EFFECT OF SUGARCANE TRASH RETENTION SYSTEMS ON FURROW IRRIGATION PERFORMANCE

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Abstract

Green Cane Trash Blanketing (GCTB) systems have not been adopted in many parts of the Australian sugar industry. Growers indicate that the primary obstacle in the adoption of GCTB systems is a lack of knowledge and information on the effect of trash retention on furrow irrigation systems. Trials were established in the Proserpine district to determine the effect of trash retention on furrow irrigation. Results from the trials have been simulated using the furrow irrigation modelling packages SIRMOD II and SRFR 4.06. Modelling tools were also used to ask 'what if' questions and extend the field results to different soil types and furrow irrigation scenarios. Field results demonstrated that trash retention increased the depth of flow in furrows and the wetted perimeter, slowed the advance rate, but did not overly affect irrigation efficiency. For growers intending to convert to GCTB systems, the furrow irrigation modelling indicated that they are likely to experience longer advance times or require higher inflow rates and deeper flow depths with GCTB systems. Losses to deep drainage are likely to be higher under GCTB systems, the highest losses are expected on low infiltration soils at moderate furrow lengths.

Introduction

Green Cane Trash Blanketing (GCTB) was initially practiced in the Australian sugar industry until the 1930s, when the spread of disease to cane cutters from contact with rat urine and labour shortages during World War II forced the cane to be burnt prior to cutting (Stewart and Wood, 1987). GCTB was re-introduced to the Australian sugar industry in the late 1970s to combat problems associated with the deterioration of burnt cane in wet conditions and soil erosion from high intensity rainfall (Wood, 1991). Advantages of GCTB that influenced growers to use the practice include reduced irrigations in dry years, improved soil structure, better weed control, flexibility with harvesting, reduced erosion and reduced labour (Norrish, 1996; Small, 2000). However growers in the Burdekin Delta and some of the wetter regions of the central Queensland district (ie. Mackay and Proserpine) have not adopted GCTB systems. One of the most commonly cited reasons for the poor adoption of GCTB systems is a lack of information and support for growers on the effect of GCTB with furrow irrigation. Growers have expressed a number of concerns about the potential effect of trash blankets including; overtopping of furrows, increased advance times, higher losses to deep drainage and reduced application efficiency (Holden and McMahon, 1997). This trial was conducted to investigate the effect of trash blankets on the performance of surface irrigation.

Trial Design and Measurement

Field trials were established in the Proserpine district to determine the effect of trash retention on furrow irrigation. Due to a high incidence of rainfall over the trial period, the opportunities for irrigation were limited. The field site was irrigated on the 17th of October and 19th of December 1999. The field site consisted of three blocks of five GCTB furrows and three blocks of five burnt (raked furrows), 30 furrows in total. The trial was harvested 'green' without the use of a trash fire. The burnt treatments were established by raking and burning trash after the site had been harvested.

For each of the 30 furrows being monitored, the irrigation advance was measured every 20 metres, inflow was measured using the time to fill a bucket of known volume and small impeller meters were attached to the fluming to monitor the flow variation. Runoff was also measured in 6 of the 30 furrows and change in soil moisture measured in each of the trial treatments. Furrow shape and wetted depth was determined in the upper 20 meters of each furrow by measuring the profile shape, at three locations. The cut-off time for both irrigations was 540 minutes.

Table 1: Details of field site

Location	*Proserpine Qld*	**Surface Texture**	*Sodic Sandy Loam*
Monitoring Period	*1998- 2000*	**Subsoil Texture**	*Medium Clay*
Soil Name	*Koolachu*	**Soil Depth (cm)**	*60-100cm*
Soil Type	*Sodic Duplex*	**PAWC (mm)**	*56*
Aust Soil Class	*Grey Sodosol*	**Block Slope %**	*0.50*
Northcote	*Dy 3.41, 3.31.*	**Block Length**	*304m*

Furrow simulation modelling tools SIRMOD II (Walker, 1998) and SRFR 4.06 (USDA, 1997) were employed to analyse data collected from the field trials. Modelling was employed to overcome problems associated with data variability and inconsistencies resulting from differences in soil parameters, inflow and furrow shape. The use of simulation modelling also enabled extrapolation of field data to a range of other field conditions including differences in trash retention (Manning's *n*) and furrow length. Soil infiltration parameters for SIRMOD II simulations were generated from field data using Infilt V5 (McClymont *et al.*, 1999), where as infiltration parameters for SRFR 4.06 were taken from characteristic soil infiltration curves (SCS, 1984).

