Using raised beds to reduce waterlogging of pastures - impact on runoff and soils

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Abstract

Research and industry experience indicates that growing field crops on raised beds can lead to substantial grain yield increases on waterlogging prone soils. In a 2 year south west Victorian trial, growing grazed pastures on raised beds was investigated. One third of a 14 ha poorly drained paddock had raised beds (1.7 m beds, 0.3 m furrows) installed, a third had hump and hollows (25 m wide) installed and a third was left undrained. Each treatment had hydraulically isolated 2.5 ha areas with flumes and automated equipment to measure and sample surface runoff water. The trial area was sown to Italian ryegrass (*Lolium multiflorum* Lam.) each autumn and grazed from mid winter until early summer with sheep. Raised beds proved to be very effective in removing excess water from the pasture. No runoff occurred during the 2006 drought year. During 2007, raised beds had the most runoff (47.1 mm), the undrained least (17.4 mm) with the hump & hollows intermediate (26.7 mm). Both drainage treatments had higher concentrations and total loads of P and N in runoff water with 0.5 and 0.4 kg P/ha losses from the raised beds and hump & hollows respectively compared to 0.1 kg P/ha for the undrained. Corresponding N losses were 6.3, 2.1 and 0.9 kg N/ha. Soils in the two drainage treatments were in better physical condition at the end of the trial with aeration porosities at field capacity of 16.3%, 11.8% and 7.0% for the raised beds, hump & hollows and undrained respectively.

Key Words

Raised beds, waterlogging, drainage, runoff, soil health

Introduction

Poor soil drainage leading to periodic waterlogging limits the production of crops and pastures on many soil types in south eastern Australia (MacEwan et al. 1992). In south west Victoria there has been the widespread adoption of raised beds for field cropping to reduce the severity and duration of waterlogging (Peries et al. 2004). In a review of the results of research trials, demonstrations and surveys comparing grain yields from raised beds and flat land over a diverse range of environments and soil types in southern Australia, Wightman *et al*. (2005) reported a positive grain yield response for beds in 40 out of 56 comparisons with an average yield response of +35%. In light of such crop responses, livestock producers have asked if similar improvements in herbage DM production from grazed pastures grown on raised beds could be obtained. As cropping raised beds have been found to increase the quantity of and decrease the quality of runoff water compared to undrained pasture (Johnston et al. 2003), it is important to determine the likely effects if pastures are grown on raised beds. This study determined the effect of raised beds on runoff, nutrient loss and soil physical health. Effects on pasture production are described in Ward and Jacobs (2010).

Methods

Study site and trial establishment

The trial was conducted on a commercial sheep farm (38? 03'S, 143? 10'E) near Derrinallum in south west Victoria. The soil is a poorly drained, light clay described as a Grey Vertosol (Isbell 1996) derived from Quaternary basalt. Initial soil tests (0-10 cm) indicated a soil pH_{H2O} of 5.0, electrical conductivity of 0.33 dS/m, Olsen P of 26 mg/kg, available K of 208 mg/kg and CPC S of 114 mg/kg. During the autumn of 2005 a 14 ha pasture paddock was cultivated and divided into three equal areas. Raised beds (1.7 m beds, 0.3 m furrows) and "hump and hollow" (25 m wide beds) drainage were installed using commercial cropping equipment on a third each of the area, with the remaining one third of the paddock being left as an undrained control. The paddock was fenced along the boundaries between treatment areas to form three paddocks. In January 2006 a road grader was used to form one 2.5 ha hydraulically isolated catchment in each of the three treatments. Calibrated flumes connected to a central datalogger were installed at the outlet of each of these catchments to measure runoff volumes. Automatic water samplers either collected water samples at 0.2 mm runoff intervals or following manual activation during flow events. Within 24 hours of collection, water samples were placed in -15?C storage, until they could be analysed for total nitrogen (TN), total phosphorus (TP), Electrical Conductivity (EC) and total solids (TS).

In April of both 2006 and 2007 the existing pasture was sprayed out with a knockdown herbicide, Roundup Max (540 g/L glyphosate) at 2.0 L/ha. The trial area was direct drilled to Italian ryegrass (*Lolium multiflorum* Lam.) cv. Crusader at 25 kg/ha on 26 April 2006 and a mixture of Crusader at 10 kg/ha and Abundant at 15 kg/ha on 12 May 2007. In both years, the seed was drilled with 80 kg/ha of DAP (14.4 kg N/ha, 16 kg P/ha). The establishing pasture was topdressed with urea at 100 kg/ha (46 kg N/ha) and 120 kg/ha (55.2 kg N/ha) on 16 July 2006 and 3 July 2007 respectively. Triple superphosphate was broadcast at 100 kg/ha (20 kg P/ha) in April 2006. Each of the three treatments were stocked with mature, in-lamb Coopworth ewes on 14 July 2006 initially at 7.5 ewes/ha, increasing to 12 ewes/ha on 10 August. The ewes lambed down on the trial grazing it through the winter-spring period until the lambs were weaned and removed from the trial on 8 November 2006. In 2007, maiden, in lamb Coopworth ewes were used, being introduced to the trial at 9 ewes/ha on 19 July 2007, increasing to 13.6 ewes/ha on 22 August. Lambs were weaned on 3 December 2007.

