BUREAU OF SUGAR

EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA

FINAL REPORT – SRDC PROJECT BSS173
QUANTIFYING THE SOCIO-ECONOMIC IMPACTS OF HARVESTING RESIDUE RETENTION SYSTEMS

by
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SD01012

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EXECUTIVE SUMMARY

This project was jointly funded by the Sugar Research and Development Corporation and Land and Water Australia (formally Land and Water Resources Research and Development Corporation) from 1996 to 2002.

The project was established after concerns that regulations on burning cane overseas would be introduced in Australia, and the socio-economic implications would not be known. There are a number of issues associated with burning of cane both before and after harvest. These include health concerns, pollution, nuisance and cleaning issues.

The effect of the imposition of burning restrictions on growers was also a major concern, particularly with respect to furrow irrigation. Field trials were carried out in the Proserpine district to determine the effect of trash on furrow irrigation and to develop management methods to overcome any difficulties. These trials were used in conjunction with APSIM (an agricultural production simulator) and SIRMOD (a surface irrigation model) to determine optimal furrow irrigation under a number of situations.

Grower surveys were carried out to compare production costs in burnt and trash blanketing systems in the Burdekin and Proserpine districts, as well as to determine growers' opinions and attitudes towards trash blanketing. A community survey was also conducted in these two districts to assess the attitudes of communities to smoke and ash emissions, impacts of smoke and ash emissions on these communities, and their level of knowledge about canegrowing practices. The surveys showed that the cost of converting and producing cane from a burnt production system to green cane trash blanketing (GCTB) is variable among individuals, but is not necessarily prohibitive. Growers in suitable situations for GCTB can make some significant economic and social benefits from changing to GCTB.

The community survey showed that, although there are some basic areas of concern (health, cleaning) about the effects of smoke and ash emissions from cane and trash fires, these are not substantial. Those members of the community who know about the various issues associated with producing cane in a GCTB system are more accepting of cane fires and the resulting trash and smoke. The members of the community who vocalise their negative views of smoke and ash emissions are those who have less understanding about industry practices. A survey of doctors in Queensland canegrowing areas showed that there was no direct correlation between smoke and ash emissions and increased health problems in communities where cane burning is common. Therefore, to alleviate communities' concerns about the impacts of cane and trash fires there needs to be an educational program aimed at the community to inform them of the various problems associated with converting from burnt to GCTB systems.

These surveys formed the basis of the socio-economic analysis. Cost-benefit analyses at a farm and regional level based on data gathered in these surveys were conducted taking into account a variety of sugar prices and yield outcomes.

The main conclusions were:

- conversion to GCTB is unlikely to make currently efficient furrow irrigation systems inoperable or result in massively higher irrigation losses;
- in most situations, the conversion to GCTB will require an increase in irrigation inflow rates to overcome the reduced flow rate within the furrow and to minimise deep drainage losses;
- there is a higher level of knowledge of GCTB in the Burdekin district than the Whitsunday district;
- respondents in both districts who did not know about various problems associated with GCTB demonstrated a more aggressive attitude towards smoke and ash emissions.

1.0 INTRODUCTION

Research and industry workshops have identified a range of factors acting as barriers to the adoption of green cane trash retention methods in the central region of the sugar industry. The activities included a previous project funded by SRDC (BS109S: Constraints to the adoption of green cane trash blanketing in central and southern regions) and industry workshops funded by both SRDC and the local sugar industry. These were titled 'Sustainable farming systems for the Australian sugar industry'; 'Alternative uses for cane tops and trash'; and 'Cane firing and other burning practices for the local industry'.

Outcomes from these activities indicated that the greatest constraints from a grower perspective were based on the unsuitability of, and increased risk with, trash retention on heavier soil types, trash retention on sites with poor internal drainage, variation linked to rainfall events in suitability for trash retention between, and within seasons, and the lack of reliable economic data for comparison between green and burnt production methods.

Another issue that was identified as poorly understood, but with an important influence on adoption processes and policy issues, was the transfer of benefits and costs within the sugar industry and between the industry and the wider community.

This project addresses these issues, and supports the continued adoption and development of harvesting residue retention methods in the Proserpine/Burdekin region. It also assesses the socio-economic benefits and/or costs of trash retention, and considers the impact of changes in the adoption of trash retention systems on the farming, milling, and broader community sectors.

The project defines the areas suitable for trash retention under current management systems and varying climatic conditions. It also implements a participatory research programme to overcome agronomic limitations and improve current management systems.

2.0 BACKGROUND

The practice of leaving unburnt cane trash after harvesting is known as green cane trash blanketing (GCTB). GCTB is a beneficial management tool that helps to protect soil against erosion, conserves moisture in the early stages of growth, boosts weed control, increases soil organic matter, and improves soil structure in the long term. All of these things lead to cost savings for the grower because fewer production inputs, including chemicals, water, machinery and labour, are required.

While some regions have embraced trash retention systems, perceived or real agronomic and economic limitations have prevented most growers in the Burdekin region and some in the Proserpine region from adopting the practice.

From the community perspective, there is a great deal of pressure to reduce the levels of burning because it is believed that the smoke from cane fires can cause respiratory problems, while the ash emitted is considered a nuisance when it falls in residential areas.

Growers can either experience great advantages or disadvantages from practising GCTB, depending on their individual circumstances (ie soil type, field design and rainfall zone). Some of the advantages growers could potentially gain include increased yield and/or ccs in suitable areas, no burnt cane penalty charged by mills, and production cost savings in fertiliser, machinery, labour, chemicals and irrigation. Another major advantage of green cane production is that there is no risk of having burnt cane left in the paddock waiting to be harvested after rain.

There are also a number of disadvantages to GCTB, which include increased harvesting costs, increased harvesting losses, irrigation difficulties, slow ratooning, and increased water use on some soil types.

3.0 OBJECTIVES

This project aimed to define the areas of Proserpine/Burdekin suitable for trash retention based on site physical characteristics, assess the socio-economic issues related to trash management and overcome current agronomic limitations to trash retention. The project also aimed to assist the sugar industry and catchment managers to evaluate trash retention systems and provide a sound basis for decision making and strategic planning at both the farm and regional level. The main output of this project was to enable the industry to implement wider adoption of trash retention systems.

The primary objectives of the project were to:

1. undertake a socio-economic assessment of harvesting residue retention systems in the Burdekin and Proserpine districts;
2. assess profitability and risk of trash retention in the Burdekin and Proserpine districts;
3. investigate management methods to overcome agronomic limitations of current trash retention systems through a participatory research program;
4. support and extend the adoption of trash retention systems based on agronomic suitability and economic management issues;
5. evaluate the project methodology, and the data utilised for socio-economic assessment.

Appendix 1 details all of the individual milestone objectives and the achievement criteria that were used to measure their progress.

3.1 Achievement of objectives

A detailed cost-benefit analysis has been completed and published under the title: 'Cost-benefit analysis of green cane trash blanketing for farm and regional sectors', which is attached with this report in Appendix 2. The analysis includes outputs of the growers' survey, the community survey, case studies, partial budgeting, various cost-benefit analyses, and utilises data gathered from trials, surveys, APSIM, as well as historical data. This analysis completes the requirements to fulfil project objectives one and two.

The analysis shows that there are both economic advantages and disadvantages of green cane trash blanketing at both a farm and regional level. From the grower's perspective, if the farm is deemed highly suitable to GCTB (ie suitable soil type, slope, row length), the grower will incur reduced production costs if he/she converts from burnt cane production to GCTB production. The partial budget shows that a gain of around $320 per hectare is attainable for a farm suitable to GCTB.

The case study farm in this analysis shows the effect of a change to GCTB on a farm that is less suitable to GCTB, where considerable changes need to be made to the farm which require additional finance. The analysis showed that the change to GCTB may result in negative gross margins for the first crop cycle, but after this the gross margins are positive.

At a regional level, the analysis shows that ccs is the main factor behind benefits and costs to the overall district as a result of a change to GCTB by 30% of the district. If ccs is increased in that area, the total district gross margins will also be increased, while if ccs is reduced in that area, total district gross margins will be lowered.

Objective three was achieved through the development and adaptation of the Best Practices Guide for Green Cane Trash Blanketing (see Appendix 3). The aim of this booklet was to draw together information from various research on green cane trash blanketing into one simple package to enable growers to easily access research results. This document will outline some of the factors that will help growers decide if they can utilise trash blanketing successfully and will also suggest a number of best management practices to maximise this success.

Objective four of the project has been completed through a number of activities, including bus tours, shed meetings, field days, newsletters, newspaper articles and conferences.

Earlier in the project, a bus tour was organised for Burdekin growers around the Burdekin district to inspect various GCTB situations. Talks were given by Burdekin growers with GCTB experience and a green cane harvester operator. Presentations outlining the various advantages and disadvantages associated with GCTB were given to the CANEGROWERS executive, (one in 1998, one in 2000) as well as a presentation to the Rural Fire Council in 1998.

A second bus tour for Burdekin growers was conducted in conjunction with the 2001 project review. Burdekin growers were taken around the Proserpine district, although unfortunately due to bad weather we could only inspect one trial. Proserpine growers spoke about their general experiences with GCTB, while David Hinschen, the President of the Proserpine cane harvesters' association discussed harvesting in relation to GCTB. The day overall was a success, as shown by a survey filled in by Burdekin growers on the bus trip home. A report of this survey is attached to this document.

Articles on GCTB research have also been published in local newspapers and grower newsletters, ensuring a high level of dissemination of information to growers in both districts.

Information has been presented to industry at field days in both the Burdekin and Central districts in 1999, 2000 and 2001. Posters presenting information were on display, as well as information leaflets, while project staff were available to talk to growers and answer their questions on the day.

Annual BSES shed meetings over the past three years in both the Proserpine and Burdekin districts were a successful tool in extending information to growers. In February each year, these shed meetings are held in a number of locations around each district (nine in the Burdekin, four in Proserpine) to present results and information from research to the growers.

Demonstration sites in the Burdekin district were developed in conjunction with the Rural Water Use Efficiency project. Two sites were set up during the 2001 harvesting season at Giru and Mona Park, with various irrigation monitoring equipment. Growers were taken to these sites and presented with information from the project, as well as given demonstrations of irrigations in a GCTB situation.

Table 1 summarises the various extension activities carried out throughout the project.

Table 1: A summary of extension activities

Date	Extension Activity
Mar-98	Presentation to Rural Fire Council
May-98	Presentation in Australian Canegrower magazine
Sep-98	Bus tour to Dalbeg
Sep-98	Presentation to JCU postgraduate students
Sep-98	Article appearing in the Advocate newspaper
Oct-98	Presentation to CANEGROWERS executive
Feb-99	GCTB workshop organised by SRDC
Feb-99	Shed meetings in both Proserpine and Burdekin Districts
Apr-99	Article appearing in the Advocate newspaper
May-99	Burdekin and Central district BSES field days
Oct-99	Irrigation workshop held in Proserpine
Dec-99	Grower newsletter - circulated to Burdekin growers
Feb-00	Shed meetings in both Proserpine and Burdekin Districts
Apr-00	Article appearing in the Advocate newspaper
May-00	Burdekin and Central district BSES field days
Jun-00	Presentation to Burdekin staff on research to date
Mar-01	Newsletter circulated to Burdekin growers
Apr-01	Radio presentations in weeks leading up to bus tour
Apr-01	Bus tour for Burdekin growers to Proserpine
Aug-01	Seminars presented to BSES staff on final research
Oct-01	Field days at demonstration sites in the Burdekin

The adoption of several furrow irrigation optimisation computer programs has enabled farmers to design furrow structures and field designs to best cater for optimal water usage. The report detailing these computer generated models is attached in Appendix 9. The specific software code developed for the purposes of generating these data is available directly through BSES.

The final objective of the project was to evaluate the methodology used in the project. This was done initially as a self-assessment by the project team, in which we identified the positive outcomes of the project and the problems associated with the project. These included both unavoidable problems such as weather, data unavailability and disease and avoidable problems such as lack of agronomic trials in the Burdekin district.

Positive outcomes of the project identified by the project team at that stage included:

- mapping;
- socio-economic model development;
- development of best practices guidelines;
- submission of ASSCT papers;
- successful and timely submission of all milestones and fulfilment of all requirements.

The next stage of the evaluation of project methodology was the project review in April 2001, which included a bus tour around the Proserpine district for Burdekin growers and review panel. Feedback from the review panel stated that:

'An extensive range of studies has been conducted in this project, and reported in milestones and review presentations. Some difficulties had occurred in the field with weather conditions and plant disease but the R&D was generally well conducted and well documented.'

'Presentations were clear and well organised. The presentations during the bus tour provided a good background to the more detailed information presented at the review.'

'The final evaluation of the project should focus on the success of the methodology in achieving the project's objectives. It should also consider the requirements for further R,D&E.'

To complete the project methodology evaluation, the project team has collated their thoughts and opinions on how the project was undertaken and how the various components of it were integrated.

Mapping was initially seen to be a major component of the analysis. However, this was hampered by the lack of data, in particular, slope data. No soil data were available for the Burdekin delta area, while farm block data were also limited for the Burdekin district. The methodology and framework for creating suitability and risk maps were established and can easily be modified, as new knowledge becomes available.

The irrigation component of the project was well conducted and returned sound results, although this could have been more detailed. The project required multiple irrigation events on a range of soil types, in particular cracking clays. However, given the extremely high amounts of rain received over the trial period, a surprisingly large volume and quality of data were obtained. Of particular concern is the lack of data detailing changes in Manning's n over time and the possible effects of leaf detachment on Manning's n later in the season.

The irrigation modelling component of the project was a considerable success, because differences between burnt and GCTB systems' irrigation performance were quantified, and presented in an extension tool with management advice and recommendations for growers intending to convert to GCTB systems.

With respect to the crop growth-modelling component of the project, concerns arose with the use of APSIM, the unfortunate timing of software upgrades, and uncertainty about current rates of leaf detachment and trash breakdown as discussed earlier in this report. Given the project was only ever going to employ available technology, difficulties encountered with this component of the project were outside the control of the project officers.

It is realised that the value of many projects can be enhanced with the addition of economic and/or social analyses; however, these components will not necessarily interact with agronomic or scientific aspects directly. The interaction between the socio-economic and agronomic components of this project was not definite. Although these components were not clearly linked, they were not completely unrelated, rather they proceeded in parallel to each other. The project team made every effort to make the two components integrate but this was difficult due to a number of factors, including the fact that staff were located in two different regions.

Advice to future project developers is to design a primarily agronomic or scientific project with a socio-economic analysis on the outcomes of the initial research.

4.0 METHODOLOGY

To complete the analysis, a community survey was undertaken to ascertain attitudes of the community towards smoke and ash emissions, as well as their level of knowledge of issues associated with cane production, including irrigation, harvesting and environmental aspects. A grower survey was also conducted to form the basis of the economic analysis, collecting information about production costs in burnt and GCTB systems. Field trials carried out in the Proserpine district collected agronomic information about these two systems, including the effects of GCTB on yield and the effect of trash on furrow irrigation.

4.1 Community survey

In 1998, the community survey was mailed to 10% of households in the Burdekin (650 households) and Whitsunday (440 households) Shires. Individual respondents were selected to represent their households, and these were selected at random from the Electoral Role, updated for the October 1998 Election. Everyone registered to vote had an equal chance of being selected and so the opinions of growers were also represented in those of the community as a whole. A copy of the Burdekin survey is attached in Appendix 4. A survey was also made of doctors with general practice from Mackay to

Mossman in an attempt to measure the impacts of the smoke emissions on the health of the community.

As well as collecting general information about the individual being surveyed, the questionnaire obtained details on attitudes towards smoke and ash emissions from cane and trash fires, opinions on the effect of smoke and ash emissions on individuals, the community, visitors and the environment. The survey also collected information about the level of knowledge of GCTB in each of the communities.

4.2 Growers' survey

Detailed economic information about burnt and GCTB production systems was obtained from face-to-face style interviews with growers in the Burdekin and Proserpine districts. The survey consisted of three main sections, with introductory questions to collect general information about the farm, including farm number, varieties grown, and the length of farmer's experience with GCTB (if applicable). The second section asked questions regarding the use of on-farm activities such as land preparation, fertilising, irrigation, chemical applications and harvesting, as well as other changes in practice required to adapt to GCTB, such as re-levelling blocks and the purchase of new equipment. The third section collected information about attitudes to and perceptions of GCTB and decision-making factors and information sources, which will be useful for the extension component of the project. A final section was devoted to collecting farmers' observations about GCTB, by making note of comments made during interviews.

4.3 Field trials

Three field trials were conducted in the Proserpine area to investigate the effect of GCTB on furrow irrigation efficiency. All trials used Q124, the most popular variety in the Central district. The details of these trials are given in Table 2.

Table 2: Trial site details and characteristics

	Muller	**Ruddell**	**Orr**
Location	Crystalbrook	Strathdickie	Crystalbrook
Soil type	Koolachu	Benholme	Koolachu
Surface texture	Sodic sandy loam	Cracking clay	Sodic sandy loam
Subsoil	Medium clay	Medium-heavy clay	Medium clay
Depth (cm)	60-100	100+	60-100
Crop cycle	2nd Ratoon	2nd Ratoon	n/a
Slope (%)	0.00495	0.00158	0.00425
Site length (m)	304	290	n/a

The Muller and Ruddell trials were monitored to assess the effect of trash blankets on waterlogging duration, stalk elongation and harvest yields. Waterlogging events were logged using field instrumentation, and growth measurements and water-table depths were recorded every 1-2 days. As well as using harvest yields to gauge the waterlogging effect, growth differences for different conditions were also measured.

The Orr trial was established to investigate the effect of GCTB in furrow irrigation, and to investigate relationships between the trash mass and the hydraulic resistance parameter, Manning's n, which is used in surface irrigation models.

Due to the widespread outbreak of orange rust throughout the Proserpine district in Q124 in the 1999-2000 season, it was decided that alternative field sites would be used for the 2000-2001 season. Q124 in the field trials performed extremely poorly in the 1999-2000 season and the entire district was aiming to reduce the use of this variety significantly. In addition, the growers whose blocks were used for field trials were also not keen to see the trials continue, given the quality of the Q124 crop.

The new varieties chosen were Q138 and Q135. Q138 was a popular alternative variety to Q124 in the wetter areas of Proserpine. Growth measurements, waterlogging periods, water-table depths and soil moisture readings were monitored throughout the season. The details of the field sites are given in Table 3.

Table 3: Site details and characteristics for new trial sites

	Penhallurick	**Simpson**	**Faletti**
Location	Conway	Strathdickie	Proserpine
Variety	Q138	Q138	Q135
Soil name	Preston	Victoria Plains	St Helens
Soil type	Duplex	Cracking clay	Alluvial
Aust soil class	Grey dermosol	Black vertosol	Brown dermosol
Surface texture	Gravelly clay loam	Cracking clay	Sandy-clay loam
Subsoil	Yellow-brown clay	Med-heavy clay	Grey-brown clay
Depth (cm)	<60	150+	120+
Crop cycle	1st ratoon	1st ratoon	1st Ratoon
Slope (%)	2% (up to 5.5%)	0.2 %	0.5 %
Site length (m)	500 m	280 m	250
Trash situation*	GCTB	Burnt	GCTB

*****Indicates whether the grower normally practises GCTB or a conventional burnt system on the field site.

4.4 Modelling (APSIM)

Originally it was intended that APSIM (an agricultural production simulator) would be used to investigate the effect of trash retention on crop production, soil water usage and some basic nutrient analysis. From this analysis, and historical yield data from GCTB and burnt cane trials, the effect of trash retention on profitability was investigated for different climatic regions and soil types.

Investigation into the use of APSIM for determining the effect of trash retention on yield ran into an unexpected problem that is yet to be resolved. Investigation of short-term analysis revealed that, in all years, the amount of trash at harvest is up to 2000 kg/ha higher for the burnt cane simulations than the GCTB simulations. Originally this was believed to be a problem associated with the leaf detachment function in APSIM; however, it is now believed to be due to differential breakdown rates of the newly detached leaves as demonstrated in Figure 1.

This problem was raised with APRSU and CSIRO staff, who were able to replicate the results in both the APSFront and full APSIM environments. Further simulations (Figure 2) revealed a large difference (up to 300 kg/ha) in the total nitrogen in the first soil layer. It is believed that this would impact on the C:N ratio of the residue and result in faster breakdown of the trash in the GCTB simulations. It has also been noted that the residue contribution to soil N as the pool breaks down is greater for the GCTB scenarios.

Figure 1

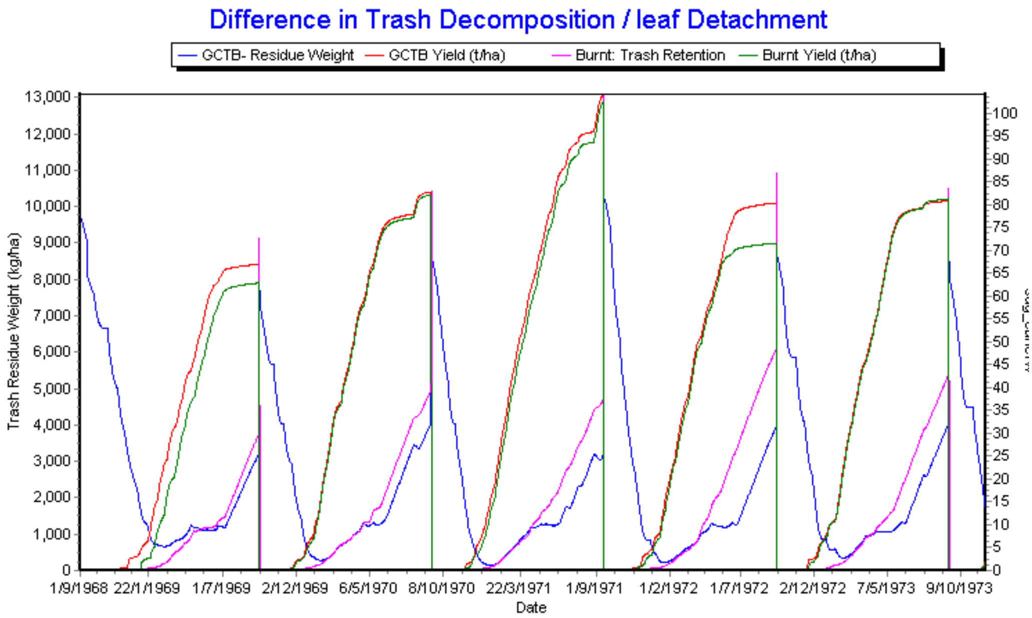
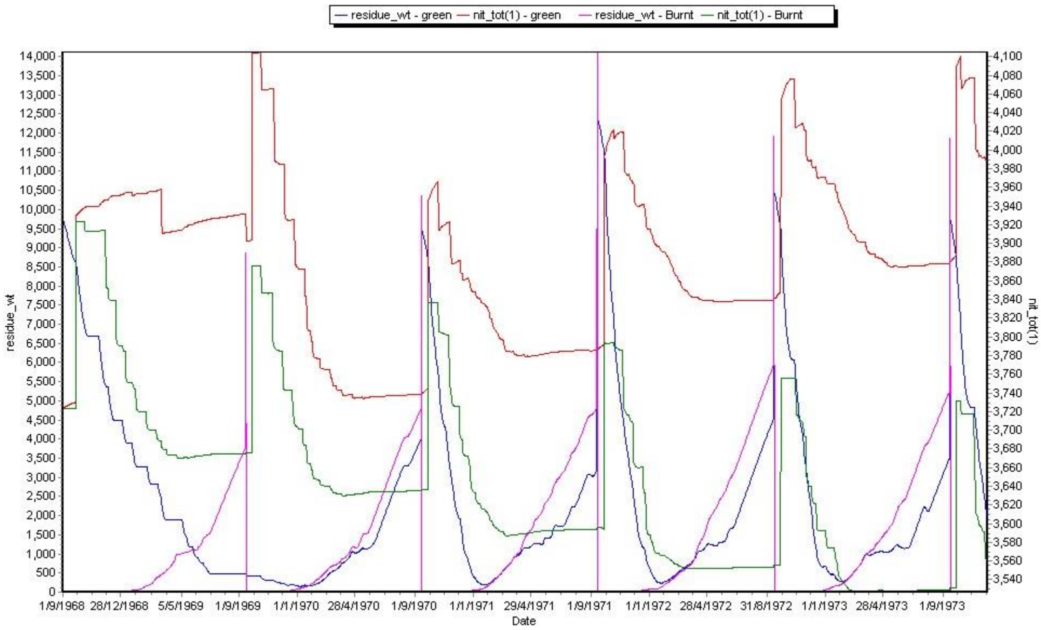


Figure 2
Trash decomposition in green and burnt simulations



While this explanation may be valid and the outcomes of the modelling realistic, there is a need for further scrutiny of both trash decomposition and leaf detachment rates before analysis of yield or soil moisture differences with trash management could be conducted with a high degree of certainty.

4.5 Mapping

GIS was used to identify areas where GCTB would be suitable for Proserpine and areas of the Burdekin River Irrigation Area (BRIA), mapped at an individual farm block scale. If undertaken manually, the mapping process would have been significantly prolonged, given that there are in excess of 6,000 farm blocks in Proserpine alone. For Proserpine, land resource data from the Proserpine Integrated Land Use Study and the Mackay Sugar Cane Land Suitability Study were used, whereas for the BRIA, data were obtained from the Department of Primary Industries soils information database. No data were available for the Burdekin Delta. Farm block maps were overlaid on the land resource maps to link the limitation data for every farm block, as can be seen in Figure 3.

Figure 3
Map of farm blocks overlaid on the soil UMAs

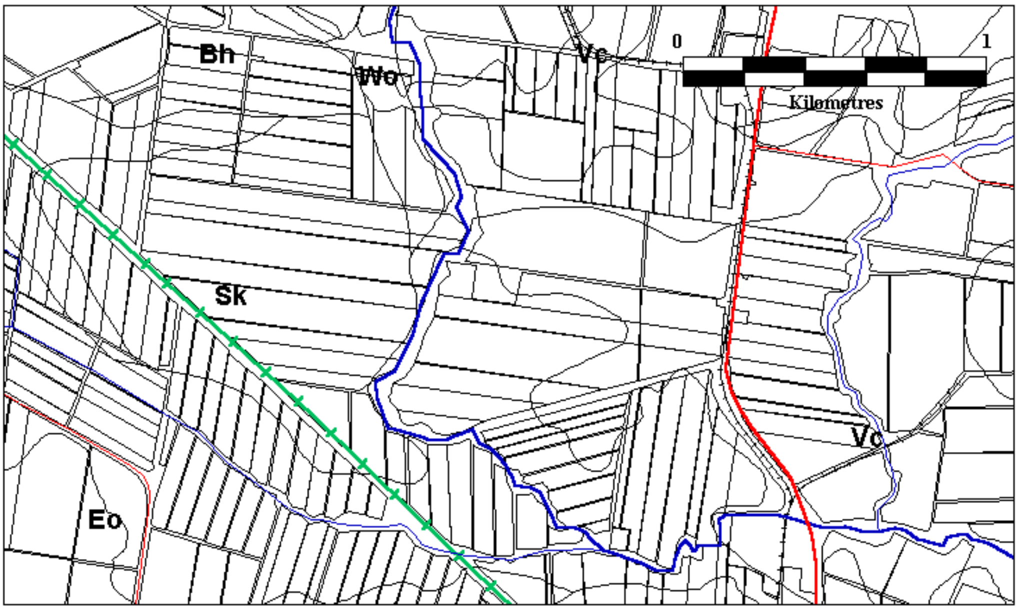
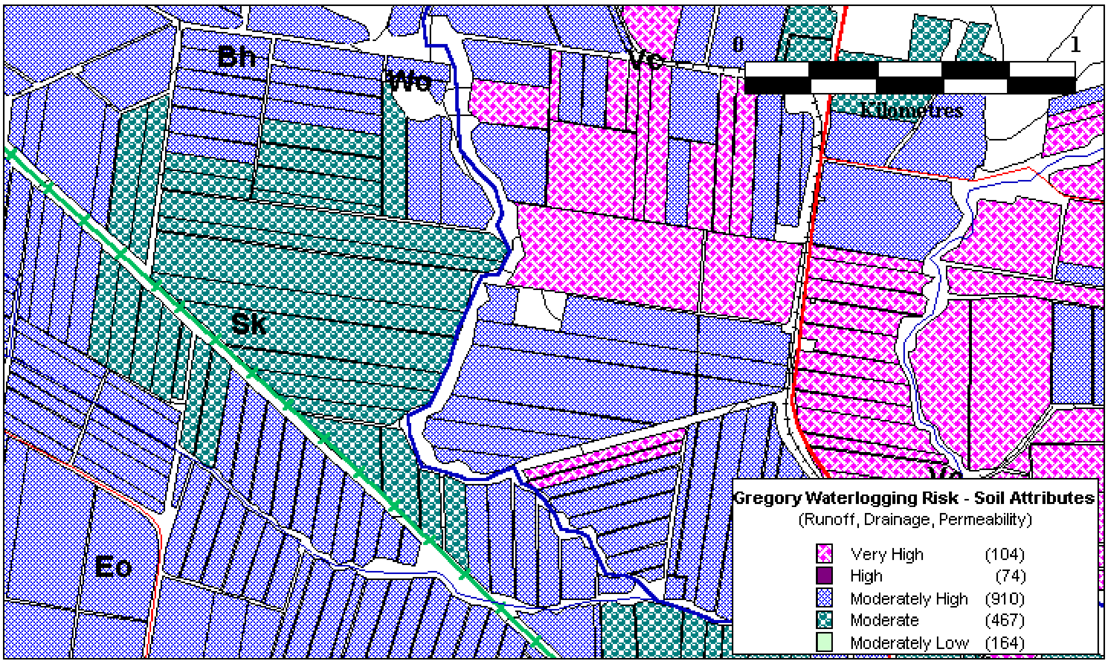


Figure 4:
Map of GCTB waterlogging risk associated with soil characteristics



Suitability information for the GCTB maps was derived from biophysical attributes of each UMA (Unique Mapping Area) on the suitability maps. A UMA represents a region of similar soil and land characteristics, and is named after the dominant soil type (Hardie, pers. com.). Information generated from each UMA includes data on soil characteristics such as slope, sodicity, drainage and soil water availability.

Land suitability classes for each UMA were ranked into suitability classes from 1 to 5, with class 1 representing land with no or negligible limitations, and class 5 representing unsuitable land with extreme limitations. Suitability and risk classes for GCTB were then produced for each UMA. The classes were created using an expert panel, which contained local growers, BSES and CPPB staff, and staff involved in the Proserpine Integrated Land Use Study.

Map suitability classes were varied as appropriate for each region due to availability of data and suitable methods for presentation. Different environmental criteria between regions also affect the suitability of GCTB, as is highlighted in Figure 4, showing the marked difference in GCTB adoption between the regions. For Proserpine, the limitation data presented in Tables 4 and 5 were used.

Table 4: Biophysical attributes of GCTB suitability determination for Proserpine and BRIA

	Runoff		**Drainage**		**Permeability**		**Modal slope, %**		**PAWC, mm**		**Erosivity**	
Range	1-4		1-5		1-4		0 - > 6		20 – 150		1 – 5	
	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value
	1 2 3 4	Very slow Mod. rapid Rapid Very rapid	1 2 3 4 5	Poor Imperfect Mod. good Good Rapid	1 2 3 4	Very slow Slow Moderate High	1 2 3 4 5 6	0 - 0.5 0.5 - 1 1 - 1.5 1.5 - 2 2 - 6 >6	1 2 3 4 5 6	126-150 101-125 76-100 61-75 41-60 0-40	1 2 3 4 5	All soils < 1% slope Unif, Grad, NonSD 1-2% slope Sodic Duplex 1-2% slope Unif, Grad, NonSD 2-4% slope Sodic Duplex 2-4% slope
Data: Min, Max	1	4	1	5	1	4	0	>6	20	150	1	5
Meaning	Very slow	Rapid	Poor	Rapid	Very slow	High	No slope	High slope	Low soil water	High soil water	No erosion	High erosion
GCTB Risk	High	Low	High	Low	High	Low	High	Low	Low	High	High#	Low
GCTB Suitability	Low	High	Low	High	Low	High	Low	High	High	Low	Low	High

 # Regarded as a high risk because of the slope, not the erosion characteristics

It is important that values are ranked from 1 to 4+ in increasing order of GCTB suitability, ie GCTB is much more suitable for a PAWC (Plant Available Water Capacity) with a ranking of 4 than for a PAWC with a ranking of 1.

