Raised bed cropping in southern Victoria – A snapshot of a productive and sustainable option for waterlogging prone soils

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Abstract

The area under broad acre raised bed crops in southern Victoria has increased from 300ha in 1997 to 35,000ha in 2003. The enhanced crop yield on raised beds compared to traditional ‘flat’ cropping results from better drainage and differences in soil structure below the depth of tillage resulting in an improvement in the plant available water (PAW) capacity. These differences in soil physical properties assist crops to survive the extreme weather events and achieve yield stability across years.

Media summary

Improved drainage and soil structure differences through raised bed cropping have seen southern Victorian farmers break regional yield barriers and create significant land use change.

Key words

Drainage, subsoil, plant available water.

Introduction

Significant land use change, accompanied by rise in productivity has occurred in high rainfall (500mm+) zone of South-west Victoria over the last seven years as a result of farmers adopting raised bed cropping to overcome waterlogging on a diverse range of soil types. Despite rainfall being evenly distributed throughout the growing season (May to January), the predominantly hard-setting subsoils in the region frequently result in perched water tables (waterlogging) aggravated by low evaporation. Since 1995, the Southern Farming Systems (SFS) partnership has been examining cropping and livestock enterprises in the region with a view to changing the traditional farming systems and exploring options to enhance farmer profitability. The “raised bed” cropping system developed by SFS has shown promise in its ability to withstand the adversities of waterlogging and produce significant yield increases across several trial sites and farmer paddocks in southern Victoria.

The enhanced crop yield achieved using raised beds compared to traditional cropping on ‘the flat’ results from improved drainage (Wightman, 1997) and increased root proliferation (Peries *et.al*., 2001; SFS, 2000) under conditions of minimum tillage and controlled traffic necessitated by raised beds. The standard of crop management has also advanced amongst the more enterprising farmers, who, in less than three years of ‘bed farming’ have achieved on average a two-fold increase in yield (Wightman, unpublished data). This paper briefly discusses the reasons for improved crop performance on raised beds with particular emphasis on soil structure and soil water characteristics which are leading to yield increases and contributing to yield stability across variable seasonal conditions.

Materials and Methods

Installation of raised beds

The change of land use from conventional long-term pasture or flat cropping to cropping on raised beds involves several stages. The soil is initially tilled to a depth of approximately 8-10cm using a disk harrow. The soil is then cultivated using tyne implements such as a scarifier or chisel plough to a depth of 20cm. Sometimes a deep ripper is used to gain depth. A “bedding” machine is then used to mound the soil into beds. A set of crumble rollers at the back of the bedding machine lightly compacts the soil on the raised beds and breaks clods. Over time and with several cropping and/or grazing cycles the bed height can reduce but periodical renovation operations ensure that the collapse of beds would not interfere with the uniform sowing/establishment of seed. At sowing, press wheels are used behind the sowing tynes to ensure adequate seed-soil contact. The shallow grooves left on the beds by the press wheels act as a reservoir for water harvesting. The water moves through these grooves into the beds and when bed surfaces (bed height) is saturated, moves sideways into the main furrow between beds and is carried away from the paddock preventing long-term waterlogging.

Crops on raised beds

The “drainage demonstration” trial (SFS, 1996) conducted at Gnarwarre near Geelong (38˚ 10’S, 144˚ 08’E) in the 550mm rainfall zone was the first demonstration of ‘best practice’ drainage through raised beds compared to flat cropping. While other forms of drainage (wide raised beds, underground agric pipes and moles) were also trialed, cost and other considerations have at present led to farmers adopting narrow raised beds (1.7 to 2.0m wide) as the key tool for alleviating waterlogging in broad acre cropping in this region. The area under raised beds in Victoria has increased over the last seven years from 300ha in 1997 to 35,000ha in 2003 (Wightman, unpublished data). The total cropping area has increased from 100,000 to 300,000ha during the same period. A sample of 18 trials, demonstrations and farmer surveys over the last five years has shown that on average raised beds produced 20% higher yield compared to conventional cropping. While the average cereal yield in the region still remains around 2.5 to 3.0 t/ha (SFS, 2002) the more entrepreneurial farmers have realised yields as high as 8.5 t/ha in recent times.