The impedance to flow caused by trash lying within a furrow is described as surface roughness and measured in terms of the empirical coefficient Manning's *n*. To a large extent, the effects of trash retention on furrow irrigation systems are represented by Manning's *n*. By manipulating values of Manning's *n,* the effect of trash retention can be simulated by furrow irrigation modelling tools. Manning's *n* is calculated by the equation:

$$n = \frac{AR^{2/3}S^{1/2}}{Q}$$

where: n = Manning's n (dimensionless)
A = Cross-sectional area of flow, m^2
R = Hydraulic radius, quotient of cross-sectional area and wetted perimeter, m
S = Slope of bed, m/m
Q = Inflow rate of water, m^3/s

Effect of Trash Retention on Irrigation Attributes

Hydraulic resistance

The hydraulic resistance (ie Manning's *n*) was calculated both directly from field measurements (ie using the above equation), and inversely by using a calibration procedure in the furrow simulation models. A "calibrated" Manning's *n* was obtained using the SRFR furrow irrigation model by adjusting the roughness coefficient until the simulated depth of water in the furrow equalled the measured value (for a known furrow shape, wetted perimeter, inflow rate and furrow slope). The "calibrated" Manning's *n* obtained using the SIRMOD II model was obtained by adjusting the roughness coefficient until the simulated advance rates matched the measured data.

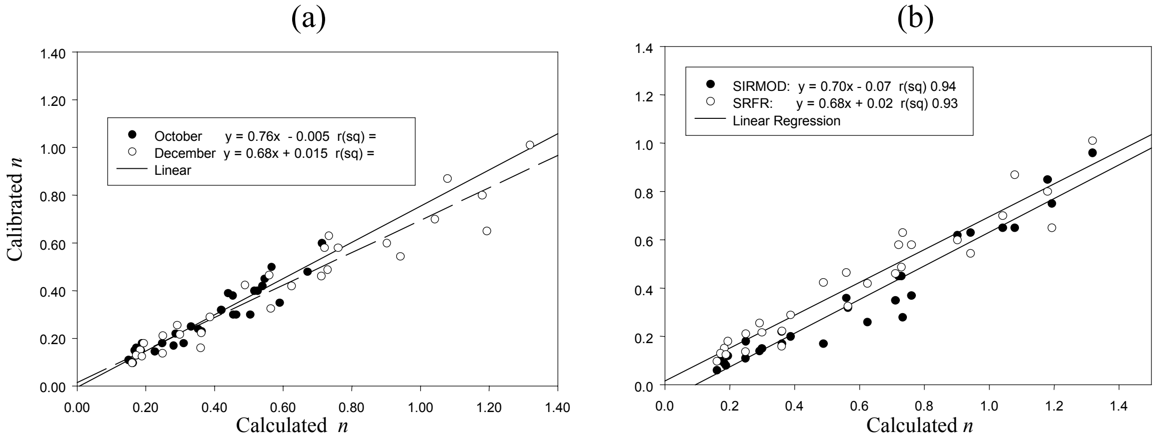


Figure 1: Correlation between calculated and calibrated Manning's *n* values obtained (a) using SRFR 4.06 modelling and (b) using SIRMOD II and SRFR 4.06 modelling for the December irrigation only

Calibrated values for Manning's *n* (SRFR 4.06 and SIRMOD II) were significantly ($P<0.05$) correlated with the directly calculated values. However the calibrated values were on average 30% lower than the directly calculated values (Figure 1a). Calibrated values determined using SIRMOD II were slightly lower than those obtained using SRFR 4.06 (Figure1b). Differences between the directly calculated and "calibrated" values of Manning's *n* are most likely attributable to a breakdown in the assumptions that (a) normal flow conditions have been established at the upstream end of the furrow and that (b) the furrow profile, slope, and hydraulic parameters measured in upper 20 metres of the furrow length are consistent with the full furrow length. The appropriateness of the Manning's equation to adequately describe the flow characteristics in small channels with high resistance to flow ratios is also questionable. While the difference observed between the calculated and the calibrated values for Manning's *n* has a comparatively small effect on the simulation of irrigation events, it does confirm the need to calibrate the simulation model performance using the Manning's *n* term (McClymont *et al.*, 1996).

