FINAL REPORT

CSO204

Evaluating Impacts of Deep Drains on Crop Productivity and the Environment

PROJECT DETAILS

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Summary

This research evaluated the impact of deep, open drains on groundwater levels, soil root zone salinity, crop productivity, drain design and effectiveness, and the environment. The study, at 10 sites in Western Australia (WA), found the impact of drains on shallow and deep groundwater levels was significant, provided the drains were more than 2m deep and initial water levels were shallow. The effect of drains often extended to distances (>200-300m) from the drain. Pre-drain soil root salinity in the shallow layers was high. Post-drainage salinity remained low (below thresholds for barley and wheat) at most sites throughout the monitoring period. At all sites, the crop productivity improved after drainage.

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Old or Archival Reports (Projects that concluded in 2007 or earlier)

The information contained in these older reports is now several years old, and may have been wholly or partially superseded or built upon in subsequent work funded by GRDC or others. Readers should be aware that more recent research may be more useful for their needs. Findings related to agricultural chemical use are also potentially out of date and are not to be taken as a recommendation for their use.

Conclusions

The study concluded that deep, open drains are effective in lowering groundwater levels. In order to be effective they should be more than 2m deep. Lenses of porous material which exist within the top few metres of the soil profile and a ferricrete layer between 1.5m and 2.5m of the soil profile enhance their effectiveness far above predictions based on hydraulic properties of the bulk soil matrix. Their areal influence often extends at distances (>200-300m) from the drain. The drains are not likely to be effective if they are shallow. If effective, they are most likely to improve crop productivity by lowering the saline, shallow water tables and leaching the excessive salts from the soil profile. Without deep, open drains and relatively deeper groundwater levels, the leaching of salts from the soil profile will not be likely. Leaching of salts into the drains is most likely to reduce soil surface layer salinity. The surface layer salinity is relatively higher in summer because of excessive evaporation and relatively lower during winter because of salts leaching after rainfall events.

At drained sites, there was also evidence of an increase in the soil surface layer pH. The salinity of shallow and deep groundwater ranged between 4,000 milliSiemens per metre (mS/m) and 8,000mS/m. This is not likely to change over time with the present level of drainage. Dry and wet weather cause some variation in water quality, but there were no visible long-term temporal trends. The flow rates from drains depend on the groundwater levels and drain effectiveness. Because of the shallow initial groundwater levels, the flow rates in the drains were significant during the early monitoring period. Base flow at the sub-catchment outlet from the present length of drainage is expected to be approx. 4ML/day. The drain water salinity is expected to remain unchanged at the present level of drainage. The drain water pH ranged between 2.5 and 3.5 most of the time during the past five years of monitoring. With the level of drainage in the sub-catchment, the drain water pH is also not expected to change. The drain water contained higher levels of aluminium (Al), iron (Fe), and manganese (Mn). These heavy metals are also expected to remain at similar levels.

Recommendations

For the past five years, data were collected and monitoring carried out about the impacts of drains on groundwater levels, crop productivity, soil root zone salinity, drain design and maintenance and quantity and quality of flow. These data were analysed and interpreted to evaluate the impacts of deep, open drains on groundwater levels, crop productivity, soil root zone salinity, drain design and effectiveness and drain water quantity and quality. Based on these detailed scientific evaluations, guidelines about drain design and effectiveness were framed. These guidelines were presented at the Salinity Engineering Conference in Perth, Western Australia (WA), in November, 2004, and at Dryland Drainage Workshop, Merredin, WA, during March, 2005. A workshop brochure about the main findings of this study and drainage guidelines was prepared and distributed to grain growers, drainage consultants, landcare officers, regulators and drainage contractors. These recommended guidelines, if followed, will help improve drain design and effectiveness and reduce maintenance costs.