Soil Variability

Major cropping soils in the region are of volcanic origin, high in clay and generally very dense at depth restricting both water movement and root penetration. In conventional land use (pasture), soils have been further compacted by grazing livestock and uncontrolled trafficking of farm machinery. The yellow Sodosol (Isbell, 1996) and its variants are more widespread in the region than the readily cracking, self-mulching Vertosol which are known to be more productive due to its better aeration, greater depth of aggregates (Sarmah *et.al*., 1996) and soil water characteristics. The major problem facing the cropping farmers on yellow Sodosols is its low permeability and hard-setting nature due to poor structure that leads to a perched water table during the long, cool, winter growing season. While the Vertosol too could become waterlogged under intense rainfall events, these soils are less likely to remain waterlogged for extended periods due to their greater permeability.

Productivity on beds

A “systems trial” on beds commencing in 1998 compares the productivity of continuous cropping versus two (2 x 2) and four-year (4 x 4) phases of pasture/grazing between crops using two Vertosols, one of which is Sodic at depth with behaviour similar to a Sodosol (‘Sodic Vertosol’). Recent investigations have also focussed on the use of deep-rooted lucerne pasture, particularly in its ability to break through the hostile, impermeable subsoil (compaction repair) as against the shallow rooted perennial mixed pastures.

Improvements to plant available water capacity

Minimum tillage and controlled traffic are essential components of a raised bed cropping system. The systems trial was also intended to capture the variability of the soil and assess the effect of planned rotations on soil structure and soil water characteristics under these conditions, which were expected to be impacting on crop performance. After three years of rotations on beds the soil bulk density, porosity and the upper and lower levels of plant available water on beds were compared with the flat pasture situation in the two main soil types on which the raised beds were installed. On similar soil, a cropping phase was commenced after a 5-year lucerne pasture phase and measurements were undertaken to compare its effect on soil water characteristics with that of continuous cropping and the long-term (4 x 4) mixed crop and pasture system.

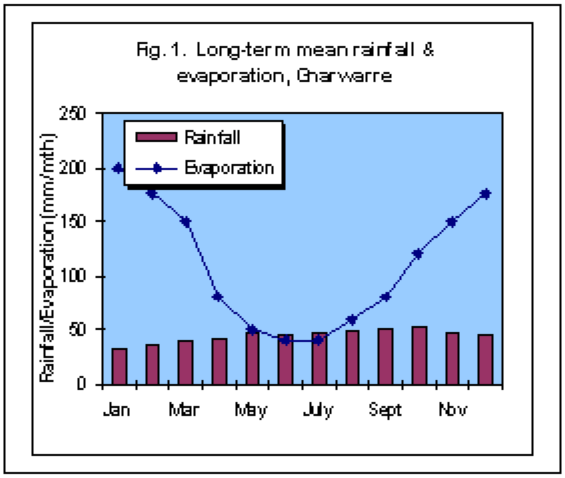

Fig. 1. Long-term mean rainfall & evaporation, Gharwarre

Results and Discussion

Impact of rainfall on productivity

The long-term (100-year mean) rainfall (RF) and evaporation for the region shown in Figure 1 suggests a uniform RF distribution throughout the year. However, during the period of this investigation the annual RF remained sub-optimal in most years except in 2001, when heavy pre-season rains caused severe waterlogging, delayed sowing and consequently depressed crop yield. However, average to above average yields was realised in more recent years (2002 and 2003) despite heavy rainfall events in winter and spring with no severe events of waterlogging.

'Systems' productivity

A simple comparison suggests that the continuous cropping system is superior in productivity to any system involving a pasture phase under the RF and growing season conditions experienced at the site of trial. Table 1 shows data from selected plots on different soil types and compares the cumulative productivity (1999 to 2002) of each plot, with all crop yield converted to dry sheep equivalents (DSE) per hectare (after Walcott & Zuo, 2003) based on the metabolisable energy content in grain. Most traditional wool farmers who have taken to raised bed cropping over the years are convinced that cropping is the more profitable option but it will be some time before all sustainability issues with regard to other systems become clear.

Table 1. Comparison of productivity between systems/soil types, 1999 to 2002

Treatment	Soil	1999/2000	2000/01	2001/02	2002/03	Total DSE/ha	Mean DSE/ha
Cont. Cropping	SV	Canola (2.3)	Wheat (2.9)	Field. Pea (1.9)	Barley (4.3)		
⇨		17.02	14.5	8.6	20.1	61.33	15.3
Yld. As DSE							

