the soil profile under ponded conditions (saturated flow).

METHOD

A disc permeameter (Perroux and White, 1988) was used to measure the infiltration rates of water into unponded and ponded soil profiles at sites used in an existing trial (Table 1). Measurements were taken in spring 1998 when soil conditions at all sites were universally dry. While the exact dimensions and operating procedures of the disc permeameter are contained in the operation manual (CSIRO, 1988), a brief description is given below.

A 20cm diameter steel ring is gently forced, approximately 5mm into the soil surface, taking care not to disturb the soil (Figure 1). The outside edge of the ring and the soil surface is then sealed with wet betonite clay to prevent sideways flow of water under the ring. A clear polycarbonate disc placed on the ring is adjusted until a 5mm gap between the soil surface and the bottom of the disc is achieved. The volume of this gap is equal to the volume of the water held in a side tube with an air inlet valve. The valve is opened and water flows from the side tube filling the gap between the soil surface and the disc. As water enters the soil profile it is replaced by water from the larger graduated water reservoir. A simple program on a laptop computer is used to record the time as the water level falls past each graduation mark.

Figure 1. Disc Permeameter and laptop computer

Table 1. Site Characteristics for three Ponding Sites

Site	Soil Texture	Land System and Unit*	Bank Age	Bank Length (3 Banks)
Erldunda S 25o 24’ 44” E 133o 04’ 23” (200 km Sth of Alice Springs)	0-20 cm Sandy clay Loam 20-40 cm Clay loam 40-50 cm Light clay	Ebenezer Land System, Land Unit 1 Gravel strewn calcrete plains with calcareous earth soils. Sparse shrubs and low trees with short grasses and forbs and minor bluebush (*Maireana astrotricha*).	10 years	180 m, 180 m, 300 m
Hamilton Downs S 23o 33’ 50.6” E 133o 09’ 10.4” (50km NW of Alice Springs)	0-60 cm Medium Clay	Hamilton Land System, Land Unit 1 Alluvial plains with scalded stony surfaces, shallow gullies and minor gilgais. Short grasses and forbs with some areas of Neverfail (*Eragrostis xerophila*)	2.5 years	120 m, 120 m 120 m
Mt Riddock S 21o 43’ 00.5” E 133o 45’ 36.0” (200 km NE of Alice Springs)	0-30cm Sandy clay Loam 30-70 cm Clay Loam	Alcoota Land System, Land Unit 4 Alluvial flats on gently undulating plains with stony surfaces and some gilgais. Mainly red coarse textured soils. Short grasses and forbs with Neverfail (*Eragrostis xerophila*), and Mitchell grass (*Astrebla pectinata*).	7 years	150 m -180 m

* Source: (Perry *et al*. 1962)

RESULTS

Sorptivity

At all three sites, the ponded soil profiles had higher average sorptivity than the unponded soils (Table 2). The increased sorptivity in water ponded soils ranged from a low of 33% at Mt Riddock, 49% at Hamilton Downs to a high of over 600% at Erldunda.

The graphed sorptivity phases (Appendix 2, Sorptivity Graphs), show that at all sites there was a great deal of variation over the length of the sorptivity phase.

Table 2. Sorptivity (mm/hr $^{1/2}$)

Site	Ponded Soil Profiles	Unponded Soil Profiles
Erldunda		
Average	46.3	6.0
Range	19.4 – 72.2	3.9 – 8.6
Hamilton Downs		
Average	58.6	39.3
Range	7.8 – 86.4	35.6 – 44.5
Mt Riddock		
Average	54.3	40.8
Range	10.5 – 78.2	4.1 – 63.5

Steady State Flow Rates

Two sites, Hamilton Downs and Mt Riddock recorded approximately 1.5 times higher average steady state flow rates on the ponded soils than on the unponded soils (Table 3). At Erldunda the average steady state flow rates for the ponded and unponded soils were very similar.