Table 5: Biophysical attributes of GCTB suitability determination for Proserpine and BRIA

	Landform element		Block length, m		Topsoil clay, %		Fertility		Sodicity, ESP		Rockiness	
Range	1 – 5		0 – 1400		<10% - >50%		Very Low -High				<10% - >50%	
	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value	Index	Value
	1 2 3 4 5	Floodplain Terrace Slope Rise Steep	1 2 3 4 5	> 800 800-601 600-401 400-201 200-0	1 2 3 4 5 6	< 10% 10-20% 20-30% 30-40% 40-50% > 50%	1 2 3 4 5 6	High Mod High Moderate Mod Low Low Very Low	0 1 2 3 4 5	<6 6-14 14-20 20-30 30-40 >40	0 1 2 3 4	No cobble; <20% gravel <2% cobble 20-50% gravel; 2-20% cobble 50-90% gravel; 20-50% cobble >90% gravel; >50% cobble
Data: Min, Max	1	5	< 200	> 800	5	55	1	6	0	>40	0	4
Meaning	Flat or flooded	High slope or well drained	Short	Long	Low clay Topsoil	High clay topsoil	High fertility	Very low fertility	Low ESP	High ESP	No rocks	High frequency of rock cover
GCTB Risk	High	Low	Low	High	Low	High	Low	High	Low	High	Low	High
GCTB Suitability	Low	High	High	Low	High	Low	High	Low	*	High	*	High

** Low sodicity and/or rockiness soils and are dependent on other factors to determine GCTB suitability*

For Proserpine, the suitability of GCTB is dependent on both biophysical attributes and management factors. Hence, several maps for each region were produced to represent different land, climatic and management features. Features included waterlogging risk and furrow irrigation suitability. Many areas, particularly in Proserpine that had keenly adopted GCTB, were rated as a waterlogging risk, such as cane grown on a poorly drained sodic duplex. Maps were also produced showing where GCTB would be expected to be beneficial. Map attributes were summed and weighted and ranked from Very Low (Risk or Benefit) to Very High. Economic benefit maps were also created for the Proserpine district using the growers' survey data collection. However, detailed maps of the Burdekin district were unable to be generated due to insufficient geographic data being available for the district.

5.0 RESULTS AND DISCUSSION

5.1 Community survey

Off-site impacts were also addressed for the cost-benefit analysis. One of the possible off-site impacts of burning cane prior to harvest is the potential health hazard of smoke emissions. The impact of the smoke was measured through a survey made of doctors with a general practice from Mackay to Mossman. This included doctors practising in areas south of the Burdekin where there has been a recent reduction in the amount of burning; in areas north of the Burdekin where nearly all burning of cane prior to harvest has ceased, and in the Burdekin area where the majority of cane is still burnt prior to harvest. Doctors in the Townsville area were excluded from the survey. Doctors were asked if they thought that there were any health-related changes connected with the increase in green cane harvesting. In recognition of their busy schedule, they were contacted by mail and asked to respond at their convenience. Those doctors who responded were keen to point out that their opinions were based only upon anecdotal evidence, and any suggested connection did not imply a causal relationship. It was also commonly pointed out that it was unrealistic to make any generalisations about a possible connection between asthma and smoke emissions. On the one hand, the incidence of asthma is increasing in Australia generally, and on the other, asthma is being better managed, resulting in less case presentations to doctors.

It is known that as the population gets older there will be an increasing number of people with breathing related problems and any increase in particulate matter in the air will adversely affect people with such problems. However, there was no clear evidence from doctors that there were health impacts directly related to burning cane (see Appendix 5). Some concern was voiced over recent increases in the incidence of leptospirosis and a possible link to reduced burning, but a recent study showed these increases were not connected with the sugar industry (see Appendix 6). Evidence from this survey provided inconclusive results, but did not indicate that further investigation was warranted.

Principally, local residents feel the off-site impacts of smoke and particulate emissions. Initially, attempts were made to estimate the value of clean air to the community, through an application of the Contingent Valuation Method (a method applied in environmental economics to place a monetary value on a non-market environmental good). Considerable time was invested in developing the method, but after careful consideration and with advice from other professional economists, the method was deemed too limited for the intended purpose. While the method would result in a value that the community places on clean air, the legitimacy of any estimated value would always be disputed, because the method itself invokes much discussion in the scientific literature. In addition, the method of acquiring such a value is quite rigorous and yields little additional information. It was decided to develop a more general survey and explore community attitudes to smoke emissions in more detail.

A questionnaire survey was developed and mailed out to 10% of households in the Burdekin and Whitsunday Shires. The results of the survey are attached in Appendix 7. Overall, the responses to most sections of the community survey were similar in both districts. However, respondents in the Burdekin district did demonstrate better knowledge of the advantages and disadvantages of GCTB. This is probably due to Burdekin respondents typically being more closely aligned to the sugar industry. Burdekin respondents live closer to cane paddocks and either work in or have family members who work in the sugar industry.

Initially, it was expected that Burdekin Shire respondents would be more tolerant of smoke and ash emissions because sugar is such an important part of the local economy, while the Whitsunday respondents would be less tolerant, because they would be more concerned about general pollution. However, the survey results indicated that respondents in the Whitsunday Shire were less affected by smoke and ash emissions, and consequently were more tolerant of the lower level of emissions, compared with respondents in the Burdekin Shire.

The fact that Burdekin respondents live closer to cane paddocks is likely to be a contributing factor to them being more personally affected by smoke and ash. In the Whitsunday region, the minority of the community sample was affected personally by smoke and ash emissions, while in the Burdekin district this group was the majority.

The respondents in each region identified different concerns associated with smoke and ash emissions from the two regions. Almost half of the Burdekin respondents identified ‘extra cleaning’ as the major issue, with ‘health problems’ and ‘nuisance’ as the other main reasons for being affected by smoke and ash. The largest group in the Whitsunday sample (24%) indicated that they were personally affected by ash because it is a nuisance. Other reasons for being affected were health related problems, cleaning and poor visibility on roads.

The majority of Whitsunday respondents did not see cane fires as being important tourist attractions, while the majority of Burdekin respondents did. Burdekin respondents were concerned that smoke and ash gave the area a ‘dirty’ appearance to visitors, while Whitsunday respondents were more concerned that visitors would suffer asthma and other breathing problems caused by smoke and ash. Whitsunday respondents were also concerned about the danger on roads due to poor visibility in smoke.

Respondents in both districts generally believed that it would be a good idea to reduce smoke and ash in the area and, although they mostly agree that burning should not be banned completely, growers should not be free to burn cane or trash as they wish.

The survey found that there is a high level of knowledge of GCTB in the Burdekin, which reflects the close connection between the community and the sugar industry. Although there is not the same level of knowledge of GCTB in the Whitsunday Shire, residents there are less settled and live further away from cane paddocks than Burdekin respondents. Fifty-eight per cent of respondents in the Burdekin Shire either work themselves, or have a family member that works in a sugar-related industry, compared with 23% in the Whitsunday Shire.

A high percentage of respondents from both regions knew the various benefits of GCTB, such as reducing soil erosion and suppressing weed growth. Burdekin respondents were more aware of the problems associated with trash blankets than Whitsunday respondents. Sixty-eight per cent of Burdekin respondents knew that it costs more to harvest green cane than burnt, while only 38% of Whitsunday respondents knew this. Only 40% of the respondents from the Whitsunday region knew that a major benefit of trash blankets is reduced cultivations, while almost two-thirds of Burdekin respondents knew this. Further data analysis showed that respondents who did not know about various problems associated with GCTB demonstrated a more aggressive attitude towards smoke and ash emissions. The findings from this survey were presented in a paper at the 2001 Australian Society of Sugar Cane Technologists Conference in Mackay.

5.2 Growers' survey

Production costs of both burnt and GCTB cane in Proserpine were found to be lower than in the Burdekin. However, profits were significantly higher for Burdekin growers in both GCTB and burnt crops. The full results from this survey were published as a BSES internal report in 2000. This report is attached in Appendix 8.

Labour costs are included and the sugar industry award rates were obtained from the Department of Employment, Training and Industrial Relations (Paul Gwydir, DETIE personal communication, August 1999).

Data from the survey for fertiliser, chemical, tractor and implement costs were used to calculate total costs of each farm activity for each farm surveyed. The costs shown in the following tables are averages across all farms surveyed and do not represent any one typical farm.

5.2.1 Burdekin district

Average yield for the 1999 season was used in these calculations, because individual farm yields were not available at the time of this report. Cane yields ranged from 112 tonnes per hectare to 124 tonnes per hectare in the 1999 season. For the purpose of this analysis, a cane yield of 116 tonnes per hectare with a commercial cane sugar (ccs) of 15 units was used.

The calculated average production costs, income and profits of both burnt and GCTB cane in the Burdekin are shown in Table 6. The differences between each system are also shown in the right-hand column of the table. As indicated (Table 6), it costs $46.48 more per hectare to grow a plant crop under GCTB, while in a ratoon crop it is $67.33 per hectare cheaper to grow cane under GCTB. The gross margin in GCTB is also $46.48 per hectare less than burnt cane in a plant crop, while in a ratoon crop the gross margin in GCTB crops is $67.33 per hectare higher than burnt crops.

Table 6: Average production costs, income and gross margins in the Burdekin district

Cost	GCTB $/ha	Burnt $/ha	Difference (G-B)
Land preparation			
Pre-plant	151.09	154.49	-3.40
Post-plant	43.10	28.68	14.42
Ratoon	14.02	29.61	-15.59
Planting	335.51	340.15	-4.64
Fertiliser			
Planting	238.48	276.58	-38.11
Post-plant	254.63	240.49	14.13
Ratoon	224.84	332.27	-107.43
Herbicides			
Plant	80.82	60.30	20.52
Ratoon	50.42	50.81	-0.40
Insecticides	77.34	89.86	-12.52
Irrigation	233.32	228.99	4.33
Harvesting	661.25	609.50	51.75
Total cost:			
Plant	**2075.53**	**2029.05**	46.48
Ratoon	**1183.85**	**1251.18**	-67.33
Income	**2982.36**	**2982.36**	
Cane price	**25.71**	**25.71**	
Gross margin:			
Plant	**906.83**	**953.31**	-46.48
Ratoon	**1798.51**	**1731.18**	67.33

Costs were calculated for each farm activity as follows:

Land preparation
The cost of land preparation includes tractor and implement costs, as well as the labour for the tractor operator. Common methods of pre-plant land preparation include one or two rippings, one or two discings and one rotary hoe pass. This cost assumes that the land is already in cane production, and therefore does not include costs of land clearing, laser levelling or plough-out.

Post-plant land preparation includes standard activities such as cutaway, grubbing, strawberry harrow and filling-in. Ratoon land preparation included some cultivations or trash incorporation.

Planting
Planting costs are either the price paid to a contractor, or the cost of planting by the farmer. If the grower plants his/her own cane, the cost used includes the labour for all of the workers involved, the cost of running the tractor and planter, and the cost of planting material (seed cane).

Fertiliser
The fertiliser costs are calculated using 1999 fertiliser prices. The value of fertiliser at planting is the cost of fertiliser alone, while the post-plant and ratoon fertiliser cost includes the fertiliser cost as well as tractor, implement and labour costs.

Ameliorants
Ameliorants include lime, gypsum, mill mud and ash. In the Proserpine district, this cost also includes the application of dunder. Contractors apply these and the cost shown in this report is a reflection of the price charged by the contractors.

Herbicides
Herbicide costs were also calculated using 1999 chemical prices, and includes the cost of chemicals, tractor, implement (boom spray) and labour.

Insecticides
The insecticide costs shown in this analysis vary between the two regions. The insecticide cost in the Burdekin district is incurred in the plant crop only because it represents the application of suSCon during planting. In the Proserpine district, the insecticide cost is incurred in ratoon crops only because it represents the application of chemicals such as Lorsban® for the control of army worms. This cost includes the chemical, tractor, implement and labour costs involved with the chemical application.

Irrigation
Irrigation costs were difficult to calculate and compare between farms. Depending on the source of irrigation water, they could pay up to $40 per megalitre for water, while others do not pay anything at all. Another difficulty experienced in calculating this cost was the fact that most growers do not know how much water they use to grow their crops. This was overcome by asking growers to estimate their water use, which means there are some inaccuracies in these costs.

Harvesting
Harvesting costs are calculated by multiplying the cane yield per hectare by the contract price of harvesting per tonne. This method was also used for calculating the harvesting cost for the few growers who harvested their own cane.

Income and profits for each farm were calculated, and finally average cost, income and profits were calculated for the two systems, burnt and GCTB farms, in each district. Cane prices were calculated using the 1999 sugar price of $255 per tonne (CANEGROWERS, December 1999, *The Burdekin District CANEGROWER*).

5.2.2 Proserpine district

Farm numbers were recorded during interviews and yields were then linked to cost data to calculate average income and profits for Proserpine growers. The average costs, income and profits of both burnt and GCTB systems in Proserpine are shown in Table 7. From this information it can be seen that it costs $16 more per hectare to grow a plant crop under GCTB, while in a ratoon crop it is $12.74 per hectare cheaper. The gross margin is $63.09 per hectare higher for a burnt system in a plant crop, while in a ratoon crop it is $34.34 per hectare higher than GCTB systems. The gross margin of GCTB cane in the Burdekin was lower than burnt cane in the plant crop, but higher in ratoons.

Table 7: Average production costs, income and gross margins in the Proserpine district

Costs	GCTB $/ha	Burnt $/ha	Difference (G-B)
Land preparation			
Pre-plant	160.15	149.92	10.23
Post-plant	79.46	0.00	79.46
Ratoon	0.00	11.20	-11.20
Planting	221.66	229.50	-7.84
Fertiliser			
Planting	327.05	322.20	4.85
Post-plant	246.82	223.25	23.57
Ratoon	136.58	180.00	-43.42
Insecticides			
Plant	66.67	73.50	-6.83
Ratoon	71.06	32.50	38.56
Pesticides	10.57	13.21	-2.64
Ameliorants	161.04	228.00	-66.96
Irrigation	43.42	79.20	-35.78
Harvesting	520.49	491.97	28.53
Total cost:			
Plant	**1826.75**	**1810.75**	16.00
Ratoon	**782.12**	**794.87**	-12.75
Income	**1907.08**	**1954.17**	-47.09
Gross margin			
Plant	**80.33**	**143.32**	-63.09
Ratoon	**1124.96**	**1159.30**	-34.34

5.2.3 Growers' decision making tools and opinions of GCTB

Production costs of both burnt and GCTB cane in Proserpine were lower than in the Burdekin; however, profits were significantly higher for Burdekin growers in both GCTB and burnt crops.

The profit of GCTB cane in the Burdekin was lower than burnt cane in the plant crop, but higher in ratoons. The reverse of this was the case for Proserpine growers.

Waterlogging and irrigation difficulties were the primary cause for concern in using GCTB among surveyed growers, while cost savings in labour, water and chemicals, as well as improved soil quality were the most important benefits of using GCTB. Another major benefit of GCTB was the removed risk of having rain after the cane has been burnt, leaving it in the paddock waiting to be harvested when it becomes dry enough, resulting in lowered yields.

Burdekin growers who already farm using traditional burning methods had an extremely negative view of GCTB, while growers who burnt their cane in Proserpine were not so negative and often burnt their cane because of biophysical factors including soil type. Many of these growers had farms or blocks in areas suitable to GCTB and welcome its benefits.

Growers in both districts who use GCTB emphasised the fact that they had dramatically reduced their labour input on the farm, which gave many of them more time to pursue additional employment or to engage in recreational activities.

The majority of growers in both districts indicated that they get most information about new farming methods and technologies from other farmers and also rely heavily on their past experience. They also like to receive this information through publications such as BSES Bulletins and handbooks, and seeing demonstrations on farms or at field days.

5.3 Field trials

The initial trials undertaken in Proserpine were performed over a two-year period, after which the prevalence of orange rust in Q124 forced the trials to be terminated. The trials were located on a sodic duplex soil, where GCTB had been keenly adopted, and on a cracking clay soil, where GCTB was seen as a risk due to increased inundation periods. Harvest results can be seen in Tables 8 and 9. The GCTB treatment produced significantly greater yields in both seasons on the sodic duplex soil. On the cracking clay soil (Table 9), the burnt treatment produced greater (not significant) yields from the 1999 harvest, yet a significantly greater yield was obtained from the GCTB treatment in the 2000 harvest. It should be noted that yields for both trials were reduced for the 1999-2000 season due to the appearance of orange rust in Q124.

Table 8: Average harvest yield results for sodic duplex soil trial

	1998-1999 (1st Ratoon)		1999-2000 (2nd Ratoon)	
	Burnt	**GCTB**	**Burnt**	**GCTB**
Cane (t/ha)	72.50[a]	83.69[b]	46.92[a]	53.07[b]
ccs	16.94	16.63	14.83	14.36
Sugar (t/ha)	12.28[c]	13.93[d]	6.97[c]	7.63[d]

Values with the same index within years were not significantly different (p=0.05)

Table 9: Average harvest yield results for cracking clay soil trial

	1998-1999 (1st Ratoon)		1999-2000 (2nd Ratoon)	
	Burnt	**GCTB**	**Burnt**	**GCTB**
Cane (t/ha)	66.44[a]	62.30[a]	62.29[a]	67.15[b]
ccs	16.86	16.69	14.61	14.83
Sugar (t/ha)	11.20[c]	10.42[c]	9.10[c]	9.96[d]

Values with the same index within years were not significantly different ($p=0.05$)

5.3.1 Effect of trash on waterlogging

No consistent growth rate trend was obvious in the sodic duplex soil during the December 1999 to March 2000 rainfall events (Figure 5), because water-table depths were fairly similar. However, it can be seen that the GCTB cane growth rates were superior to the burnt cane growth rates during the early season measurements when the water-table was below 1 m. Figure 5 illustrates the dominance of GCTB or burnt cane compared to water-table depths during the 1999-2000 season.

GCTB growth rates were superior to burnt growth rates in the cracking clay soil during the November to January period, when the water-table was rarely at the surface (Figure 6). When the water-table was at or near the surface during this period, the GCTB growth rates were similar to or less than burnt growth rates.

During the February to March period growth rates were similar; however, GCTB produced equal or slightly greater growth rates for the whole of March. It should be noted that growth rates for the November to January period for both treatments were 15-40 mm/day, whereas growth rates for the February to March period were less than 10 mm/day. The differences in water-table depths between the two treatments demonstrated that GCTB retained moisture in the soil profile for greater periods than a burnt system at this site.

Inundation periods for the GCTB and burnt systems in the sodic duplex soil (Tables 10 and 11) were similar in both years. Inundation periods in the cracking clay soil were also similar in 2000. However, the burnt treatment received significantly greater inundation than the GCTB treatment in 1999. Contrary to popular perceptions, the results showed more inundation on the sodic duplex than the cracking clay soil in both years. The effect was significant for both GCTB and burnt systems in 1998-99 (Table 10) but not significant for either treatment in 1999-2000 (Table 11). The differences in inundation periods between the soil types were due to the low PAWC and shallow A-horizon of the sodic duplex, compared to the cracking clay.

Figure 5:
Differences between cane grown under GCTB and burnt systems compared to water-table depths for sodic duplex soil trial (2R 1999-2000)

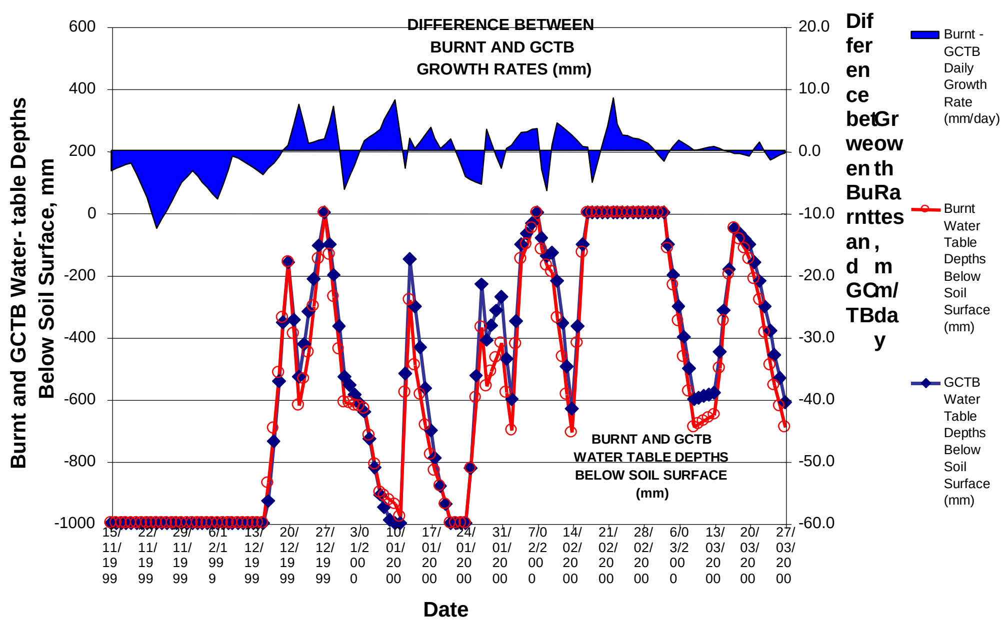


Figure 6:
Differences between cane grown under GCTB and burnt systems compared to water-table depths for cracking clay soil trial (2R 1999-2000)

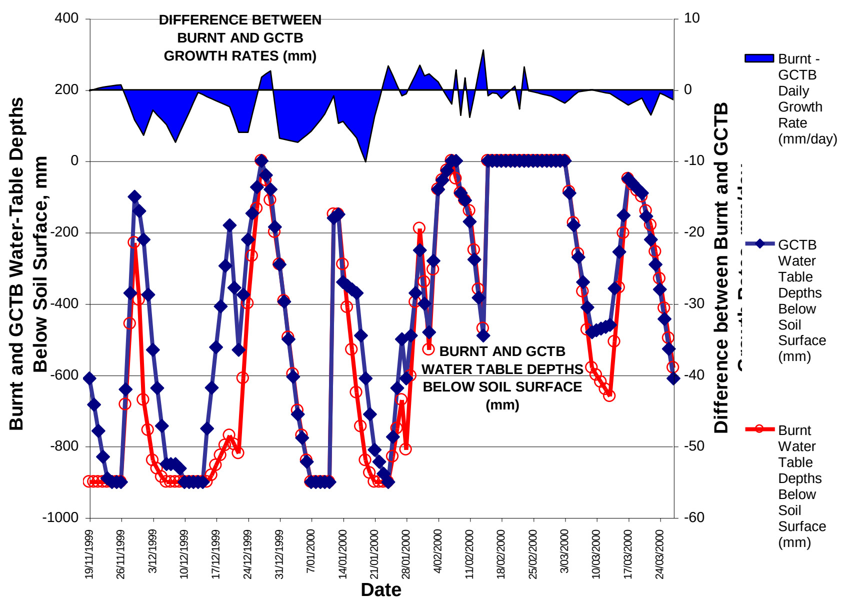


Table 10: Average inundation per day for the period 7/1/1999 to 14/3/1999

	Trial 1(Sodic duplex soil)		Trial 2 (Cracking clay soil)	
	GCTB	**Burnt**	**GCTB**	**Burnt**
Inundation h/day	13.1[a]	12.6[a]	9.2[b]	10.5[c]
Rainfall* mm	988[d]		1058[d]	

***Rainfall is for the inundation measurement period only.**
Values with the same index were not significantly different (p=0.05)

Table 11: Average inundation per day for the period 11/1/2000 to 29/3/2000

	Trial 1(Sodic duplex soil)		Trial 2 (Cracking clay soil)	
	GCTB	**Burnt**	**GCTB**	**Burnt**
Inundation h/day	9.9[a]	9.8[a]	8.7[a]	8.7[a]
Rainfall* mm	1123[d]		1008[d]	

*Rainfall is for the inundation measurement period only.
Values with the same index were not significantly different (p=0.05)

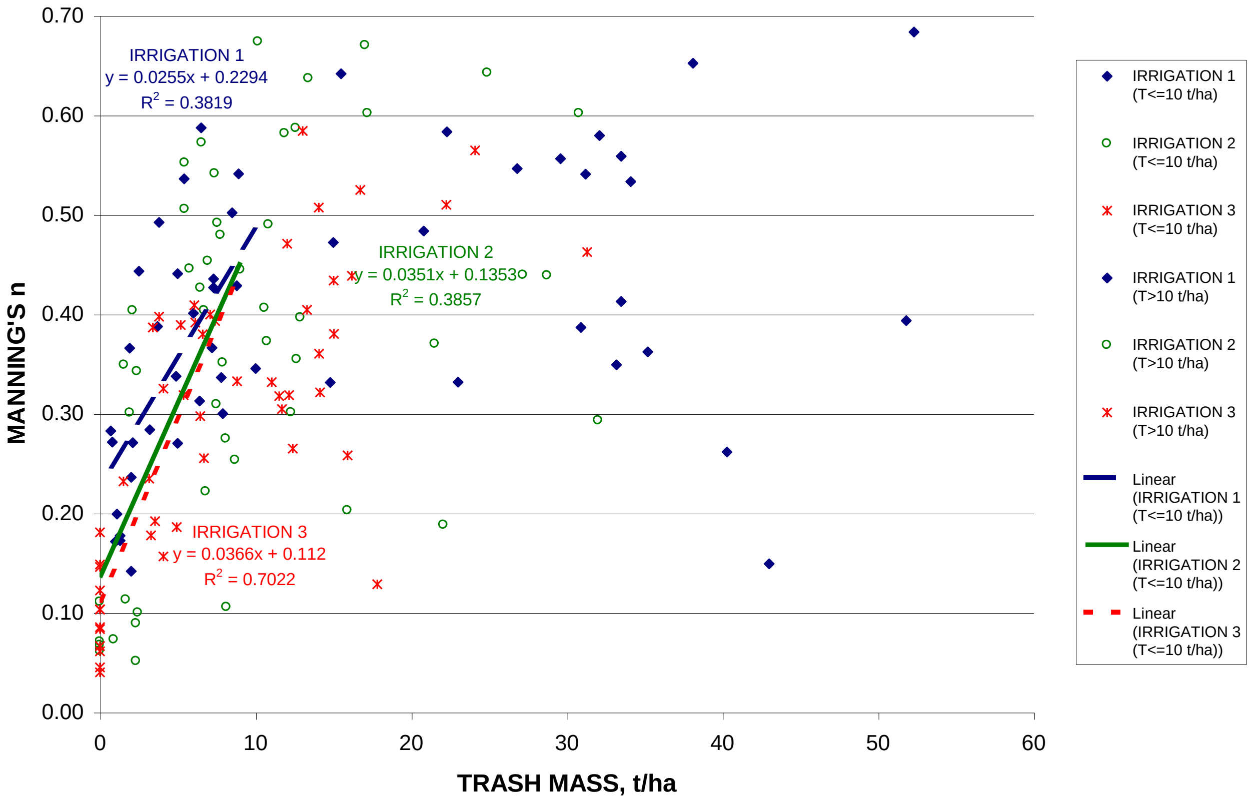
Results presented in Table 12 show that the hydraulic resistance (Manning's n) decreased in association with the decomposition of the trash blanket as the season progressed. During the measurement period, observed settling of trash allowed more water to flow over, rather than under and through (and in some cases transporting) the trash blanket. This trash settling also contributed to a reduced Manning's n.

Table 12: Average Manning's n for each irrigation

Irrigation event	Average trash mass, t/ha	Average Manning's n
Irrigation 1 – 5/11/1999	12.44[a]	0.397[x]
Irrigation 2 – 16/12/1999	9.96[b]	0.376[x]
Irrigation 3 – 21/1/2000	8.07[c]	0.293[y]

Values with the same index were not significantly different (p=0.05)

Figure 7:
Manning's n versus trash mass results for the furrow irrigation trial

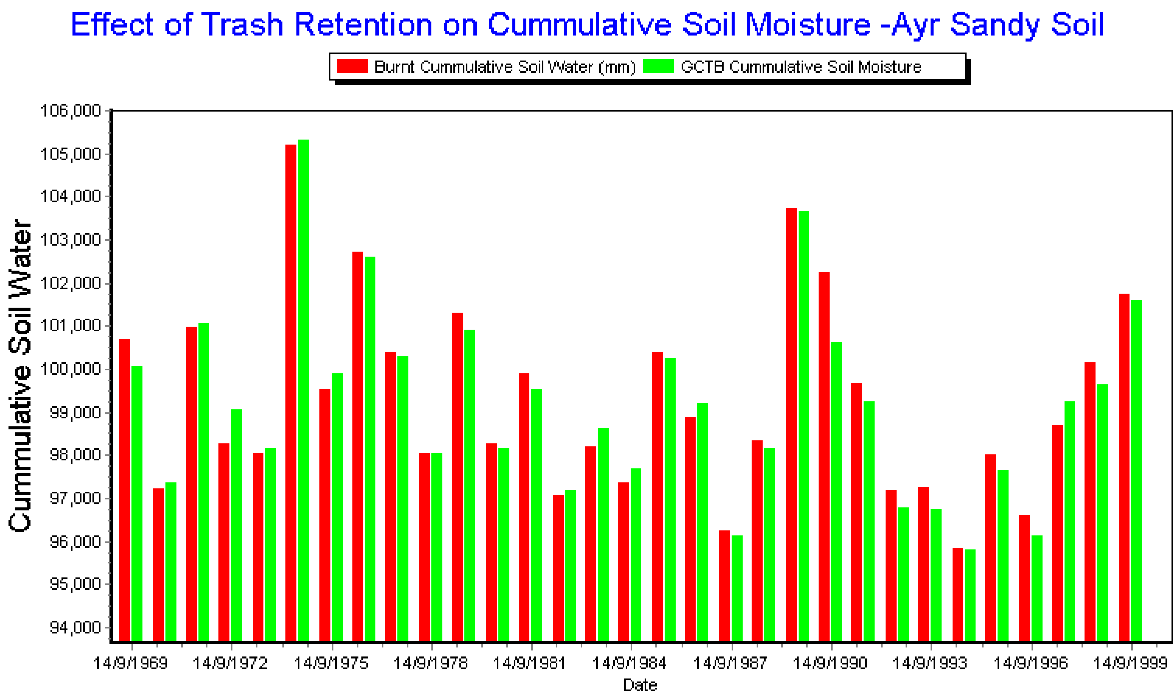


Polynomial curves, linear regressions and bent stick regressions were fitted to the three sets of data shown in Figure 7. (Linear regression only fits points where trash mass < 10 t/ha). A firm relationship between Manning's n and the trash mass could not be established; however, the Manning's n values presented in Table 12 did not differ significantly between trash masses of 9.96 t/ha and 12.44 t/ha. This indicated that as the trash mass exceeded 10 t/ha, the Manning's n began to plateau out. Despite some outlying points, the data indicate that the point at which additional trash become negligible with respect to Manning's n is between 10 and 20 t/ha.