(2x2)	SV	Wheat (3.6)	DSE-days 1248	DSE-days 1893	Canola (1.8)		
Yld. As DSE		18.0	8.44	12.81	13.32	52.57	13.1
(4x4)	SV	DSE-days 714	DSE-days 1044	DSE-days 1412	DSE-days 690		
Yld. As DSE		4.83	7.06	9.55	4.67	26.10	6.5
(4x4)	Vert	Canola (1.1)	Wheat (4.17)	Field. Pea (2.9)	Barley (3.9)		
Yld. As DSE		8.14	20.85	13.05	18.33	60.37	15.1
(2x2)	Vert	Canola (1.8)	Wheat (4.9)	DSE-days 1460	DSE-days 498		
Yld. As DSE		13.32	24.45	9.88	3.37	51.02	12.8
Cont. Cropping	Vert	Wheat (2.7)	Field.Pea (1.84)	Barley (5.0)	Canola (1.8)		
Yld. As DSE		13.5	8.28	23.5	13.32	58.6	14.7

Note: 2x2 and 4x4 are crops and pasture rotations involving 2 and 4 years of mixed pasture respectively. SV-Sodic Vertosol, Vert- Vertosol. The 4x4 treatment on Vertosol has only had the cropping phase yet and for comparison it represents a continuous cropping up to the 2002 seaon.

'Systems' sustainability

Alleviation of waterlogging appears to be a key factor contributing to improved yields on raised beds. In the higher rainfall areas where farmers have attempted cropping on flat country, complete crop failures frequently result due to severe waterlogging (Wightman, unpublished data) suggesting that raised beds significantly minimise risk in regions prone to waterlogging. Rapid drainage and the release of air filled porosity following a waterlogging event on raised beds will minimise the setback to crops. The accompanying wetting and drying cycles on beds will also increase the depth of aggregates on certain soils (Sarmah *et.al.*, 1996) and provide a better environment for root exploration.

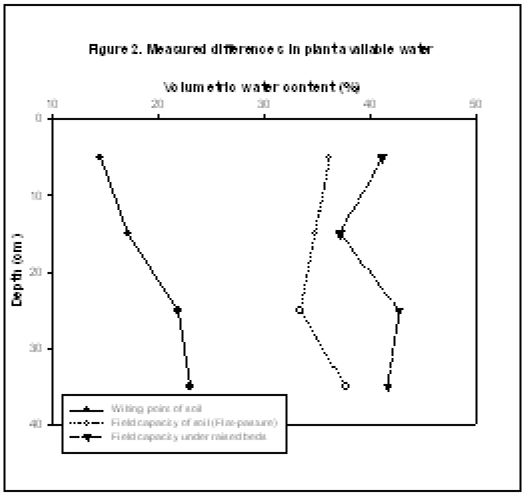

Figure 2 shows improvements in PAW capacity observed to a depth of 40cm in the comparison between long-term pasture on the flat and cropping on raised beds. It shows that the PAW in the crop root zone is now about 20% greater than if the crop was grown on the flat. These observed differences were a consequence of the measured differences in soil bulk density and porosity now experienced by the crops in the root zone, similar to those reported elsewhere in southern Australia (Cotching and Dean, 2001). It also appears that the increases in PAW capacity extend beyond the initial depth of tillage (20cm) in the installation of the beds, suggesting that initial tillage (mixing of topsoil and subsoil) was not the only contributory factor (Whitebred *et.al*., 1998) to changes experienced by plants in the immediate root zone. The four years of controlled traffic cropping appears to have contributed to improved soil structure in the root zone resulting in enhanced plant growth. Similar results have also been reported from Queensland (McHugh, 2003). Treatments using deep-rooted perennial lucerne also appear to provide even greater opportunities with enhanced PAW capacity compared to continuous cropping and the 4x4 system. At the end of five years of lucerne, PAW capacity measured was greater compared to other systems. This increase in PAW capacity should aid crops in prolonging the onset of waterlogging in case of severe rainfall events and conversely should also provide greater reserves of water to crops during grainfill when water stress can occur in this environment. A problem with newly bedded paddocks has been the early production of heavy crops (dry matter) that do not actually convert to grain resulting in poor harvest indices. This could in part be due to the lack of access to adequate soil water during grain filling, while high available nitrogen from recent mineralisation of organic matter and early sowing could also be contributory factors. The problem of low Harvest Index could be partially overcome if the PAW capacity of the soil is increased. The differences in soil structure also appears to spread to deeper layers in the soil as a result of the removal of compaction through controlled traffic and such conditions favouring better soil biological activity in the subsoil (McHugh, 2003; David Malinda pers. comm.).

Conclusions

Crops on raised beds in broad acre experience a better soil environment compared to crops on the flat and these differences lead to significant improvements in crop productivity. Work continues to advance our understanding of the management considerations that help farmers achieve the best outcomes from raised bed cropping.

Acknowledgment

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