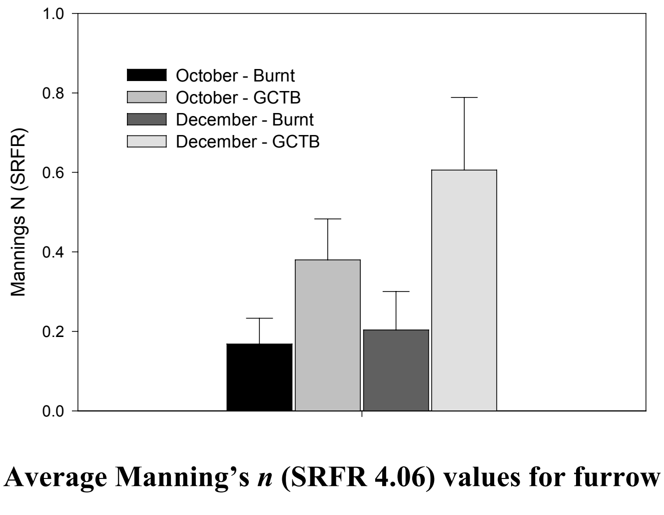


Figure 2: Average Manning's *n* (SRFR 4.06) values for furrow irrigations

Results from the two irrigations demonstrated that the GCTB treatments had significantly ($P<0.05$) higher impedance to flow (Manning's *n*) than the burnt treatments (Figure 2). Paired T-test analysis demonstrated that the Manning's *n* increased significantly in the GCTB treatments between the October and December irrigations despite the average dry trash weight decreasing from between 9 and 10 t/ha (interpolated data) to 6.85 t/ha. This increase is likely to be due to changes in the arrangement, orientation and transportability of the trash as it decays and packs down. Values for Manning's *n* in both the burnt and GCTB treatments are extremely high, and tend to be higher than previously published figures for furrow irrigation in the Australian sugar industry (Table 2).

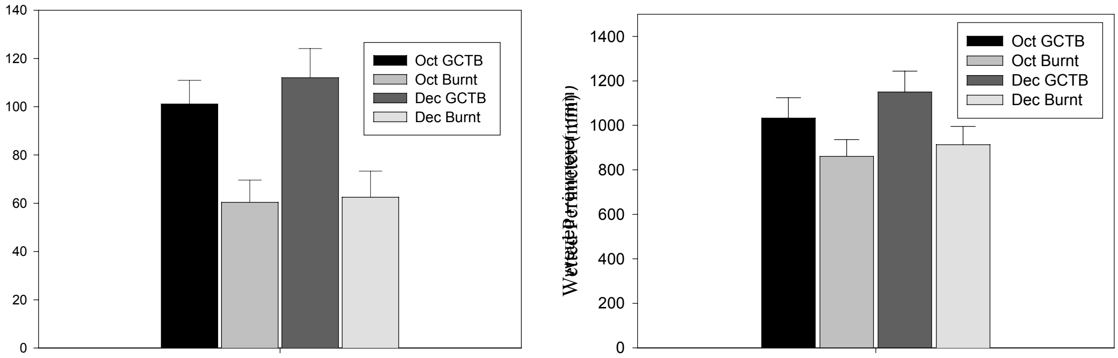
Table 2: Manning's *n* values previously published for burnt and GCTB furrow irrigation of sugarcane

	Burnt			**GCTB**		
Location	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**
Rita Island	0.05	0.02	0.01-0.06			
Jarvisfield	0.10	0.03	0.06-0.17			
Home Hill	0.15	0.09	0.05-0.40			
Proserpine	0.09	0.04	0.05-0.18	0.46	0.16	0.26-0.67
Burdekin	0.04	0.02	0.02-0.06	0.09	0.04	0.05-0.12
Clare	0.09	0.04	0.03-0.13	0.25	0.08	0.17-0.47
Burdekin				0.17	0.07	0.08-0.32

(From Newell *et al.*, 2001; Holden and Sutherland, 1998; Raine and Bakker, 1996)

Furrow wetting and overtopping

The depth of water in the GCTB treatment was almost twice that of the burnt treatments (Figure 3a). The wetted perimeter was also significantly ($P<0.05$) greater in the GCTB treatments compared to the burnt treatments (Figure 3b). However, the broad flat nature of the furrows resulted in a smaller increase in wetted perimeter with increasing trash than might be expected with narrow V-shaped furrows.


(a)

(b)

Figure 3: Effect of trash retention on depth of water in the furrow, and wetted perimeter