5.4 Modelling (APSIM)

A 31-year simulation based on the Ayr DPI climate station and a sandy soil, which is thought to be similar to the alluvial soils in the Burdekin Delta, was conducted to investigate the difference in yield and soil moisture storage of GCTB systems. Analysis in Figure 8 demonstrates that differences in the predicted yield were less than 10 t/ha and usually less than 5 t/ha. Analysis reveals the GCTB had greater than 3 t/ha yield advantage over the burnt system in nine out of 31 years, while the burnt system yielded greater than 3 t/ha more cane in seven out of 31 years. Neither system yielded more than 3 t/ha difference in 15 of 31 years.

Figure 8:



Yield results correlate with the soil moisture analysis, which demonstrates that GCTB may or may not result in higher soil moisture storage depending on the cropping year. This was unexpected and needs field validation before APSIM predictions can be more widely extended.

In conjunction with trial research, APSIM was used to develop best practice guidelines for managing GCTB problems, in particular, furrow irrigation. A useful tool for extension officers to use, when advising growers on how to manage a change to GCTB, is the manual contained in the report “Furrow Irrigation Optimiser” (Appendix 9). This document contains look-up tables that extension officers can use to assist growers wishing to change from burnt cane production to GCTB. Initially these tables were developed to reflect typical conditions for the BRIA and Delta regions of the Burdekin. Interest amongst extension officers in the Central district resulted in the inclusion of further soil types and a larger range of slopes and furrow lengths, so that these tables could be used throughout the sugar industry. As interest grew in the project, it was decided to make the table more universally applicable to a larger range of soil types, field conditions and trash management.

Economic data were also added to some general APSIM runs to provide an assessment of profitability and risk of trash retention in both the Burdekin and Proserpine districts. Results from these simulations are shown in Tables 13 and 14.

Table 13: Combined APSIM and cost data results

	Burnt			GCTB		
	Yield t/ha	GM $/ha	GM $/tonne	Yield t/ha	GM $/ha	GM $/tonne
Sandy soil	148.31	2552.20	17.10	150.26	2648.79	17.57
Clay soil	172.92	3209.17	18.44	174.57	3297.70	18.92
Heavy clay	164.09	2973.36	18.03	169.10	3151.74	18.58
Kalamia	137.43	2417.34	17.59	123.42	2110.64	17.10
Silt	185.25	3693.94	19.94	172.88	3431.05	19.85

Table 14: Differences between burnt and GCTB

	Difference (G-B)		
	Yield t/ha	GM $/ha	GM $/tonne
Sandy soil	1.95	96.59	0.47
Clay soil	1.65	88.53	0.48
Heavy clay	5.01	178.38	0.55
Kalamia	-14.01	-306.7	-0.49
Silt	-12.37	-262.89	-0.09

These results demonstrate that in sandy, clay and heavy clay soils, GCTB cane has higher yields and also higher gross margins than burnt cane. This was not the case in the Kalamia and silt soils, in which burnt cane yielded higher and also had a higher gross margin (GM) than GCTB cane. The main reason for this is that the GCTB cane used more water than the burnt cane and therefore cost more to grow.

5.5 Mapping

Suitability and risk mapping of the Burdekin district has been carried out and is summarised in Tables 15 and 16.

Table 15: Summary of suitability/risk/benefit mapping in the Burdekin

Number of map units (blocks)							
	Very high	High	Moderately high	Moderate	Moderately low	Low	Very low
Waterlogging risk	245	0	1519	904	13	0	0
Furrow irrigation risk	4	202	1141	1318	15	1	0
Moisture retention benefit	0	17	399	1044	987	230	2
Erosion retention benefit	0	0	40	499	751	1219	172
Overall suitability	**0**	**0**	**53**	**1479**	**818**	**313**	**0**

Table 16: Summary of suitability/risk/benefit mapping in the Burdekin

	Percentage of map units (blocks)						
	Very high	**High**	**Moderately high**	**Moderate**	**Moderately low**	**Low**	**Very low**
Waterlogging risk	9%	0%	57%	34%	0%	0%	0%
Furrow irrigation risk	0%	8%	43%	49%	1%	0%	0%
Moisture retention benefit	0%	1%	15%	39%	37%	9%	0%
Erosion prevention benefit	0%	0%	1%	19%	28%	45%	6%
Overall suitability	0%	0%	2%	56%	31%	12%	0%

An example of an economic map is given in Figure 9. This map shows the various ranges of potential gross margins in ratoon crops under GCTB in the Proserpine district. Figure 10 is an agronomic suitability map for the same area in the Proserpine region. The relationship between these two maps is quite clear. The areas mapped as being unsuitable to GCTB in Figure 10 correspond to areas in Figure 9 that return lower gross margins, and vice versa.

Figure 9:
Gross margins of GCTB ratoons in Proserpine district

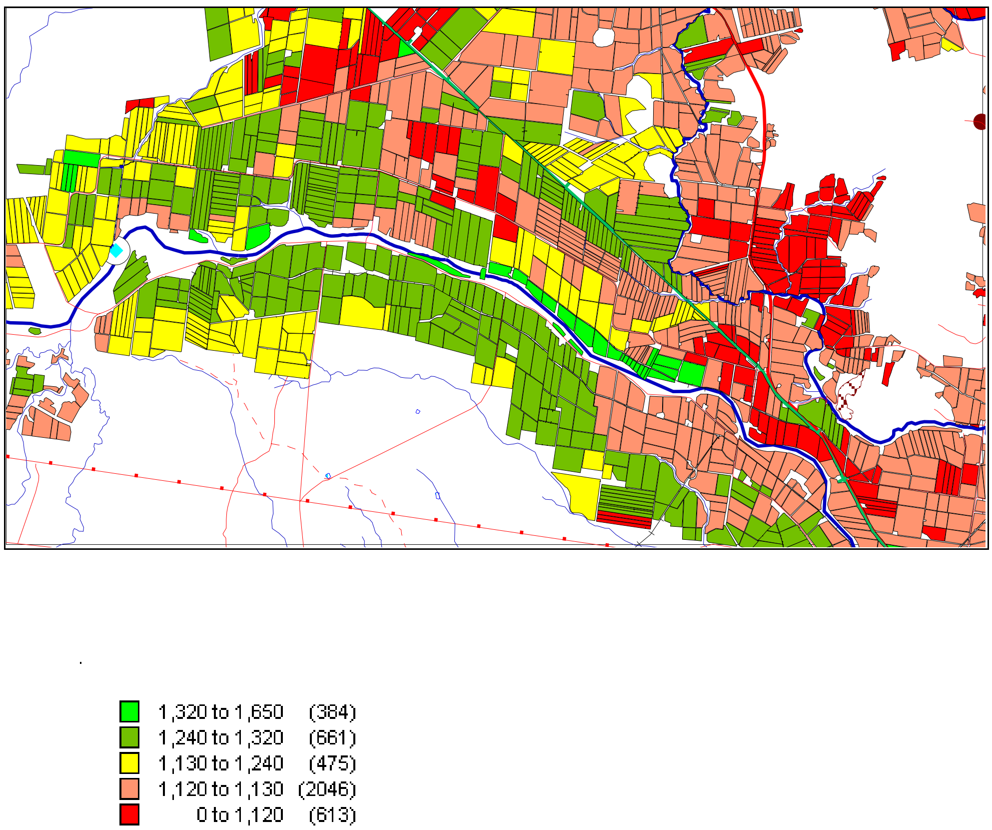
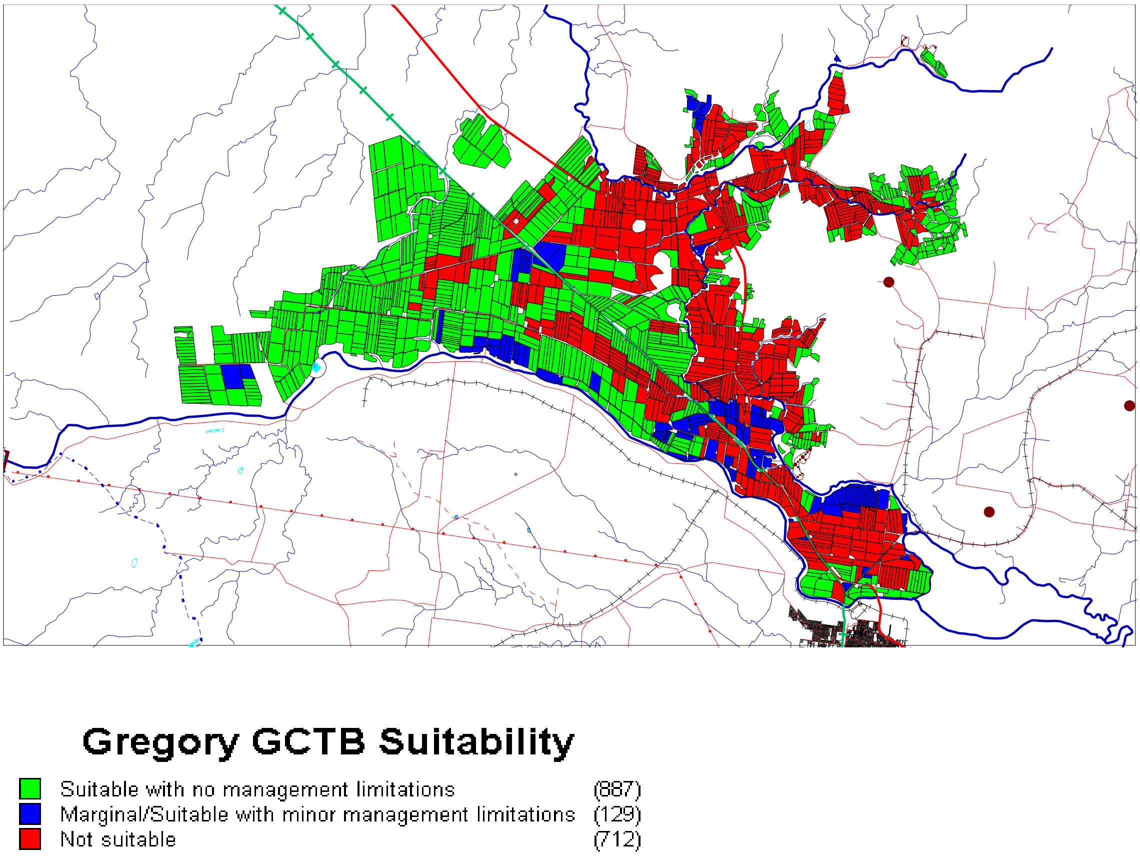


Figure 10:
GCTB suitability in the Gregory area of the Proserpine district



6.0 DIFFICULTIES ENCOUNTERED DURING THE PROJECT

In the course of this project there have been a number of obstacles that were both avoidable and unavoidable. Heavy rain in Proserpine in 1998 resulted in flooding, which adversely affected trials by relocating the trash. The 2000 season was affected by the plant disease orange rust, which significantly reduced yields. These trials were deemed to be no longer viable and new sites were established.

Since the majority of the trials were conducted in the Proserpine district, the area's high rainfall meant that some irrigations on trials were delayed or skipped, limiting the collection of some data.

Availability of data for the GIS work proved to be a problem, with basic farm maps for the Burdekin district being unavailable until November 2000. A lot of the data collected in the project are linked to soil types and only a limited area of the soils for the Burdekin district has been mapped.

During the course of the project there has been a high level of staff turnover, which meant that some time was lost and some tasks needed to be re-done. The loss of 40% of a research assistant's time meant that there were extra costs of hiring casual labour. There were difficulties in finding casual labour and some of those hired were inexperienced and had to be trained to do the required tasks.

Although trials are held on growers' farms with their co-operation, problems arise when the growers fail to notify BSES staff of various activities including irrigations or harvesting. During the course of this project, one trial site was harvested without the knowledge of the project staff, despite regular contact with the grower concerned, resulting in the loss of data for this site. This was unlikely to have been avoided with increased grower communication and seems to be a common risk associated with conducting research on commercial farms.

7.0 APPLICATION OF RESULTS TO THE INDUSTRY

The main outputs of the project include the financial evaluation of the green cane trash blanket retention system (based on a total socio-economic assessment), the Best Practice Guide for Green Cane Trash Blanketing, the furrow irrigation optimiser software package and a range of extension articles and items. Due to the extent of grower, extension officer and community involvement in the project, there has been a better adoption by the industry and community of the outcomes of the project.

BSES extension staff and some Cane Protection and Productivity Board staff have been briefed and involved in a wide variety of project activities. Furthermore, industry groups such as the millers and CANEGROWERS have also been involved in the project and its outcomes. Numerous bus tours, site inspections, talks and presentations have been given to industry and community groups throughout the project areas. There have also been a number of newspaper and radio presentations outlining the major outcomes and benefits of the project. The demonstration sits, in particular, have proved an invaluable asset to the trash retention system. The major outcomes of the project were also presented in several ASSCT papers.

One of the more significant developments resulting from the project was the Best Practices Manual for Green Cane Trash Blanketing. This document has proved most valuable in the delivery of results to the industry and in facilitating some change in attitudes to Green Cane Retention Systems in the Central areas. As with most manuals of this type, the documentation itself is only a small part of the change of attitude process. Ongoing commitment from R&D and industry groups alike are required to continue the momentum initiated by the project.

At a more practical level, the furrow irrigation optimiser has also helped in transferring the major results of the project to on-farm operational considerations. Training in the operation of the software has been provided to a range of industry groups and the software continues to provide a framework for on-going farm operational considerations relevant to the design and layout of furrows and farm blocks alike.

8.0 RECOMMENDATIONS

Further GCTB trials in the Burdekin district, particularly in the BRIA would be of value to support current modelling analyses. Suitability and risk mapping, as well as cost-benefit analyses, could be extended as soil maps are produced for the Burdekin delta. Additional crop growth modelling could also be carried out with the release of updated APSIM software.

The current investment in the project has provided invaluable information in the development and understanding of the green cane retention systems and the practical implementation of the system. However, ongoing commitment to this farming system is required to continually challenge the thinking and comfort zone of the industry in order to maximise its use of the valuable information contained in the project outcomes. It is highly recommended that all sectors of the industry continually monitor the issues contained in this project and challenge every opportunity for its adoption throughout the industry. Whilst no prescriptive methodologies are available for many aspects of the project, the implementation of the components of the work must be tried in the context of the complete farming system and its impact on the total value chain through the industry. Both industry and R&D providers should continue to ensure that funding is available for a continual monitoring and challenging of the industry to maximise the delivery of many of the benefits identified throughout the project.

9.0 PUBLICATIONS ARISING

Numerous publications have arisen from this project. The major publications have been listed below.

Newell, G., Hardie, M. and Adams, M. (2001) 'An overview of green cane trash blanketing research undertaken in the Proserpine mill area'. Proc. Aust. Soc Sugar Cane Technol. 23:168-175.

Newell, G. (2001) 'Green cane trash blanketing suitability in Proserpine'. Proc. Aust. Soc. Sugar Cane Technol. 23:461-481.

Small, F.G. and Newell, G. (2001) 'Best Management Practices for green cane trash blanketing'. Proc. Aust. Soc. Sugar Cane Technol. 23:461-481.

Small, F.G. (2000) 'A comparison of production costs in burnt and green cane trash blanketed systems in the Burdekin and Proserpine districts – a growers survey'. BSES, 2000.

Small, F.G. and Windle, J. (2001) 'Community and grower attitudes to smoke, ash and green cane trash blanketing in the Burdekin and Whitsunday districts'. Proc. Aust. Soc. Sugar Cane Technol. 23:246-251.

Table 17 presents a summary of all major publications arising from the project.

Table 17: A Summary of Publications

	Publications	Published in:
1	Cost Benefit Analysis of Farm and Regional Sectors	BSES Report
2	*Furrow Irrigation Optimiser*	BSES Report
3	GCTB - Can it Work in the Burdekin?	The Advocate
4	*Reduced Costs with Green Cane Trash Blanketing*	The Advocate
5	Green Cane Trash Blanketing	The Advocate
6	*Scoping Study*	BSES Report
7	Effect of Trash Retention on Trash Blanketing	BSES Report
8	*Using GIS to Display Areas of GCTB Suitability*	BSES Report
9	An overview of green cane trash blanketing research undertaken in the Proserpine mill area	ASSCT
10	*Green cane trash blanketing suitability in Proserpine*	ASSCT
11	Best Management Practices for green cane trash blanketing	ASSCT
12	*A comparison of production costs in burnt and green cane trash blanketed systems in the Burdekin and Proserpine districts – a growers' survey*	BSES Report
13	Community and grower attitudes to smoke, ash and green cane trash blanketing in the Burdekin and Whitsunday districts	ASSCT
14	*A Partial Budget*	BSES Report
15	Cost Benefit Analysis for a Hypothetical Farm	BSES Report

10.0 ACKNOWLEDGEMENTS

The author gratefully acknowledges funding support from the Sugar Research and Development Corporation and Land and Water Australia for this project, as well as the financial and infrastructure provided by BSES and the many grower and industry personnel involved in the project.

The cooperation of growers in both the Burdekin and Proserpine districts in conducting field trials, surveys and extension activities and the support of BSES extension and research staff in both districts, as well as members of productivity boards, and CRC staff are also acknowledged.

11.0 REFERENCES

CANEGROWERS, December 1999, The Burdekin District CANEGROWER

Gwydir, Paul, August 1999 D.E.T.I.E. personal communication.

Makeham, J.P. and Malcolm, L.R. (1993). *The Farming Game Now*. Cambridge University Press, Melbourne.

Scott, Fiona, 1998 *Farm Budget Handbook 1998: Summer Crops Northern NSW.* NSW Agriculture, Tamworth.

APPENDICES

APPENDIX 1: BSS173 Project objectives and measures of achievement

MILESTONE		DESCRIPTION	ACHIVEMENT CRITERIA
1	01/10/96	*Signing of project agreement*	• All parties signed the project agreement
2	01/01/98	*Appointment of Research Officer and Research Assistant*	• Research officer commences in Burdekin • Research officer commences in Proserpine
3	30/11/98	*Scoping study completed and participatory research treatment implemented*	• Project Launched • Completion of stakeholder workshops and scoping study (including identification of relevant off-site issues to be addressed in the socio-economic model) • Researcher and Grower expert panel convened • Participatory on farm R&D program designed • Agreement reached and trial treatments implemented for plant cane on cooperator farms
4	30/04/99	*Scoping study, workshop outcomes and research program presented to review meeting*	• Review report accepted by SRDC and LWRRDC • Representative field sites identified and permission obtained for use • Characterisation of sites commenced • Collation of GIS database completed • Initial GCTB maps produced for the Proserpine area • Review of existing field trial data • Outline of key community industry issues prepared
5	01/02/00	*Grower and community surveys completed*	• Grower and community surveys conducted • Overview of survey processed and data collection prepared
6	01/05/00	*Socio-economic model completed*	• Socio-economic model developed as conceptual framework for assessing issues related to the adoption of GCTB • Best practice information collated • Plan of participatory extension activities prepared • Biophysical suitability factors listed and availability date outlined • Project budget post 1999/00 reviewed
7	31/12/00	*Farming system analysis completed*	• Farming system analysis completed • Standard costs and best practice guidelines developed • Cost benefit analysis criteria developed • Review report accepted by SRDC and LWRRDC
8	31/12/01	*Identification of improved management strategies under GCTB on high risk sites and socio-economic analysis completed*	• Results from farm trials for first and second ratoons compiled including field site characterisation • Field days/trial walks/bus trips undertaken • Irrigation modelling completed and used to characterise optimal farm layout design • Crop growth modelling completed • Standard costs and best practices guide completed • Cost benefit assessment for farm and regional sectors completed • Project methodology evaluated

APPENDIX 2
Cost Benefit Analysis of Green Cane Trash Blanketing for Farm and Regional Sectors

BUREAU OF SUGAR EXPERIMENT STATIONS
QUEENSLAND, AUSTRALIA

PROJECT REPORT - SRDC PROJECT BSS173

QUANTIFYING THE SOCIO-ECONOMIC IMPACTS OF HARVESTING RESIDUE RETENTION SYSTEMS

COST-BENEFIT ANALYSIS OF GREEN CANE TRASH BLANKETING FOR THE FARM AND REGIONAL SECTORS

by

Fiona Small

PR01003

BSES Publication
Project Report PR01003

November 2001

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1.0 INTRODUCTION

This document is a collation of economic analyses carried out as a requirement for the SRDC and LWA funded project BSS173 *"Quantifying the socio-economic impacts of harvesting residue retention systems"*. The project aims to support and extend the adoption of trash retention systems based on agronomic and economic suitability. This analysis fulfils the requirements for the final milestone report.

This report has two major components, firstly the cost-benefit analysis of the adoption of green cane trash blanketing (GCTB) at a farm level, which demonstrates implications of GCTB through the use of a partial budget and also a case study of one farm. The second component of the report is the cost-benefit analysis for the Burdekin district for a change from a 100% burnt cane production system to a system with 70% burnt cane and 30% GCTB cane. This analysis is conducted at three sugar price levels, low, medium and high.

2.0 COST-BENEFIT ANALYSIS FOR ADOPTION OF GCTB AT A FARM LEVEL

2.1 A partial budget to show a change from burnt to GCTB

A partial budget is a useful tool used to evaluate proposed changes to a farming operation. It compares the extra expenses and revenues from a proposed change to the existing activity. All of the favourable aspects of the change are balanced against all the unfavourable aspects, and are given a dollar value where possible. A partial budget will be able to tell you if there is going to be a net gain or loss from a change.

When calculating a partial budget, the following steps are taken:

1. Establish a clear picture of the proposal or alternative to be considered.
2. Determine the relevant physical information and assumptions on production and prices.
3. Identify any changes in capital requirements.
4. List changes in costs and income over time.
5. Establish the return on extra capital invested and compare the result with other opportunities for investment.
6. Evaluate any changes in asset value over time.
7. Take account of intangible factors which cannot be considered in the budget, eg risk (Makeham, J.P. and Malcolm, L.R., 1993).

In this study we are using a partial budget to evaluate a proposed change on a hypothetical farm which is currently growing 100 hectares of sugarcane, yielding 115 tonnes of cane per hectare with a ccs of 14.95. Approximately 30% of the soil on this farm is sodic or deep draining, and it is believed that this area would benefit from GCTB. The proposed change would be to replace the 30 hectares of burnt cane with GCTB cane.

Research has shown that there is minimal difference in cane yield under a GCTB system. However, ccs is likely to rise, so we will assume that yield in the GCTB areas will be 115 tonnes per hectare with a ccs of 15.95. It has been shown that GCTB systems can use more water than burnt cane, so we will also assume that one megalitre of water per hectare extra is used in GCTB. From grower surveys in the Burdekin, the average cost of producing burnt cane is $1,640 per hectare, while the cost of producing cane under a GCTB system is $1,629.70 per hectare. This is inclusive of extra harvesting costs and the extra water cost.

We will also assume that the sugar price is $300 per tonne, which means that the price for burnt cane will be $30.14 per tonne, and the price for GCTB cane will be $32.84 per tonne.

To make the 30 hectares of land suitable for GCTB, it would need to be laser levelled, and the farmer would need to either hire or purchase a stool splitter for fertiliser application. We will assume that the cost of redesigning the block is $1,000 per hectare, and that the farmer purchases a stool splitter for $6,500. Capital can be released upon undertaking a new activity, for example, by selling any implements not needed by GCTB. However, since 70 hectares of the farm will still be producing burnt cane, this will not be possible.

If the farmer has to borrow money to finance this change, we will assume that the farmer borrows $36,500 at 8% interest per annum. The average borrowing would be $18,250 and the interest on this will be $1,460. There will also be a tax on the extra taxable income, which is calculated at 20 cents in the dollar to be $1,858.76.

The farmer may experience decreased production costs over time through the reduction in fertiliser inputs after the first crop cycle as a result of improved soil fertility. It may also be possible that water use will decrease as a result of the improved soil structure over time, which will also lower production costs in the GCTB area. Income for both the GCTB cane and the burnt cane will vary over time according to the sugar price and ccs levels.

It may also be possible for the farmer to reduce harvesting costs considerably in time as contractors are pressured by GCTB growers and market competition to reduce their prices. On the other hand, it is possible that the harvesting costs for the GCTB cane may be higher than $5.75 per tonne, as cases of up to $6.60 per tonne are not uncommon.

Another minor cost in producing burnt cane is the 9.8 c per tonne penalty it incurs from the mill, which at 115 tonnes per hectare is around $338.10 per hectare.

The partial budget is shown in full in Table 1.

TABLE 1

A partial budget for changing 30 ha of burnt cane land into 30 ha of GCTB land

30 hectares burnt		**30 hectares GCTB**	
A. Revenue forgone		**C. Revenue gained**	
30 ha burnt, 115 t/ha, 14.95 ccs	$ 103,983.00	30 ha GCTB, 115 t/ha, 15.95 ccs	$ 113,298.00
Price @ $30.14/t		Price @ $32.84/t	
B. Costs avoided		**D. Costs incurred**	
9.8c/t burnt cane penalty	$ 338.10	*Increased water 1 ML/ha @ $18/ML*	$ 540.00
Harvesting cost	$ 18,285.00	*Harvesting cost*	$ 19,837.50
Production cost for burnt cane	$ 30,917.70	*Production cost for GCTB cane*	$ 28,909.20
Total	$ 49,540.80	Total	$ 49,286.70
E. Gain from present activity	**$ 54,442.20**	**F. Gain from proposed activity**	**$ 64,011.30**
G. Difference (F-E)	**$ 9,569.10**		
		Average borrowings	$ 18,250.00
H. Total gain	**$ 9,569.10**	Interest at 8%	$ 1,460.00
I. Average marginal tax rate	$ 0.20	Tax on extra taxable income	$ 1,621.82
J. Extra taxable income	$ 8,109.10		
K. Gain after tax	$ 7,947.28		
L. Capital required	$ 36,500.00		
M. Capital released	0	Net extra initial capital investment	$ 36,500.00
N. Net capital investment (L-M)	$ 36,500.00	Net gain after tax	$ 7,947.28
O. Extra capital return after tax (K/N)	0.22	Net gain after tax (%)	21.8
		Opportunity interest cost	$ 2,920.00

2.2 Interpretation of the partial budget

The main factors to take into consideration when deciding whether to undertake a new activity include risk, financial aspects, capital gains prospects, and other more intangible aspects.

2.2.1 Risk

When changing from burnt cane farming to GCTB, there are a number of risks involved. These include production risks, such as a cold, wet snap occurring after harvest, which may result in slow and uneven ratoon development and the possibility of diseases such as pineapple disease. There is also the risk that the harvesting contractor may harvest the crop carelessly, resulting in stool damage, harvesting losses and increased dirt levels. There are also price risks which occur if the sugar price falls; however, this would affect burnt cane as well.

The before-tax break-even income from GCTB is calculated in Table 2.

TABLE 2
Break-even income

Break-even income	
Gain from GCTB	$ 64,011.30
Gain from burning	$ 54,442.20
Balance	$ 9,569.10
Break-even income (yields and prices) required is:	
Income 'x' = burning gain + GCTB costs + opportunity interest cost	
Income x = $ 106,648.90	

To break even with the burning activity, the income from the GCTB crop has to be $106,648.90 in total or $3,554.96/ha. There are many combinations of yields (tonnes of cane and ccs), sugar price, harvesting and irrigation costs that could achieve this income. Table 3 shows three 'negative' combinations, where in each case either the cane yield (tonnes per hectare), ccs or sugar price is significantly reduced.

In the 'Most likely' column, there are combinations of cane yield, ccs and sugar price that are most likely to be achieved if the proposal to change from burnt cane production to GCTB is undertaken. The most likely income is $113,298, which is well above the break-even income.

In the first case, cane yield is reduced from 115 tonnes per hectare to 110 tonnes per hectare, giving an income of $108,372, which is still above the break-even income. Therefore, if the change from a burnt cane production system to GCTB is made and results in reduced yields of up to 5 tonnes per hectare, the grower is still making a financial gain.

The second combination shows the effect of low ccs, thus reducing the income to $94,668, which is significantly lower than the break-even income; however, trials have shown that it is unlikely that ccs will be reduced - in fact it is more likely to be higher under a GCTB system. The third case shows that income will be $98,463 when the sugar price is at $260 per tonne, which is also well below the break-even income; however, a reduced sugar price would also have a similar effect on the burnt cane systems.

TABLE 3
Most likely and potential combinations of cane yields and sugar price

	Most likely	Possible
Lower tonnes of cane		
tonnes per hectare	115	110
ccs	15.95	15.95
sugar price $/tonne	300	300
Income	**$ 113,298.00**	**$ 108,372.00**
Lower ccs		
tonnes per hectare	115	115
ccs	15.95	13.95
sugar price $/tonne	300	300
Income	**$ 113,298.00**	**$ 94,668.00**
Lower sugar price		
tonnes per hectare	115	115
ccs	15.95	15.95
sugar price $/tonne	300	260
Income	**$ 113,298.00**	**$ 98,463.00**

2.2.2 Financial aspects

The critical values in the budget are the yields and prices of cane, and the variable costs of producing both burnt and green cane.

The proposal is also financially feasible, as it will more than pay for its overhead and variable costs, as well as extra interest repayments. The farmer will experience more tax on any extra taxable income that may be generated as a result of the project, but this is also easily covered.

This proposal to convert 30 hectares of burnt cane into 30 hectares of cane under a GCTB system is economically sound. The extra returns from the GCTB area exceeds the earnings from the burnt cane, as well as the amount a similar investment could earn in an alternative use that the farmer may consider. There is return on investment of 21.8%, which is exceptional when compared to other investment opportunities using the opportunity interest cost.

The opportunity interest cost is the gain that the money could earn in another use, in this case calculated at 8% to be $2,920, which is around $6,600 less than the gain from the proposed change to GCTB.

2.2.3 Capital gains aspects

The likelihood of capital gains being made is small, since the land will probably retain its value with inflation, whether it is under GCTB or not. It may be possible to make small capital gains in the future as the soil quality improves, or even further into the future as cane burning becomes a rare practice for whatever reason. If the GCTB area is well established its value may be increased.

2.2.4 Other aspects

The change to GCTB has a number of other advantages which are a little more difficult to place a monetary value on. These are things such as improved weed and grub control, better relationships with close neighbours and community by reducing the farm's smoke and ash emissions, and more personal leisure time for the farmer because fewer ground workings are required once the crop is planted.

The farmer and/or employees' skills is another issue to take into consideration. The inexperience in GCTB may cause some problems in the initial stages, but by seeking advice from more experienced farmers or professional advisers, irrigation scheduling, and good record keeping, these problems should be overcome.

On a broad scale, by changing to GCTB in this highly suitable area, the farmer is fulfilling the CANEGROWERS Code of Practice, which aims to provide "reasonable and practicable measures for minimising the risk of harm to the environment" (CANEGROWERS).

2.2.5 Summary of partial budget

If the most likely outcomes occur, the farmer will gain around $9,500 per year more from the 30 hectares of land under a GCTB system than would have been received if the cane in that 30 hectares had been burnt. This is a gain of approximately $320 per hectare. The yields and prices required to achieve a break-even income are easily obtainable, while the most likely yields and prices will give the farmer greater rewards if achieved.

2.3 A cost-benefit analysis on a case study farm

A cane farmer in the Burdekin River Irrigation Area with a 100 hectare farm on relatively flat country, with average row lengths of 1 km and slope of 0.01%, decides to change from conventional, ie burning cane before harvest, to GCTB. In a 'normal' year in most of the fields, this farmer would burn cane prior to harvest and then rake the trash and burn it after harvest. There would then be two cultivations and one herbicide application in each ratoon for weed control, as well as applying 12 megalitres of water in eight irrigations. The farmer employs contract harvesters, and has received the average results in Table 4.

TABLE 4
Average yields for case study farm

Crop class	Yield t/ha	ccs	Sugar t/ha
Plant	130	15	19.5
1st R	120	15	18.0
2nd R	110	14	14.7
3rd R	100	14	12.6

The operating costs for this situation are outlined below:

Land preparation: Two deep rippings, two discings and two rotary hoe passes for pre-planting ground preparation. In the ratoon crops there are only two passes with a scarifier. All operations are carried out using a Case 8930 tractor, which costs $42.82/hr to run as calculated by NSW agriculture..

