NATIONAL PROGRAM FOR
Sustainable Irrigation

Research Bulletin

Long-term sustainability of precision irrigation

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Taking subsoil infiltration measurements in a drip-irrigated vine row near Tanunda in the Barossa Valley, South Australia

The presence of enough water, nutrients, beneficial organisms along with the absence of toxins and pathogens are often considered sufficient for good soil fertility. The role of soil structure in plant growth is often overlooked. Soil structure is a *physical* property defined by the size, abundance and continuity of pore spaces in the soil. Soil structure has a profound impact on the environment of plant roots by regulating the drainage and strength of soil[1].

The consequences of poor drainage and of high strength in soil are far-reaching. Poor drainage hinders the leaching of salt from the root zone, denies oxygen to growing roots, retards soil biological activity and limits the uptake of water and nutrients. High soil strength makes soils difficult to penetrate and is caused by any process that makes the soil denser, such as compaction or the collapse of soil pores under irrigation. This impedes the development of an extensive root system by forcing the roots to grow into existing pores which may be limited in number. Plants with small root systems confined by poor soil structure are prevented from foraging for water and nutrients and are therefore more dependent on regular applications of both.

Soil structure can be degraded by heavy vehicle compaction of moist soil but also by irrigation; either because of saline water (alternating with good water from rain) or just because of prolonged wetness. In this regard, precision irrigation is deceptive in that the amounts of water applied are modest, but concentrated in small areas. Application of 1 megalitre (ML) per hectare (ha) by drip irrigation would seem to be equivalent to 100 millimeters (mm) of water. But this water is applied only to a very small fraction of the field and may effectively equate to several thousand mm concentrated at a point. If the water quality is poor there is additional potential for critical damage to soil structure.

This project aims to assess soil structural decline under precision irrigation and to suggest management strategies to avoid it. The work so far has largely been confined to drip-irrigated vineyards in the Barossa Valley.

1 The size of important pores in soil ranges from nano-metres (nm) to milli-metres (mm). The smaller pores are largely products of soil texture; these give a soil its water-holding capacity and are not substantially changed by soil management. The larger pores are associated with drainage and strength, are often relics of biological activity (e.g. decayed roots) and are critically affected by soil management.

Assessing soil structure

Unlike measurements of soil chemical properties (e.g. pH, nutrient availability, organic carbon etc) which normally require only small samples to be collected and evaluated in the laboratory, measuring soil structure is much more time-consuming and difficult. This is because it involves multiple measurements which must all be made on larger, intact soil samples either in the field or the laboratory. A major difficulty in this project lies in finding reliable "control" sites where the soil is identical but has never been irrigated. In a vineyard the mid-row area is generally unsuitable as it may not have been deep-ripped during establishment, may have a cover crop in winter and experiences traffic compaction. Our approach has been to work in vineyards where individual drippers are well-spaced (2 metres or more) and to conduct measurements directly under, and midway between, drippers.

In this project drainage is assessed by measuring infiltration rates of water (mm/hr) with a CSIRO disc permeameter. This measurement is made at the bottom of a hole near the interface of the topsoil and subsoil where drainage problems become evident. Infiltration rates need to be sufficient (10-100mm/hr) to cope with substantial rainfall and irrigation events.

Soil strength, which is critically dependent on soil water content, is measured as penetration resistance in mega-Pascals (MPa) on intact soil samples of known water content in the laboratory. Measurements of penetration resistance in the field are possible but comparisons are more difficult because of the uncertainty in the water content of soil at various points in the field. Even so, field penetration resistance measurements give some idea of the level of difficulty roots are encountering. Penetration resistance values greater than 1 MPa are widely regarded as a serious impediment to root growth.

A fracture surface at the boundary of topsoil and subsoil prepared for infiltration measurements; roots and macro-pores are clearly visibile.

Infiltration measurements under way using disc permeameters

Aeration is measured as air-filled porosity, calculated as the difference between the water contents of saturated soil and soil drained to field capacity. Generally speaking, air-filled pores should occupy about 25% of the whole soil volume; soils where this is less than 10% are poorly aerated.

Results so far....

Initial work in the project has been at 18 sites within 8 vineyards. Water quality is generally good; only 4 of these sites have been irrigated with moderately saline water (EC ›2dS/m).