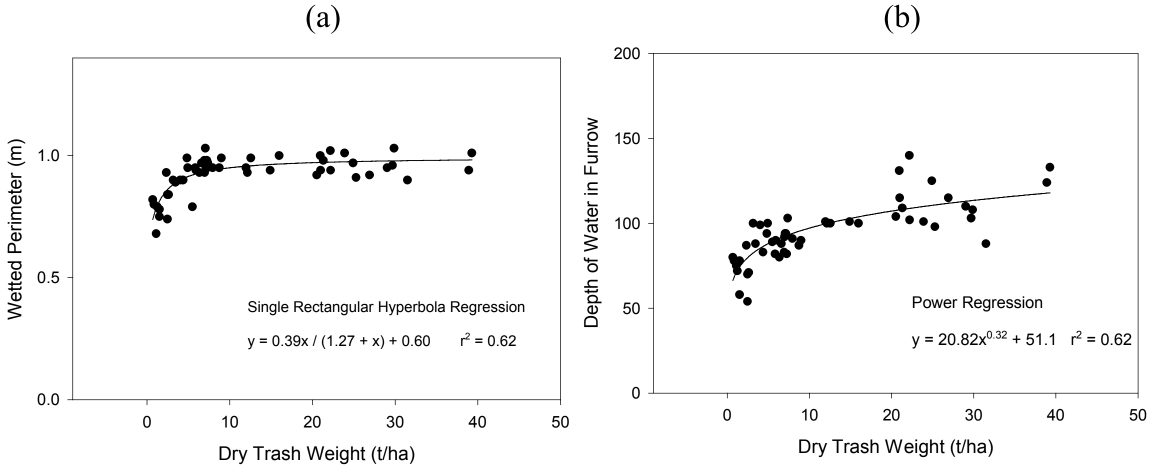


Figure 4: Effect of trash weight on (a) depth of water in the furrow and (b) wetted perimeter

In a separate analysis (Newell *et al.,* 2001), the effect of trash weight from each of the furrows was compared with the wetted perimeter and depth of water in the furrows (Figure 4). As trash weight exceeded 10 t/ha the effect of the additional trash on the wetted perimeter and depth of water in the furrow was small. This is likely to be due to either the rafting (floating) effect of the trash, or lack of additional trash interception by water in the furrow. This finding is important as it indicates that in situations where there is abundant trash (>10 t/ha), there should be little additional effect on the wetted perimeter, depth of flow, or impedance to flow (Figure 4) from trash weights greater than 10 t/ha.

Growers have expressed concern that furrow irrigating with GCTB may result in overtopping of furrows. Growers require information on the depth and shape of furrows required for converting to GCTB systems. The effect of trash management on the depth of flow was investigated with the use of the SRFR furrow simulation model. Simulations were conducted at inflow rates of 1, 2.5 and 3.5 L/s for a high infiltration silty loam (soil curve 0.7, SCS 1984) at a slope of 1/600 (or 0.16 %). The two furrow shapes were determined from unpublished data collected during previous studies that recorded 'typical' furrow shapes in the Burdekin and central district.

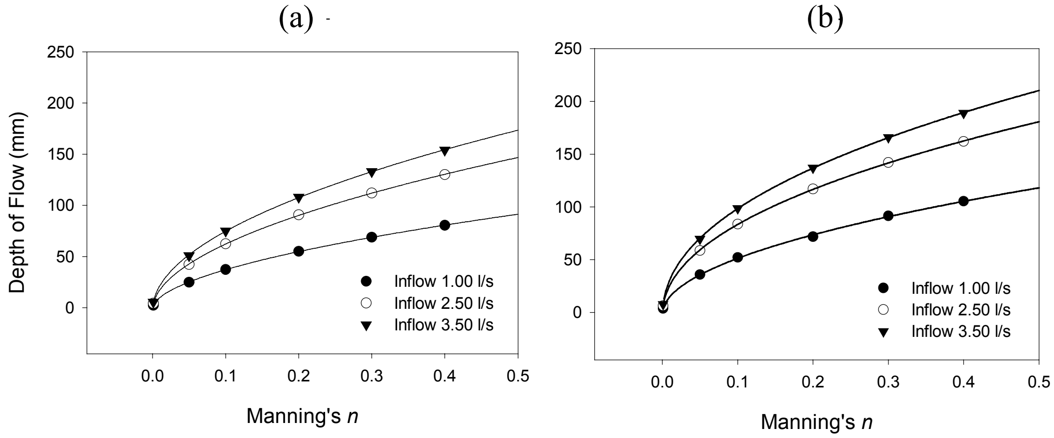


Figure 5: Effect of trash management (Manning's *n*) on the depth of flow at the head of (a) U-shaped furrows and (b) V-shaped furrows for three inflow rates

The depth of water in the furrow is dependent on both the Manning's *n* value (impedance from trash retention) and inflow rate (Figure 5). Depending on inflow rate, converting to GCTB systems could double the depth of flow in both U and V shaped furrows. Considering most furrows are between 150 and 200 mm deep, trash retention (*n* ~ 0.35) is unlikely to result in overtopping at flow rates up to 3.5 L/s in U shaped furrows but may result in overtopping in V-shaped furrows at flow rates greater than ~2.5 L/s (depending on actual furrow depth). Growers intending to convert to GCTB systems may need to consider increasing furrow depth or modifying furrow shape to accommodate the expected increase in flow depth.