Planting contractors: $345.80/ha.

Fertiliser: Five bags/hectare of mix at planting, then 7.5 bags/ha of urea after planting, then six bags/ha on ratoons.

Herbicides: 1.5 L/ha of Gramoxone at plant with planter, then 6 L/ha of Gesapax Combi, 0.5 L/ha of Diuron and 2 L/ha of Amitran, 0.5 L/ha of 2,4-D by air between plant and first harvest, and ratoons.

Insecticides: 24 kg/ha of suSCon® in the plant crop.

Irrigation: 12 ML per hectare at $38.60/ML in 10 irrigations.

Harvesting: Contractors are used, who charge $5.30/t to harvest.

These operating costs are summarised in Table 5.

TABLE 5
Summary of operating costs for burnt cane production

	Plant $/ha	1st ratoon $/ha	2nd ratoon $/ha	3rd ratoon $/ha
Planting	345.80	0	0	0
Fertiliser	40	100	100	100
Herbicide	82.53	76.58	76.58	76.58
Other pesticide	255	0	0	0
Irrigation	463.20	463.20	463.20	463.20
Harvesting	689	636	583	530
Tractor operations	346.24	124.28	124.28	124.28
Total variable costs $/ha	**2,221.77**	**1,400.06**	**1,347.06**	**1,294.06**

Assuming the farmer receives $30 per tonne and the yields shown above, this will result in gross margins as shown in Table 6.

TABLE 6
Gross margins for burnt cane production

	Operating costs $/ha	Income $/ha	Gross margin $/ha
1st Plant	2,221.77	3,900	1,678.23
1st Ratoon	1,400.06	3,600	2,199.94
2nd Ratoon	1,347.06	3,300	1,952.94
3rd Ratoon	1,294.06	3,000	1,705.94

2.3.1 Changing to GCTB

In the first crop cycle of practising GCTB, we assume the yields are reduced by around 10 tonnes per hectare due to a number of factors, including management experience, and then in the following three crop cycles, yields increase by 5% in each crop class (Table 7).

TABLE 7
Expected yields following a change to GCTB

Crop class	Yield t/ha	ccs	Sugar t/ha	Income $/ha
1st Plant	120	15	18	3,600
1st R	110	15	16.5	3,300
2nd R	100	14	14	3,000
3rd R	90	14	12.6	2,700
2nd Plant	126	15	18.9	3,780
1st R	115.5	15	17.33	3,465
2nd R	105	14	14.7	3,150
3rd R	94.5	14	13.23	2,835
3rd Plant	132.3	15	19.85	3,969
1st R	121	15	18.19	3,638.25
2nd R	110.25	14	15.44	3,307.5
3rd R	99	14	13.9	2,976.75

2.3.2 Capital costs of changing to GCTB

Firstly, there would be the initial outlay of money to redesign the farm layout, including shortening of rows. This would mean re-levelling of fields, installation of more pumps and pipes, as well as the purchase of a new fertiliser box with coulters rather than tines. Overall, this investment is estimated to be around $1,000 per hectare. The farmer will obtain a bank loan for the initial outlay of capital at an interest rate of 8% per annum.

The operating costs associated with a GCTB system are outlined below:

Land preparation (not including laser levelling): One deep ripping, two discings and one rotary hoe pass for pre-plant land preparation. No land workings in ratoons.

Planting: contractors at $345.80/ha.

Fertiliser: Five bags/hectare of Delta Crop King mix at planting, then 7.5 bags/ha of urea after planting, then 16 bags/ha of Delta Crop King mix on ratoons.

Herbicides: 1.5 L/ha of Gramoxone at plant with tractor, then 6 L/ha of Gesapax Combi, 0.5 L/ha of Diuron and 2 L/ha of Amitran by air between plant and first harvest.

Insecticides: 24 kg/ha of suSCon in the plant crop.

Irrigation: The amount of water applied is expected to be 12 ML in the first year, then fall to 11 ML in the second year, then 10 ML from the third year onwards. The number of irrigations is expected to fall to seven after the third year.

Harvesting: Contractors will be used, who will charge $6.30/t to harvest the crop green.

These operating costs for three crop cycles are summarised in Table 8.

TABLE 8
Summary of operating costs for GCTB in three crop cycles

	Plant	**1st ratoon**	**2nd ratoon**	**3rd ratoon**
Planting	345.8	0	0	0
Fertiliser	24	63.37	63.37	63.37
Herbicide	110	25	25	25
Other pesticide	255	0	0	0
Irrigation	463.2	424.6	386	386
Harvesting	756	693	630	567
Tractor operations	173.12	0	0	0
Total variable costs $/ha	**2,127.12**	**1,205.97**	**1,104.37**	**1,041.37**

	2nd Plant	**1st ratoon**	**2nd ratoon**	**3rd ratoon**
Planting	345.8	0	0	0
Fertiliser	24	63.37	63.37	63.37
Herbicide	110	25	25	25
Other pesticide	255	0	0	0
Irrigation	386	386	386	386
Harvesting	793.8	97.65	661.5	595.35
Total variable costs $/ha	**2,087.72**	**572.02**	**1,135.87**	**1,069.72**

	3rd Plant	1st ratoon	2nd ratoon	3rd ratoon
Planting	345.8	0	0	0
Fertiliser	24	63.37	63.37	63.37
Herbicide	110	25	25	25
Other pesticide	255	0	0	0
Irrigation	386	386	386	386
Harvesting	833.49	762.3	694.58	623.7
Tractor operations	173.12	0	0	0
Total variable costs $/ha	**2,127.41**	**1,236.67**	**1,168.945**	**1,098.07**

2.3.3 Financial revenue

In the past, the farmer received prices around $30 per tonne for burnt cane, so to compare the two cane production systems we will assume that the farmer will still get $30 per tonne for the GCTB cane. With the above forecasted yields, the farmer is expected to receive the income and gross margins shown in Table 9.

TABLE 9
Income and gross margin for GCTB production

Crop class	Yield t/ha	Income $/ha	GM $/ha
1st Plant	120	3,600	1,472.88
1st R	110	3,300	2,094.03
2nd R	100	3,000	1,895.63
3rd R	90	2,700	1,658.63
2nd Plant	126	3,780	1,692.28
1st R	115.5	3,465	2,892.98
2nd R	105	3,150	2,014.13
3rd R	94.5	2,835	1,765.28
3rd Plant	132.3	3,969	1,841.59
1st R	121	3,638.25	2,401.58
2nd R	110.25	3,307.5	2,138.55
3rd R	99	2,976.75	1,878.68

The differences in gross margins before and after the change to GCTB are shown in Table 10. Basically, it shows that the farmer will experience decreases in gross margins in the first crop cycle, and then increases in the following crop cycles.

TABLE 10
A comparison of gross margins before and after changing to GCTB

	GM before change $/ha	GM after change $/ha	Difference
1st Plant	1,678.23	1,472.88	-205.35
1st Ratoon	2,199.94	2,094.03	-105.91
2nd Ratoon	1,952.94	1,895.63	-57.31
3rd Ratoon	1,705.94	1,658.63	-47.31
2nd Plant	1,678.23	1,692.28	14.05
1st Ratoon	2,199.94	2,892.98	693.04
2nd Ratoon	1,952.94	2,014.13	61.19
3rd Ratoon	1,705.94	1,765.28	59.34
3rd Plant	1,678.23	1,841.59	163.36
1st Ratoon	2,199.94	2,401.58	201.64
2nd Ratoon	1,952.94	2,138.55	185.61
3rd Ratoon	1,705.94	1,878.68	172.74

3.0 COST-BENEFIT ANALYSIS FOR THE REGIONAL SECTOR

Currently in the Burdekin canegrowing district in north Queensland, around 5% of the area is harvested green. It is estimated that around 30% of the region has soils that are suitable to GCTB. A cost-benefit analysis can be used to demonstrate the difference in gross margins between 100% of the area using a burnt production system and a change to 70% using burning and 30% using GCTB.

This analysis focuses on the Burdekin region, and calculates the average changes in gross margins for the **entire** district as a result of 30% of the district changing to GCTB. A number of calculations are made in this analysis, including cane prices at low, medium and high sugar prices and ccs levels, total and average income, total and average costs, gross margin per hectare and per tonne.

3.1 Outcomes considered

This cost-benefit analysis has been conducted for a number of different outcomes resulting from a change from a 100% burnt cane production system to 30% GCTB system. Past research and statistics about GCTB show that it can perform differently in various situations. It is possible that one or more of the following circumstances could occur in a GCTB system:

- A loss in cane yield by 5%.
- An increase in cane yield by 5%.
- A gain in ccs of 1 unit.
- A loss in ccs of 1 unit.
- An increase in water use of 1 megalitre per hectare.
- A decrease in water use of 1 megalitre per hectare.
- No change from burnt.

The cost-benefit analysis has been conducted using various assumptions about the amount of change in cane yield, ccs and water use. Calculations have been made for each individual outcome as well as all possible combinations of outcomes.

3.2 Data sources

The average costs of production for GCTB systems and burnt systems were gathered from grower surveys conducted as a milestone requirement for BSS173: 'Quantifying the socio-economic impacts of harvesting residue retention systems'. The costs shown include inputs such as fertiliser, water, chemicals, machinery and labour, while income is calculated using the average yield for the 1999 season, which was 115 tonnes per hectare with an average ccs of 14.95. Cane prices are calculated using low, medium, and high sugar prices of $260, $300 and $340 per tonne, respectively. The sugar price for the 1999 season was an all time low price around $260 per tonne. The 2001 sugar price is expected to be approximately $340 per tonne.

3.3 100% of Burdekin district using burnt cane production systems

The cane price is $26.20 per tonne for cane with a ccs of 14.95 at the low sugar price, $30.15 per tonne at the medium sugar price and $34.09 per tonne at the high price. At these prices, average income for the Burdekin district ranges from $3,013.12 per hectare at the low sugar price to $3,919.78 per hectare at the high sugar price.

From the grower survey, the average cost of production in a burnt system is $1,640.12 per hectare; giving gross margins of $1,373 per hectare, $1,826.33 per hectare and $2,279.66 hectare at the low, medium and high sugar prices, respectively. The gross margin at the low sugar price is $11.94 per tonne, while the gross margin per tonne of cane is $15.88 per tonne and $19.82 per tonne at the medium and high sugar prices, respectively. These calculations are summarised in Table 11.

TABLE 11
Summary of prices, income and gross margins for 100% of the Burdekin district using burnt cane production systems

	Sugar price @ $260/t	Sugar price @ $300/t	Sugar price @ $340/t
Price	$26.20	$30.15	$34.09
Average income $/ha	$3,013.12	$3,466.45	$3,919.78
Gross margin $/ha	$1,373.00	$1,826.33	$2,279.66
Gross margin $/tonne	$11.94	$15.88	$19.82

3.4 Cost-benefit analysis for a change to GCTB in 30% of the Burdekin district

In this section the same calculations are made as for the burnt system, but using different assumptions. Here, we assume that 30% of the Burdekin changes to GCTB production without any major capital outlays to do so, and the remaining 70% continues to use burning methods. The GCTB area incurs a lower production cost due to reduced inputs required, as determined by the grower survey. Again, the analysis is carried out at three sugar prices, low ($260 per tonne), medium ($300 per tonne) and high ($340 per tonne).

3.5 Cost-benefit analysis at the low sugar price of $260 per tonne

If 30% of the Burdekin district was to convert to GCTB production, at low sugar prices, and with no change in yield, ccs or water use, the average district gross margin is $1,368.47 per hectare or $11.90 per tonne. This is equivalent to around $94.5 million gross margin for the total district. The gross margin in the GCTB area is $21.70/ha higher than in the burnt area. This difference is the same at all price levels because it is a proportional difference.

The first scenario assessed for a change to GCTB is that there will be an increase in cane yield of 5% in the GCTB area. With an increase in yield alone, the GCTB gross margin is $173 per hectare higher than the burnt cane production system. This gross margin is increased by even larger amounts if there is also an increase in ccs of 1 unit, and/or water use decreases by 1 megalitre. The highest increase in gross margin occurs when the GCTB area experiences increased yields, increased ccs and decreased water use. This difference in gross margins between GCTB and burnt systems is $474.50 per hectare.

On the other hand, if ccs is decreased by 1 unit, the gross margin in the GCTB area will be negative, regardless of water use. The difference in gross margin could be as much as $128 per hectare in favour of the burnt system.

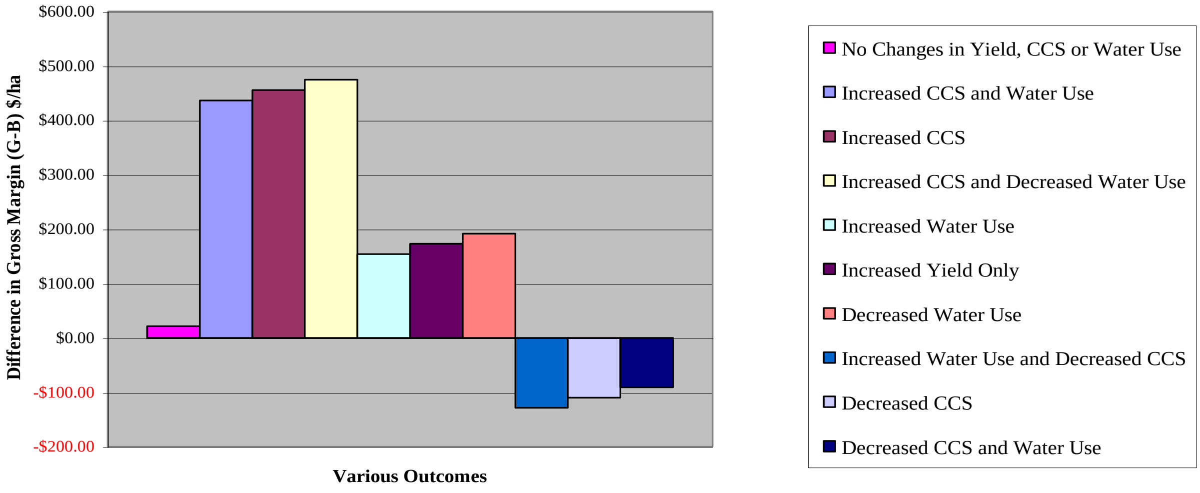
These results are illustrated in Figure 1, part (a).

Similar outcomes are shown in part (b) of Figure 1, where the analysis assumes there is no change in cane yield. However, ccs decreases result in much larger losses for the GCTB area, with gross margins being up to $400/ha less than the burnt systems.

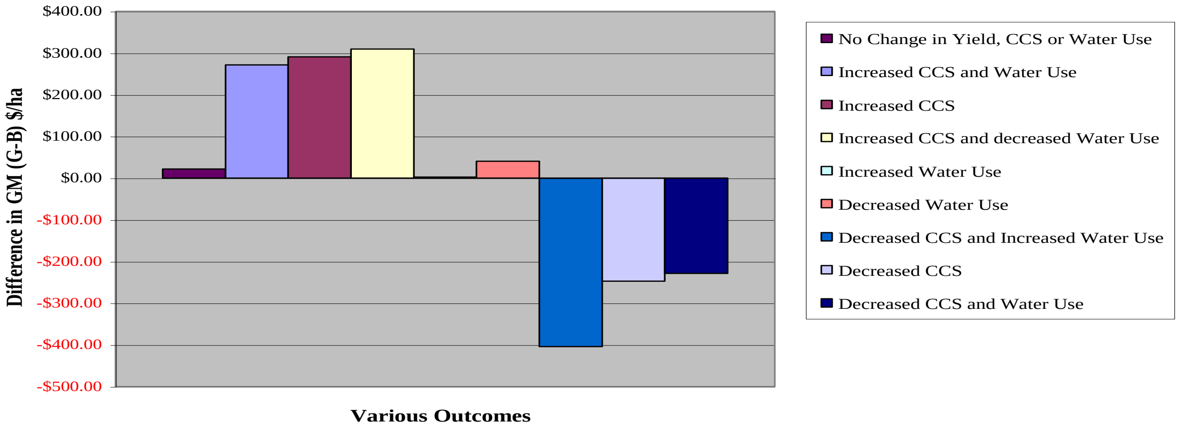
With decreased cane yields of 5% in the GCTB area, increased ccs and decreased water use, gross margins can be up to $150 per hectare higher than in the burnt area. However, with either decreased ccs or no change in ccs, gross margins in GCTB areas will be much lower than in burnt areas. As highlighted in part (c) of Figure 1, ccs decreases can reduce gross margins by over $400 per hectare lower than the burnt system.

Figure 1: Difference in gross margins between GCTB and burnt systems (G-B) at low sugar prices ($260 per tonne)

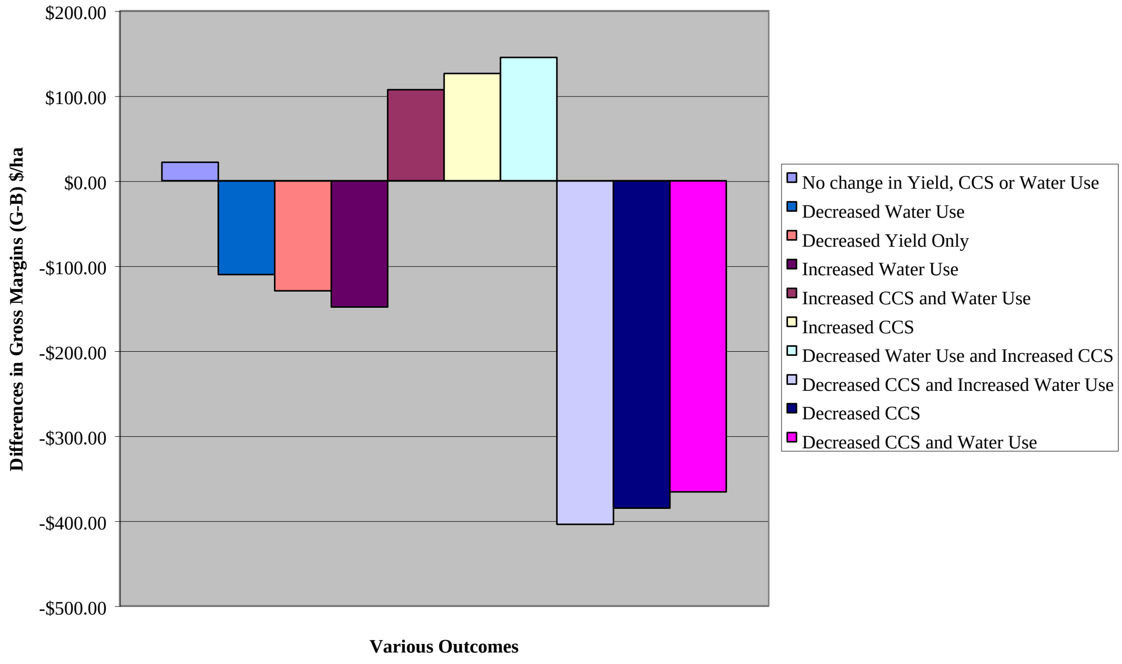
(a) 5% increase in cane yields in GCTB area



(b) No changes in cane yields in GCTB area



(c) 5% Decrease in cane yields in GCTB area



3.6 Cost-benefit analysis at the medium sugar price of $300 per tonne

If 30% of the Burdekin district was to convert to GCTB production, at medium sugar prices, and with no change in yield, ccs or water use, the average district gross margin is almost $126 million, $1,821.80 per hectare or $15.84 per tonne.

Again, the first scenario assessed for a change to GCTB at medium sugar prices is that there will be an increase in cane yield of 5% in the GCTB area. With this increase in yield, the GCTB gross margin is $195 per hectare higher than the burnt cane production system. This gross margin is increased by even larger amounts if there is also an increase in ccs of 1 unit, and/or water use decreases by 1 megalitre, giving gross margin increases of up to $540 per hectare.

However, if ccs is decreased by 1 unit, the gross margin in the GCTB area will be lower than the burnt area whether water use increases or not. This difference in gross margin could be as much as $150 per hectare.

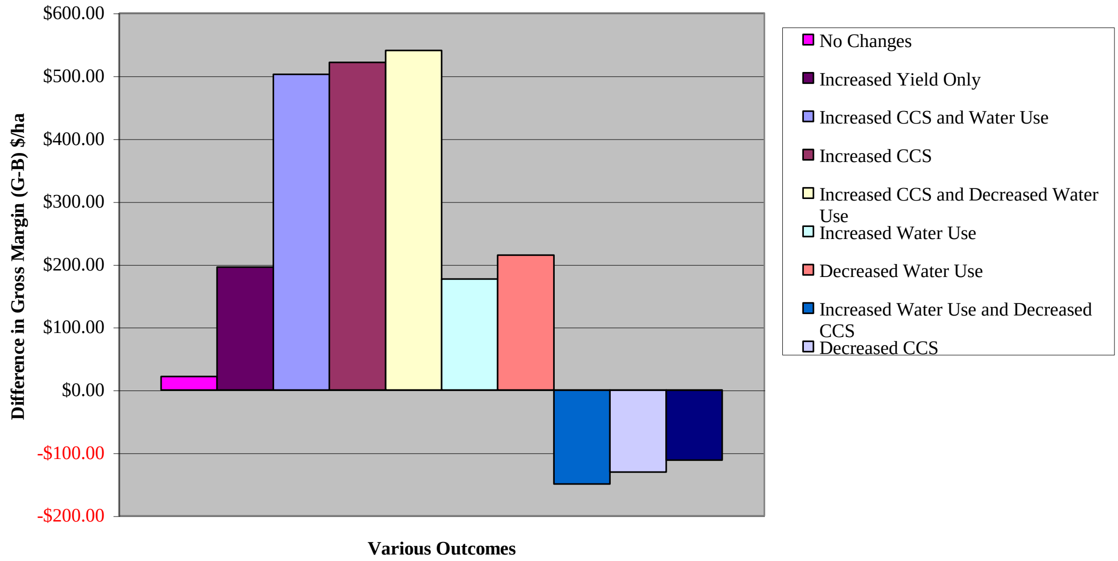
These results are illustrated in Figure 2, part (a).

In part (b) of Figure 2, where the analysis assumes there is no change in cane yield, ccs decreases result in losses for the GCTB area, with gross margins being over $300 per hectare less than the burnt systems.

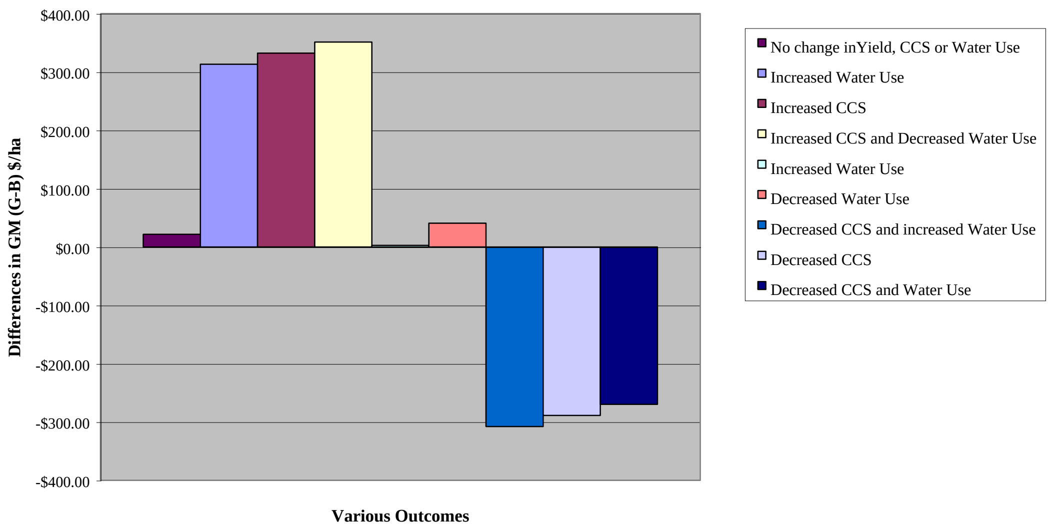
If cane yields are decreased by 5% in the GCTB area, as shown in part (c) of Figure 2, increased ccs and decreased water use, gross margins can be more than $160 per hectare higher than in the burnt area, while ccs decreases can reduce gross margins by up to $470 per hectare.

Figure 2: Difference in gross margins between GCTB and burnt systems (G-B) at medium sugar prices ($300 per tonne)

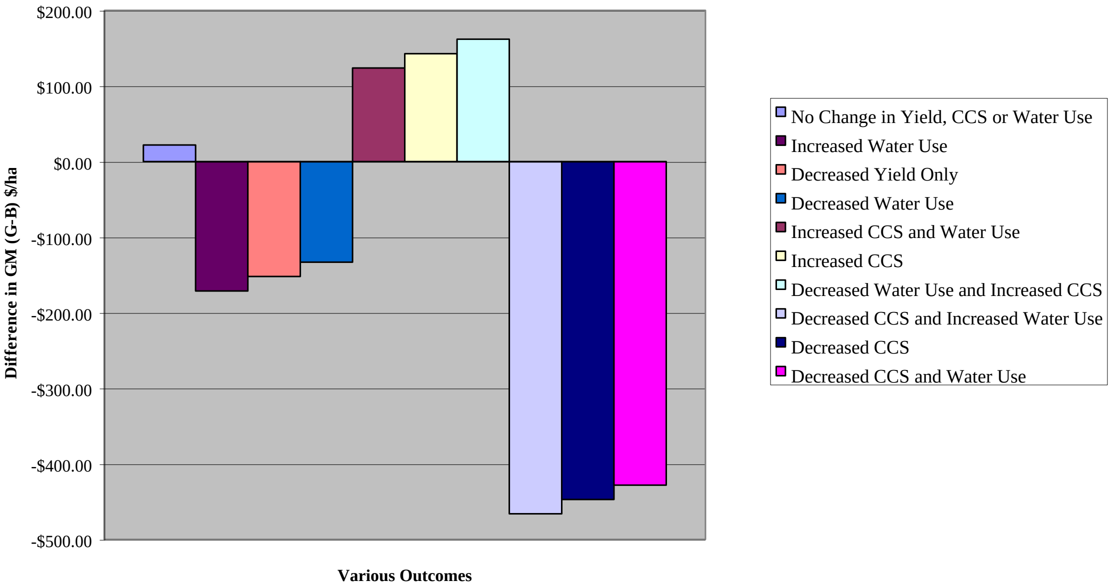
(a) 5% increase in cane yields in GCTB area



(b) No changes in cane yields in GCTB area



(c) 5% decrease in cane yields in GCTB area



3.7 Cost-benefit analysis at the high sugar price of $340 per tonne

The analysis has been carried out for a third time to assess a change for 30% of the district to GCTB under a high sugar price of $340 per tonne. With no change in yield, ccs or water use, the average district gross margin is $2,275.13 per hectare or $19.78 per tonne. This is a total district gross margin of $157 million.

Increased cane yields of 5% in the GCTB area increase the gross margin $218 per hectare higher than the burnt cane production system. This gross margin is increased more when there is also an increase in ccs of 1 unit, and/or water use decreases by 1 megalitre, giving gross margin increases over $600 per hectare for the GCTB area.

If ccs decreases by 1 unit, the gross margin in the GCTB area will be lower than the burnt area whether water use increases or not. This difference in gross margin could be up to $170 per hectare less than the burnt area's gross margin.

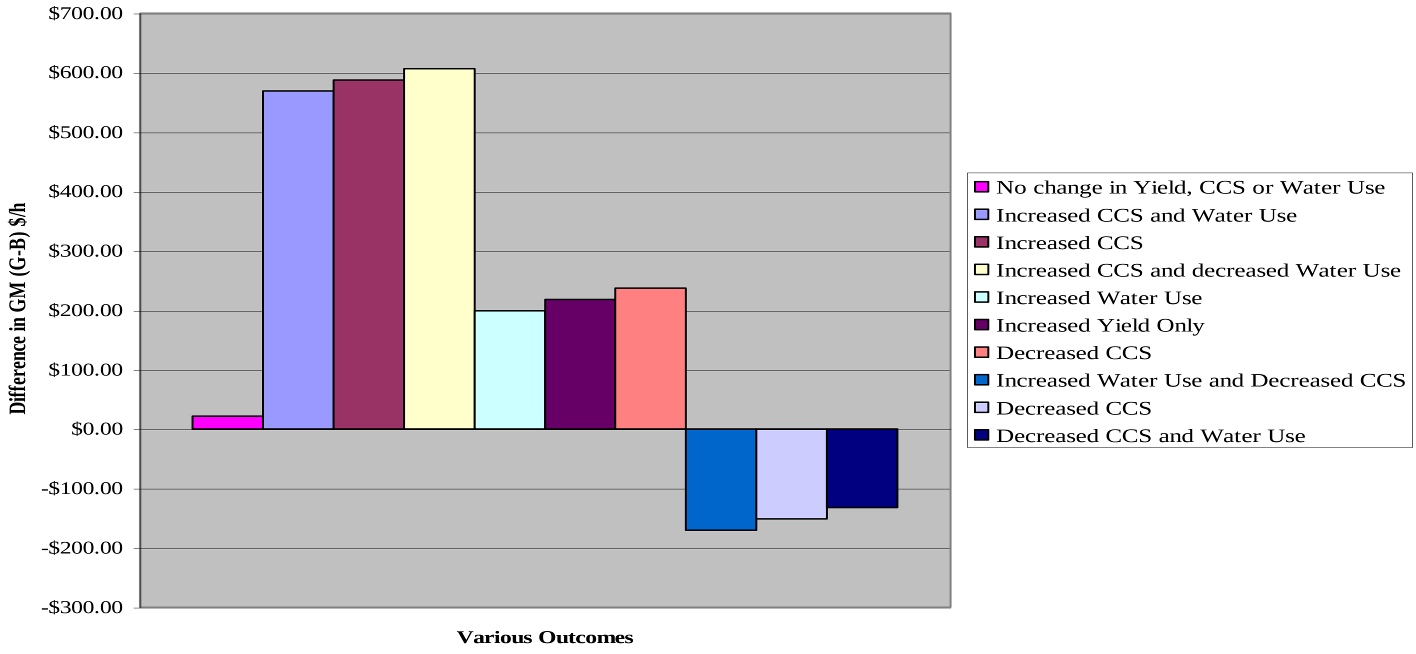
These results are illustrated in Figure 3, part (a).

Part (b) of Figure 3, which displays the differences in gross margins between GCTB and burnt areas when there is no change in cane yield, shows that ccs decreases result in losses for the GCTB area. Gross margins in the GCTB area are almost $350 per hectare less than in the burnt areas.

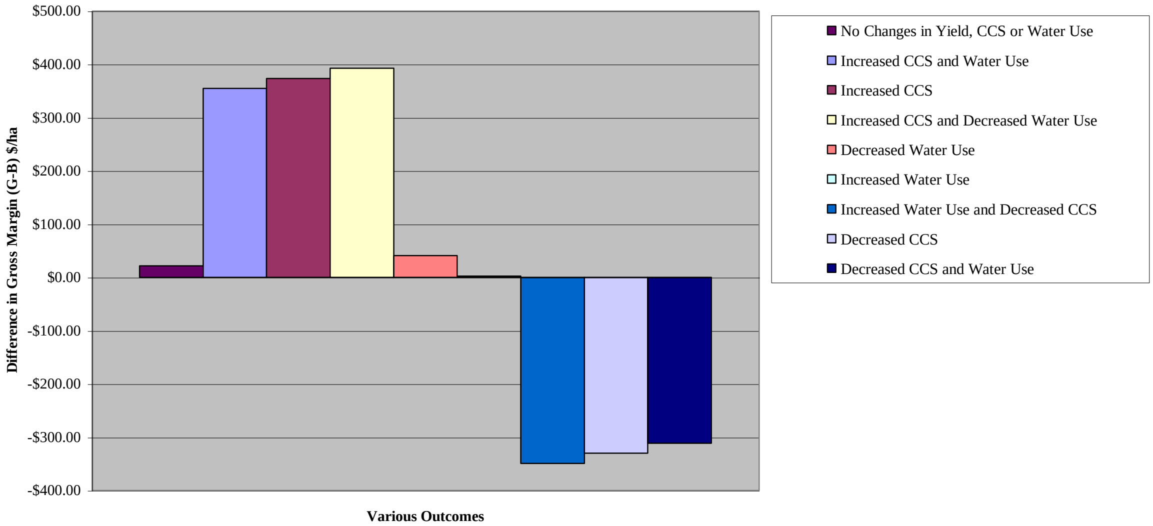
When cane yields are decreased by 5% in the GCTB area, as shown in part (c) of Figure 3, with increased ccs and decreased water use, gross margins can be around $180 per hectare higher than in the burnt area, while ccs decreases can reduce gross margins by up to $530 per hectare.