Infiltration rates were generally poor. Two thirds of the sites were below 2 mm/hour and more than one quarter were less than 0.4 mm/hr. The rates midway between, and directly under drippers were similar in 60% of cases. Otherwise they were much larger midway between the drippers.

Penetration resistance measured in the laboratory at field capacity (–10 kPa) was generally high with an average value of 1.1 MPa. At the 4 salt-affected sites, penetration resistance was 26% greater between drippers. At the other 14 sites, penetration resistance was 29% greater under drippers.

Field penetration resistance 24-48 hours after irrigation was assessed at 35 points in 2 vineyards. In Vineyard 1, only 7% of measurements were below 1 MPa while 38% were above 2 MPa. In Vineyard 2, 80% of measurements were above 2 MPa and 40% were above 4 MPa.

Air-filled porosity at field capacity (–10 kPa) was also poor. Two thirds of the samples studied were below 5% and almost all were below 10%. Air-filled porosity was generally greater (by about 50%) midway between drippers.

What does all this mean?

The poor infiltration rates strongly suggest that there is occasional waterlogging in these subsoils. However, with good irrigation management this may be restricted to major rainfall events. This is borne out by grower observations of surface ponding in the winter.

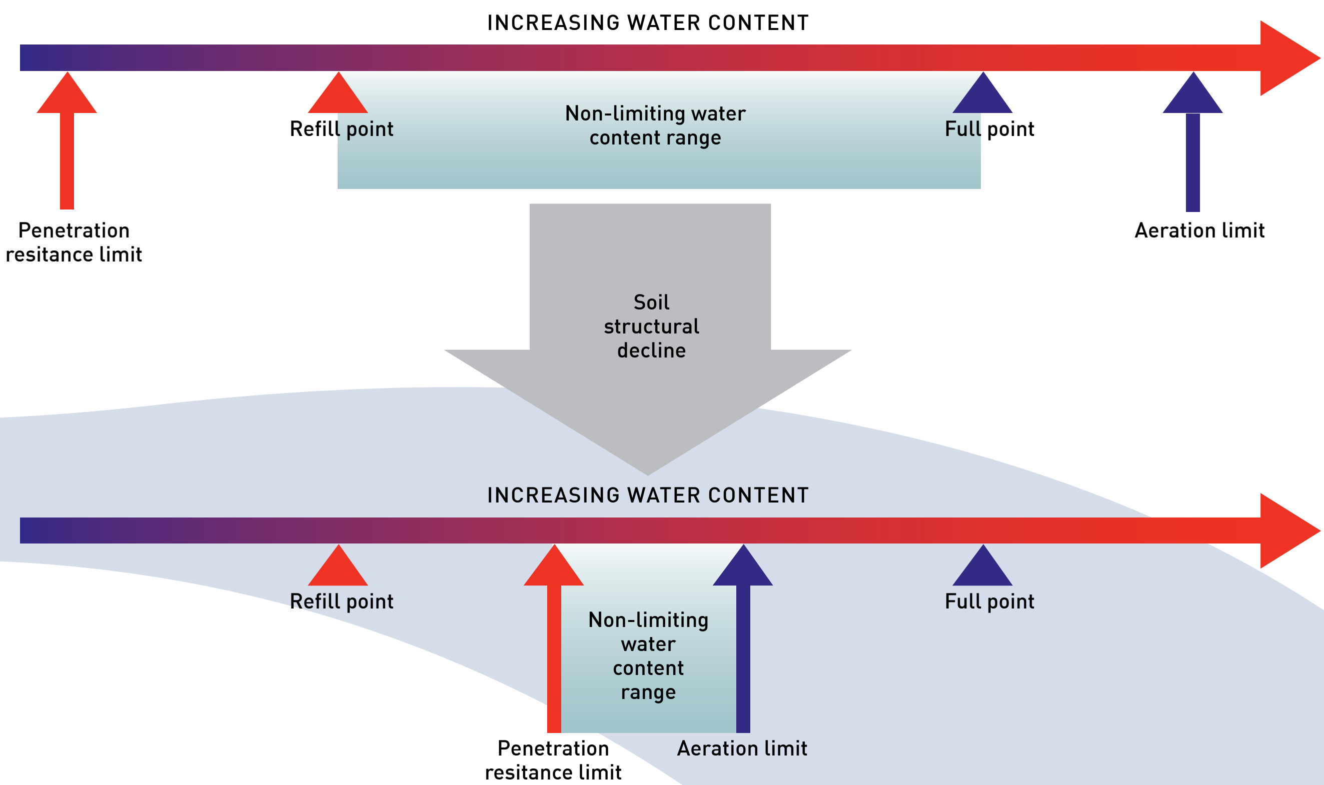

Figure 1 The "window" of non-limiting water contents being closed by soil structure decline. Subsoils with poor structure are a lost resource because their water contents make them inhospitable for root activity much of the time. Adapted from Letey (1985).

