FINAL REPORT

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

DAW717

Soil & surface water management for profitable crops & pastures on waterlogged & saline land

PROJECT DETAILS

PROJECT CODE:	DAW717
PROJECT TITLE:	SOIL & SURFACE WATER MANAGEMENT FOR PROFITABLE CROPS & PASTURES ON WATERLOGGED & SALINE LAND
START DATE:	01.01.2002
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Summary

The project investigated the ability of raised beds (RB) to: a) prevent waterlogging; b) enhance leaching; c) minimise capillary rise; d) reduce on-site recharge; and e) restore profitable cropping and pasture growth on waterlogged and saline land.

Three sites in Western Australia (WA) representative of waterlogged and saline landscapes were set up to compare a normal seedbed control with differently managed beds under crop and pasture. Seasonal dynamics of root zone salinity, pasture biomass and grain yield were monitored.

Growing crops on beds improved crop, but not pasture, production. Variability of seasons, sites and unstable seedbeds prevented conclusive findings on leaching and the control of capillary rise.

Conclusions

Based on observations and the results obtained at the Cunderdin and North Stirlings sites in medium rainfall and Woodanilling in high rainfall regions from 2002 until early 2006, which included two dry years, the RB and the no-tillage (NT) treatments provided some gains in the productivity of the crops but not the pasture. The yield from the beds at Cunderdin and North Stirlings in 2004 was an exception due to the very dry finish and the high plant numbers in the rows on the beds. Cunderdin, being the driest site of the three sites tested, showed the least improvement in productivity, while in Woodanilling, the wettest site, the beds created the largest productivity increase.

The comparison between the RB and the NT beds revealed very little difference between these two techniques. At Woodanilling, the NT beds yielded consistently more, while in North Stirlings, this was the opposite - albeit marginally. The NT beds are implemented without any prior soil cultivation and do not receive an annual renovation and furrow cleaning treatment, except for some furrow cleaning every two to three years. Therefore, the much smaller effort required to implement and maintain the NT beds would make the NT beds more beneficial than the RB. Notwithstanding the lower input required for a crop seedbed in this type of beds, however, there remains a need for the furrows to be cleaned/graded each year to clear them of stubble blockages.

If cropping is considered for areas prone to waterlogging and salinity, such as the flood plains of the Beaufort River and/or the North Stirlings 'sump', the implementation of a bedding system - either RB or NT - will be profitable. The expected benefits would be gained from productivity gains achieved by removing the impact of waterlogging, rather than reducing the salinity and the increase in land value that follows.

The other scenario to utilise these areas is to establish a healthy sward of perennial and salt tolerant pasture species and to graze them lightly, or perhaps cut them for hay (the maintenance of perennial ground cover will result in some reduction in salinity). While such a management option does not require the intensive drainage system of bedding, it does require an effective form of surface drainage.

Recommendations

Unless conclusive evidence can be obtained of the ability of RB to reduce salinity (and investigations are continuing via funding provided by the Cooperative Research Centre for Salinity, National Landcare Program (NLP) and Australian Centre for International Agricultural Research (ACIAR), the output of a revised 'Raised Bed Farming Manual' be withdrawn.

Further appraisal of the effectiveness of RB with graded furrows will be available early in 2008. Furrows were graded at the

Woodanilling site prior to the 2007 season, which was a drought. Should this refinement prove effective, the commitment to publish a second edition of this manual will be reactivated and the publication will carry due recognition of GRDC's investment in this work.

Outcomes

Economic
The application of an intensive surface drainage system to waterlogged and saline land has economic benefits in terms of productivity gains for existing cropping areas, as well as an expansion of land available for broadacre cropping that was previously only available for pasture production. The reduction of waterlogging benefits the production of broadacre crops in these areas with measured yield differences of more than 1t/ha of grain in an average wet year, even though variable seasons will moderate such gains. Economic analyses of the benefits of bedding show that an area of 100ha can have a net benefit of $60/ha, but this will depend on the magnitude of the yield increase.

Environmental
Waterlogging is often the precursor of salinity, hence a reduction in the waterlogging by using beds might arrest the spread of salinity. But once salinity has expressed itself, the introduction of beds is not sufficient to reduce the impact of salinity. The beds will, however, improve the productivity and, hence, the water use efficiency, increase the runoff and hence reduce the deep drainage - and therefore, by definition, the recharge and accession of the ground water. These benefits will be more pronounced when the beds are integrated into a general drainage management plan because any bottleneck in the flow of water in a planar landscape, such as where the trial sites are located, will reduce the effectiveness of the beds.