Figure 3: Difference in gross margins between GCTB and burnt systems (G-B) at high sugar prices ($340 per tonne)

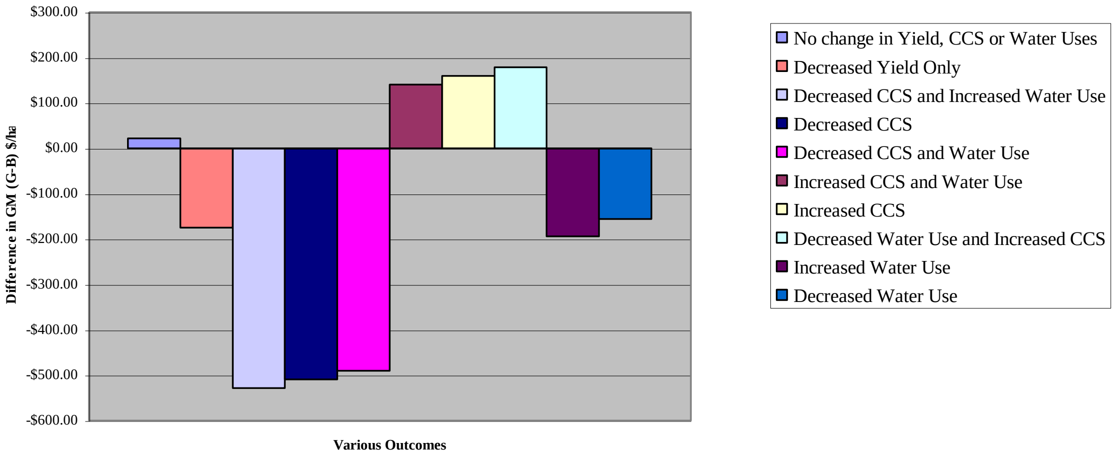
(a) 5% increase in cane yields in GCTB area



(b) No changes in cane yields in GCTB area



(c) 5% decrease in cane yields in GCTB area



3.8 Summary of outcomes at the three sugar prices

Table 12 summarises the various circumstances where GCTB will give better or worse outcomes for the total district if there is a change from a 100% burnt system to a system that is 70% burnt and 30% GCTB at each of the three sugar price levels. This section compares the gross margins of the 100% burnt system to various scenarios that could result with a change to the 70% burnt and 30% GCTB system.

In the Table 12, where the gross margin difference is positive, the 100% burnt system would be favourable, and vice versa. For example, after a change to the 70% burnt and 30% GCTB system in a period of low sugar prices, the district would experience on average increased gross margins of $125 per hectare, if cane yield and ccs is increased in the GCTB area.

On the other hand, if cane yield and ccs are decreased and water use is increased in the GCTB area, the district's gross margins will be an average of $132 per hectare lower than if the entire district was using a burnt system. In a year of high sugar prices, this loss in gross margin could be almost $170 per hectare.

These charts tell a similar story for all sugar price levels, that ccs is the main driver behind major changes in gross margins. If an increase in ccs occurs, the gross margin is increased by a greater proportion than if yields are increased or if water use is decreased. The sugar price reflects the amount by which gross margins are changed. For example, when yield and ccs are increased and water use is decreased, at low prices the GCTB area has a gross margin which is around $475 per hectare higher than the burnt area. At medium prices this figure is $540 per hectare while at high prices it is over $600 per hectare more than the burnt cane gross margin.

Yield changes alone have a moderate effect on gross margins, while water use is only a minor factor in regional gross margins and changes associated with it are only minimal. At low prices, a decrease in water use results in a GCTB gross margin that is $40 per hectare higher than the burnt cane gross margin, while an increase in yield gives a $172 per hectare higher gross margin, and an increased ccs gives a GCTB gross margin that is $455 per hectare higher than the burnt cane.

The effect of 30% of the Burdekin district changing to GCTB on the overall district average gross margins is demonstrated in Table 12. There are three sections in Table 12, each showing the increase or decrease in total district gross margins as a result of 30% of the district undertaking GCTB and experiencing various changes in yield, ccs or water use. In the table, when the gross margin difference is negative, the GCTB area has increased the overall district gross margins. If the gross margin difference is positive, the GCTB area has reduced the overall district gross margins.

At any sugar price, if there are decreased yields without an increase in ccs, the GCTB area is reducing the total district gross margins. However, with an increase in yields in the GCTB area at any sugar price level, if the ccs either stays the same or increases by one unit, the GCTB area increases the total district average gross margins. Also, a decrease in ccs in the GCTB area will always result in overall district gross margins being reduced, regardless of any changes in yield or water use.

TABLE 12
A summary of outcomes at various sugar prices

(a) Difference in district gross margins as a result of various outcomes at low sugar prices

Yield	ccs	Water use	Gross margin difference (B-G) $/ha
5% increase	1 unit increase	1 ML increase	-$119.34
		Same	-$125.04
		1 ML decrease	-$130.74
	Same	1 ML increase	-$34.58
		Same	-$40.28
		1 ML decrease	-$45.98
	1 unit decrease	1 ML increase	$50.19
		Same	$44.49
		1 ML decrease	$38.79
Same	1 unit increase	1 ML increase	-$70.50
		Same	-$76.20
		1 ML decrease	-$81.90
	Same	1 ML increase	$10.23
		Same	$4.53
		1 ML decrease	-$1.17
	1 unit decrease	1 ML increase	$131.73
		Same	$85.26
		1 ML decrease	$79.56

Yield	ccs	Water use	Gross margin difference (B-G) $/ha
5% decrease	1 unit increase	1 ML increase	-$21.66
		Same	-$27.36
		1 ML decrease	-$33.06
	Same	1 ML increase	$55.04
		Same	$49.34
		1 ML decrease	$43.64
	1 unit decrease	1 ML increase	$131.73
		Same	$126.03
		1 ML decrease	$120.33

(b) District gross margin changes as a result of various scenarios at medium sugar prices

Yield	ccs	Water use	Gross margin difference (B-G) $/ha
5% increase	1 unit increase	1 ML increase	-$139.18
		Same	-$1.17
		1 ML decrease	-$150.58
	Same	1 ML increase	-$41.38
		Same	-$47.08
		1 ML decrease	-$52.78
	1 unit decrease	1 ML increase	$56.43
		Same	$50.73
		1 ML decrease	$45.03
Same	1 unit increase	1 ML increase	-$82.92
		Same	-$88.62
		1 ML decrease	-$94.32
	Same	1 ML increase	$10.23
		Same	$4.53
		1 ML decrease	-$1.17
	1 unit decrease	1 ML increase	$103.38
		Same	$97.68
		1 ML decrease	$91.98
5% decrease	1 unit increase	1 ML increase	-$26.66
		Same	-$32.36
		1 ML decrease	-$38.06
	Same	1 ML increase	$61.84
		Same	$56.14
		1 ML decrease	$50.44
	1 unit decrease	1 ML increase	$150.33
		Same	$144.63
		1 ML decrease	$138.93

(c) District gross margin changes as a result of various scenarios at high sugar prices

Yield	ccs	Water use	Gross margin difference (B-G) $/ha
5% increase	1 unit increase	1 ML increase	-$159.02
		Same	-$164.72
		1 ML decrease	-$170.42
	Same	1 ML increase	-$48.18
		Same	-$53.88
		1 ML decrease	-$59.58
	1 unit decrease	1 ML increase	$62.67
		Same	$56.97
		1 ML decrease	$51.27
Same	1 unit increase	1 ML increase	-$95.34
		Same	-$101.04
		1 ML decrease	$104.40
	Same	1 ML increase	$10.23
		Same	$4.53
		1 ML decrease	-$1.17
	1 unit decrease	1 ML increase	$115.80
		Same	$110.10
		1 ML decrease	$104.40
5% decrease	1 unit increase	1 ML increase	-$31.66
		Same	-$37.36
		1 ML decrease	-$43.06
	Same	1 ML increase	$68.64
		Same	$62.94
		1 ML decrease	$57.24
	1 unit decrease	1 ML increase	$168.93
		Same	$163.23
		1 ML decrease	$157.53

4.0 SUMMARY

These analyses aim to give a basic background to the various issues associated with GCTB for farms and regional sectors. Individual circumstances, including debt loading, need to be taken into account for assessment for a particular block or farm.

The analysis has shown that there are both economic advantages and disadvantages of GCTB at both a farm and regional level. From the grower's perspective, if the farm is deemed to be highly suitable to GCTB, ie suitable soil type, slope, row length, the grower will incur reduced production costs if he/she converts from burnt cane production to GCTB production. The partial budget shows that a gain of around $320 per hectare is attainable for a farm suitable to GCTB.

The case study farm in this analysis shows the effect of a change to GCTB on a farm that is less suitable to GCTB, where considerable changes need to be made to the farm which require additional finance. The analysis showed that the change to GCTB may result in negative gross margins for the first crop cycle, but after this the gross margins are positive.

At a regional level, the analysis shows that ccs is the main factor behind benefits and costs to the overall district as a result of a change to GCTB by 30% of the district. If ccs is increased in that area, the total district gross margins will also be increased, while if ccs is reduced in that area, total district gross margins will be lowered.

5.0 REFERENCES

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APPENDIX 3 :
Best Practice Guide for Green Cane Trash Blanketing

BEST PRACTICE GUIDE FOR GREEN CANE TRASH BLANKETING

Contents:

- Background to Green Cane Trash Blanketing
- Whether to Change?
- Field Layout
- Fertiliser Requirements
- Irrigation Practices
- Pest Management
- Weed Management
- Harvesting
- Economics and Farm Management
- Environment

This publication was produced as part of a project carried out by the Bureau of Sugar Experiment Stations titled: BSS173: "Quantifying the Socio-economic Impacts of Harvesting Residue Retention Systems". This project is jointly funded by the Sugar Research and Development Corporation (SRDC) and the Land and Water Resources Research and Development Corporation (LWRRDC).

The aim of this booklet is to draw together information from various research on green cane trash blanketing into one simple package so growers can easily access research results.

Background to Green Cane Trash Blanketing

The practice of burning cane prior to harvest was introduced in North Queensland in the 1930's as a result of manual canecutters contracting diseases such as Leptospirosis. This is a potentially lethal disease spread to humans through contact with water or soil contaminated with urine of infected animals such as rats. However, since the introduction of mechanical cane harvesters, the risk of harvester operators being exposed to the disease has been significantly reduced and green cane harvesting has become an accepted practice for most of the industry once again.

The practice of leaving unburnt cane trash after harvesting is known as Green Cane Trash Blanketing (GCTB). GCTB is a beneficial management tool that helps to protect soil against erosion, conserves moisture, boosts weed control, increases soil organic matter and improves soil structure in the long term. All of these things lead to cost savings for the grower as fewer production inputs including chemicals, water, machinery and labour are required.

Trial results so far have shown that GCTB yields similar tons of cane per hectare to burnt cane, and can have a higher CCS than burnt cane. This means that the grower can receive a higher price for the cane, and with the lower production costs, experience greater profits. In supplementary irrigated areas, yields can be improved by the moisture retention benefits of the trash blanket.

It also confers external benefits on the community by reducing smoke and ash emissions from cane and trash fires, as well as decreasing the risk of possible health problems. The emissions of smoke and ash from cane fires both before and after harvest are a major social concern.

The technique has been adopted in many regions of the industry because of the agronomic, economic and social benefits.

Whether to Change?

Growers wanting to change to green cane trash blanketing need to take a number of factors into consideration, for example:

- Does my farm/paddock have soils that will benefit from trash blanketing?
- What changes to infrastructure will I need to make?
- What risks are involved?
- How will the change be financed?

A SWOT analysis should be conducted before undertaking a new venture. This involves working out what the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats (**SWOT**) of the change will be and deciding if the strengths and opportunities outweigh the weaknesses and threats of the new system.

This document will outline some of the factors that will help growers decide if they can utilise trash blanketing successfully and will also suggest a number of best management practices to maximise this success.

Field Layout

When the paddock is being prepared for planting, it is important the row spacings are consistent and at least 1.52m wide. It is also important to have a well-formed wide hill of 300mm height to maximise cane pick-up and reduce dirt incorporation at harvest. Blocks that have long furrows and low slope particularly require high hills.

In some trash blanketed paddocks in the Burdekin, growers have used a coulter to cut and part the trash down the middle of the furrow to direct the water, as shown in the photograph below. This grower has also removed the trash in the top end of the furrow.

Trash cut down centre of furrow with a coulter to direct water

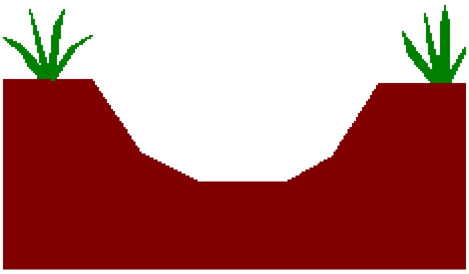
Slope

On blocks that are trash blanketed, slopes of greater than 0.125% (1 in 800) are recommended. Slopes of 0.125% are common for the Herbert district, where GCTB is practiced by over 99% of the district. Slopes steeper than this value allow water to drain off in rainfed conditions within one to three days, so as to reduce the waterlogging risk.

Slopes of 10% or more are used to grow cane with current machinery. Growers in the wet belt of Tully-Innisfail-Babinda commonly use trash blanketing on these slopes. The trash blankets offer protection to the soil surface from erosion. Furrow irrigation is not recommended for slopes greater than 3% (Holden, 1998), particularly in burnt systems as there is greater risk of erosion.

Furrow Shape

Trash blanketing acts as a resistance to the flow of water down the furrow, causing water to stay near the top of the field for longer than would be typical for a burnt furrow. V-shaped furrows are recommended for soils with high permeability and/or low slopes. This kind of furrow allows water to travel downfield at a much quicker rate than is produced from a broad based furrow. Broad based or U-shaped furrows are appropriate for soils where infiltration is a problem, or on steep slopes where high velocity can cause erosion.



U-Shaped Furrow

V-Shaped Furrow

Row Length

Generally long row lengths are only appropriate for blocks with low permeability, such as cracking clays. Freely draining alluvial soils should not have row lengths greater than 400m to reduce losses to deep drainage, particularly on trash blanketed blocks. Furrow lengths greater than 1000m on soils with low permeability require large inflow rates to allow the water to reach the end of the furrow. Inflow rates will be discussed further in the Irrigation Practices section of this publication.

Soil Type

GCTB is more appropriate in soils with low infiltration rates, such as sodic soils. The trash blankets conserve the moisture for longer periods than a bare soil surface, and also protects the highly erosive topsoil. Sodic soils generally have low permeability, so a trash blanket reduces the velocity of water travelling down the furrow, increasing the infiltration opportunity.

Furrow irrigated sandy soils require short furrow lengths to enable the water to cover the entire field. However these soils generally have a low moisture holding capacity, so they would benefit from GCTB more than a cracking clay soil. As the season progresses, a trash blanket will also assist freely draining soils by leaving the soil compacted, (ie no cultivation) therefore reducing the infiltration capacity of the soils.

In high rainfall districts where there is little irrigation, cane needs to be grown on soils with good drainage. Heavy clays in drainage depressions would need surface and sub-surface drainage installed to grow cane without risk of excessive waterlogging. The level of GCTB adoption (over 80%) in the wet belt of Queensland (Tully-Innisfail-Babinda) shows that trash blanketing can be successful if appropriate management practices are used.

Overhead irrigation is suitable for all soil types, however sprinkling rates should be reduced as the soil permeability is reduced, to allow water to drain freely into the soil and not be ponded on the surface. For example, sprinkler rates of 50mm/hr are suitable for a sandy soil with a slope of less than 5%, whereas a heavy clay with a similar slope would not be able to handle a sprinkler rate of greater than 5 mm/hr without some form of waterlogging (Holden, 1998).

Drip irrigation is appropriate for all soil types, as there is little risk of waterlogging or inefficiently irrigating the cane if the system is installed properly and well managed.

Variety Selection

When selecting varieties to be grown under a green cane trash blanket, growers need to consider a number points:

- choose varieties that are freely trashing which makes harvesting easier and could reduced extraneous matter in mill
- choose varieties that ‘stand up’ and do not lodge – this also assists harvesting
- choose varieties that are tolerant of waterlogging
- choose varieties that ratoon well under cooler conditions

Varieties that are most commonly used for GCTB in the Burdekin are Q163, Q117, Q96 and Q127. In the Proserpine district growers choose Q124, Q135, and Q138 in GCTB areas.

Fertiliser Requirements

It is recommended for all growers that they do a soil test at the start of each cropping cycle ie between ploughing out previous ratoons and planting new crop. It is also important that if a grower wants to reduce fertiliser applications during a crop cycle, they should carry out another soil test.

A grower should take the following steps when collecting soil for testing:

- Firstly decide if field is uniform, know where there are changes in soil
- Sample distinct soil types separately
- If the field is big (say over 20ha) divide into 10-15ha areas for soil sample collection
- Take samples randomly spread across paddock in 'W' shape
- Lightly brush off surface trash
- Sample to a shovel depth of around 25cm

Current Fertiliser Guidelines (Kilograms per Hectare):

Burdekin

	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulfur (S)
Fallow Plant	135 - 150	0 – 80	0 - 80	0 - 25
Ploughout – Replant	210 - 250	0 – 80	0 - 100	0 - 25
Ratoons	210 - 250	0 – 40	0 - 100	0 - 25

Proserpine

	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulfur (S)
Fallow Plant	120 - 150	20 - 80	0 – 100	0 - 25
Ploughout – Replant	160 – 200	20 - 80	0 – 100	0 - 25
Ratoons	160 - 200	0 - 25	0 – 120	0 - 25

Rates for GCTB:

In the first and second crop cycles using GCTB (plant crop and 4 ratoons), growers should use current recommended fertiliser rates for nitrogen. After the second crop cycle, growers can reduce recommended nitrogen rates by around 10%.

Larger reductions in nitrogen applications up to 25% can be made after 4 crop cycles. It is important that growers trial reduced fertiliser rates in small areas before applying them to large areas of their farms.

Fertiliser application and placement on trash blankets is a common issue. Some growers use a stool splitter, however most would prefer not to disturb the stool. A popular method of applying fertiliser to cane under a trash blanket is to side dress with a coulter running along the side of the stool. Below surface application is recommended wherever possible, however, is surface application is necessary, place it in a band close to the stool and delay application until cane has reached 50cm in height.

Fertilisers should not be applied in the inter-row as run-off and leaching losses are high and the nutrients are less available to plant roots.

Fertiliser boxes should be calibrated with each change of product.

Irrigation Practices

There is a wide range of irrigation scheduling tools available to growers, and it is advised that growers make best use of them. Examples of these tools range from basic evaporation pans to soil water monitoring devices such as tensiometers and Diviners™.

Current Irrigation Practices

As can be seen in the table below, only 25% of irrigators in Proserpine use furrow irrigation, whereas almost three-quarters of growers utilise winch or overhead irrigation. In contrast, the Burdekin in almost exclusively furrow irrigated, which is a major limitation to GCTB in the BRIA, due to the flat landscape and long furrows that are prevalent in that area. Growers in the Burdekin prefer to furrow irrigate because it has a lower capital cost than using overhead or drip irrigation systems, and there are few water restrictions in the region.

Brief Summary of Irrigation Preferences (Tilley & Chapman, 1999)

District	**Growers with Irrigation (%)**	**Furrow**	**Spray***	**Drip**
Proserpine	85	25	74	1
Burdekin	100	99.5	0.4	0.1

***** Spray irrigation includes Winch, Centre Pivot, Lateral Move and Hand Shift Spray irrigation.

Other Forms of Irrigation

… blanketed block using furrow irrigation

Alternate Furrow Irrigation

Alternate furrow irrigation is the practice of irrigating every second furrow. This allows the inflow rates to be doubled while covering the same amount of ground. For example, instead of applying 1 litre/second to 20 rows, 2 litres/second would be applied to 10 alternate furrows. By increasing the furrow inflow the resistance to flow caused by a trash blanket is overcome.

Irrigating a trash blanketed block using alternate furrow irrigation

Drip Irrigation

Drip irrigation is the most expensive form of irrigation, however it only provides water for the crop's requirements, and as such has application efficiencies of over 95%. Well managed drip irrigation would be advantageous in areas where water restrictions are present, however approximately only 2.5% of caneland in Queensland is irrigated using this method. There are additional management opportunities with drip irrigation, such as fertigation. Once the system is installed there are low labour costs.

Overhead Irrigation

Overhead irrigation is the most popular form of irrigation in the Proserpine district. This type of irrigation is favoured in areas where only supplementary irrigation is needed, or where there are restrictions on the amount of water available. However, they are unsuitable for use in windy conditions.

Overhead irrigation includes Winch, Centre Pivot, Lateral Move and Hand Shift Spray irrigation. It is a more expensive alternative compared to furrow irrigation, however it generally produces better application efficiencies. It is more appropriate than furrow irrigation for trash blanketed caneland that has very little or non-uniform slope.

An overhead irrigator

Inflow Rates

Inflow rates for trash blanketed furrow irrigation are dependent on the soil type, slope, furrow shape and row length. These rates are usually determined by the capacity of the pump or underground, and other non-block characteristics.

High flow rates, such as 7.5 $L.s^{-1}$ are ideal for highly permeable soils, even on flat slopes. Moderate flow rates such as 1.5 $L.s^{-1}$ are suitable for soils with lower permeability and short furrow lengths, however the flow rates should increase with an increase in furrow length.

Pest Management

Canegrubs

Canegrubs are the major insect pests of Australian sugarcane. In some areas of northern Queensland (Ingham to Innisfail), numbers of greyback canegrub are lower in trash-blanketed cane than where cane trash has been burnt (Robertson and Walker 1996). The mechanism responsible for low numbers of greyback canegrub in GCTB-fields is unknown, but may be mortality due to disease. Greyback canegrubs from trash-blanketed blocks often have higher levels of disease than those from burnt blocks (Table 1). Trash-blanketing and minimum tillage practices may aid in reducing grub damage by promoting the persistence of canegrub pathogens such as *Metarhizium* and *Adelina*.

Table 1: Effect of GCTB on per cent infection of greyback canegrubs by the disease-causing microorganisms, *Adelina* sp. and *Metarhizium anisopliae*. (*data source needs to be acknowledged: Robertson et al. final report BS120S*).

Trash management	Adelina		Metarhizium	
	Average	Range	Average	Range
Burnt	9%	0-20%	0.5%	0-2%
Retained	28.3%	5-63%	17.3%	0-28%

Trash blanketing may not reduce numbers of Childers canegrub, a major canegrub pest in southern Queensland. No data are available for other canegrub species.

Cane Weevil Borer

Weevil borer is a significant pest of cane in northern Queensland (Tully-Mossman). Numbers of weevil borers are high where GCTB occurs. Damage due to weevil borer was greatly reduced following the introduction of pre-harvest burning in the 1940s. The widespread adoption of GCTB in the 1990s was followed by an increase in damage due to weevil borer. Adults are attracted to decomposing cane left following harvest. Damage by weevil borers can be reduced by planting tolerant varieties, minimising harvest residues and rat damage, and the applying the insecticide Regent ®.

Armyworms

Armyworms (caterpillars of at least six species) can occur in trash-blanketed cane in spring in all sugar-growing districts. Moths are attracted to fermenting cane to lay eggs. The caterpillars feed on leaves and can severely defoliate plants. In severe infestations, a series of defoliations can occur and may result in yield loss. In most cases, a field receives only one significant infestation a year. Spraying armyworm infestations is not generally recommended as it is often too late to control caterpillars by the time infestations are noticed.

Weed Management

Trash blanketing provides a cover which reduces the likelihood of grass and broadleaf emergence. This decreases herbicide applications, therefore reducing input costs. Surveys have shown that in GCTB's, growers have cut back on herbicide applications by approximately three quarters, which is quite a large saving in production costs. This includes machinery and labour costs. Trash blanketing changes the dominant species and the weed control program needs to be adjusted.

Many growers have concerns about vines in cane, which can be difficult to manage. Vines can be a problem in both burnt and trash blanketed cane, and can be controlled by spraying with herbicides such as Actril, Atrazine, 2,4-D, MCPA and Starane.

Harvesting

Generally, it costs around 45 cents per ton extra to harvest green cane, but it is not uncommon for growers to pay up to $1 per ton more. There are many advantages and disadvantages of harvesting green. Some advantages of green cane harvesting include:

- There is less wear and tear on some mechanical components
- Savings in time and labour by not having to burn cane, as well as removing the danger of personal injury during fires.
- Contractors receive a 45c/ton premium for harvesting green
- No burnt cane levy
- Less risk of burnt cane left in paddock after rain

Green cane harvesting in the Burdekin district

The major disadvantages of harvesting green are:

- Harvesting is more difficult as visibility is poor in tall, erect green cane
- Harvesting is slower in large crops
- Feeding components of harvesters can stall if large amounts of green cane enter the harvester. This can cause damage to the stool.
- Harvest losses may increase
- It is difficult to harvest grub damaged cane green, as exposed stools are more easily damaged or pulled out of the ground.
- When green cane is lodged it tends to pick up more dirt, especially in wet conditions.

Many of these harvesting problems are not specific to green cane and are also a problem in burnt crops.

To avoid some of these disadvantages, the following best practices should be considered:

- pour rates and ground speed need to be slower
- basecutter blades need to be kept sharp and square to reduce stool damage
- basecutter blade box should be adjusted – the further forward the box the better.
- extractors should be high volume and low pressure.

Haulout equipment:

- All haulouts should avoid running over drills to minimise stool damage.
- Avoid harvesting blocks that are very wet.
- High flotation equipment is recommended to avoid compaction and stool damage.

Farm Management

It is recommended that growers wait until the beginning of a crop cycle before changing to GCTB so that any changes to field design or irrigation methods can be made. This will avoid any loss in yield/profits as a result of mismanagement. Growers should seek advice from a professional organisation such as BSES to assess the suitability of the block for GCTB.

Increased Profits

With the potential increases in cane yield and CCS levels combined with savings in labour, fertiliser, water and chemical costs, growers have the opportunity to increase their gross margins by using green cane trash blanketing.

Record Keeping

Record keeping is important for all growers, whether they use GCTB or not. It is even more important for growers using GCTB for the first time in order for them to see whether they are making savings or not and to keep track of where their expenditure is.

Communication

Communication is collecting and exchanging information, expressing ideas, feelings and attitudes. Good communication is an essential business management tool. Bad decisions, family disagreements, stress, anger, frustration and interpersonal conflict are all symptoms of bad communication.

Environmental Impacts

There are many aspects of GCTB that reduce the environmental impacts of growing sugarcane.

By harvesting cane green, the burning of cane prior to harvest is eliminated, thus reducing air pollution. Reduced air quality from burning causes problems in the wider community. Some people suffer respiratory problems during the harvest season, while most residents complain about the nuisance caused by ash falling over town.

A cane fire in the Burdekin district

Trash blankets reduce soil erosion where cane is grown on slopes. This reduces land degradation and improves water quality as it reduces the sediment running into rivers and any particles of fertiliser/herbicide/pesticide that may be attached to the sediment.

The trash remaining after harvest contains many nutrients. Rather than burning the trash and losing these nutrients, trash blanketing can reduce the need for additional fertiliser inputs.

Trash blankets increase the organic matter in the soil, which improves soil quality. Organic matter improves soil structure, and increases the soil fertility.

Trash blankets have more earthworms and micro-organisms (bacteria, fungi etc) in the top layer of soil than burnt paddocks

Trash blankets improve soil moisture conservation and reduce the number of irrigations on some soil types. Trash increases water infiltration, reduces surface soil crusting and lowers evaporation rates.

GCTB requires fewer cultivations which reduces growers' production costs and problems associated with soil compaction. There is reduced chemical use in GCTB systems as less herbicide applications are required.

Trash blankets can cause problems in some areas when floods occur the trash is washed off the cane paddocks onto roads and highways and also into creeks, rivers and drains, resulting in a high organic loading to waterways. Riparian vegetation along creeks can provide a buffer to trap trash before it moves into streams and reduce the impacts of flood waters.

A potential environmental concern with green cane trash blanketing is the problem of water quality, where water forms ponds in the paddock. The trash breaking down in these ponds contains tannins, and has a high oxygen biological demand. That is, oxygen in the water is consumed by the microbes that break down the organic matter. If this water runs into creeks, rivers and dams it can deplete dissolved oxygen levels in the water and cause fish kills. This is particularly a concern if run-off occurs soon after harvest as the high sugar levels remaining infield as lost juice and billets also have high biological oxygen demand. This issue is largely untested and may or may not be directly related to trash blanketing.

To minimise ponding, paddocks should be laser levelled where and when appropriate. Water should be kept in the paddock but if this is not possible it should be recycled. Where possible, water should be aerated over a rubble causeway or a drop box. Run-off from the first irrigation after harvest should be avoided.

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APPENDIX 4:
Community Survey: Attitudes to Smoke/Ash Emissions in the Sugar Industry

ATTITUDES TO
SMOKE/ASH EMISSIONS
IN THE SUGAR INDUSTRY

A COMMUNITY SURVEY

THE SUGAR INDUSTRY IN THE BURDEKIN REGION

Sugarcane is the major agricultural crop in the Burdekin region. There are about 820 growers in the area and last year 8.4 million tonnes of sugarcane were harvested. The sugar industry produced 1.1 million tonnes of raw sugar, creating jobs for about 2000 people. The industry contributes about $400 million directly and another $600 million indirectly to the Burdekin economy.

This survey has been designed to assess local community views and attitudes to smoke and ash emissions from sugar production, in the Burdekin region. Many people in the community rely on the sugar industry for their livelihood and it is important to know your opinions.

THIS IS AN OPPORTUNITY FOR YOU TO HAVE YOUR SAY.

HOW TO FILL OUT THE QUESTIONNAIRE

To answer most of the questions you only need to circle a number. Please circle the number, which is closest to your view. Here is an example:

Example

Do you think the government should spend more or less on public health?

Spend more on health	…	…	…	…	(1)
Doesn't matter	…	…	…	…	2
Spend less on health	…	…	…	…	3
Don't know	…	…	…	…	4

If you think the government should spend more on health, you would circle `1' as shown.

Sometimes you will be asked to rank things in order of importance. Mark 1 beside the statement which you think is most important, 2 beside the next etc. It is like allocating your preferences at the election. Here is an example:

Example

Which of the following areas do you think are more important for the government to increase spending? <u>Rank them in order of importance.</u>

Spend more on health	…	…	…	…	3
Spend more on education	…	…	…	…	1
Spend more on roads	…	…	…	…	2
Spend more on job creation	…	…	…	…	4

This means you think it is most important for the government to increase spending on education and least important to increase spending on job creation.

Sometimes you need to write an answer - in that case, write your answer in the space provided.

It will help you to read through the questionnaire first and think about the issues before completing the survey.

<u>There are no right or wrong answers to any of the questions</u>. You should simply give your opinion.

GENERAL ISSUES

How concerned are you about the following issues in the Burdekin region?