Table 3. Steady State Flow (mm/hr)

Site	Ponded Soil Profiles	Unponded Soil Profiles
Erldunda		
Average	10.1	9.6
Range	6 – 17.4	9 – 10.2
Hamilton Downs		
Average	33.3	11.9
Range	13.2 – 45	7.2 – 14.4
Mt Riddock		
Average	20.2	12.2
Range	8.4 - 36	8.4-25.2

Cumulative Infiltration

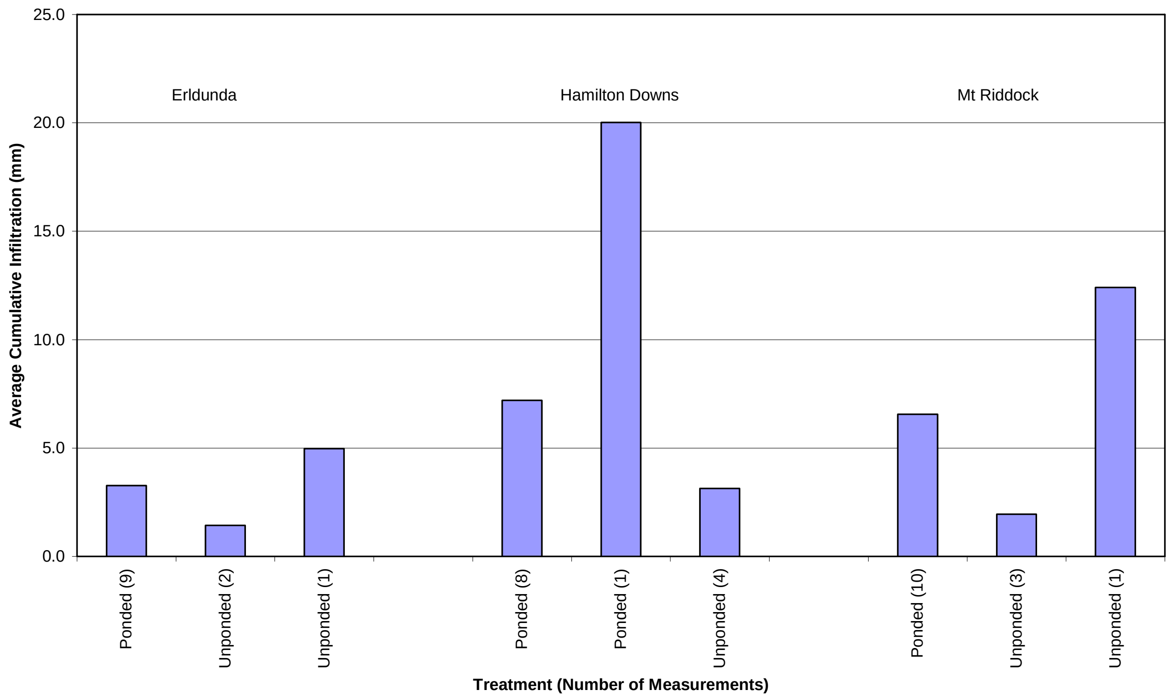

Figure 2. Average Cumulative Infiltration into Ponded and Unponded Soil Profiles after 10 minutes

All sites had reached steady state flow before 10 minutes and combined with the sorptivity of the soil profile was used to calculate the cumulative infiltration after 10 minutes (Figure 1). At Erldunda the strong sorptivity phase in the ponded treatment was reflected in the higher cumulative infiltration into the ponded soil profiles than the unponded, with the exception of one unponded soil profile which recorded a substantially higher than all other ponded and unponded sites. This trend was repeated at the other two sites with the ponded soil profiles having higher cumulative infiltration than unponded treatments. Several exceptions to this occurred, with one unponded site at Mt Riddock and a ponded site a Hamilton Downs having the highest cumulative infiltrations for their respective sites.

DISCUSSION

Major differences in soil type and the age of the ponding banks at the three study sites prevent any comparison of infiltration rates between the sites. However, the results clearly show that at all sites, the areas treated with ponding banks had higher average initial infiltration rates (sorptivity), steady state flows and total infiltration after 10 minutes than unponded soils.

These results are consistent with infiltration rates measured behind two ponding banks and an adjacent unponded area near Alice Springs (Reu, unpublished data). Substantially higher infiltration rates were recorded behind a 20 year-old ponding bank compared to an 18 month-old bank, with the unponded scalded area having very low infiltration rates.

To identify some of the influences on water infiltration into unponded and ponded soil profiles, it is necessary to look at two of the important phases of infiltration, sorptivity and the rate of steady state flow.