Achievements/Benefits

Land degradation in the form of saline, waterlogged scalds is the largest and most intractable natural resource issue threatening agriculture in WA. Virtually unproductive salt-affected land is estimated to cover approx. 1.8 million hectares, or 10% of the agricultural land in WA. Furthermore, this area is predicted to double in the next 20 years. Seasonal waterlogging is a conspicuous precursor to salinity and estimates of its occurrence range from 1 million to 2 million ha.

Work on the use of RB in WA (project DAW500) as a means of preventing waterlogging has shown that waterlogging can be eliminated and crop yields increased. This work covered a wide range of soil and climatic conditions in WA, but no saline conditions, and the need arose to assess the potential of RB for reclaiming saline and waterlogged land.

No quantitative evidence existed on the ability of RB to make waterlogged saline land more productive. There was no doubt, however, that permanent RB have the properties (stable, drained and aerated root zones) to prevent waterlogging and enhance the leaching of salt from the root zone of crops and pastures. Hence, their competent application to waterlogged saline land carried expectations that RB would:

1. Eliminate waterlogging in the root zone and prevent the deleterious interaction between waterlogging and salinity;
2. Enhance the leaching of salt from the root zone of crops and pastures;
3. Through the creation and maintenance of a stable low density layer of surface soil, reduce capillary rise replenishment of salt in the root zone;
4. Efficiently remove excess surface and root zone water from the site and reduce on-site recharge of the groundwater system; and
5. Rehabilitate saline land to the extent that it can produce profitable crops and pastures.

RB (an annual blade ploughing) and NT beds (no cultivation after construction) were compared to a control (no-tillage crop establishment and no surface drainage) on waterlogged saline land at Cunderdin (annual average rainfall of 350mm), Woodanilling (annual average rainfall of 450mm) and North Stirlings (annual average rainfall of 400mm). The soil conditions at each site ranged from waterlogged, non-saline to extremely saline to badly waterlogged to sometimes waterlogged depending on the micro-topography of essential planar land surfaces.

Salt dynamics

Most of the seasonal fluctuations in root zone salinity were expected. Every autumn and winter, rainfall under conditions of low evaporation leach most of the salt from the surface layers into the deeper soil layers. Some is washed off and leaves the site in runoff water. Every spring, as rains diminish and transpiration and evaporation rise, salt is transported from the deeper soil layers back to the surface, provided the root zone was moist. Occasional summer rain also provided some leaching, as occurred at Cunderdin early in 2004 and 2006.

The annual blade ploughing of the soil in the RB was intended to enhance the leaching effectiveness of the RB as the soil profile in the top 20-30cm would be less wet than the soil in the other treatments. This allowed slower and more efficient leaching flows through the soil matrix. In addition, it was expected that the lower bulk density of the topsoil in the RB would limit the capillary rise in the early summer when the weather warms up and the soil dries out. This was supposed to reduce or prevent salt accumulation in the surface soil of beds. Highly spatially and temporally variable salinity data showed no significant difference in the seasonal dynamics between the RB and the control. Seasonally rapid increases and decreases occurred in both treatments.

The lack of any distinct reduction in the salt content of the annually blade-ploughed RB appears to have been due to two main but interacting factors. The most saline areas on all experimental sites coincided with small depressions in the surface topography. These were bare, eroded scalded areas at the beginning of the experimental period and the bedformer was then only capable of making furrows and beds parallel to the existing surface. This created furrows and beds that were also depressed and water ponded in the furrows in these areas. These saline areas were also highly dispersive, with exchangeable sodium percentages of a magnitude of 60 to 10 times the dispersive threshold value of 6.0.This combination ensured that soil in the bed was wet, which, with its dispersiveness, ensured it slumped back to a consolidated condition over winter and allowed salts to accumulate in the surface soil during spring and summer. Reclamation of these soils requires 100% drainage efficiency of furrows and the addition of structure stabilising organic matter.

Broadscale surveys of changes in the salinity using an EM-38 median plot apparent electrical conductivity (ECa) revealed some large changes in the plot median, with most plots showing a reduction in the median ECa following the soil cultivation and establishment of good crops and pastures, some of which at Woodanilling remained at April 2006. These plots were on areas where the furrow drainage was complete and where the areas were too flat and waterlogged to be cropped and were left to develop a thick sward of ungrazed annual ryegrass (*Lolium ridgidum*) pasture. Also, in North Stirlings, the pasture plots had lower ECa plot medians compared to the beginning of the trial period. The annual blade ploughing treatment of RB was not practised on these pasture areas and so there was no testing of the effectiveness of this treatment under pasture.