	Very Concerned	Concerned	Unconcerned	Don't Know
Condition of major roads	1	2	3	4
State of the economy	1	2	3	4
State of the environment	1	2	3	4
Quality of education	1	2	3	4

Which of the following do you think has the most impact on the environment (land/sea/air/water) in the Burdekin region? <u>Rank in order of importance</u>.

Tourism … … … … ☐
Cattle grazing … … … … ☐
Local population … … … … ☐
Sugar industry … … … … ☐
Horticulture (fruit & veg) … … … … ☐

DON'T KNOW … … … … ☐

Which of the following do you think has the most impact on the economy in the Burdekin region? <u>Rank in order of importance</u>.

Tourism … … … … ☐
Cattle grazing … … … … ☐
Local population … … … … ☐
Sugar industry … … … … ☐
Horticulture (fruit & veg) … … … … ☐

DON'T KNOW … … … … ☐

EXPERIENCE IN THE SUGAR INDUSTRY

How long have you lived in the Burdekin region? ... No of years___

<u>If two years or under</u>

Before that did you live in a sugar growing area?

YES ... 1
NO ... 2

Do you or does anyone in your family work in a sugar-related industry, ie growing, milling, harvesting, etc?

YES ... 1
NO ... 2

How far from the nearest cane paddock do you live?

Bordering a cane paddock	…	…	…	…	1
Less than 100m	…	…	…	…	2
Between 100m to 500m	…	…	…	…	3
Between 500m and one kilometre…	…	…	…		4
More than one kilometre	…	…	…	…	5

ATTITUDES TO SMOKE EMISSIONS

The following questions ask for your opinion on the effects of smoke emissions. You should mention both good and bad effects, whichever you feel are important.

There are three kinds of smoke emission associated with sugar production:

1. Cane fire -The cane is burnt prior to harvest
2. Trash fire - The cane tops and leaves remaining after harvest, are burnt.
3. Mill emissions - Smoke from the mill chimneys

Burning the cane before harvest results in a very hot but short-lived fire. These fires, usually lit at night, make a spectacular sight and are viewed by some as a tourist attraction. Although smoke from these fires can cause visibility problems, they are more noted for the black ash or "black snow" which blows into residential areas.

Trash fires do not produce the black ash but they burn for longer than a cane fire and result in more smoke. Smoke from a trash fire is much worse if the cane is not burnt prior to harvest because there is more trash to burn.
Smoke from mill chimneys should rise high into the sky but it adds to air pollution, particularly when the smoke remains low in the sky.

Were you aware of the difference between these types of smoke/ash?

YES	…	…	…	…	1
NO	…	…	…	…	2
DON'T KNOW	…	…	…	…	3

Have you seen smoke/ash from the following sources? Tick the relevant boxes.

Smoke from a sugar mill … … … … ☐
Smoke from a cane fire … … … … ☐
Ash from a cane fire … … … … ☐
Smoke from a trash fire … … … … ☐

Does the smoke/ash from sugar production affect you personally in any way?

YES … … … …1
NO … … … …2
DON'T KNOW … … … …3

If yes, give details

____
____
____
____

Does the smoke/ash from sugar production affect anyone else in your household in any way?

YES … … … …1
NO … … … …2
DON'T KNOW … … … …3

If yes, give details

____
____
____
____

Do you think the smoke/ash from sugar production affects other people in the local community in any way?

YES … … … …1
NO … … … …2
DON'T KNOW … … … …3

If yes, give details

____
____
____
____

Do you think the smoke/ash from sugar production has any effect on people visiting the Burdekin area?

YES	…	…	…	…1
NO	…	…	…	…2
DON'T KNOW	…	…	…	…3

If yes, give details

____
____
____
____

Do you think the smoke/ash from sugar production in the Burdekin region has any impacts outside the Burdekin area?

YES	…	…	…	…1
NO	…	…	…	…2
DON'T KNOW	…	…	…	…3

If yes, give details

____
____
____
____

The questions above have asked your opinion on the effects of smoke/ash from sugar production.
If you have provided details of any impacts (good and/or bad), please list the two that you think are most important.

1____
____
2____
____

SMOKE/ASH EMISSIONS - MANAGEMENT OPTIONS

The next section lists various statements and options for the management of smoke/ash emissions. You should circle the answer that most closely follows your opinion.

	Strongly Agree	**Agree**	**Neither Agree nor Disagree**	**Disagree**	**Strongly Disagree**
The sugar industry is an important part of the economy in this area and smoke/ash needs to be tolerated.	1	2	3	4	5
Reducing the amount of smoke and ash in the area is a good idea	1	2	3	4	5
Cane fires are an important tourist attraction	1	2	3	4	5
Cane and trash burning is acceptable if some restrictions are introduced to reduce the impact on the community.	1	2	3	4	5
The burning of cane and trash should be banned completely.	1	2	3	4	5
Sugar mills should reduce their smoke emissions	1	2	3	4	5
Growers should be free to burn cane/trash as they wish	1	2	3	4	5

THE COSTS OF REDUCING SMOKE/ASH EMISSIONS

The following section is designed to assess your opinion on some of the associated costs if some restrictions were placed on smoke emissions. This is to find out your opinion on the matter. <u>There is no suggestion that restrictions will be imposed</u>.

Burning cane has been part of sugar production for a long time. Green cane harvesting and retaining the leftover trash, (known as green cane trash blanketing) where neither cane nor trash are burnt, requires a change in farming practice.

Experience with green cane trash blanketing has shown that while there are many benefits associated with the practice there are also some problems.

Growers who stop burning and convert to a new system may experience some income loss in the early years as they change and learn new farming practices.

If forced to stop burning some growers may experience more serious production losses. Any decline in growers' income could effect the local economy.

Who do you think should bear the costs associated with reducing smoke/ash emissions? Circle more than one answer if necessary.

Growers … … … …1
Mills … … … …2
Community via:
Shire council … … … …3
State government … … … …4
Federal government … … … …5
Other (please specify) … … … …6

Do you think these growers should be compensated for any losses?

YES … … … …1
NO … … … …2
DON'T KNOW … … … …3

If NO, give reason

Imagine that a complete ban is placed on cane burning in this area and that a trust fund is created to compensate those growers who would loose money. Imagine also, that local residents would be directly involved in the running and management of the fund. Would you be willing to contribute money to this fund?

YES … … … …1
NO … … … …2
DON'T KNOW … … … …3

If YES:
Assume an annual payment must be made for a five year period while growers adapt to the new conditions. How much would you personally be prepared to contribute, per year, for five years?

$1-$10 ... 1
$11-$20 ... 2
$21-$50 ... 3
$51-$100 ... 4
$101-$500 ... 5

Would you also be willing to contribute, but a lesser amount, if some restrictions were placed on cane burning but not a total ban?

YES	… … … …1
NO	… … … …2
NEED MORE INFORMATION	… … … …3
DON'T KNOW	… … … …4

KNOWLEDGE OF GREEN CANE TRASH BLANKET

Green cane trash blanket is a farming practice where the cane is cut green and not burnt before harvest. The cane tops and leaves remaining after harvest (trash) are left on the ground as a layer of mulch (blanket). There are many benefits associated with this practice, but there are also some problems and not all aspects of the practice may be considered appropriate. Under certain conditions, growers may decide to burn their cane and/or trash. So while increased adoption of green cane trash blankets would reduce the amount of smoke emissions, the practice is not suited to all farming conditions.

The next section lists various statements to determine how much you know about green cane trash blankets. Place a circle around the number which you think is correct.

	True	**Sometimes True**	**False**	**Don't Know**
Contractors charge less to harvest green cane than burnt cane	1	2	3	4
Trash blankets can block the flow of irrigation water in a furrow	1	2	3	4
Trash is rubbish and should be thrown away	1	2	3	4
Most cane-growers in this region use trickle irrigation	1	2	3	4
Trash blankets reduce cultivations	1	2	3	4
Trash blankets can lead to waterlogging	1	2	3	4
Trash blankets encourages weed growth	1	2	3	4
Trash blankets can reduce soil erosion	1	2	3	4

BACKGROUND DETAILS

In this final section you are asked for some background details about yourself to make sure that the <u>people who are involved in this survey are from a wide range of backgrounds.</u>

ALL INFORMATION WILL BE KEPT CONFIDENTIAL. - NO RECORD WILL BE KEPT OF YOUR NAME OR ADDRESS.

In which district do you live? ________________________ Post Code_______
(eg Rita Is, Clare, Home Hill, etc)

What is your age? ________Years

What is your gender?

MALE. … … … …1
FEMALE … … … …2

What is the highest level of education you have obtained or are obtaining?

Primary (years 1-7) … … … …1
Secondary (year 8 and above) … … … …2
Higher or post school
    Diploma or trade certificate … … … …3
    Tertiary or higher degree … … … …4

Other (specify) ....

What is your current work status?

Employed full/part time … … … …1
Home duties … … … …2
Unemployed/looking for work … … … …3
Retired … … … …4
Full time student … … … …5

Other (specify) ....

What is your occupation, what type of work do you do?

____
____
____
____

To the best of your knowledge please indicate the total income earned last year by yourself and your husband/wife/partner (if applicable). <u>This is your income from all sources before tax or anything else is taken out</u>. (This is to assess if respondents represent a range of income groups)

Under $20,000 … … … …1
$20,001 - $40,000 … … … …2
$40,001 - $60,000 … … … …3
Over $60,000 … … … …4
DON'T KNOW … … … …5

How many members of your family live in this household, including yourself?

Adults (18 and over) ……..
Children ……..

We would like to thank you for co-operation in completing this survey.
If you would like to make any further comments please write them in the space below.

APPENDIX 5
Health Related Impacts of Cane Burning

Health Related Impacts Of Cane Burning - Regional Views

Doctors Contacted	**70**
Doctors Responding	**15**
% Response	**21**

Burdekin - majority of cane still burnt

Doctors Contacted	7
Doctors Responding	3
% Response	43

Response	No of responses
Little if any obvious impact	2
Increase in burn cases	2
Increase allergic sinusitis	1
Increase stress in women from cleaning black snow	1

North - Ingham to Mossman - nearly 100% now cut green

Doctors Contacted	27
Doctors Responding	5
% Response	19

Response	No of responses
Not there long enough	1
Little if any obvious impact	3
Burning has adverse effect on those with breathing problems	1
Concern over increased incidence of Leptospirosis	2
Increased respiratory problems relating to mould (trash blanket)	1

South - Whitsunday and Mackay - recent increases in green harvesting

Doctors Contacted	36
Doctors Responding	7
% Response	19

Response	No of responses
Not there long enough	1
No noticeable impact	2
Aggravated asthma cases in harvest season	2
Increased sinusitis in harvest season	1
Concern over increased incidence of Leptospirosis	1

Health Related Impacts of Cane Burning - A Summary

Doctors contacted	70
Doctors responding	15
% Response	21

Response	No of Responses
Not there long enough	... 2
Little if any obvious impact	...7
↑ breathing related problems	...5
↑ bum cases	...4
Concern over increased incidence of Leptospirosis	... 3
↑ mould related respiratory cases (trash blanket)	...1
↑ stress in women from cleaning	...1

Note: several doctors mentioned that two trends were evident in relation to asthma that obstructed any possible connection with cane burning. The incidence of asthma was generally on the increase, but better management meant less case presentation.

APPENDIX 6
Leptospirosis Notifications by Occupation

Leptospirosis Notifications by Occupation, Queensland, 1992-1996

Occupation	No	%
Agricultural worker	8	3
Animal associated	32	13
Banana worker	20	8
Cane farmer	9	4
Dairy farmer	16	7
Meat worker	37	16
Shooter	3	1
Student	8	3
Unemployed	3	1
Miscellaneous	38	16
Unknown	64	27
Total	238	100

Source: Smythe et al (1997) "Review of leptospirosis notifications in Queensland 1985 to 1996" Communicable Diseases Intelligence 21(2):17-20

APPENDIX 7
Community Survey: Attitudes to Smoke/Ash Emissions in the Sugar Industry Results

ATTITUDES TO SMOKE/ASH EMISSIONS IN THE SUGAR INDUSTRY

A COMMUNITY SURVEY

Burdekin and Whitsunday Shires

Summary of Results

Interim Report

SRDC/LWRRDC Project BS173

SUMMARY

The two shires used for comparison are quite different from each other. The Burdekin Shire has a very settled community, and sugar is the mainstay of the economy. In the Whitsunday Shire, sugar is second to tourism in economic importance, and many people live there for lifestyle reasons. The Whitsunday community is less settled, and respondents have not lived in the Shire for as long as those in the Burdekin. Respondents in the Burdekin generally live closer to sugarcane fields and are more likely to have some connection with the sugar industry.

Some sections of the community appear to be more interested in the issues raised in the questionnaire and a different proportion are represented in the group responding to the survey, compared with that of the general community. There are more respondents from residential rather than rural areas; more women than men in the Whitsunday Shire; more of the higher educated (particularly in the Whitsunday Shire); and more teachers in the Burdekin Shire. This is an interim report and further statistical analysis will be conducted on the results to assess the extent to which the opinions of these respondents affect the overall results.

In both shires, more respondents are concerned about the impacts of smoke/ash emissions on other people in the community than are concerned about any impact on themselves. The most frequently mentioned impact on the community relates to health; in particular, the possible impact on people with asthma and breathing related problems. In the Burdekin, the impact of ash on the community is also important, more so than in the Whitsunday Shire. Ash is considered a general nuisance; it is dirty, gets everywhere, and requires more cleaning.

The effects of smoke/ash emissions have more impact on individuals in the Burdekin Shire than the Whitsunday Shire, but in both shires, the greatest area of concern for themselves, is the impact of ash.
The impact of emissions on other household members is mainly related to health issues, but the impact of ash is also important.

When listing the overall most important impacts, health is again of most concern in both shires, with the impacts of ash being a secondary concern in the Burdekin. Environmental concerns are of secondary concern in the Whitsunday Shire, and have a higher profile in the Burdekin Shire.

It appears that when considering the impacts on themselves, respondents are most concerned about the effects of ash emissions, but when considering the impact on other people, respondents are more concerned about the possible health effects of smoke/ash emissions. This is a serious concern as a nuisance can be tolerated, but it is harder to tolerate something that affects your health. Although ash is basically a general nuisance problem, it does carry an implied cost to the community in terms of extra cleaning and possible damage to personal property. As the main burden of cleaning falls on women, they are more inconvenienced by ash than are men.

The section on general issues indicates that the majority of respondents believe that reducing smoke/ash emissions is a good idea and, although most respondents do not think

that burning should be banned, most also do not think growers should be free to bum as they wish. It appears that most respondents are prepared to tolerate emissions to some extent, but they also think the impact on the community should be reduced. However, although the majority of respondents in both shires are prepared to tolerate emissions to some extent, there are many people in the Burdekin Shire that do not appear to be so tolerant.

There is a high level of knowledge of Green Cane Trash Blanketing (GCTB) in the Burdekin compared with the Whitsunday Shire, which reflects the degree of influence the sugar industry has in the Burdekin. It also implies that respondents understand there are some difficulties associated with the practice, particularly in the Burdekin.
Initially, it was expected that Burdekin respondents would be more tolerant of smoke/ash emissions because sugar is such an important part of the economy, and Whitsunday respondents would be less tolerant, because they would be more concerned about general pollution. However, the survey results indicate that respondents in the Whitsunday Shire are less affected by smoke/ash emissions, and consequently are more tolerant of the lower level of emissions, compared with respondents in the Burdekin.

INTRODUCTION

Assessing community attitudes to smoke emissions is one component of a much broader project that is investigating a variety of issues relating to Green Cane Trash Blanketing (GCTB). The project is based in the Proserpine and Burdekin regions, and is jointly funded by SRDC[1] and LWRRDC[2].

The project arose out of earlier work that identified a range of factors acting as barriers to the adoption of GCTB in the Central and Burdekin regions of the sugar industry. The greatest constraints from a grower's perspective were based on the following:

- Trash blankets on heavier clay soils and deep draining soil types
- Trash blankets on sites with poor internal drainage
- Variation linked to rainfall events in suitability for trash blankets both within and between seasons
- Difficulties harvesting a large, lodged crop
- Slow ratooning of GCTB cane
- The lack of reliable economic data for comparison between green and burnt production methods

The project is designed to address these issues and will define areas suitable for trash blanketing under current management systems. It will implement a participatory research program to; overcome agronomic limitations; improve current management systems and to support the adoption of GCTB where suitable. The project will also assess the socio-economic benefits and costs of GCTB, on the growing and broader community sectors.
The agronomic component of the project has been concentrated in Proserpine where field trials have been established to collect data to:

- help assess the agronomic limitations of GCTB
- assist in the development of GCTB suitability maps of the area
- assist in the development of best practice guidelines and optimal farm layout design

[1]SRDC - Sugar Research and Development Corporation
[2] LWRRDC - Land and Water Resources Research and Development Corporation

Further field trials will be established in the Burdekin region to trial and demonstrate management practices to overcome some of the agronomic limitations.

The socio-economic component of the project has so far focused on the off-site impacts of GCTB in order to address the costs and benefits from a community perspective. Future work will include:

- The development of standard costs associated with GCTB to include in the best practice guidelines, including the costs associated with changes in farm design that may be required under a GCTB system.
- An analysis of factors that influenced current GCTB growers to change farming practices in the two regions. Lessons from these experiences will be applied to promote the adoption of GCTB where agronomically and economically suitable.
- Assessing the costs and benefits of GCTB from the farm and regional sectors

Overall, the project focuses more specifically on the impacts of GCTB from a grower's perspective. However, it will also assess the impacts at the regional level, which will include an investigation of both the on-farm and off-farm costs and benefits. The off-farm impacts include the possible effect of farming practices on the surrounding environment and on people in the community who share that environment. One benefit to the community of GCTB is the reduction in smoke and ash emissions and the questionnaire survey was designed to assess community attitudes to these emissions.

As the project is jointly located in the Burdekin and Whitsunday area, it was decided to survey and compare the views of these two communities. While sugar is the mainstay of the Burdekin economy, it is second in importance to tourism in the Whitsunday Shire. Many people live in the Whitsunday area for lifestyle reasons and it might be reasonable to expect the community to be more concerned about the environmental impact of smoke/ash emissions from sugarcane production, and less tolerant of these emissions compared with the Burdekin community. However, the level of emissions is much lower in the Whitsunday Shire as GCTB has been rapidly adopted in recent years, and last year 70% of the cane in the shire was harvested green. The level of adoption has remained low in the Burdekin and less than 5% of the crop is generally cut green.

THE QUESTIONNAIRE SURVEY

The objective of the survey was to find out what people in the community (and this includes growers) think about the effects of smoke and ash emissions on themselves and other people. It investigated the different types of impact, and considered the extent to which the communities are prepared to tolerate them. Additional information was gathered to assess the understanding of GCTB within the community and to see if people are aware of the benefits and problems associated with the practice. The survey assessed the extent to which people think growers should be compensated, if losses are incurred while changing to a GCTB system, and also, to assess if people are prepared to contribute towards any compensation payment.

The questionnaire survey was designed to be quick and easy to answer, as it was hoped this would encourage people to respond. The survey was mailed out to 10% of households in the Burdekin (650 households) and Whitsunday (440 households) Shires. Individual respondents were selected to represent their households, and these were selected at random from the Electoral Role, updated for the October 1998 Election. Everyone registered to vote had an equal chance of being selected and so the opinions of growers were also represented in those of the community as a whole.

The questionnaires were sent out in the second week of December 1998. A prize was offered to provide an incentive for people to return the survey and the draw for the prize was held on the 28th January 1999. In the Whitsunday Shire, 25 questionnaires (6%) were returned through the dead letter post and further questionnaires were sent out in replacement. However, as some people live in the Shire on an itinerant basis, it is likely that more surveys did not reach people, but were not returned. In the Burdekin Shire, the population is more stable and while some surveys may not have reached respondents, none were returned through the dead letter post.

Initially, it was intended to accept completed questionnaires after the January deadline for the draw. However, on 22nd January an article about the survey appeared in one of the local Burdekin newspapers. The questionnaire was designed to assess community attitudes on a range of topics, and certainly was not about whether or not growers should be allowed to burn. Unfortunately, the article presented a biased view of the survey under the headline, " To burn or not to burn". This upset some people, and stirred up some extreme opinions. Consequently, all responses received after the article appeared (15) were not included in the subsequent analysis for the Burdekin Shire. In total, 189 surveys (29%) were returned, 15 were removed leaving 174 questionnaires, (27%) of the initial sample, to be used in the final analysis. In the Whitsunday Shire, 128 surveys were returned, one of which was not completed as the respondent lived on Hamilton Island and felt too removed from the issue to be able to complete the questionnaire. In total, 127 questionnaires, 29% of those sent out, were used in the final analysis.

BACKGROUND DETAILS

To assess the attitudes and opinions of people in a community, it is best to ask everyone (the population) but, if resources are limited, it may only be possible to ask some people (the sample). In this survey, 10% of the population was sent a questionnaire, and the replies of those who responded (the sample) have been used to represent the opinions of the community as a whole. To ensure the opinions of these respondents (people completing and returning a questionnaire) come from a wide range of backgrounds, respondents were asked to provide some personal details. These details have been compared, where possible, with information supplied by the Australian Bureau of Statistics from the 1996 Census, to assess if certain characteristics of the respondents (the sample) are similar to those of the community as a whole (the population). It should be noted that at this preliminary stage, tests of statistical significance have not been conducted to assess the importance of the differences discussed in this section.

Rural and Residential

The majority of the Burdekin Shire residents live in Ayr and Home Hill, which is reflected in the distribution of respondents from rural and residential areas. However, 5% more people in Ayr and Home Hill received a questionnaire, and 5% less in rural areas, than the corresponding distribution of the population (Table 1). The sample was selected at random so there was no reason for this apparent bias, but as names were selected from the electoral role, it is possible that some people living in rural areas supplied a residential address, possibly of a family member, to the electoral commission. There was also a higher proportion of surveys returned from Brandon and Giru than had been sent out (Table 1). However, the peripheral rural areas surrounding these small towns have no separate name, and it is probable that some of the respondents from Brandon and Giru should have been classified as rural.

Table 1: Rural and Residential Distribution of the Population and the Sample

		BURDEKIN SHIRE			
		Population[a]		Sample	
		No of Households	%	% Sent out	% Returned
Ayr and Home Hill		4228	65	70	70
Brandon and Giru		451	7	7	14
Rural		1827	28	23	16
	Total	**6506**	**100**	**100**	**100**
		WHITSUNDAY SHIRE			
		Population[a]		Sample	
		No of Households	%	% Sent out	% Returned
Airlie Beach and Cannonvale		1544	35	35	43
Proserpine		1120	26	25	28
Rural		1700	39	40	29
	Total	**4364**	**100**	**100**	**100**

[a] Australian Bureau of Statistics

In the Whitsunday Shire, the proportion of households receiving a survey in rural and residential areas corresponded to the population distribution (Table 1), but a higher proportion of people living in Airlie Beach and Cannonvale responded, than people from rural areas. These communities are closer to the ocean than Proserpine and people are more likely to live there for lifestyle reasons, which is perhaps why they were more interested in completing the questionnaire.

Overall, it appears that a lower proportion of people living in rural areas responded to the survey than people living in residential areas, which suggests that the issue of smoke/ash emissions is more important to people living in residential areas.

Gender

In the Burdekin Shire, the gender distribution of the sample followed that of the population, but in the Whitsunday Shire, a higher proportion of women responded than were represented in the community (Table 2).

Table 2: Gender Distribution of the Sample and the Population

	Burdekin Shire		**Whitsunday Shire**	
Gender	Population[a]	Sample	Population[a]	Sample
Female	48	48	49	56
Male	52	52	51	44
Total	**100**	**100**	**100**	**100**

[a] Australian Bureau of Statistics

Age

In both Shires, a higher proportion of respondents were represented in the 35 to 54 years age group, and a lower proportion were in the youngest age group, compared with the age distribution of the community (Table 3). In the Burdekin Shire, there were also fewer survey respondents represented in the older age groups, than in the community. Although some older people may not have been interested in the issues, others may have been unfamiliar with, and uncomfortable about, expressing their opinions in a questionnaire, and could have been deterred by the survey method.

The average age of respondents was the same in each Shire; 43 years.

Table 3: Age Distribution of the Population and the Sample

	BURDEKIN SHIRE		**WHITSUNDAY SHIRE**	
Age	% Population[a]	% Sample	% Population[a]	% Sample
15-24[b]	19	7	19	7
25-34	18	18	24	23
35-44	19	31	19	27
45-54	16	24	16	21
55-64	12	12	11	14
65-74	10	5	8	7
75 +	6	3	3	1
Total	**100**	**100**	**100**	**100**

[a] Australian Bureau of Statistics (ABS)
[b] The ABS figures included people over 15 whereas the survey only included people over 18

Occupation

A comparison could not be made between the work status of the sample and the population as the Australian Bureau of Statistics (ABS) uses different categories to those used in the survey. For example, ABS classifies women working at home and retirees as "not in the labour force". Similarly, the ABS classifications for occupation are different from those used in the survey.

In general, respondents had a wide range of occupations (Table 4), though there appeared to be a relatively low representation of growers, especially in the Whitsunday Shire and an over-representation of teachers in the Burdekin Shire. This might indicate a lack of interest in the topic by Whitsunday sugarcane growers, and conversely, teachers in the Burdekin may have been particularly interested in the topic.

Table 4: Occupation of Respondents

Occupation	**BURDEKIN SHIRE**		**WHITSUNDAY SHIRE**	
	Respondents		Respondents	
	No.	%	No.	%
Home Duties	25	14	15	12
Sugar related (Growers)	25(9)	14	2(1)	2
Other farming/producer related	22	13	3	2
Retired	17	10	17	14

Occupation	BURDEKIN SHIRE		WHITSUNDAY SHIRE	
Education	1 7	10	8	6
Administration	14	8	12	9
Retail	9	5	17	14
Health & community service	8	5	3	2
Trade	7	4	6	5
Finance	7	4	2	2
Tourism	4	2	16	13
General Labour	4	2	3	2
Unemployed	4	2	3	2
Transport	3	2	-	-
Property development	2	1	4	3
Full time student	1	1	6	5
Other	5	3	9	7
Total	**174**	**100**	**126**	**100**

It should be noted that while 10% of all households were selected in the survey, questionnaires were sent to a named individual within the household. Women classified under "home duties" may be part of a cane-growing household. Similarly, people classified as retired, may also be retired cane growers. Consequently, the opinions of sugarcane growers may be represented to a greater extent than is indicated in Table 4. In addition, while one individual in a household may have received a questionnaire, another member may have completed and returned the form. When a male grower received a questionnaire, his wife may have completed the form. Similarly, if a teacher was present in the household, she/he may have been keener to complete the questionnaire than the addressee.

The extent to which individuals are influenced by the opinions of other people in their household, and by those around them, can only remain a matter of speculation.

Education

In both Shires, respondents came from a range of educational backgrounds, with the largest proportion having secondary education. It was not possible to compare the proportion of primary and secondary educated respondents in the sample with the population, as these statistics were not available from the Australian Bureau of Statistics. However, there was a higher proportion of respondents with a tertiary or higher degree, than was represented in the population (Table 5), indicating that people from this group were either more interested in the issues or were more inclined to complete a questionnaire. One unfortunate aspect of using a questionnaire as a method of assessing people's opinions is that it disadvantages people with poor literacy skills who are unable to complete the form.

Table 5: Education Distribution of the Population and the Sample

	BURDEKIN SHIRE		**WHITSUNDAY SHIRE**	
Education	% Population[a]	% Sample	% Population[a]	% Sample
Primary (yrs1-7)	na	10	na	3
Secondary (year 8 +)	na	49	na	40
Diploma/Trade Certificate	18	24	23	28
Tertiary or Higher Degree	4	17	7	29
Total		**100**		**100**

[a] Derived from the Australian Bureau of Statistics (ABS), 1996
na - Not available

RESULTS

General Issues

This section was designed to focus attention on environmental and economic issues, and to familiarise the respondent with the survey process. No importance or inference is attached to the results.

How concerned are you about the following issues in the Burdekin/Whitsunday Region? Condition of major roads - State of the economy - State of the Environment - Quality of Education

Over 80% of Burdekin respondents and 78% of Whitsunday respondents indicated they are either concerned or very concerned about each issue.

Which of the following do you think has the most impact on the environment/ economy? Tourism - Cattle grazing - Local Population - Sugar Industry - Horticulture

In the Burdekin shire, nearly all respondents obviously think sugar has the most impact on the economy (Table 6), but they do not all think it has the most impact on the environment (14% place the population first and 9% place horticulture first). While a general pattern of ranking emerges for the main industries, respondents are not so clear about the impacts of the local population on the environment.

Table 6: Impacts on the Economy and Environment: Ranking and percentage of responses

Burdekin Shire								
	Impact on Environment				**Impact on economy**			
	Rank	Response	Rank	Response	Rank	Response	Rank	Response
Sugar	1st	68%	2nd	12%	1st	93%		
Horticulture	2nd	55%	3rd	17%	2nd	69%	3rd	14%
Population	3rd	33%	4th	21%	3rd	39%	4th	25%
Cattle	4th	41%	3rd	39%	4th	43%	3rd	30%
Tourism	5th	62%	4th	20%	5th	59%	4th	18%
Whitsunday Shire								
	Impact on Environment				**Impact on economy**			
	Rank	Response	Rank	Response	Rank	Response	Rank	Response
Sugar	1st	43%	2nd	24%	1st	64%	2nd	29%
Horticulture	1st	39%	2nd	31%	2nd	57%	1st	33%
Population	2nd	27%	3rd	25%	3rd	45%	4th	30%
Cattle	4th	39%	3rd	24%	4th	45%	3rd	28%
Tourism	5th	54%	4th	24%	5th	65%	4th	21%

In the Whitsunday Shire, tourism contributes more to the local economy than does sugar (tourism is worth approximately $250 million compared with approximately $100 million for sugar), but a third of respondents think that sugar contributes the most (Table 6). As in the Burdekin Shire, respondents are generally less clear about the impact of the population on the environment.

Only 17% and 10% of respondents in the Burdekin and Whitsunday Shires respectively, list the impacts on the environment in the same order as those on the economy. This provides a good indication that people completed the questionnaire in a responsible manner and were thinking clearly about their responses beforehand, rather than simply equating economic importance with environmental impact.

Experience in Sugar Industry

The Burdekin Shire has a more settled community than the Whitsunday Shire, and the average length of time respondents have lived in the Burdekin Shire is 26 years, compared with 15 years in the Whitsunday Shire. Only 4% of Burdekin respondents compared with 14% of Whitsunday respondents have been resident for two years or less.

Sugar is obviously a much more dominant part of life in the Burdekin than the Whitsunday Shire. A much larger percentage of respondents in the Burdekin Shire either work themselves, or have a family member that works in a sugar related industry, compared with the Whitsunday Shire (58% and 23% respectively). Also, respondents in the Burdekin Shire live in much closer contact with sugarcane production than those in the Whitsunday Shire. Nearly all the Burdekin respondents (93%) live closer than one kilometre from a cane paddock compared with 50% in the Whitsunday Shire, and 26% of the Burdekin sample border a cane paddock compared with half that percentage in the Whitsunday Shire.

Attitudes to Smoke/Ash Emissions

This section of the questionnaire provided a simple description of the different types of smoke/ash emission from sugarcane production and asked respondents if they were aware of these differences. It then went on to ask respondents if they thought these emissions affected themselves and others in any way, and if so, they were asked to provide details.

Only 10% of respondents in the Burdekin Shire are not aware of the differences between smoke/ash from a cane fire, smoke from a trash fire when the cane has been harvested green, and smoke from a trash fire when the cane has been burnt prior to harvest. The proportion is more than double (23%) in the Whitsunday Shire.