Water advance rates

Growers have expressed concern that trash retention will reduce the advance time of current irrigations, resulting in higher pumping costs, reduced efficiency and considerably increasing the time required to irrigate the whole farm. The effect of trash retention on advance rate involves a complex interaction between furrow length, slope, inflow rate and soil type. Modelled data has been presented instead of measured data as differences in inflow rate between the two treatments don't allow for direct comparison.

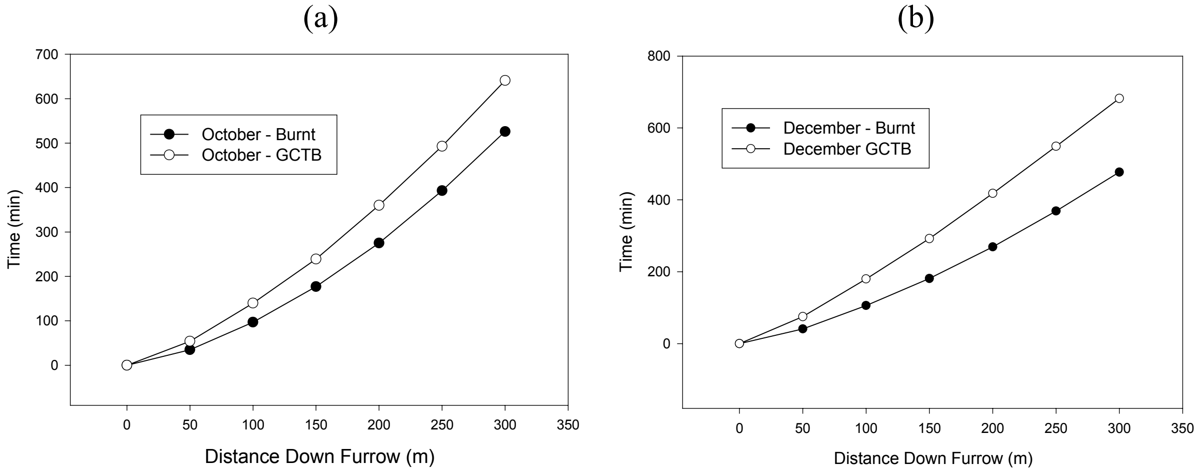


Figure 6: Modelled advance rates for (a) October irrigation and (b) December irrigation
(Corrected for identical furrow shape, soil parameters and inflow rate)

The advance rates in the GCTB treatments were considerably slower than the burnt treatments. The advance time for the full furrow length of the GCTB treatment during the December irrigation was 275 mins (65%) longer than the advance for the burnt treatment. Simulations were conducted using SRFR and the infiltration characteristics for a high infiltration silty loam (soil type 0.7, SCS 1984) and a lower infiltration clay loam (soil type 0.2, SCS 1984) to assess the affect of Manning's *n* on furrow advance. All simulations were conducted using a slope of 1:600 and U-shaped furrows supplied at inflow rates of 1.0 L/s and 2.5 L/s.

The time required to irrigate fields was found to be significantly affected by the soil texture (ie. infiltration characteristic), the level of trash associated with GCTB and inflow rate (Figure 7). The advance time increased with increases in either the infiltration characteristic and/or level of trash. However, the effect of increased advance time due to GCTB is likely to have a greater influence on shorter furrow lengths where the relative difference in advance time is much greater. For example, the introduction of GCTB into a 600 m long field with clay loam soils and irrigated at 1.0 L/s (Figure 7b), would take 70% longer (ie. an extra 569 minutes) compared to the burnt furrows. However, with 300 m long furrows, the introduction of GCTB would require a 180% increase in advance time (ie. an extra 200 minutes) compared to the burnt furrows.

At inflow rates of 1 L/s, trash retention had little effect on the advance rate for the higher infiltration silty loam. However, the clay loam demonstrates notable differences in advance times for increasing furrow lengths (Figure 7 a, b). At a furrow length of 600 m, the clay loam would have had an advance time of 830 mins for burnt furrows and 1275 mins for GCTB furrows (54% longer). Assuming growers matched the cut-off time to the advance time, irrigating the GCTB furrows would have resulted in an additional 40 mm or 0.4 ML/ha irrigation, 26% less application efficiency but 11% higher irrigation requirement. This demonstrates the need for higher flow rates with earlier cut-off times when furrow irrigating with GCTB.