Soil penetration resistance is generally high but under field conditions in recently irrigated soil, it is excessive and there may only be very narrow "windows" of opportunity during the growing season when the soil is wet enough, and therefore weak enough, to permit root elongation.

Aeration is generally at critical levels in these subsoils when they are at field capacity and, although this will improve as the soil dries, the soil penetration resistance will simultaneously increase to critical levels.

In short, these subsoils have only a narrow range of water contents in which neither high penetration resistance nor poor aeration is a problem. This conclusion supports our common field observation of roots growing across rather than into the subsoil at the boundary of topsoil and subsoil. In many cases, this boundary was only about 35cm deep, creating a rather constricted effective root volume. While the severity of this problem will obviously depend on soil texture and depth of topsoil, it will demand careful irrigation management to maximise the time in which root growth is not impeded by either high penetration resistance or poor aeration while maintaining plant water requirements.

This situation is summarised in Figure 1. For an irrigated soil in good structural condition (top of figure), there is a wide range of water contents where there are no physical limitations to root activity. However, in a structurally degraded soil (bottom of figure) this range of water contents is much narrower. In this case the wet soil becomes water-logged and poorly aerated after irrigation. As the soil dries, the soil can be resistant to root penetration well before reaching the refill point.

Although the structural conditions in these soils are generally poor, the research suggests there is no strong evidence that these conditions have been aggravated by irrigation. In cases where irrigation water quality has been good, slower infiltration rates, higher penetration resistance and lower aeration were generally observed under drippers. However, the variability was high.

There are two factors that might undermine the value of the position between drippers as a "control". First, the generally poor infiltration rates seem to be sufficient to cause considerable lateral flow of water across the topsoil/subsoil boundary from the point directly beneath the dripper. Second, the salt from irrigation water has been shown to accumulate between drippers so that during winter, soil structural decline will occur midway between, rather than directly under drippers. Both of these effects tend to negate soil structural differences between the under-dripper and between-dripper positions.

We are currently pursuing improved "control" measurements and also intend to study sites where water use is higher than the 1-2 ML/ha common in the Barossa Valley.

How can poor subsoil conditions be avoided or improved?

The hostile subsoils we have described above are a lost resource that needs to be reclaimed. This would improve root volume, water use efficiency and resilience of irrigated plants to our current lack of water and the variability of the Australian climate. To do this, the depth of soil available to roots must increase and soil structure must be improved and protected. Many of the approaches to achieving this have been described by the work of Bruce Cockroft and his co-workers (Murray, 2007).

The soils we have examined in this project seem to have retained few benefits from their original deep-ripping. There appears to be a need for greatly improved preparation strategies to enable permanent planting enterprises to create and then sustain good, useable soil depth. These include:

- improved ripping and mounding operations
- the stabilisation of soil by gypsum if needed (well in advance of deep tillage) and
- deep-rooted cover crops.

The depth and structural quality of this deeper root zone must then be sustained by two broad strategies:

1 minimise practices that degrade soil structure such as machine traffic, prolonged periods of soil wetness and the use of saline irrigation water, particularly where there are no regular gypsum applications.

2 continuously regenerate and improve soil structure at depth. Realistically this can be achieved only by the continuous death and regrowth of an extensive root system and its associated soil fauna. The roots of the crop plant alone may not be sufficient to achieve this and there may be a need to supplement these with the roots of extensive cover crops. Clearly, this must be carefully managed as it balances the benefits of a sustained deep root zone against plant competition for water.

References

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For more information on this project

- **visit the NPSI website at www.npsi.gov.au**
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NATIONAL PROGRAM FOR **Sustainable Irrigation**

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The National Program for Sustainable Irrigation defines and invests in research on the development and adoption of sustainable irrigation practices in Australian agriculture. The aim is to address critical emerging environmental management issues, while generating long-term economic and social benefits that ensure irrigation has a viable future.

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