Residents of the Whitsunday Shire are less affected by smoke/ash emissions than those in the Burdekin, mainly because there is less burning of cane, but also because more people generally live further from a cane paddock than residents in the Burdekin. This is reflected in the responses. The majority of Burdekin respondents (62%) think that smoke/ash affects them personally in some way, and approximately half think that other household members are also affected. In contrast, the majority of Whitsunday respondents (57%) think they are not personally affected and 63% (including those living alone) do not think there is an impact on other household members (Table 7).

In both Shires the majority of respondents (74% in the Burdekin and 70% in the Whitsunday Shire) think there is some effect on other people in the local community. However, only 36% and 41% of respondents in the Burdekin and Whitsunday Shires respectively, think there is any impact on people visiting the area, and only 17% of respondents in both shires, think there is any impact outside the Shire (Table 7).

Table 7: Percentage of Responses on the Impact of Smoke/Ash Emissions[a]

	Individual		Household		Community		Visitors		Outside	
Response	B[b]	W[c]	B	W	B	W	B	W	B	W
Yes	62	40	49	31	74	70	36	41	17	17
No	36	57	48	63	9	10	30	37	52	58
Don't Know	1	2	2	5	16	18	33	20	30	23
No Response	1	1	1	2	1	2	1	2	-	2
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

[a] Respondents were asked, "Do you think smoke/ash from sugarcane production affects you personally in any way (any one else in your household/ other people in the community/ people visiting the area/ outside the area)
[b] Burdekin Shire
[c] Whitsunday Shire

Respondents who indicated that smoke/ash emissions did have some impact were asked to provide details. A degree of caution is needed when interpreting the results from this section, which are presented in Table 8. The manner in which this information was collated meant that the different types of impact were recorded, and up to three types were recorded for each respondent. If one respondent mentioned three separate impacts, each was given equal weighting. Details of the type of impact were then grouped into seven categories; Ash, Smoke and Ash, Smoke, Health, Environment, Benefits, Other.

Does the smoke/ash from sugarcane production affect you personally in any way?
Only 61% and 40% of the Burdekin and Whitsunday respondents respectively think there is any impact on themselves. The type of impacts respondents describe, are similar in the two shires, with effects relating to ash being mentioned most often. Specific effects mainly relate to "general nuisance", "ash gets everywhere", "gives a dirty appearance", and increases the amount of cleaning required. In the Burdekin Shire, a greater number of responses relate to ash having an impact on personal/private property (23% of responses in this category) compared with the Whitsunday Shire (17%) and ash having an impact on commercial enterprise (4% in the Burdekin and not mentioned in the Whitsunday Shire).

Under the "smoke and ash" category, effects are related to general nuisance, having to close windows to stop smoke and ash coming inside, and problems related to leaving washing on the clothesline.

In the Whitsunday Shire, the greater percentage of responses classified under "smoke", are related to smoke causing a traffic hazard (a traffic accident associated with smoke from a trash fire, had occurred earlier in the year)Other effects are associated with general nuisance, odour, and trash smoke.

Health issues are an important concern and these are principally related to smoke emissions. Nearly half of the impacts mentioned under "health" relate to breathing problems and/or asthma (46% and 48% in the Burdekin and Whitsunday Shires respectively). Allergies and sinus/nasal problems are also an important concern, in the Burdekin (34% of responses in this group), but to a lesser extent in the Whitsunday Shire (24%).

In the Burdekin Shire, respondents do not consider an impact on the environment affects them, personally, as do a few respondents in the Whitsunday Shire.

Does the smoke/ash from sugarcane production affect anyone else in your household in any way?
Less than half the respondents, 49% and 31% in the Burdekin and Whitsunday Shires respectively (though people living alone would not have responded) think there is any impact on other household members. Again, responses in the two Shires are similar. Health issues are of most concern and in both Shires over half the responses in this category involve people with breathing related difficulties and asthma.
Problems with ash are second in importance, and the problem of smoke being a traffic hazard is of more concern in the Whitsunday Shire.

Table 8: Respondents Opinion on the Type of Impact from Smoke/Ash Emissions

Impact	BURDEKIN		WHITSUNDAY	
	No of Responses	% of Responses	No of Responses	% of Responses
YOURSELF[a]				
Ash	73	**42**	29	**36**
Ash + Smoke	23	**13**	9	**11**
Smoke	20	**11**	15	**19**
Health	50	**29**	21	**26**
Environment	-	**-**	4	**5**
Other	8	**5**	2	**3**
Total	174	**100**	80	**100**
HOUSEHOLD[b]				
Ash	38	**33**	20	**34**
Ash + Smoke	7	**6**	4	**7**
Smoke	10	**9**	9	**15**
Health	53	**46**	22	**37**
Environment	-	**-**	3	**5**
Other	7	**6**	1	**2**
Total	115	**100**	59	**100**
COMMUNITY[c]				
Ash	68	**34**	33	**22**
Ash + Smoke	19	**9**	9	**6**
Smoke	14	**7**	14	**9**
Health	88	**44**	83	**56**
Environment	9	**4**	4	**3**
Other	4	**2**	6	**4**
Total	202	**100**	149	**100**
VISITORS[d]				
Ash	22	**29**	9	**12**
Ash + Smoke	2	**2**	3	**4**
Smoke	6	**8**	13	**18**
Health	22	**29**	27	**37**
Environment	4	**5**	9	**12**
Benefits	14	**18**	4	**5**
Other	7	**9**	8	**11**
Total	77	**100**	73	**100**
OUTSIDE[e]				
Ash	1	**3**	1	**4**
Ash + Smoke	3	**8**	4	**16**
Smoke	1	**3**	1	**4**
Health	0	**-**	1	**4**
Environment	28	**80**	15	**60**
Benefits	1	**3**	-	**-**
Other	1	**3**	3	**12**
Total	35	**100**	25	**100**

[a] Effect on the respondent themselves
[b] Effect on other household members
[c] Effect on other people in the community
[d] Effect on visitors to the Shire
[e] Effect outside the Shire

Do you think the smoke/ash from sugarcane production affects other people in the local community in any way?
Respondents are more concerned about the possible effects of smoke emissions on other people in the community than on themselves, with 74% and 70% of respondents in the Burdekin and Whitsunday Shires respectively, indicating they think there is some kind of impact on other people in the community. In both Shires, the majority of respondents are concerned about health impacts, but to a greater degree in the Whitsunday Shire. Within this category, asthma is of most concern, amounting to 38% and 35% of responses; breathing related problems accounting for 19% and 31% of responses; and, allergies and sinus/nasal problems accounting for 15% and 12% of responses, in the Burdekin and Whitsunday Shires respectively.

As cane fires have a greater impact in the Burdekin community, there is more concern about the impact of ash than is the case in the Whitsunday Shire.

Do you think the smoke/ash from sugarcane production has any effect on people visiting the area?
There is less concern about the impact on people visiting the Shires, with only 36%and 41% in the Burdekin and Whitsunday Shires respectively, answering "yes" to this question. Health issues are again of most concern, particularly in the Whitsunday Shire where the traffic hazard associated with smoke and the environmental impacts (principally related to reduced air quality) are of more concern than in the Burdekin Shire. In the Burdekin Shire, the effect of ash is an important concern, particularly as it seen to "give the area a dirty appearance". Burdekin respondents think there are more benefits associated with cane fires (related to the spectacle of a cane fire and the novelty associated with that and the "black snow") than respondents in the Whitsunday Shire.

Only 17% of respondents in each Shire think there are any impacts outside the area, with the impact on the environment being the principal area of concern.

To make a distinction between the relative importance of different impacts, respondents were asked to list those they thought most important. Many respondents who gave details of impacts did not complete this section, and just over half the respondents in each Shire provided any details (59% and 53% in the Burdekin and Whitsunday Shires respectively).

Health impacts are of most concern (Table 9) and, within this group, the effect on people with breathing related problems and asthma account for 40% and 47%; unspecified general health problems account for 41% and 35%; and allergies and sinus/nasal problems account for 13% and 9% of responses, in the Burdekin and Whitsunday Shires respectively.

The second most commonly mentioned impacts relate to the general nuisance and extra cleaning associated with ash in the Burdekin Shire and with environmental factors such as air pollution and general environmental pollution in the Whitsunday Shire. When considering the most important impacts, environmental considerations have a higher profile in the Burdekin Shire than they did in the previous impact questions.

Table 9: Respondents Opinion on the Most Important Effects of Smoke/Ash Emissions

Most important	Burdekin		Whitsunday	
	No of Responses	% of Responses	No of Responses	% of Responses
Ash	51	**28**	15	**13**
Ash + Smoke	8	**4**	5	**4**
Smoke	20	**11**	16	**14**
Health	63	**34**	43	**38**
Environment	24	**13**	25	**22**
Benefits	11	**6**	6	**5**
Minor Impact	4	**2**	-	**-**
Trash fire > impact than cane fire	2	**1**	-	**-**
Other	2	**1**	5	**4**
Total	185	**100**	115	**100**

General Opinions

A series of statements was presented in the questionnaire, with five options for response, which ranged from strongly agree to strongly disagree. The results are displayed in Table 10.

Table 10: Percentage of Responses to General Opinion Statements

Statement	Response	Burdekin (%)	Whitsunday (%)
The Sugar industry is an important part of the economy in this area and smoke/ash needs to be tolerated	Strongly Agree	26	27
	Agree	24	28
	Neither Agree nor disagree	14	14
	Disagree	20	18
	Strongly disagree	13	10
	No Response	3	3
	Total*	**100**	**100**
Reducing the amount of smoke and ash in the area is a good idea	Strongly Agree	43	47
	Agree	28	30
	Neither Agree nor disagree	19	17
	Disagree	5	2
	Strongly disagree	4	2
	No Response	1	2
	Total	**100**	**100**
Cane fires are an important tourist attraction	Strongly Agree	13	9
	Agree	24	26
	Neither Agree nor disagree	34	25
	Disagree	20	21
	Strongly disagree	7	16
	No Response	2	3
	Total	**100**	**100**

Cane and trash burning is acceptable if some restrictions are introduced to reduce the impact on the community	Strongly Agree	15	22
	Agree	37	45
	Neither Agree nor disagree	13	10
	Disagree	22	9
	Strongly disagree	10	9
	No Response	3	5
	Total	**100**	**100**
The burning of cane and trash should be banned completely	Strongly Agree	21	11
	Agree	11	6
	Neither Agree nor disagree	14	23
	Disagree	26	27
	Strongly disagree	25	30
	No Response	3	3
	Total	**100**	**100**
Burning trash has more impact than burning cane	Strongly Agree	20	10
	Agree	30	32
	Neither Agree nor disagree	29	45
	Disagree	15	6
	Strongly disagree	4	2
	No Response	2	5
	Total	**100**	**100**
Growers should be free to burn cane/trash as they wish	Strongly Agree	9	9
	Agree	11	13
	Neither Agree nor disagree	11	14
	Disagree	32	32
	Strongly disagree	35	28
	No Response	2	4
	Total	**100**	**100**

* Some respondents did not respond to the statement

The sugar industry is an important part of the economy in this area and smoke/ash needs to be tolerated.
Responses are similar in both Shires, with approximately half the respondents either agreeing or strongly agreeing with the statement; a third or under, disagree to some extent. Relatively few respondents strongly disagree.

Reducing the amount of smoke and ash in the area is a good idea.
A clear majority of respondents in both Shires agreed to some extent with this statement (70% and 75% in the Burdekin and Whitsunday Shires respectively), with most of those strongly agreeing. Very few respondents disagree with the statement.

Cane fires are an important tourist attraction.
Responses to this statement are varied and some respondents agree, some disagree and others neither agree nor disagree; no clear position emerges. More respondents in the Whitsunday Shire strongly disagree, compared with the Burdekin Shire.

Cane and trash burning is acceptable if some restrictions are introduced to reduce the impact on the community.

Over half the respondents agree or strongly agree with this statement, with the proportion being higher in the Whitsunday Shire. A larger percentage of Burdekin respondents disagree with the statement.

The burning of cane and trash should be banned completely.

Over half the respondents either disagree or strongly disagree with this statement, although a higher percentage agreed and strongly agree in the Burdekin compared with the Whitsunday Shire.

Burning trash has more impact than burning cane.

In the Whitsunday shire, most respondents, neither agree nor disagree with this statement, though 42% agree to some extent. In the Burdekin, a smaller percentage, are undecided and most respondents agree to some extent. A larger percentage in the Burdekin Shire, strongly agree compared with the Whitsunday Shire.

Growers should be free to burn cane/trash as they wish.

In both Shires the majority of respondents disagreed to some extent with this statement.

To summarise the results of this section, the clearest response to emerge is that most respondents believe that reducing the amount of smoke and ash is a good idea; very few respondents disagree. Most respondents do not think burning should be banned, but they also do not think that growers should be free to burn cane/trash as they wish. It appears that most respondents are prepared to tolerate emissions to some extent, with the majority agreeing that the sugar industry is an important part of the economy and smoke/ash needs to be tolerated. Most respondents also agree that cane and trash burning is acceptable if some restrictions are introduced to reduce the impact on the community.

Although in both shires the majority of respondents are prepared to tolerate emissions to some extent, there is a substantial group of people in the Burdekin Shire that do not appear to be so tolerant. A third of Burdekin respondents do not think emissions should be tolerated because sugar is an important part of the economy. A third also disagree that burning is acceptable if some restrictions are introduced to reduce the impact on the community, and the same proportion think that burning should be banned completely.

In the Whitsunday Shire, the reduced amount of smoke emissions and the greater distance people live from cane fields mean that smoke/ash emissions have less effect on the community and people are more prepared to tolerate these emissions. Although- there is a section of the Whitsunday community that is less prepared to tolerate emissions, it is not as large as that in the Burdekin Shire. Less than a third (28%) do not agree that emissions should be tolerated because sugar is an important part of the economy. Only 18% do not agree that burning is acceptable, if some restrictions are introduced to reduce the impact on the community, and only 17% think that burning should be banned completely.

Although the smoke from a trash fire has more impact than smoke from a cane fire, it is hard to compare the impacts of two types of fire, as cane fires have the added impact of ash emissions. In general, 13 respondents think the impact of burning trash is greater than burning cane. However, a large proportion, (the majority in the Whitsunday Shire), have no clear opinion on the matter.

The one issue that induces a mixed response is whether or not cane fires are a tourist attraction. More respondents in the Whitsunday Shire, compared with the Burdekin Shire, strongly disagree with the statement. This is probably related to results from the previous section on the type of impacts, which suggest that some respondents believe tourists see cane burning as having a negative environmental impact.

The costs of reducing smoke/ash emissions

This section explained to respondents that, under current farming practices, GCTB might not be suitable in all circumstances. Consequently, given existing conditions, a change to GCTB may benefit the community, but for some growers there would be extra costs incurred. Some growers could expect yield declines and some may have to make expensive infrastructure changes to avoid serious production losses.
Respondents were reminded that any reduction in growers' income could affect the local economy, and were then asked if they thought growers should be compensated for any losses.

The majority of respondents do not think growers should be compensated (59% and 50% in the Burdekin and Whitsunday Shires respectively). A smaller percentage in the Burdekin Shire think growers should be compensated, compared with the Whitsunday Shire (23% and 30% respectively), and just under 20% in both Shires "don't know". Respondents who do not think growers should be compensated were asked for their reasons. The reasons given are presented in Table 11.

Table 11: Reasons for Not Providing Growers with Compensation

Reason	**Burdekin** Responses		**Whitsunday** Responses	
	No.	%	No.	%
Must learn to adapt to changes -others have	37	32	38	51
Have financial resources to absorb extra costs	10	9	4	5
Losses are part of farming - good yrs and bad	8	7	5	7
Benefits greater than costs - losses small	8	7	4	5
Have responsibility to community/environment	6	5	4	5
Get enough financial support from other sources	6	5	3	4
Growers should be given time to adapt	6	5	2	3
Other areas converted without compo	6	5	1	1
Should compensate the community for nuisance	6	5	1	1
Losses can be written off against tax	5	4	1	1
Against any restrictions	5	4	1	1
Need incentives to change, not compensation	1	1	5	4
Other	11	10	6	8
Total	**115**	**99**	**74**	**97**

The largest percentage of reasons provided by each area, 32% in the Burdekin and 51% in the Whitsunday Shire, relate to the idea that growers should adapt to new/changing conditions, (environmental legislation, workplace health and safety regulations, best practice guidelines etc.) as other industries have had to do, without compensation. Several respondents involved in the tourist industry in the Whitsunday

Shire commented that they did not get compensation if wet weather keeps tourists away. A further 32% of responses in the Burdekin and 22% in the Whitsunday Shire relate to growers being assisted in other ways, and that any associated losses, which may be small, especially compared to the long term benefits, should be absorbed as part of a long term farming management plan.

If people in the community do not like the effects of smoke/ash emissions, it might be reasonable to expect them to contribute towards reducing these emissions, particularly those who think growers should be compensated for any losses incurred in changing to GCTB. A hypothetical situation was described in the questionnaire that suggested a trust fund would be established, managed by the local community, to compensate growers who incurred losses if a ban was placed on burning. Respondents were asked if they were prepared to contribute to this fund. Very few responded affirmatively to this question; only 5% and 3% of respondents in the Burdekin and Whitsunday Shires respectively. This implies that respondents are not prepared to contribute towards reducing smoke/ ash emissions.

Knowledge of Green Cane Trash Blanketing

This section was designed to assess the extent of community knowledge of GCTB. It was also meant to reinforce a notion that had already been introduced; that while GCTB might reduce smoke emissions, it is not a simple farming system and there can be problems associated with the practice. Respondents were presented with a series of statements to which they could answer, true, sometimes true, false or don't know. The results are presented in Table 12.

Table 12: Percentage of Responses to Statements about Green Cane Trash Blanketing

Statement	Response	Burdekin	Whitsunday
Contractors charge less to harvest green cane than burnt cane	True	2	4
	Sometimes True	5	3
	False	67	37
	Don’t Know	25	53
	No Response	1	3
	Total	**100**	**100**
Trash blankets can block the flow of irrigation water in a furrow	True	47	29
	Sometimes True	34	31
	False	6	8
	Don’t Know	12	29
	No Response	1	3
	Total	**100**	**100**
Trash is rubbish and should be thrown away	True	4	2
	Sometimes True	12	10
	False	71	70
	Don’t Know	11	15
	No Response	2	3
	Total	**100**	**100**

Most cane growers in this region use trickle irrigation	True	25	9
	Sometimes True	5	10
	False	57	40
	Don't Know	11	39
	No Response	2	2
	Total	**100**	**100**
Trash blankets reduce cultivation	True	45	30
	Sometimes True	15	9
	False	11	13
	Don't Know	26	45
	No Response	3	3
	Total	**100**	**100**
Trash blankets can lead to waterlogging	True	39	24
	Sometimes True	30	33
	False	8	6
	Don't Know	22	35
	No Response	2	2
	Total	**100**	**100**
Trash blankets encourage weed growth	True	3	5
	Sometimes True	6	6
	False	71	57
	Don't Know	18	29
	No Response	2	3
	Total	**100**	**100**
Trash blankets can reduce soil erosion	True	62	61
	Sometimes True	15	10
	False	5	3
	Don't Know	17	23
	No Response	1	3
	Total	**100**	**100**

Contractors charge less to harvest green cane than burnt cane.
Contractors charge more to harvest cane green, because they cannot see so well (when the cane is burnt it clears the trash, leaving only the tops and **the** stalk) and have to go slower. To compensate for the slower speed and extra fuel use, contractors charge more for harvesting cane green. However, to respond correctly to this statement, requires specialised information, that generally, people in the community could not be expected to know.

A high percentage of respondents in the Burdekin Shire (67%) and 37% in the Whitsunday Shire know that the statement is false. While over half the Whitsunday respondents (53%) do not know whether or not the statement is correct, only 25% of Burdekin respondents do not know. Very few people give an incorrect response.

Trash blankets can block the flow of irrigation water in a furrow.
This is a technical statement that generally only people involved in growing sugarcane would be expected to know. If a furrow is very long and there is little slope, it is true that the presence of a trash blanket can impede the flow of water. The statement can be considered true, or sometimes true, and a high percentage of respondents know the

correct answer (81% and 60% in the Burdekin and Whitsunday Shires respectively). Again, a larger proportion of Whitsunday respondents, do not know the answer compared to those in the Burdekin, and few respondents answer incorrectly.

Trash is rubbish and should be thrown away
The word used for residues, "trash", has negative connotations and is associated with rubbish and being thrown away. This statement was included to assess if the terminology affects people's perceptions.

Apparently, people are not greatly influenced by this terminology and a clear majority in both Shires, (70%), respond correctly. A lower proportion indicate they do not know (particularly in the Whitsunday Shire), compared with other statements in this section.

Most cane growers in this region use trickle irrigation
This statement is incorrect; furrow irrigation is used throughout the Burdekin Shire and although other forms of irrigation are becoming more common in the Whitsunday Shire, furrow irrigation is still used by most cane growers.

In the Whitsunday Shire less than half the respondents (40%) answer correctly, and a similar percentage, indicate they do not know. In the Burdekin Shire, more respondents are correct in their reply (57%) but 25% are completely wrong. However, it is likely that some respondents are unfamiliar with the terminology and think trickle irrigation is in fact furrow irrigation.

Trash blankets reduce cultivations
This statement is correct. Trash remains as a cover on the soil, and is left to decompose. The ground is left uncultivated, and apart from fertiliser and possible weedicide applications, there is no need for machinery to enter the paddock until harvesting time.

Respondents are generally not so clear about the truth of this statement. Less than half the
Burdekin respondents (45%) and less than a third of the Whitsunday respondents (30%) answer correctly. The majority of Whitsunday respondents (45%) and 26% of Burdekin respondents do not know the correct answer.

Trash blankets can lead to waterlogging
Trash blankets reduce evaporation, which helps the soil retain moisture, and it takes longer to dry out. This has the advantage of extending the time between irrigations, but with poor drainage, heavy clay soils may become waterlogged after heavy rain, or irrigation, and the trash blanket slows the drying out process. Consequently, this statement is a correct, but to know this, requires a technical level of knowledge.

Most respondents appear to be aware of this problem, and 68% in the Burdekin and 57% of respondents in the Whitsunday Shires answer correctly; few people are wrong, but 22% and 35% in the Burdekin and Whitsunday Shires respectively indicate they do not know.

Trash blankets encourage weed growth
This may be considered a more general and less technical statement, as some people use mulch in their gardens to control weeds. The presence of a trash blanket does suppress the growth of many, but not all weeds. A clear majority, provide the correct response, 71% in the Burdekin and a lower 57% in the Whitsunday Shire. Few respondents answer incorrectly, though a higher percentage of respondents in the Whitsunday Shire compared with the Burdekin, do not know the answer.

Trash blankets can reduce soil erosion
This statement is correct, but requires a more technical level of knowledge, although not to the same extent as some of the previous statements. A relatively high percentage of respondents in both shires (78% and 70% in the Burdekin and Whitsunday Shires respectively), answer correctly. Again, very few answered incorrectly.

In summary, there generally appears to be a high level of knowledge of GCTB in the Burdekin, which reflects the close connection between the community and the sugar industry. Although there is not the same level of knowledge of GCTB in the Whitsunday Shire, this is more of a reflection on the high levels in the Burdekin rather than low levels in the Whitsunday Shire. It should be remembered that 58% of respondents in the Burdekin Shire either work themselves, or have a family member that works in a sugar related industry, compared with 23% in the Whitsunday Shire.

Some of the statements included in this section require a level of specialist or technical knowledge that only people involved in sugarcane production would normally be expected to know. Nonetheless, a high percentage of respondents know about the difficulties associated with irrigation (very well known in the Burdekin), and problems of waterlogging. Respondents are also generally well informed that trash blankets can reduce soil erosion and suppress weed growth.

The statement, "trash blankets reduce cultivations" was included in this section as it was thought to require a less technical and more general level of knowledge. This was based on the consideration that retaining residues and reduced tillage have been publicised through their adoption in other farming sectors as well as the sugar industry. It is somewhat surprising that fewer respondents in both shires know the correct response to this statement, than to the more technical statements. Reducing cultivations is a major benefit of trash blankets, it reduces the labour input on a farm, reduces machinery use and maintenance, and reduces soil compaction problems from machinery use. It appears the technical problems and associated costs of GCTB may be more widely recognised than the benefits.

APPENDIX 8
Grower's Survey on Burnt and Green Cane Trash Blanketing Farming Systems in the Burdekin and Proserpine Districts - Report

BUREAU OF SUGAR EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA

PROJECT REPORT
SRDC PROJECT BSS173

QUANTIFYING THE SOCIO-ECONOMIC IMPACTS OF HARVESTING RESIDUE RETENTION SYSTEMS

GROWERS' SURVEY ON BURNT AND GREEN CANE TRASH BLANKET FARMING SYSTEMS IN THE BURDEKIN AND PROSERPINE DISTRICTS

by
Fiona Small
PR00003

The Sugar Research and Development Corporation are funding this project during 1996 to 2002 financial years as a joint venture with BSES.

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1.0 INTRODUCTION

The purpose of this report is to present the findings from a canegrowers' survey, conducted in the Burdekin and Proserpine districts in 1999. The survey was carried out as a milestone requirement for an SRDC[1] and LWRRDC[2] jointly funded project, BSS173: 'Quantifying the socio-economic impacts of harvesting residue retention systems'. This project aims to support and extend the adoption of trash retention systems based on agronomic and economic suitability. The survey collected quantitative data to establish and compare the costs of cane production in burnt and green cane trash blanket (GCTB) systems. In addition, qualitative data on the attitudes and perceptions of cane farmers towards GCTB were gathered.

2.0 SURVEY DESIGN

The survey consisted of three main sections, with some introductory questions to collect general information about the farm, including farm number, varieties grown, and the length of farmer's experience with GCTB (if applicable). The first section asked questions regarding the use of on-farm activities such as land preparation, fertilising, irrigation, chemical applications and harvesting, as well as other changes in practice required to adapt to GCTB, such as re-levelling blocks and the purchase of new equipment. The second section collected information about attitudes to, and perceptions of GCTB, as well as the decision-making factors and information sources, which will be useful for the extension component of the project. A final section was devoted to collecting farmers' observations about GCTB, by making note of comments made during interviews.

Final design of the survey was a result of a number of drafts, scrutinised by various BSES[3] extension and research officers, productivity board staff, private economists and sociologists. A pilot survey of a small group of growers in the Burdekin district was also used to ensure there was no ambiguity in the questions.

The questions in the first section of the survey were designed to collect cost information for various farm activities on both canegrowing systems – burnt and green cane trash blanket (GCTB). Questions were structured to facilitate the collection of costs for all standard farm operations. For example, if a farmer were asked 'how much does it cost you per hectare to cultivate?' they would not know, or would guess, providing an extremely inaccurate response. Instead, the farmer was asked 'what size tractor and implement do you use, how long does it take you and how many passes do you do?' By asking the questions in this way, the standard costs for each operation could be more accurately estimated and more meaningful comparisons could be made between farms.

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[1] Sugar Research and Development Corporation
[2] Land and Water Resources Research and Development Corporation
[3] Bureau of Sugar Experiment Stations

Difficulties with questions on irrigation practices were experienced during interviews, as many growers were not aware of the amount of water they use or what it costs them to irrigate. The responses to these questions are therefore less accurate and reflect growers' own estimates.

3.0 SURVEY SAMPLE

Survey samples were obtained by randomly selecting 10% of the growers from mill address lists including both burnt and GCTB growers. Eighty-two growers were surveyed in the Burdekin district and 25 in the Proserpine district. Letters were sent to these growers, introducing the project and explaining the purpose and importance of the survey. Follow-up phone calls were then made to assess farmers' willingness to participate in the survey, and if agreeable, appointments were made to have an interview with the surveyor to complete the survey.

Some difficulty was experienced in obtaining willing participants for the survey, largely due to the fact that the survey was carried out during the harvesting season. Many growers were restricted from participating in the survey as they had other commitments including both on-farm and off-farm jobs. To compensate for these unwilling growers, more were randomly selected from the mill lists until a 10% sample was obtained.

Surveys were conducted with farmers at a time and place convenient to them. This was usually during the day at their homes, however, some preferred to come to the BSES offices to answer the questions. The majority of the survey was completed following grower consultation. However aspects of the survey relating to decision-making and sourcing of information pertaining to farming practice technologies were completed by the grower at the time of the interview or at a later date.

4.0 SURVEY ANALYSIS

Survey data were analysed using Microsoft Excel. Differences in estimated costs between burnt and GCTB systems were observed for land preparation and crop establishment. Obviously a plant crop in a GCTB system would be treated no differently to a plant crop in a burnt system, and therefore no differences in costs would be expected. The differences in these costs reflects differences between farmers of standard practices reflecting personal experience, location specific reasons and farmer preferences. A larger survey sample would have allowed us to properly estimate such influences.

Current season costs of fertilisers, chemicals and ameliorants (gypsum, lime, etc) were collected from local distributors, while costs of implements and tractors were calculated using new prices and included depreciation, interest and operating costs. All price data reflect those applicable to the local area. An example of a calculation of a tractor’s total cost per hour is shown in Table 4.0.

TABLE 4.0

Calculation of tractor costs

Tractor	**95 hp**
New Price	$77,700
Trade-in	$34,965
Interest Rate	0.1%
Yearly work	800 hrs
Trade-in age	6.25 yr
Depreciation	$6,837.60
Interest	$5,633.25
Insurance	$563.33
Tractor Overhead Costs $/hour:	**$16.29**
Diesel $0.36/L, 19L/hr	6.84
Engine oil $2.45/L, 0.06L/hr	0.147
Trans. Oil $2.95/L, 0.076L/hr	0.0258
Air filter - primary $57/filter, 500hrs/filter	0.114
Air filter - second $68/filter, 500hrs/filter	0.136
Fuel filter $34/filter, 500hrs/filter	0.068
Hydraulic oil filter $81/filter, 1000hrs/filter	0.081
Oil filter $13/filter, 250hrs/filter	0.052
Trans. Oil filter $52/filter, 1000hrs/filter	0.052
Transmission filter $22/filter, 1000hrs/filter	0.022
2 large tyres @ $990/tyre, 3500hr/tyre	0.566
2 small tyres $220/tyre, 3500hrs/tyre	0.126
Tubes - large $135/tube, 6000hrs/tube	0.0225
Tubes - small $25/tube, 6000hrs/tube	0.0042
2 batteries $140/battery, 2400hrs/battery	0.1167
Repairs	3.00
Tractor Variable Costs $/hour:	**$11.37**
Total Tractor Costs $/hour:	**$27.66**

SOURCE: NSW Agriculture, Farm Budget Handbook 1998

4.1 Production costs

Labour costs are included and the sugar industry award rates were obtained from the Department of Employment, Training and Industrial Relations (Paul Gwydir, D.E.T.I.E. personal communication, August 1999).

Data from the survey for fertiliser, chemical, tractor and implement costs were used to calculate total costs of each farm activity for each farm surveyed. The costs shown in the following tables are averages across all farms surveyed and do not represent any one typical farm. The ranges of costs for each activity are given in section 5 of this report.

Costs were calculated for each farm activity as follows:

Land preparation
The cost of land preparation includes tractor and implement costs, as well as the labour for the tractor operator. Common methods of pre-plant land preparation include one or two rippings, one or two discings and one rotary hoe pass. This cost assumes that the land is already in cane production, and therefore does not include costs of land clearing, laser levelling or plough-out.

Post-plant land preparation includes standard activities such as cutaway, grubbing, strawberry harrow and filling-in. Ratoon land preparation included some cultivations or trash incorporation.

Planting
Planting costs are either the price paid to a contractor, or the cost of planting by the farmer. If the grower plants his/her own cane, the cost used includes the labour for all of the workers involved, the cost of running the tractor and planter, as well as the cost of planting material (seed cane).

Fertiliser
The fertiliser costs are calculated using 1999 fertiliser prices. The value of fertiliser at planting is the cost of fertiliser alone, while the post-plant and ratoon fertiliser cost includes the fertiliser cost as well as tractor, implement and labour costs.