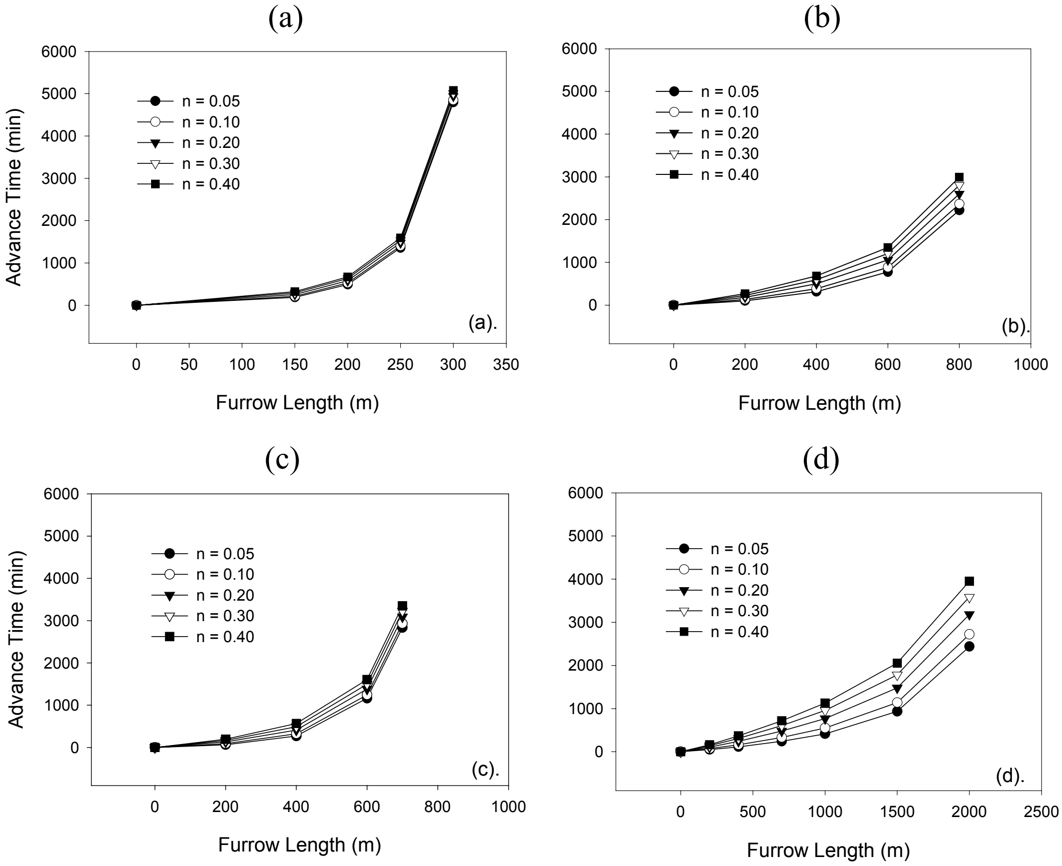


Figure 7: Effect of trash retention (Manning's *n*) on advance times for (a) silty loam, inflow 1 L/s, (b) clay loam, inflow 1 L/s, (c) silty loam, inflow 2.5 L/s, and (d) clay loam, inflow 2.5 L/s

Irrigation Performance

Trash retention systems have little effect on irrigation performance when assessed using measures of application efficiency, irrigation adequacy, runoff and infiltrated depth (Figure 8). These findings are surprising given the deeper flow depths and slower advance times associated with GCTB systems. Differences in flow rate between the GCTB and burnt treatments (October irrigation difference = 0.23 L/s) and only 73% of GCTB furrows reaching the end of the furrow in the December irrigation are likely to be masking the true effect of trash blankets on furrow irrigation efficiency.

The effect of trash retention on irrigation efficiency was investigated by modelling the effect of Manning's *n* on deep drainage losses for a high infiltration silty loam (soil type 0.7, SCS 1984) and for lower infiltration clay loam (soil type 0.2, SCS 1984) using the SRFR model. All simulations were conducted for a slope of 1:600 with U-shaped furrows. The cutoff time for all simulations was set to the final advance time to minimise runoff loses. Deep drainage was classified as any infiltrated water which exceeded a 60 mm (0.6ML/ha) target application volume. Additional losses from runoff were not considered in this analysis. The acceptable level for deep drainage loss was set at <15%.

