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Evaluating a multi-level subsurface drainage system for improved drainage water quality

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ABSTRACT

This paper describes a multi-level drainage system, designed to improve drainage water quality. Results are presented from a field scale land reclamation experiment implemented in the Murrumbidgee Irrigation Area of New South Wales, Australia. A traditional single level drainage system and a multi-level drainage system were compared in the experiment in an irrigated field setting. The single level drainage system consisted of 1.8 m deep drains at 20 m spacing. This configuration is typical of subsurface drainage system design used in the area. The multi-level drainage system consisted of shallow closely spaced drains (3.3 m spacing at 0.75 m depth) underlain by deeper widely spaced drains (20 m spacing at 1.8 m depth). Data on drainage flows and salinity, water table regime and soil salinity were collected over a 2-year period.

Comparisons of water and solute movement between the multi-level drainage system and a single level drainage system are presented. Differences in the performance of the multi-level and single level drainage systems were found in the water table regime, drain water salinity and soil salinity.

1. Introduction

Irrigation development throughout Australia has caused a significant change in the natural hydrological cycle and groundwater systems over the past 50–100 years. A significant part of all irrigation areas in Australia has water tables within 2 m of the soil surface creating waterlogging and salination problems.

In many cases the problems associated with shallow water tables have been controlled by the installation of subsurface drainage systems. Already within the Murray Darling Basin there are approximately 90,000 ha of subsurface drainage, mostly in irrigated perennial horticulture and pasture. The existing subsurface drainage discharge has a significant impact on the salt load in streams and rivers. For example, in the Murrumbidgee Irrigation Area only 7% of the area has subsurface drains but this area contributes 30% of the salt load leaving the area. In today's social climate the search to manage our natural resource base sustainably and allow equity for future generations dictates that exporting environmental problems is no longer acceptable and we must aim to minimize off site environmental impacts as much as possible.

In a review by Christen et al. (2001) of subsurface drainage systems in irrigation areas in Australia, it was shown that in many cases the drainage salt loads are 5–10 times greater than that applied through the irrigation water, even after reclamation of the root zone was completed,

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indicating that such systems typically remove stored geologic salt as well as that applied with the irrigation water. This stored salt is mainly from below the root zone and its removal offers little benefit to the crop. Hornbuckle and Christen (1999) reviewed assessments of salinity in irrigated soils for the Murrumbidgee Irrigation Area (MIA) in south eastern Australia. They found that soil salinity showed a general increase with depth. From the study it was shown that there was on average a four fold increase in the amount of salt stored at a 1–2 m depth compared to that stored in the top 1 m of soil. Similar investigations (Ayars et al., 1999; Guitjens et al., 1997) in other semi arid irrigated regions have indicated similar soil salinity profile trends.

For farms with existing drainage systems, controlled drainage has been advocated and can be an effective tool for managing salt loads, (Ayars, 1996; Hornbuckle et al., 2005). However, where a new drainage system is to be installed there is the opportunity to design a drainage system that provides adequate salinity and waterlogging control whilst minimizing salt loads. Flow paths to drains have been shown to have a large effect on the salinity of drainage water and flow path depths are a function of the drain depth and spacing (Jury, 1975a,b). The shallower and more closely spaced the drain the shallower the depth of water flow paths. Considering this, shallow drains placed in areas with soil salinity profiles such as those found in the MIA, should have much reduced drain water salinities and hence present less of a drainage water disposal problem.

The use of a shallow drainage system, has been shown in the past to be effective in waterlogging protection, but controlling soil salinisation is less certain (Christen and Skehan, 2001; Hermsmeier, 1973; Ghaemi and Willardson, 1992). Theoretically, resalinisation from capillary rise can occur from considerable depths depending on the soil type (Talsma, 1963), hence if shallow drainage systems are used there is the potential for salinisation from capillary up flow. Considering the need to minimize salt loads and ensure that re-salinisation does not occur a multi-level drainage system is proposed. Removal of water from the shallow drainage system limits the amount of water that is available to be drained by the deeper system, hence while total drainage volumes may remain the same, salt loads are likely to be reduced due to the shallow drains being placed in less saline soil and having shallower flow paths. This multi level drain approach should thus control soil salinisation while still having the benefits associated with reduced salinity drainage water and effective waterlogging control.

The study aim was to compare the performance of a traditional single level drainage system to a multi-level drainage system in an irrigated field setting. The specific objectives were to:

(1) Compare drainage volumes and salinity, and hence salt loads.
(2) Compare the effectiveness of salt leaching in relation to root zone removal of salts.
(3) Determine the effectiveness of water table and waterlogging control.

2. Materials and methods

2.1. *Site description*

The experimental site was a 3 ha commercially irrigated vineyard situated in the Murrumbidgee Irrigation Area (MIA) of New South Wales, Australia, which lies at latitude 34°S and longitude 146°E. The MIA climate is described as 'Mediterranean' or semi-arid. The summers are hot and dry, winters are mild with frosty nights. Mean annual rainfall is 418 mm, but is highly variable ranging from 140 to 700 mm annually. Mean annual potential evapotranspiration (ETo) is 1800 mm. Only during the winter months can mean rainfall match or exceed ETo. Irrigation water supply is from the Murrumbidgee River, at the experimental site the electrical conductivity of irrigation water from this source was between 0.1 and 0.15 dS/m during the course of the investigations.

The experimental site had not been irrigated for several decades, whilst surrounding areas had been continuously irrigated. This led to severe salinisation of the area. Fig. 1 shows the average soil salinity at the experimental site before drain installation. It can be seen that the site was extremely saline, well above the recommended salinity level of 1.5 dS/m for wine grapes which were to be grown on the site without yield loss (Maas and Hoffman, 1977). It was also apparent that the salt content of the deeper soil layers was higher than the surface layers (0–0.5 m).

The soil at the study site was an Alfisol, known as a Red-Brown Earth of the Australian Great Soil Groups (Stace et al., 1968). The surface soil is shallow and passes quickly through a clay loam to a clay. A grey subsoil develops below a depth of 0.75 m and continues to a depth of 7 m with increasing clay content with depth. Soft and hard feeling carbonates are found at depths below 0.5 m.

Grapevines (*Vitis vinifera*), of Semillon variety, were planted at the site on a 3.3 m spacing between trellised rows and a 1.7 m plant spacing within the row. Preparation for planting involved installing the subsurface drainage systems, laser leveling the site to a 1:1500 grade for surface irrigation and ripping vine rows to 40 cm depth before planting. Surrounding areas were all planted to mature grapevines and were subsurface drained.

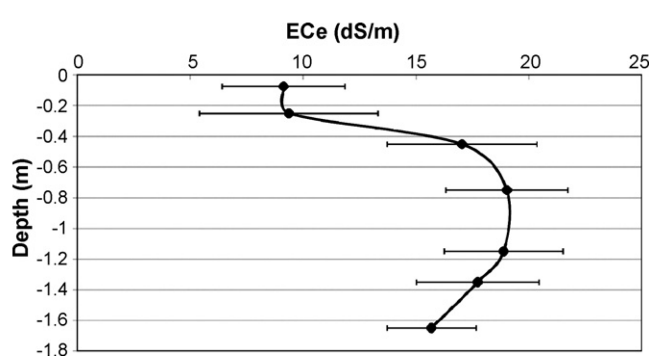

Fig. 1 – Average soil salinity (saturated paste) at the experimental site, based on 22 cores. Horizontal bars show standard deviation.