Soil Physical Measurements

A series of 10 intact soil cores (7 cm diameter) from 2.5-7.5 cm depth below the soil surface were collected at random spots from each treatment at the conclusion of the trial on 8th November 2007. These cores were assessed for soil bulk density (kg/L) and using pressure plate apparatus at 1 kPa and 10 kPa for porosity (% V/V) and volumetric soil water holding content (% V/V). Pressure plate apparatus was also used to determine the volumetric soil water holding content (% V/V) of disturbed soil samples at 1500 kPa.

Results and Discussion

Runoff volume and nutrient losses

Total annual rainfall recorded at the site during 2006 was only 409 mm (decile 1), whilst in 2007, 634 mm (decile 8) was recorded compared to the long term average of 570 mm. No surface runoff was recorded and no periods of soil waterlogging occurred during 2006. During 2007, 8 runoff events occurred, one in mid February following a summer thunderstorm, one in early November during an intense rainfall event with the remaining 6 from June to September. Total cumulative runoff for the year for the raised bed treatment was 47.1 mm compared to 17.4 mm for the undrained treatment 26.7 mm for the hump & hollows respectively (Table 1). In the undrained treatment, runoff only occurred during the February and 3 of the winter runoff events, whilst runoff occurred at all but one of the winter runoff events for the hump & hollow treatment. The raised beds demonstrated their effectiveness in removing surplus water from the pasture compared to the undrained which is consistent with that found for raised bed field cropping (Johnston *et al*. 2003).

Both the raised beds and humps & hollows had higher flow weighted concentrations of total phosphorus (TP) and total nitrogen (TN) in the runoff water than the undrained (Table 1). For both of the drainage systems, the flow weighted TP concentrations were over double the 0.6 mg P/L of the undrained. The highest concentrations of TP occurred in the February and November runoff events and the lowest in the winter, possibly due to dilution effects. Similarly, the flow weighted TN concentrations were considerably higher for the drained treatments with the humps & hollows approaching double and the raised beds over 3 times the N concentrations of the 4.7 mg N/L of the undrained treatment. The high TN concentrations are likely to have exacerbated by the aerial application of urea fertiliser in early July. All concentrations of

TP and TN for all treatments were well above those recommended as satisfactory for Victoria's inland waters (OCE 1991). Coupled with the greater runoff volumes, this resulted in the TP load leaving the pasture being 4 and 5 times higher for the humps & hollows and raised beds respectively than for the undrained. The TN load lost from the pasture was higher still with a 2 and 6 fold increase for the humps & hollows and raised beds respectively over the undrained. The raised beds also had a higher TS content in the runoff water suggesting greater soil loss under grazing than for the other treatments. The EC of the runoff water from the raised beds was markedly higher than the other treatments indicating that some leaching of salts out of the soil may be occurring.

Table 1. The surface runoff depths (mm), flow weighted means of Total P (mg P/L), Total N (mg N/ha), Total Solids (g/L) and the Electrical Conductivity (uS/cm) of runoff water and the Total P (kg P/ha) and Total N (kg N/ha) loads lost from the Humps & Hollows, Undrained and Raised Bed treatments during 2007

	Undrained	**Humps & Hollows**	**Raised Beds**
Runoff (mm)	17.4	26.7	47.1
Total P concentration (mg P/L)	0.6	1.6	1.3
Total P Load (kg P/ha)	0.1	0.4	0.5
Total N Concentration (mg N/L)	4.7	8.0	16.8
Total N Load (kg N/ha)	0.9	2.1	6.3
Electrical Conductivity (uS/cm)	20	142	597
Total Solids (g/L)	0.31	0.46	0.65