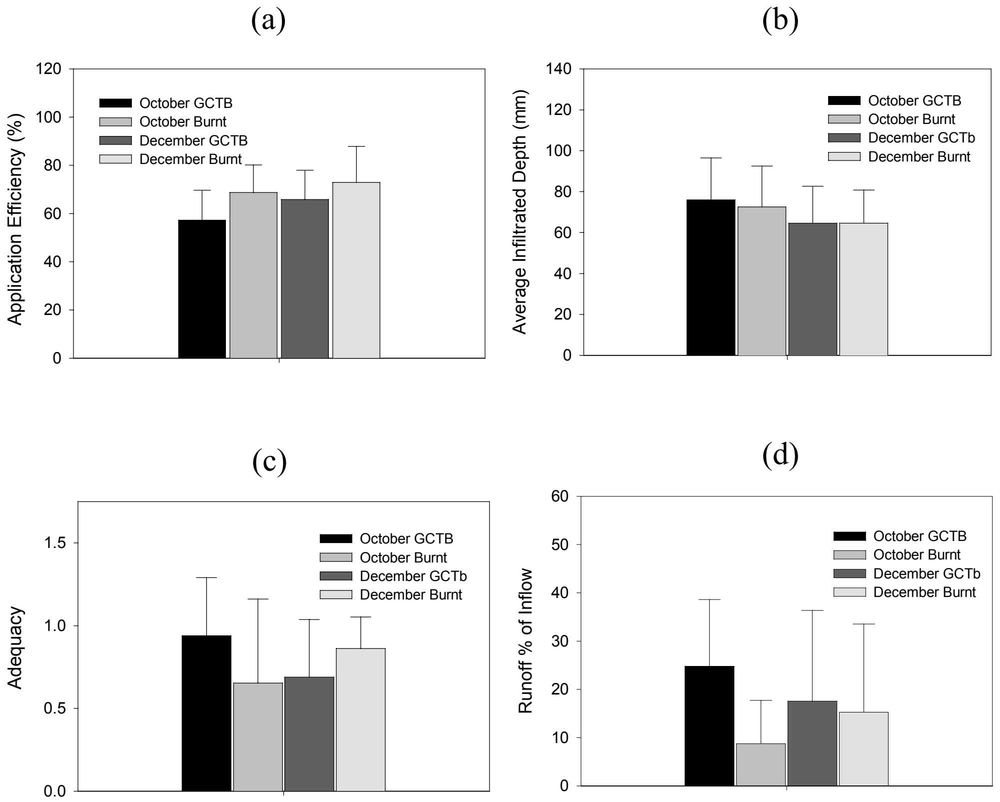


Figure 8: Comparison of irrigation efficiency and adequacy: (a) application efficiency, (b) average infiltrated depth, (c) adequacy, and (d) runoff (Irrigation efficiency and adequacy were calculated using the SRFR model, all calculations are based on a target application depth of 60 mm)

Assuming deep drainage losses higher than 15% are unacceptable, Figure 9 and Table 3 demonstrate the maximum recommended furrow length for each combination of soil type and inflow rate for both GCTB and burnt systems. The difference in recommended maximum furrow length is considerably shorter for GCTB systems particularly at 2.5 L/s inflow on the high infiltration silty loam. At an inflow rate of 1 L/s, the recommended maximum furrow length for GCTB systems was 50 m shorter than for the burnt system on the high infiltration silty loam, and 75 m shorter on the low infiltration clay loam. However, at an inflow rate of 2.5 L/s the recommended maximum furrow length for the GCTB systems on the high infiltration silty loam was 175 m shorter or half the furrow length of the burnt system.

In order to minimise additional deep drainage losses, growers intending to convert to GCTB systems, must either (i) increase the inflow rate, which will require a combination of greater pumping capacity or irrigating fewer furrows at the one time, or (ii) shorten furrow lengths, which will require significant changes to block design and farm layout.