Outcomes

At present, about 10% of the WA wheatbelt is salt-affected. This is expected to increase to 25-30% in coming decades. This research delivered a detailed and comprehensive assessment of the on-farm deep, open drainage along with assessment of the quantity and quality of flow from the drainage system. The study found that deep, open drains are a viable option for the treatment of degraded lands, provided they are more than 2m deep. There were significant improvements in crop productivity at those sites treated by deep, open drainage. Pre-drain salinity and groundwater levels, in most cases, were such that they could not support crop production. Following detailed evaluation of the impact of deep open drains on groundwater levels, soil root zone salinity, crop productivity, drain design, and quality and quantity of flow, the drainage guidelines were prepared. These guidelines were discussed during the dryland drainage workshop held in Merredin during March 2005 and delivered to grain growers. These guidelines were about drain design, construction and maintenance. If followed, these guidelines will help improve their effectiveness, reduce maintenance costs and achieve maximum economic benefit from deep drainage. A workshop brochure containing main findings of this research was also prepared and distributed among grain growers. This study found that drainage water has high levels of electrical conductivity (EC) and was acidic. The pH mainly ranged between 2.5 and 3.5. There were no temporal changes in the EC and pH of drain water throughout the monitoring period. The drain water also contained significant levels of Al, Fe and Mn. This study monitored quality and quantity of drain water at various sites, including the outlet of the sub-catchment. The environmental impacts of discharging drain water of such quality into natural creeks and rivers are unknown and beyond the scope of this project. The findings on the quality and quantity of drain water were delivered to grain growers in the form of a workshop brochure, presentations, seminars, briefings and conference papers.

Growers were implementing expensive and extensive deep drainage based on their own evaluation of effectiveness and impacts. There was a lack of independent, detailed scientific evaluation of their effectiveness, resulting in growing conflict between growers and regulators. This research, by scientifically underpinning drainage effectiveness and design, helped resolve these conflicts. The research also helped make the salinity engineering issue a serious and viable one. Following dissemination of initial findings, the WA government made a significant investment of $4 million to evaluate salinity engineering through the Engineering Evaluation Initiative (EEI).

Achievements/Benefits

This project aimed to evaluate the impacts of deep, open drains on crop productivity, root zone salinity, shallow and deep groundwater levels and the environment at the farm and sub-catchment level. To accomplish these objectives, six sites in WA (Deluis, Pini, Latham, Town in the drained areas and Bailey, John Deluise in the undrained areas (future drain) of the sub-catchment) were selected. All sites, in the drained areas were set up with instruments during 2000. Partial set up of the Bailey site was carried out in 2000. Bailey and John Deluis sites were fully set up with instruments in early 2001. The instrumentation included transects of shallow and deep piezometers for monitoring shallow and deep groundwater levels, stream gauging stations for monitoring flow rates, automatic water samplers for monitoring drain water quality, weather stations for rainfall, wind speed, radiation and other data. Soil sampling was carried out biannually to monitor soil root zone salinity and soil moisture. *In-situ* soil physical properties were measured for modelling.

The type of data collected during the past five years included crop productivity, soil root zone salinity, shallow and deep groundwater levels, salinity and pH, quantity and quality of flow in the drains, weather, soil physical parameters (at John Deluis site only), and silt deposition/erosion of the drains and spoil banks.

Crop productivity

The data on crop productivity were collected at various sites throughout the monitoring period. The results show that it improved following drainage at most sites. Other data about soil root zone salinity and groundwater levels support this conclusion. For example, pre-drain groundwater levels at the Bailey site were shallow (0.5m) with very high soil surface layer salinity. There was also temporal improvement in crop productivity after drainage. This also improved with increasing distance from the drains and it can be concluded that crop productivity generally improved following the construction of drainage at most sites. Analyses of the geographic information system (GIS) data for some of these areas show low biomass productivity in pre-drain years.

