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Performance of a tree belt for capturing overland flow from agricultural land - implications for design

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Introduction

There is growing interest in the strategic placement of tree belts in agricultural land to increase water use in areas with dryland salinity and waterlogging (Stirzaker et al., 2002; Ellis et al., 2005). Depending on the soil type, tree belts placed on hillslopes can capture excess water moving from upslope by either intercepting shallow sub surface lateral flow (Stirzaker et al., 2002), or by capturing overland flow. These processes can also be utilised to improve the productivity of tree crops in arid to semiarid areas by increasing the water supply to them. On soils with a low infiltration capacity, the principle process for delivery of excess water from upslope is by overland flow. In these areas, the introduction of tree belts into agricultural landscapes is expected to result in a slow change in soil surface attributes that improve water capture and storage processes. We describe a field experiment, using a rainfall simulator, designed to investigate the performance of a tree belt for the interception of overland flow from grazed pasture. Our results are used to highlight the main parameters to be considered when designing tree belts specifically for this purpose.

Experimental design

The experimental site was located on red duplex soil (bulk density 1.35 - 1.75 g cm^{-3}) with 12^o slope on a grazing property near Boroowa (-34^o 22’ S 148^o 42’ E), New South Wales, Australia. The slope comprised 28 m of grazed pasture draining into 12 m of tree belt at the lower end. The 15 year-old *Acacia* spp. and *Calistemon* spp. tree belt, aligned perpendicular to the slope, was originally planted by the landholder for stock shelter and biodiversity reasons. Stock were excluded from the tree belt by a fence located near the drip line of the present canopy. A bare soil area associated with tree-pasture competition and stock traffic extended 5 to 7 m beyond the fence line into the pasture.

Details of the construction of the rainfall simulator used in this experiment are described in Motha et al. (2002) and Wilson (1999).Three simulated rainfall events were applied: 45 mm hr^{-1} for 13 min duration; 45 and 75 mm hr^{-1} for 30 min duration, over the 40 x 15 m experimental area, split longitudinally so that duplicate pasture-tree belt sequences were measured. One of the sequences was retained as a single plot and measured for its combined behavior of pasture plus tree belt. The other sequence was divided into two separate plots: pasture only; and tree belt only, respectively.

For each plot, overland flow was directed into a flume and measured every 3 minutes during the rainfall simulations and during flow recession following rainfall cessation. Changes in flow patterns (spatial and temporal) and subsequent changes in surface micro topography were recorded for all events. Together with observations, flow hydrographs were used to estimate surface water storage (due to micro topography) during rainfall and recession periods.

Main results

- Overland flow from the first event (45 mm hr^{-1}; 13 minutes) was not sufficient to 'break through' the 12 m section of tree belt, and all overland flow leaving the pasture infiltrated into the soil. This represented a 37% increase in rainfall depth within the tree belt.
- Approximately 50% of the overland flow generated by the second event (45 mm hr^{-1}; 30 min) was intercepted and stored by the tree belt. This represented a 36% increase in rainfall depth within the tree belt.
- There was no measurable capture of overland flow resulting from the third event (75 mm hr^{-1}; 30 min).
- The bare soil area was observed to dominate the runoff generation from the pasture component in the early phases of all three rainfall events, and infiltration in this zone was close to zero (as determined by 'before' and 'after' gravimetric soil water profiles).
- A significant backwater formed at the interface between pasture and tree belt where there was an abrupt increase in surface roughness. Sediment accumulation in this zone immediately upslope of the tree belt. The backwater was associated with small litter dams that were present throughout the tree belt. These

structures were composed of pasture and tree litter and served to spread the surface flow and maximise the surface area in the tree belt that was available for infiltration.

- There appeared to be no appreciable differences in soil structure, between the pasture and tree belt plots, likely to be associated with interception and storage of water.

Conclusions

The tree belt significantly reduced the amount of overland flow leaving the experimental area, and the water captured represented a significant (greater than one third) increase in water supply to the trees. It is likely that tree belt designs can be optimised for this purpose and issues to be considered in this regard include:

1. The runoff coefficient of the upslope zone and how this would vary with management (e.g. crop or pasture).
2. The ratio of upslope length (crop/pasture) to downslope tree belt length.
3. Soil micro topography within the tree belt.
4. The nature, decomposition character and longevity of tree and pasture litter within the tree belt.
5. The water storage capacity within the tree belt.
6. Any prospect for soil structural changes within the tree belt (e.g. macropores) increasing the entry and storage of overland flow. These changes may be associated with older or native remnant tree belts.

The experiment highlighted the significant role of the bare soil zone, located upslope of the tree belt, as a source, rather than a sink, for overland flow. A modified tree belt design, where the fence is placed beyond this zone, may increase the potential for capture of overland flow by ground layer plants and accumulated litter.

In the absence of an extensive data set of the physical parameters required to describe the hydrological processes occurring within tree belts during overland flow events, it may be possible to develop simple empirical rules relating soil water capture potential to readily available attributes such as 2, 3 and 4 above.

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