Yield, biomass and salinity interactions

Two treatments, RB and NT beds, were imposed at the sites and used for cropping and pasture. During the trial period, one year (2002) was generally very dry, one year started off well but had a very dry finish (2004) and two years (2003 and 2005) were average - of which 2003 had a lot of summer rain in Cunderdin and 2005 was very wet initially in Woodanilling and North Stirlings. Of all sites and years, only one (North Stirlings, 2003) was highly significant. All the other site/year results were not statistically significant due to large inter-plot variation.

The experimental design had four replicates of each treatment, but the intra and inter-plot variability was so large that reliable treatment trends and differences that were statistically significant proved impossible to achieve. This was in spite of efforts to allocate plots so that each plot and treatment had similar levels and type of salinity. The variability was a consequence of the size of the plots (about 2ha), combined with changes in soil type, various levels of salinity, different levels of furrow drainage, poor timing of weed control and stubble management due to other commitments of cooperating growers. Plus, varying parts of the areas had different cropping/pasture history. For example, some plots in sections of the Cunderdin site had not been cropped for several years due to patches with elevated levels of salinity. These plots performed much worse than plots that had been cropped for many years. In some plots of Woodanilling, the weed burden was very large due to access difficulties (ponded furrows) during winter months.

The relationship between yield and salinity showed salinity had a very clear effect on yield, particularly in dry years.In wetter years this relationship was much less evident, as most of the salt was leached to deeper soil layers for most of the growing season. The use of relative yield (i.e. the yield in each point in a plot relative to the yield at a low level of salinity in that plot) provided an insight about how the individual plots and treatments behaved with regards to salinity. From these relationships it could be concluded that neither the RB or the NT beds behaved differently to the control. The productivity in all treatments tended to decrease with an increase in salinity and at the same rate.

The productivity of the pasture treatments, which was assessed with biomass imagery, was affected by rainfall from year to year, salinity and the 2003 renovation of the RB, which severely reduced the productivity in that year. When, in subsequent years, this management practice was suspended, little difference in biomass was found between the treatments. However, the composition of the pasture changed greatly in response to salinity. Capeweed (*Arctotheca calendula)* became more dominant on the beds at Cunderdin at the lower end of the salinity (i.e. more sandy topsoils), while annual ryegrass was dominant in range of 100 to 200mS/m and the more salt tolerant species such as barley grass (*Hordeum* spp.), bluebush (*Mareana brevifolia)* and ice plant (*Aptenia cordifolia*) at salinity levels of more than 200mS/m. The renovation of the RB treatment at Cunderdin reduced the survival of bluebush to the extent that it all but disappeared. Bluebush provides good grazing, particularly in combination with normal pasture and stubble and probably should be maintained if possible.

Problems with sheep, either pregnant and/or heavy with wool, foundering in the furrows (even shallow furrows) was noted as a future management challenge if RB and NT beds are to be used to grow and graze pasture.

Other research

1. During the experimental term of this project some work was done with the use of wide-spaced furrows on the control treatments. These furrows are made individually at a spacing suitable for sufficient internal drainage and practical for matching seeder width. The idea is not to drive in the furrows so any traffic remains on the soil surface as normal, hence the tractor straddles the furrows and any overlap at seeding is between the furrows. This technique of improving surface drainage is an alternative to bedding and has the advantage that conventional and unaltered seeding equipment can be used. The furrows were installed in the control plots at North Stirlings and in some plots at Woodanilling. In 2005, the yield increased from the furrowed sections by 0.26t/ha at North Stirlings and by 0.1t/ha at Woodanilling compared to the non-furrowed areas. In 2004, which was a dry year, no difference was found between the furrowed and non-furrowed areas. These wide-spaced furrows create a more easily adopted and managed surface drainage system that could be easily incorporated into controlled traffic farming (CTF). However, the overall effectiveness needs to be further investigated.

2. The coincidence between highly saline scalds and depressions precluded these areas from complete drainage. NLP funds have allowed an automatic grade laser interface with the three point linkage control of the bedformer to be assembled, which allows elevation variations of more or less than 10-15cm to be graded out of furrows to ensure all water flows to cross drains and off the paddock. This capability can be operated by a single person and it greatly increases the prospect of: (i) maintaining the looseness of beds that is achieved with a blade-ploughing of RB and (ii) improved weed control during the growing season. In the latter case, bogging and splashing will be removed and, hence, access and improved herbicide-plant contact will be achieved. These improvements are worthy of further investigation.

Additional information

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