Root zone salinity

The soil root zone salinity data were collected biannually from all sites. Analyses of the collected data showed that it improved at all drained sites. In particular, the shallow layer salinity improved substantially after the construction of drains. Pre-drain soil salinity data were collected from two sites (Bailey and John Deluise) to compare the pre and post-drain soil root zone salinity trends. Pre-drain data showed very high shallow layer salinity at both sites, which improved quickly following drainage. Soil surface layer salinity remained below the threshold for barley and wheat at most sites throughout the monitoring period. Soil root zone salinity in the deeper layers of the soil profile remained relatively unchanged. There was also some increase in the soil surface layer pH, but it was unsure if this was because of drainage.

Shallow and deep groundwater levels

Monitoring of shallow and deep groundwater levels was carried out at all sites through transects of shallow (3-5m) and deep (7-10m) piezometers. Analysis of the collected data showed that groundwater levels (shallow and deep) at drained sites decline relatively quickly following winter rains. The groundwater levels in the drained areas mainly vary between 1.5m and 2.5m of the soil surface, whereas in the undrained areas of the sub-catchment these mainly vary within 1m of the soil surface. The groundwater level data showed that deep, open drains are effective. A real influence of their effectiveness often extend at distances (200-300m) from the drain at all sites, except John Deluise where the drop in water levels was not substantial - possibly because of its isolation, clogging of the culvert and inadequate drain depth. After water levels decline to a new equilibrium (depending on drain depth) they tend to maintain that level by discharging into the drain any excess water from deep groundwater and rainfall events. A journal paper for this component of the study was published in the Australian Journal of Agricultural Research. A drainage model was developed, calibrated and used to model drain performance under extreme rainfall conditions. This model predicted that, in the case of an extreme rainfall event, it will take 12 months for the groundwater levels (200m from the drain) to decline to pre-extreme rainfall event levels.

Environment (quantity and quality of flow in drains)

During the first two years of monitoring, the flow rate was very significant in various drains. During this period, the flow and salt outflow rate varied between 5-15ML/day and 300-600t/day respectively in Town at the sub-catchment outlet. The outflow rate decreased substantially towards the end of 2002 because of dry weather conditions. It increased substantially following the winter of 2003 because of an above average rainfall year. The EC and pH of drain water at various locations did not show any significant temporal trends. It is not expected that drain water salinity and pH will improve with the present level of artificial drainage in the sub-catchment. The concentration of some of the heavy metals (Al, Fe, Mn) was very high in the drain water. The off-site impacts of drain water of such quality are unknown and beyond the scope of this project.

Silting and/or erosion of drains

Cross sections of drains at various sites were conducted annually to assess the extent of erosion and siltation in the drains beds, side slopes, berms and spoil banks. The data showed there were significant silting of the drain beds over time. Erosion of the side slopes and spoil banks caused siltation in the drains and created local obstructions and clogging of culverts at some places. An alternative drain design has been recommended, which will help minimise erosion/siltation of the drains, improve their efficiency and reduce maintenance costs.

Drainage guidelines

Based on detailed scientific evaluation of the impact of deep, open drains on groundwater levels, soil salinity, crop productivity, drain design, quality and quantity of flow, critical guidelines for the drainage design and effectiveness were framed. These guidelines were presented during the Salinity Engineering Conference in Perth (November, 2004) and at the Dryland Drainage Workshop in Merredin (March, 2005).

Other research

Initial findings regarding the effectiveness of deep, open drains helped 'salinity engineering' become significant and viable in the wheatbelt of WA. Previously, it was considered by many as unviable, uneconomic and ineffective. The WA government, through EEI, committed more than $4 million for the evaluation of farm, sub-catchment and regional scale drainage options and downstream impacts. Two of these research studies ('Regional Drainage Evaluation of the Avon River Basin' and 'Downstream Ecological and Hydrological Impacts of Drainage') have been conducted by CSIRO Land and Water in partnership with the Department of Environment, Department of Agriculture (WA), Murdoch University and the University of WA.

Intellectual property summary

Drainage guidelines have been prepared and distributed to grain growers, regulators, drainage contractors, consultants and hydrologists. These are freely available to everyone. There are no IP protection issues.