At Erldunda, while sorptivity was almost 7 times higher in the ponded soils, the steady state flow rates for both treatments were very similar. Behind the 10 year old banks small cracks were visible on the soil surface. These provided an easy path for water to flow through the soil surface and begin infiltrating into the ponded soil profile. In comparison, the unponded soil had very few of these small cracks and the hard setting soil surface acted as a barrier to water infiltrating into the soil.

While the average sorptivity of the ponded soils at Hamilton Downs was higher than the unponded, there was not the same marked difference between the ponded and unponded soils as at Erldunda. Similarly, at Mt Riddock, while the average sorptivity in the ponded soils was higher than the unponded soils, when a very low value for one of the unponded measurements was discarded, the average sorptivity of both treatments was very similar.

A clear relationship exists between vegetation cover and infiltration rates, with a mulga grove (52% total cover) found to have 10 times higher infiltration rates than an adjacent runoff zone with 7% cover (Greene, 1992). Vegetation aids water infiltration through providing organic matter for the soil surface, by plant roots forming cavities and macropores deep into the soil profile (Greene, 1992) and by protecting the soil surface from raindrop impact and sealing of the soil surface (Bridge. *et.al*, 1983). Soil macropores are also formed by ants, termites and other types of soil fauna, the presence of which are directly related to increased plant cover, organic matter and soil moisture levels.

Given this relationship between cover and infiltration rates, it was somewhat surprising that there was a lack of very large differences in sorptivity between ponded and unponded soils at Hamilton Downs and Mt Riddock. At Mt Riddock, the 7 year-old banks had well established stands of perennial grasses, while the unponded area had isolated patches of copperburrs and oatgrass with very few perennial grasses. At Hamilton Downs the differences in cover are less pronounced, with annual grasses, herbage and some perennial grasses behind the 3 year old banks and a good coverage of small oatgrass plants on the unponded site, increasing surface infiltration and sorptivity.

The effect of plant cover, macropores and soil cracks which run from the soil surface deep into the subsoil, can be further investigated by looking at the steady state flow rates for the three sites.

The sorptivity and steady state flow rates soils at Erldunda, suggest that although the infiltration rates at the soil surfaces were different, both the unponded and ponded had well structured B horizons with sufficient cracks and pores to allow water infiltration into the subsoil at very similar rates. However at Mt Riddock, although little difference existed between the sorptivity of the ponded and unponded soils, the rate of steady state flow was much higher behind the ponding banks. This is most likely due to a combination of small surface cracks extending into the subsoil and the increased cover of perennial grasses, which form old root cavities and other macropores and conduct water into the soil at a much greater rate then on the unponded soils.

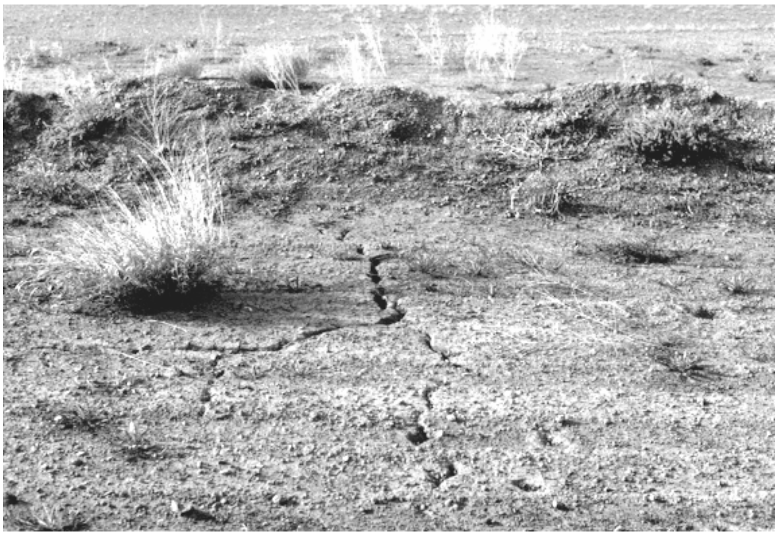

Figure 3. Large horizontal and Vertical cracks running through the ponded soil profile, Hamilton Downs

Similarly, at Hamilton Downs, the steady state flow was three times higher behind the ponding banks compared to the unponded soils. While increased vegetation cover on the ponded soils would have aided infiltration, a more important factor at this site may have been the cracking nature of the soil. The soil had a medium clay texture with swelling/shrinking properties, which led to large horizontal and vertical cracks forming in the ponded soil profile (Figure 3). These cracks, not visible in the unponded soils, would have allowed water to infiltrate into the ponded subsoil much more rapidly and at greater volume than on the unponded soils.