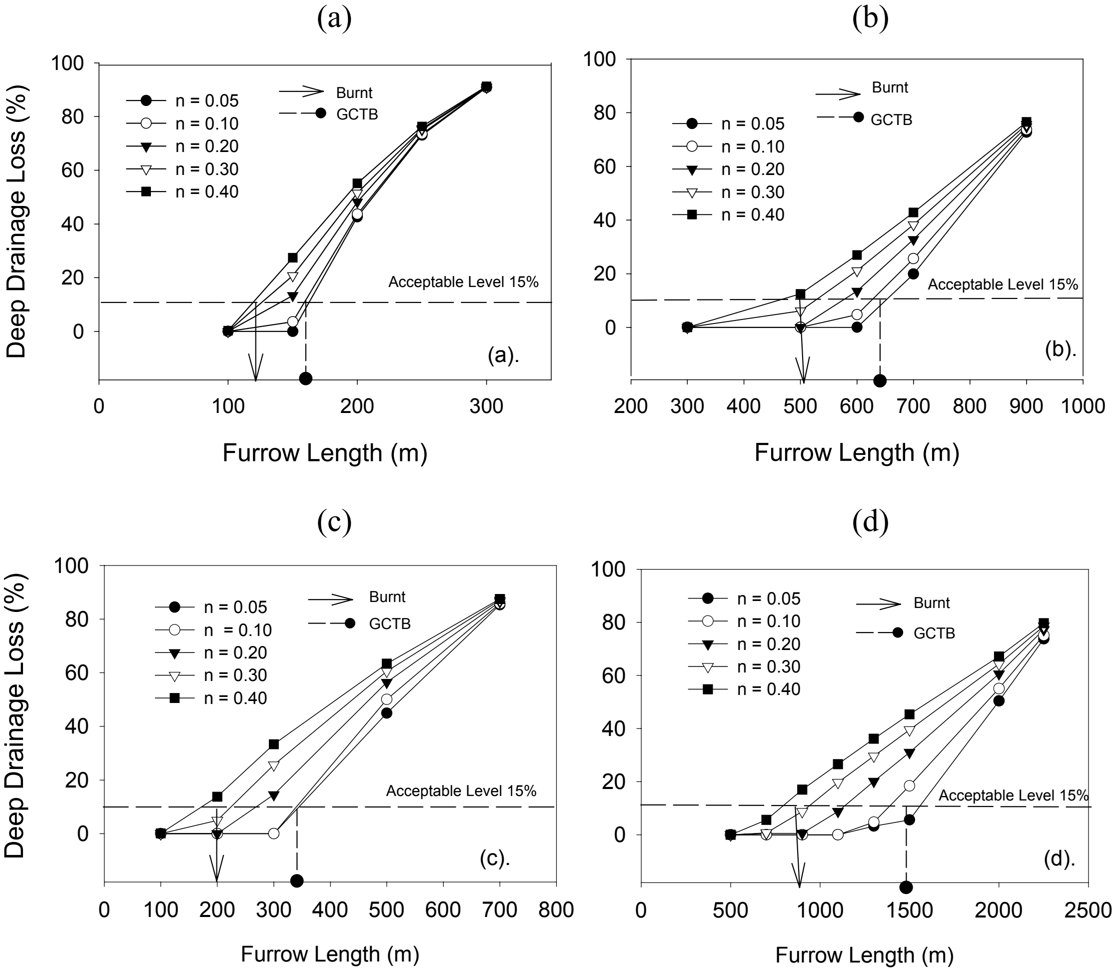


Figure 9: Effect of trash retention (Manning's *n*) on deep drainage loss (target application depth 60 mm) for (a) silty loam, inflow 1 L/s, (b) clay loam, inflow 1 L/s, (c) silty loam, inflow 2.5 L/s, and (d) clay loam, inflow 2.5 L/s (Maximum furrow length for burnt (solid arrow) and GCTB (dashed line-dot) is shown using an acceptable limit of 15% deep drainage)

Table 3: Maximum recommended furrow length to maintain deep drainage loss to less than 15% of the total inflow volume

Inflow rate	**Silty loam** (high infiltration)		**Clay loam** (low infiltration)	
L/s	**GCTB** **(*n* = 0.35)**	**Burnt** **(*n* = 0.075)**	**GCTB** **(*n* = 0.35)**	**Burnt** **(*n* = 0.075)**
1.0	125m	175m	525m	650m
2.5	175m	350m	850m	1450m

Conclusion

The retention of sugarcane trash (GCTB systems) resulted in a number of changes to the performance and operation of furrow irrigation. Manning's *n*, the roughness coefficient which describes resistance to flow was best solved using furrow simulation techniques, as direct measurement led to overestimation of Manning's *n*. Due to the broad flat nature of furrows in the study, values for Manning's *n* were up to an order of magnitude greater than values typically cited in the literature.

While the field data indicated GCTB had a minimal effect on irrigation efficiency, furrow simulation modelling indicated that differences in inflow rate, and furrow shape between the two treatments may have masked the true effect of trash retention on irrigation efficiency. Field and modelling data demonstrated that trash retention resulted in greater flow depth, greater wetted perimeter, slower advance rates, and changes to deep drainage.

For most growers the conversion to GCTB will result in deeper flow, longer advance times, and probably higher deep drainage losses. However, conversion to GCTB is unlikely to make currently efficient furrow irrigation systems inoperable or result in more than 50% higher deep drainage losses. Advance times are likely to be slower and inflow volumes will be higher, the extent of which is dependent on soil type, furrow length, inflow rate and slope. Situations will exist when furrow shape will need to be modified to account for the greater depth of flow. For many growers a conversion to GCTB will require either greater pumping capacity or shorter furrow lengths if additional deep drainage losses are to be avoided.

Limited studies of irrigation efficiency (Raine and Bakker 1996, Tilley and Chapman 1999) have demonstrated that the efficiency of both burnt and GCTB furrow irrigation systems within the Australian sugar industry are generally poor and highly variable. This suggests that the effects of converting to GCTB systems on irrigation efficiency will be small, although additive, considering the existing poor levels of irrigation application efficiency in the industry.

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