Soil Physical Measurements

By the end of the trial (Nov 2007), soil bulk densities were lowest for the raised beds at 1.27 kg/L compared to 1.33 and 1.36 kg/L for the hump & hollows and undrained respectively (Table 2). This suggests that less soil compaction occurred when the raised beds were grazed under wet soil conditions than the other treatments. Aeration porosities indicate that the soil in raised beds was better aerated than either the undrained and hump & hollows at both field capacity (10 kPa) and at close to saturation (1 kPa) (Table 2). Such higher aeration porosities would have provided a more favourable soil environment for plants growing on the raised beds compared to the hump & hollows and undrained, being greater than the critical level of 10% V/V (Gradwell 1965; Carter 1988) required for plant health and soil aeration. The differences in porosity also reduced the water holding capacity of the soil of the raised beds. The volumetric soil water content at field capacity (10 kPa) was appreciably lower for the raised bed soil at 35.8 %V/V than the undrained (41.9%) and hump & hollows (38.0%) (Table 2). The estimated plant available water (PAW); volumetric soil water content at field capacity (10 kPa) less that at wilting point (1500 kPa), for the top 100 mm of soil was lowest for the raised beds at 20.2 mm compared to 24.7 mm for the undrained and 21.2 mm for the hump & hollows. This lower water holding capacity may in part contribute to the lower pasture accumulation and observed shorter growing season observed for pasture growing on the raised beds (Ward and Jacobs, 2010).

Table 2. The bulk density (kg/L), aeration porosity (%V/V) at 1 and 10 kPa tensions, volumetric soil water content (Vol. S.W.C., % V/V) at 10 and 1500 kPa tensions for 2.5-7.5 cm depth soil cores and the estimated plant available water at field capacity in the top 100 mm of soil of the undrained, hump & hollow and raised bed treatments in November 2007 (standard deviation in parenthesis)

	Undrained	**Hump & Hollow**	**Raised Beds**
Bulk Density (kg/L)	1.36(0.072)	1.33(0.071)	1.27(0.066)
Aeration Porosity @1 kPa (% V/V)	5.9(2.71)	5.4(3.58)	10.8(4.66)
Aeration Porosity @10 kPa (% V/V)	7.0(2.69)	11.8(5.63)	16.3(4.95)
Vol. S.W.C. @ 10 kPa (% V/V)	41.9(1.56)	38.0(4.82)	35.8(4.06)
Vol.S.W.C. @ 1500 kPa (% V/V)	17.2(0.81)	16.8(0.85)	15.6(0.77)
Plant AvailableWater @ 10 kPa -100mm (mm)	24.7(2.00)	21.2(4.92)	20.2(4.15)

Conclusion

Raised beds proved to be very effective in removing excess water from pasture. However, the considerably higher total P and N concentrations in the runoff water than the undrained resulted in substantially higher P & N loads leaving the pasture and entering waterways. This may have undesirable environmental effects. By the end of the trial the soil on the raised beds was in better physical condition and was more favourable for plant growth than either the undrained or the hump & hollow treatments.

Raised bed soils had a lower bulk density and higher macroporosities indicating less compaction had occurred under wet soil grazing than the other treatments. Soil water holding capacity of the raised beds at field capacity was however reduced resulting in these soils having a lower plant available water content.

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References

Carter MR (1988). Temporal variability of soil macroporosity in a fine sandy loam under mouldboard ploughing and direct drilling. Soil and Tillage Research 12, 37-51.

Gradwell MW (1965). Soil physical conditions for winter and the growth of ryegrass plants. I. Effects of compaction and puddling. New Zealand Journal of Agricultural Research 8, 238-69.

Isbell RF (1996). The Australian soil classification. CSIRO Publishing , Melbourne.

Johnston T, White R, Nicolas M and Slattery W (2003). Runoff from raised bed crops in south west Victoria, 2001. Proceedings of the 11th Australian Agronomy Conference, Geelong.

MacEwan RJ, Gardner WK, Ellington A, Hopkins DG and Bakker AC (1992). Tile and mole drainage for control of waterlogging in duplex soils of south-eastern Australia. Australian Journal of Experimental Agriculture 32, 865-78.

Office of the Commissioner for the Environment (1991). State of the Environment Report 1991, Agriculture and Victoria's environment. Government Printer, Melbourne.

Peries R, Wightman B, Bluett C and Rab A (2004). Raised bed cropping in southern Victoria – A snapshot of a productive and sustainable option for waterlogging prone soils. In proceedings'4th International Crop Science Congress' 2004, Brisbane. http://regional.org.au/au/asa/2004/poster/1/4/670_periesrv.htm. Accessed 15 September 2010.

Ward G and Jacobs L (2010). Using raised beds to reduce waterlogging of pastures – pasture productivity effects. Proceedings of the 15th Australian Agronomy Conference Lincoln, New Zealand. Australian Society of Agronomy.

Wightman B, Peries R, Bluett C and Johnston T (2005). Permanent raised bed cropping in southern Australia: practical guidelines for implementation. In ACIAR Proceedings No. 121 – Evaluation and performance of permanent raised bed cropping systems in Asia, Australia and Mexico, Eds. C.H.Roth, R.A. Fischer and C.A. Meisner, 173-190.