One measurement on the unponded soil at Erldunda produced a sorptivity only slightly higher than other unponded measurements, but a steady state flow higher than any of the ponded or unponded soils at Erldunda. The site of this single measurement was an “island” of several bluebush (*Maireana astrotricha*) shrubs, with significantly sandier topsoil, and covering less than 10% of the unponded scalded area. The steady state flow rate of 30.6 mm/hr, three times higher than the average steady state flow rate behind the ponding banks, suggests that the deep rooted perennial shrubs enhance water infiltration into the subsoil by holding the more permeable topsoil together and quickly conducting water into the soil profile. This is consistent with the arid rangeland ecological principle of resource patchiness (Tongway et.al. 1989), where resources such as water and nutrients are concentrated in patches. In this example, the island of bluebush shrubs act as wicks in the landscape, soaking up rainfall runoff from surrounding scalded areas and storing it in the soil profile (Hobbs per.comm).

CONCLUSIONS

It is clear waterponding not only collects and holds rainfall on the soil surface for longer, the soil physical changes resulting from waterponding, greatly increase the rate of water infiltration. In central Australia, substantial runoff has been observed after rainfall in excess of 15mm (Slatyer, 1962). Given this, the more rapidly water can infiltrate into a soil profile, the less flows into creek lines and is lost from the productive pastoral areas. Slowing and concentrating rainfall runoff with ponding banks, allows greater infiltration into the soil profile, increased soil moisture levels, improved conditions for plant growth and ultimately an increase in the pastoral productivity of the ponded area.

REFERENCES

Bastin, G. (1991). Rangeland Reclamation on Atartinga Station, Central Australia. *Australian Journal of Soil and Water Conservation*. Vol 4, No 2, pp18-25.

Bridge, B.J. *et al*. (1983). The formation of degraded areas in the dry savanna woodlands of northern Australia. *Australian Journal of Soil Research*. 21, pp91-104.

Briggs, D.J. (1977). Sources and Methods in Geography – Soils. Butterworth & Co Ltd. London. pp66.

CSIRO (1988). Disc Permeameter Instruction Manual, CSIRO Centre for Environmental Mechanics, Canberra.

Greacen, E.L. (1983). In: Soils – an Australian Viewpoint, CSIRO/Academic Press, Melbourne. pp 503.

Green, D.R. (1989). Rangeland Restoration Projects in Western New South Wales. *Australian Rangeland Journal*. 11 (2), pp110-116.

Greene, R.S.B. (1992). Soil Physical Properties of Three Geomorphic Zones in a Semi-Arid Mulga Woodland. *Australian Journal of Soil Research*. 30, pp55-69.

Purvis, J.R. (1986). Nurture the Land: My philosophies of pastoral management in central Australia. *Australian Rangeland Journal*. 8(2), pp110-117.

Purvis, J.R. and Bastin, G.N. (1990) Ponding Banks on Atartinga Station. Proceedings of 6th Australia Rangelands Conference.

Perroux, K.M. and White, I. (1988). Designs for disc permeameters. *Soil Science Society of America Journal*. 52: 5, pp 1205-1215.

Rhodes, D.W. (1987). Vegetation Response and Productivity Improvements under Waterponding. Journal of Soil Conservation. V(43) pp 62-67.

Rhodes, D.W. and Ringrose-Voase A.J. (1987) Changes in soil properties during scald reclamation by waterponding. *Journal of Soil Conservation*. V(43), pp84-90.

Slatyer, R.O. (1962). Methodology of a Water Balance study conducted on a Desert Woodland (*Acacia aneura* F.Muell) community in central Australia. *UNESCO Arid Zone Res*., 16,15-26.

Tongway, D.J., Ludwig, J.A., Whitford, W.G. (1989). Mulga log mounds: fertile patches in the semi-arid woodlands of eastern Australia. *Aust.J.Ecol*. 14;263-268.

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