Ameliorants
Ameliorants include lime, gypsum, mill mud and ash. In the Proserpine district, this cost also includes the application of dunder. These are applied by contractors and the cost shown in this report is a reflection of the price charged by the contractors.

Herbicides
Herbicide costs were also calculated using 1999 chemical prices, and includes the cost of chemicals, tractor, implement (boom spray) and labour.

Pesticides
The pesticide costs shown in this analysis vary between the two regions. The pesticide cost in the Burdekin district is incurred in the plant crop only as it represents the application of SuSCon during planting. In the Proserpine district, the pesticide cost is

incurred in ratoon crops only as it represents the application of chemicals such as Lorsban for the control of army worms. This cost includes the chemical, tractor, implement and labour costs involved with the chemical application.

Irrigation
Irrigation costs were difficult to calculate and compare between farms. Depending on the source of irrigation water, they could pay up to $40 per megalitre for water, while others do not pay anything at all. Another difficulty experienced in calculating this cost was the fact that most growers do not know how much water they use to grow their crops. This was overcome by asking growers to estimate their water use, which means there are some inaccuracies in these costs.

Harvesting
Harvesting costs are calculated by multiplying the cane yield per hectare by the contract price of harvesting per ton. This method was also used for calculating the harvesting cost for the few growers who harvested their own cane.

Income and profits for each farm were calculated, and finally average cost, income and profits were calculated for the two systems –burnt and GCTB farms, in each district. Cane prices were calculated using the 1999 sugar price of $255 per ton (CANEGROWERS, December 1999, *The Burdekin District CANEGROWER*).

4.1.1 Production costs in the Burdekin district

Average yield for the 1999 season were used in these calculations, as individual farm yields were not available at the time of this report. Cane yields ranged from 112 tons per hectare to 124 tons per hectare in the 1999 season. For the purpose of this study a cane yield of 116 tons per hectare with a Commercial Cane Sugar (CCS) of 15 units was used.

The calculated average production costs, income and profits of both burnt and GCTB cane in the Burdekin are shown in Table 4.1. The differences between each system are also shown in the right-hand column of the table.

As indicated in Table 4.1, it costs $46.48 more per hectare to grow a plant crop under GCTB, while in a ratoon crop it is $67.33 per hectare cheaper to grow cane under GCTB. The gross margin in GCTB is $46.48 per hectare less than burnt cane in a plant crop, while in a ratoon crop the gross margin in GCTB crops is $67.33 per hectare higher than burnt crops.

TABLE 4.1

Average production costs, income and gross margins in the Burdekin district

COSTS:	GCTB $/ha	Burnt $/ha	Difference (G-B)
Land Preparation			
Pre-plant	151.09	154.49	-3.40
Post-plant	43.10	28.68	14.42
Ratoon	14.02	29.61	-15.59
Planting	335.51	340.15	-4.64
Fertiliser			
Planting	238.48	276.58	-38.11
Post-plant	254.63	240.49	14.13
Ratoon	224.84	332.27	-107.43
Herbicides			
Plant	80.82	60.30	20.52
Ratoon	50.42	50.81	-0.40
Pesticides	77.34	89.86	-12.52
Irrigation	233.32	228.99	4.33
Harvesting	661.25	609.50	51.75
TOTAL COSTS:			
Plant	**2075.53**	**2029.05**	46.48
Ratoon	**1183.85**	**1251.18**	-67.33
INCOME:	**2982.36**	**2982.36**	
Cane price	**25.71**	**25.71**	
Gross margins:			
Plant	**906.83**	**953.31**	-46.48
Ratoon	**1798.5**	**1731.18**	67.33

4.1.2 Production costs in the Proserpine district

Farm numbers were recorded during interviews and yields were then linked to cost data to calculate average income and profits for Proserpine growers.

The average costs, income and profits of both burnt and GCTB systems in Proserpine are shown in Table 4.2. From this information it can be seen that it costs $16 more per hectare to grow a plant crop under a GCTB, while in a ratoon crop it is $12.74 per hectare cheaper. The gross margin is $63.09/hectare less for a burnt system in a plant crop, while in a ratoon crop it is $34.35/hectare higher than GCTB systems.

TABLE 4.2

Average production costs, income and gross margins in the Proserpine district

COSTS:	**GCTB $/ha**	**Burnt $/ha**	**Difference (G-B)**
Land preparation			
Pre-plant	160.15	149.92	10.23
Post-plant	79.46	0.00	79.46
Ratoon	0.00	11.20	-11.20
Planting	221.66	229.50	-7.84
Fertiliser			
Planting	327.05	322.20	4.85
Post-plant	246.82	223.25	23.57
Ratoon	136.58	180.00	-43.42
Herbicides			
Plant	66.67	73.50	-6.83
Ratoon	71.06	32.50	38.56
Pesticides	10.57	13.21	-2.64
Ameliorants	161.04	228.00	-66.96
Irrigation	43.42	79.20	-35.78
Harvesting	520.49	491.97	28.53
TOTAL COST			
Plant	**1,826.75**	**1,810.75**	16.00
Ratoon	**782.12**	**794.87**	-12.74
INCOME:	**1,907.08**	**1,954.17**	-47.09
Gross margin			
Plant	**80.33**	**143.43**	-63.09
Ratoon	**1,124.96**	**1,159.31**	-34.35

4.2 Decision-making component of the survey

4.2.1 Results from Burdekin growers in decision-making section

All of the growers in the Burdekin district who currently practice GCTB say they resorted to GCTB because they were curious to see how GCTB works and how effective it is in minimising canegrub damage, controlling weeds and reducing the amount of water used. The other main reason why growers in the Burdekin were using GCTB was to save time and money by not having to cultivate, as many of them had other commitments including both on-farm and off-farm employment.

When asked what the most important benefits of GCTB were, the majority of growers responded by saying that not having the risk of burnt cane left in the paddock after rain and improved soil quality were important benefits of GCTB. Cost savings in chemicals and labour, improved weed control and reduced wear on machinery were also very important to a large number of growers.

Table 4.3 shows the percentage of growers who rated each benefit of GCTB as either very important, of some importance or of little importance. Of particular interest is growers' response to the 'cost savings in water' issue. Forty-three per cent of growers said cost savings in water were very important, while 43% said that cost savings in water were of little importance and the remaining 14% said it was of only average importance. This is the result of these farms being on different soil types, where obviously growers who said that cost savings in water were very important to them had experienced reduced water use as a result of using GCTB. The 43% who said cost savings in water were of little importance hadn’t experienced any significant differences in water use since using a GCTB system.

As previously mentioned, many growers do not know what their water use is, so this response is a little ambiguous. If they do not know what their water use was before trying GCTB, the response to the statement that GCTB has cost savings in water is just their perception and not based on actual data.

TABLE 4.3

Importance of various benefits of GCTB

Benefits of GCTB	**Very important % of growers**	**Of some importance % of growers**	**Of little importance % of growers**
Burnt cane not left in paddock after rain	86	14	0
Improved soil quality	83	17	0
Reduced labour costs	72	14	14
Improved weed control	72	28	0
Cost savings in chemicals	71	14	15
Reduced wear on machinery	71	15	14
Yield increases	50	33	17
Cost Savings in water	43	14	43
Less grub damage	33	50	17
More leisure time	29	43	28

Growers using GCTB were asked how important they thought various problems with the practice are. The percentage of responses to each problem is listed in Table 4.4. Waterlogging and irrigation arose as the issues of most concern, while ratooning and harvesting were of moderate concern. Both agronomic and economic evidence is available to support this concern.

TABLE 4.4

Importance of various problems with GCTB

Problems with GCTB	Very important **% of growers**	**Of some importance % of growers**	**Of little importance % of growers**
Waterlogging	71	14	15
Irrigation difficulties	67	33	0
Emergence and ratooning problems	50	33	17
Harvesting	43	14	43
Water ponding	32	18	50
Increased extraneous matter	20	40	40

Burdekin growers who currently burn their cane were asked if they had ever tried GCTB before, and what their experience with it was. Forty-three per cent said they had never tried it before, and cited a range of reasons why they hadn't, the most common reasons being slope and soil type. Of the 57% who had tried GCTB, 75% were unsuccessful due to waterlogging and irrigation difficulties. The remaining 25% stated that harvesting costs were the main reason why they did not continue with GCTB.

Thirty seven per cent of growers using a burnt system in the Burdekin district said that they realised that cost savings in water, chemicals and fertilisers were important benefits of GCTB, while 25% thought these things were of some importance. The remaining 38% could not see any benefits of GCTB.

All growers, using burnt and GCTB systems were asked where they get most of their information to make decisions concerning their farming operations. Their responses are listed in Table 4.5.

TABLE 4.5

Percentage of Burdekin growers using each information source

Information Source	% of growers
BSES Extension Officers	79
BSES/Canegrower publications	71
Other farmers	71
Past experience	64
Non-BSES magazines/newspapers	50
Field days/shed meetings	43
CPPB staff	36
Private agribusinesses	28
TV/radio	28
Internet	0

All of the growers said that they preferred to find out information about new farming methods and innovations through BSES Bulletins and other BSES publications. Forty per cent of the growers said they prefer to receive information from a combination of handbooks and manuals, as well as field days and on-farm demonstrations.

4.2.2 Results from Proserpine growers in the decision-making section

Fifty per cent of the surveyed growers using GCTB in Proserpine said they initially began the practice to conserve moisture and therefore reduce irrigation costs. Others tried it initially when they had observed other growers using it successfully, or because weather conditions forced them to cut green and the results were good.

The GCTB growers in Proserpine were also asked what they thought were the most important benefits of growing cane under GCTB, and all of them indicated that reduced labour costs were an important benefit of GCTB. Cost savings in chemicals, improved weed control and the reduced risk of having burnt cane left in the paddock after rain were also rated as very important by 83 – 84% of growers.

Table 4.6 lists the benefits of GCTB and shows the percentage of surveyed growers who rated each benefit as being very important, of some importance or of little importance.

TABLE 4.6

Importance of various benefits of GCTB

Benefits of GCTB	**Very important % of growers**	**Of some importance % of growers**	**Of little importance % of growers**
Reduced labour costs	100	-	-
Burnt cane not left in paddock after rain	84	16	-
Cost savings in chemicals	83	17	-
Improved weed control	83	17	-
Reduced wear on machinery	67	33	-
Cost savings in water	67	33	-
Improved soil quality	66	34	-
More leisure time	50	33	17
Yield increases	50	50	-
Less canegrub damage	33	33	33

Growers using GCTB were also asked about various problems they experienced with GCTB. Their responses are listed in Table 4.7. Sixty-seven per cent of the growers surveyed said they had problems with waterlogging, and 64% had experienced reduced CCS levels as a result of increased extraneous matter. Fifty per cent of the surveyed growers also said that irrigation and ratooning also caused moderate problems.

TABLE 4.7

Importance of various problems with GCTB

Problems with GCTB	**Very important % of growers**	**Of some importance % of growers**	**Of little importance % of growers**
Waterlogging	67	33	0
Increased extraneous matter	64	20	16
Water ponding	34	63	3
Irrigation difficulties	33	50	17
Harvesting	20	60	20
Emergence and ratooning problems	17	50	33

Growers in the Proserpine district, using both burnt and GCTB systems were questioned in the same way as the Burdekin growers about how and where they obtain information in relation to new farming methods and technology. Table 4.8 shows the percentages of growers who various sources of information.

TABLE 4.8

Percentage of Proserpine growers using each information source

Information source	% of growers
Other farmers	100
Past experience	84
Non-BSES magazines/newspapers	50
BSES/Canegrower publications	60
BSES Extension Officers	65
CPPB staff	50
Field days/shed meetings	33
Internet	20
Private agribusinesses	12
TV/radio	0

As illustrated in Table 4.8, Proserpine growers do not utilise the services of BSES and Canegrowers as much as Burdekin growers, but mainly rely on other farmers and past experience to gain information. A possible explanation for this could be the fact that BSES has a large research station in the Burdekin with approximately 20 extension and research staff, as opposed to the smaller centre in Proserpine with only two extension staff and two research staff. 20% of growers in Proserpine also make use of the Internet to find information, as opposed to 0% in the Burdekin. Most Proserpine growers said they liked to see new technologies demonstrated at field days or on other growers' farms.

5.0 GENERAL COMMENTS OF GROWERS

During the surveys, various general comments made by growers were recorded. Most growers using a burnt system in the Burdekin had very negative comments to make about GCTB; some examples of comments from growers in the Burdekin are listed below:

'If the whole Burdekin was forced to go green, we would have to have more fire trucks and tractors on hand to fight fires when someone throws a cigarette butt out the car window. The whole district could go up in flames – this would be a disaster out of crushing season.'

Some growers felt that sooner or later regulations would be approved which would restrict their use of cane firing, but strongly emphasised that they must always have the option to burn when it is needed:

'We must always have the option to burn – you can't harvest grub damaged cane green.'

Many Burdekin growers made comments about irrigation difficulties in a GCTB system being the main reason why they don't use GCTB.

'It takes a lot longer to irrigate under a trash blanket – you can't see up the rows where the water is up to.'

'Slope is the most important factor – large capital outlays to change slopes, drill lengths and install more irrigation equipment. This would work out to be around $1000/ha to change from burning to GCTB.'

A small number of growers made negative comments about GCTB that clearly indicated that it was their personal attitudes that prevented them to go green, with comments such as these:

'I have always burnt cane, my father always burnt cane, his father always burnt cane – there will never be a GCTB on one of our farms.'

The attitudes of growers in Proserpine who practise GCTB were completely different from the Burdekin growers, with many of them saying they have a lot more leisure time since changing to GCTB.

'You must have good drainage to go GCTB. The trash holds the harvesting gear up in the wet times, and clogs drains in heavy storms. I'm fishing at least 4 days a week since changing to green.'

'In the first year of GCTB you have to be prepared for it to be a disaster - the worms and bugs aren't there in the soil, but after the first year the soil has structure and is like peat.'

'It is important for all farmers - especially GCTB farmers to keep good records so they can monitor their costs and budget.'

Other growers say they are a lot better off financially since changing to GCTB, with many being able to sell equipment they don't need, using tractors less and by receiving higher yields.

'I sold a lot of old machinery when I changed, and now only use 1/2 the amount of diesel as before we went to GCTB.'

6.0 SUMMARY

Production costs of both burnt and GCTB cane in Proserpine were lower than in the Burdekin, however, profits were significantly higher for Burdekin growers in both GCTB and burnt crops.

The profit of GCTB cane in the Burdekin was lower than burnt cane in the plant crop, but higher in ratoons. The reverse of this was the case for Proserpine growers.

Waterlogging and irrigation difficulties were the primary cause for concern in using GCTB among surveyed growers, while cost savings in labour, water and chemicals, as well as improved soil quality were the most important benefits of using GCTB. A major benefit of GCTB was the removed risk of having rain after the cane has been burnt, leaving it in the paddock waiting to be harvested when it becomes dry enough, resulting in lowered yields.

Burdekin growers who currently farm using traditional burning methods have an extremely negative view of GCTB, while growers who burn their cane in Proserpine are not so negative and often burn their cane because of bio-physical factors such as soil type. Many of these growers have farms or blocks in areas suitable to GCTB and welcome its benefits.

Growers in both districts who use GCTB emphasised the fact that they had dramatically reduced their labour input on the farm, which gave many of them more time to pursue additional employment or to engage in recreational activities.

The majority of growers in both districts indicated that they get most information about new farming methods and technologies from other farmers and also rely heavily on their past experience. They also like to receive this information through publications such as BSES Bulletins and handbooks, as well as seeing demonstrations on farms or at field days.

7.0 REFERENCES

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Makeham, J.P. and Malcolm, L.R. (1993). *The Farming Game Now*. Cambridge University Press, Melbourne.

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APPENDIX 9 Furrow Irrigation Optimiser.

by Marcus Hardie,
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FURROW IRRIGATION OPTIMISER BY MARCUS HARDIE, BSES, MACKAY

Development

Originally this furrow irrigation optimiser was developed for the SRDC & LWA funded BSS173: 'Quantifying the socio-economic impacts of harvesting residue retention systems' project which sought to assist growers and extension staff convert burnt furrow irrigation systems to GCTB. Initially these tables were developed to reflect typical conditions for the BRIA and delta regions of the Burdekin. Interest amongst extension officers in the central district resulted in the inclusion of further soil types and a larger range of slopes and furrow lengths, such that these tables could be used throughout the sugar industry. As interest grew in the project it was decided to make the table more universally applicable to a larger range of soil types, field conditions and trash management.

Optimisation Modelling

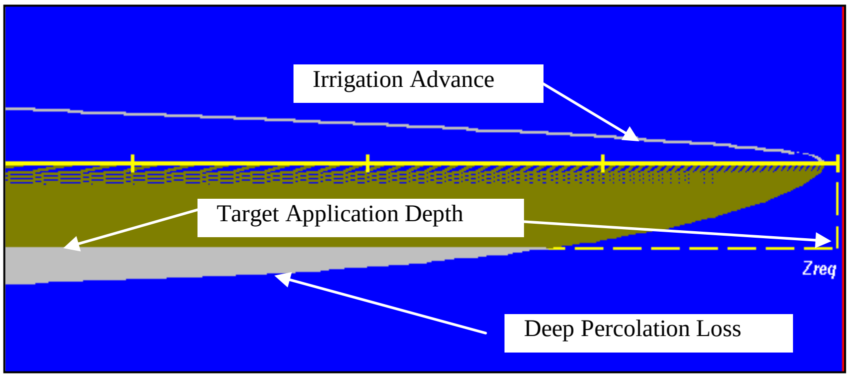

Figure 1). Components of the Furrow Irrigation Simulation.

Irrigation attributes were calculated using the hydrodynamic solution and 'design' module in the surface irrigation model SIRMOD II (Walker 1993). SIRMOD II has been widely employed and evaluated within the Australian Sugar Industry (Raine and Bakker 1996, Raine *et al.*, 1997, and Holden and Sutherland 1998). The design module is based on a target application depth or amount of irrigation to be evenly infiltrated under the soil surface (z req). Infiltration of irrigation beneath this depth is inaccessible for crop growth and considered lost from the system in the form of deep percolation (figure 1). Irrigation efficiency is calculated as the sum of the runoff and infiltration beneath the target application depth. The ‘design’ module in SIRMOD II assumes the target application depth must be filled (requirement efficiency = 100%). Inflow rate and cutoff time is then calculated to minimise both runoff and deep percolation losses. Simulations were found to over fill the target application resulting in higher than necessary losses. Corrections to the proposed cutoff time were made to optimise application efficiency while maintaining the requirement efficiency between 99 and 100%.

ASSUMPTIONS

This irrigation optimiser is a simplified output from a more complex modelling package. It is not intended to be used for all situations under all conditions. If the user does not believe the assumptions used in this optimisation adequately match conditions in the field, they should refer back to the full model procedure.

<u>1). Furrow Shape.</u>

From information received by a number of personnel in the sugar industry it was believed the U shaped furrow was applicable shape to employ for modelling purposes. Based on a furrow shape measurement from 5 locations in the Central and Burdekin districts the ‘U’ furrow shape is described as having a bottom width of 552mm, a middle width of 1152 mm, top width of 1752mm and a maximum depth of 200mm.

<u>2). Slope.</u>

Due to limitations of the model optimisations have been generated for a single slope element (uniform slope). If blocks with compound slopes cannot be reasonably represented by the optimised slopes, the user is referred to the full model procedure.

<u>3). Cutback / Block End.</u>

No provision is mode for furrows with blocked ends or cutback inflow options.

<u>4). Soil Types.</u>

Given the lack of quality soil data made available for this project, simulations have been conducted using major soil groups called ‘intake families’ which have been classified and described by the United States Soil Conservation Service (SCS) (SCS 1984). While the

SCS soil types are 'real' they may not adequately describe soils found in the sugar industry. For example, while heavy clays may be represented by the intake families there is no provision for the cracking clays which have similar texture but very different infiltration properties. This optimisation assumes field soils can be adequately represented by one of the SCS soil types, and that soil infiltration properties are consistent within the block. As field soils may differ to the SCS soils, care needs to be taken when selecting soils or applying results from the optimisation to field conditions. Field soils may also demonstrate different infiltration properties within the block.

5). Requirement Efficiency

This analysis has assumed that production benefits from irrigation are more important than irrigation losses. As such the principal concern of the irrigator is to fill the root zone (application target depth) of the whole field while minimising deep drainage and runoff losses. As such the requirement efficiency of all simulations presented in this optimisation were between 99 and 100%. By meeting the requirement efficiency, growers ensure that the whole of the block is adequately irrigated, such that the end of the block does not receive less than what is required for growth.

6). Target Application Depth (Zreq): The target application depth or amount of irrigation to be supplied to the soil was set at 60mm.

7). Trash Management.

Table 1: Reported Values for Manning's *n*

Location	Soil Type	Burnt / GCTB	Mean	SD	Range	Data Source
Proserpine (Muller)	Sodic Duplex	GCTB	0.49	0.20	0.22-1.01	Hardie et al unpublished
Prosserpine (Orr)	Sodic Duplex	GCTB (10-15 t/ha)	0.46	0.16	0.26-0.67	Hardie et al unpublished
Burdekin	?	GCTB	0.165	0.07	0.08-0.32	Raine pers. comm.
Burdekin	?	GCTB	0.09	0.04	0.05-0.12	Holden and Sutherland 1998
Claire	Alluvial Clay	GCTB	0.25	0.08	0.17-0.47	Rain and Bakker (recalculated)
Rita Island	Alluvial Loam	Burnt	0.05	0.02	0.01-0.06	Rain and Bakker (recalculated)
Jarvis Field	Alluvial – sandy loam	Burnt	0.10	0.03	0.06-0.17	Rain and Bakker (recalculated)
Home Hill	Alluvial	Burnt	0.15	0.09	0.05-0.40	Rain and Bakker (recalculated)
Proserpine (Muller)	Sodic Duplex	Burnt	0.19	0.08	0.10-0.46	Hardie et al unpublished
Prosserpine (Orr)	Sodic Duplex	Burnt	0.09	0.04	0.05-0.18	Hardie et al unpublished
Burdekin	?	Burnt	0.04	002	0.02-0.06	Holden and Sutherland 1998
Claire	Alluvial Clay	Burnt	0.09	0.04	0.03-0.13	Rain and Bakker (recalculated)

The presence of trash is important for furrow irrigation modelling as trash provides resistance to flow (Manning's n) which affects the depth of water in furrows, advance rates and infiltration. Summary of reported values for Manning's n are provide in Table 1.

Selection of appropriate Manning's *n* values was difficult due to the limited and variable nature of the available data and concerns about data quality. Originally optimisations were conducted with a range of values for Manning's *n* 0.05, 0.10, 0.2 and 0.4. Discussion with extension staff indicated that a single GCTB and burnt value for Manning's *n* would make interpretation of data easier. As such a Manning's *n* value of 0.08 was selected for the burnt simulations and 0.35 for the GCTB simulations.

HOW TO USE TABLES

This furrow irrigation optimiser consists of two parts; firstly a key for identifying the correct soil type and secondly the optimisations. Currently the soil type selector only works for burnt cane systems.

Soil Type Selector

The soil type selector is currently only available for burnt cane systems. The selector indicates the time furrow irrigation events take to reach 300 meters for different soil types, slopes and inflow rates. The selector requires measures of field slope, inflow rate for individual furrows and the time taken to reach 300m.

Step 1). Measure the block slope. If possible approximate the field slope to a single slope element.

Step 2). Measure the inflow rate from a number of furrows. Use a bucket, stopwatch and container of known volume to measure the volume of water entering a furrow for a given period of time. Note: It may be best to measure both the faster and slower furrows to get a better soil type description.

Step 3). Measure out 300m from the head of the furrow or irrigation outlet.

Step 4). Record the time taken for water to advance to 300m

Step 5). From the field slope choose the correct 'Soil Type Selector Page' and set of data.

Step 6). Identify the inflow rate (and block of data) which best corresponds to the inflow measured in the field.

Step 7). From that block of data identify the soil type that most closely matches the time recorded to reach 300m.

Worked Example.

A grower has asked you to help him increase his furrow irrigation efficiency, but you are unsure what soil type to use for the second stage of the optimiser. You measure the block slope as being 1:220 or 0.45%. You identify one of the slower and one of the faster flowing outlets and measure the flow rates at 1.65 l/s and 2.220 l/s. Having marked out 300 meters you recorded the time taken for the advance to reach 300m as 120minutes for the faster furrow and 105 minutes for the slower furrow. Using the Soil Type Selector tables, goto the 1/200 slope table. For the slower inlet goto the 1.5 l/s inflow rate, and match the time (120min) to the soil type which indicates the Clayloam I. The faster inflow of 2.2 l/s corresponds to the 2.0 l/s inflow row and the advance time of 105 min which indicates the soil type to be Clay loam II. This difference in indicated soil type is not particularly important, it demonstrates that differences in soil type and infiltration exist across the block. Also don’t be to alarmed is a clay soil is identified as a sand or vice versa, what is important is the way the soil is behaving in terms of infiltration and the irrigation. Other factors such as compaction, tillage etc may affect infiltration to a greater degree than just the soil texture.

Furrow Optimisations

Once the appropriate soil type has been selected, the user needs to know the slope, furrow length, and trash management.

Step 1). Find page corresponding to selected soil type.

Step 2). Identify data block corresponding with appropriate block slope and furrow length

Step 3). Determine if the block is best represented by the GCTB or Burnt trash management options. Cultivation, weeds and uneven surface can cause a Burnt block to behave like a GCTB.

Step 4). Read appropriate flow rate, cutoff time and the expected application efficiency and advance time.

Worked Example.

Using the Clayloam I soil type previously selected the block had a slope approximating 1:200, the furrow length is 450 m under Burnt trash management.

Using the Clayloam I page, and a furrow length of 500m, the table indicates the grower should irrigate for 1050 minutes at an inflow rate of 0.93 l/s. This irrigation is likely to result in an efficiency of 73% with almost $10m^3$ runoff per drill. It is important to note that in order to achieve the requirement efficiency the grower must irrigate for an additional 470 minutes after the advance has reached the end of the furrow.

Comments on the Final Advance Time and Cutoff Time

The relationship between the advance time and suggested cutoff time is complex and important to understand if growers are to accept the recommendations of this project. While growers may favor adjusting cutoff times to meet the advance time in order to minimise runoff losses they are invariably not meeting the irrigation requirement or suffering large deep drainage losses. The perceived need to match advance and cutoff times is not unreasonable, as growers are not able to visualise deep drainage losses or insufficient irrigation at the ends of the block. Analysis of the simulations indicates that only 50 of the 600 simulations required the irrigation to be cutoff before the advance had reached the end of the block. This tended to occur with GCTB management on alluvial soils (SCS 0-4-0.9). More commonly the simulations suggested that the irrigation be cutoff after the advance had reached the end of the block. This was particularly true of the clay soils (SCS 1.0-0.8) with Burnt trash management. Allowing irrigations to proceed after the advance time tended to result in approximately 15% runoff and 15% loss to deep drainage, while meeting the requirement efficiency. These findings suggest the need for substantial changes in the perceptions of what is ‘good’ irrigation practice and further support the need for tailwater recycling to capture the additional runoff.

Burnt Cane: Soil Type Selector I

Slope 1/100 or 1%			
Inflow Rate (l/s)	**Time to reach 300m**	**Soil Class**	**Soil Description**
1.00	96	0.01	Heavy Clay
	125	0.10	Clay
	165	0.60	Siltyloam II
	167	0.20	Clayloam I
	246	0.30	Clay Loam II
	402	0.40	Silt
	750	0.50	Siltyloam I
		0.70	Siltyloam III
		0.80	Sandyloam I
		0.90	Sandyloam II
		1.00	Sandyloam III
		a	Alluvial Loam (H.Hill)
		b	Sandy-Loam (Jarvis F.)
1.50	73	0.01	Heavy Clay
	86	0.10	Clay
	100	0.20	Clayloam I
	123	0.30	Clay Loam II
	160	0.40	Silt
	221	0.50	Siltyloam I
	330	0.60	Siltyloam II
	495	0.70	Siltyloam III
	702	a	Alluvial Loam (H.Hill)
	823	0.80	Sandyloam I
	921	b	Sandy-Loam (Jarvis F.)
		0.90	Sandyloam II
		1.00	Sandyloam III
2.00	61	0.01	Heavy Clay
	69	0.10	Clay
	76	0.20	Clayloam I
	87	0.30	Clay Loam II
	101	0.40	Silt
	121	0.50	Siltyloam I
	152	0.60	Siltyloam II
	204	0.70	Siltyloam III
	268	0.80	Sandyloam I
	270	a	Alluvial Loam (H.Hill)
	385	0.90	Sandyloam II
	391	b	Sandy-Loam (Jarvis F.)
	575	1.00	Sandyloam III
2.50	54	0.01	Heavy Clay
	59	0.10	Clay
	64	0.20	Clayloam I
	70	0.30	Clay Loam II
	77	0.40	Silt
	87	0.50	Siltyloam I
	101	0.60	Siltyloam II
	122	0.70	Siltyloam III
	146	0.80	Sandyloam I
	150	a	Alluvial Loam (H.Hill)
	186	0.90	Sandyloam II
	240	1.00	Sandyloam III
	241	b	Sandy-Loam (Jarvis F.)
3.00	50	0.01	Heavy Clay
	53	0.10	Clay
	56	0.20	Clayloam I
	60	0.30	Clay Loam II
	65	0.40	Silt
	70	0.50	Siltyloam I
	78	0.60	Siltyloam II
	88	0.70	Siltyloam III
	100	0.80	Sandyloam I
	104	a	Alluvial Loam (H.Hill)
	117	0.90	Sandyloam II
	141	1.00	Sandyloam III
	173	b	Sandy-Loam (Jarvis F.)
3.50	46	0.01	Heavy Clay
	49	0.10	Clay
	51	0.20	Clayloam I
	54	0.30	Clay Loam II
	57	0.40	Silt
	61	0.50	Siltyloam I
	65	0.60	Siltyloam II
	71	0.70	Siltyloam III
	78	0.80	Sandyloam I
	81	a	Alluvial Loam (H.Hill)
	87	0.90	Sandyloam II
	99	1.00	Sandyloam III
	136	b	Sandy-Loam (Jarvis F.)

Slope 1/200 or ½ %			
Inflow Rate (l/s)	**Time to reach 300m**	**Soil Class**	**Soil Description**
1.00	110	0.01	Heavy Clay
	141	0.10	Clay
	183	0.20	Clayloam I
	264	0.30	Clay Loam II
	417	0.40	Silt
	778	0.50	Siltyloam I
	1699	0.60	Siltyloam II
		0.70	Siltyloam III
		0.80	Sandyloam I
		0.90	Sandyloam II
		1.00	Sandyloam III
		a	Alluvial Loam (H.Hill)
		b	Sandy-Loam (Jarvis F.)
1.50	86	0.01	Heavy Clay
	100	0.10	Clay
	115	0.20	Clayloam I
	138	0.30	Clay Loam II
	179	0.40	Silt
	236	0.50	Siltyloam I
	335	0.60	Siltyloam II
	510	0.70	Siltyloam III
	717	a	Alluvial Loam (H.Hill)
	839	0.80	Sandyloam I
	976	b	Sandy-Loam (Jarvis F.)
		0.90	Sandyloam II
		1.00	Sandyloam III
2.00	74	0.01	Heavy Clay
	82	0.10	Clay
	89	0.20	Clayloam I
	100	0.30	Clay Loam II
	114	0.40	Silt
	137	0.50	Siltyloam I
	165	0.60	Siltyloam II
	212	0.70	Siltyloam III
	284	a	Alluvial Loam (H.Hill)
	289	0.80	Sandyloam I
	399	0.90	Sandyloam II
	401	b	Sandy-Loam (Jarvis F.)
	590	1.00	Sandyloam III
2.50	66	0.01	Heavy Clay
	71	0.10	Clay
	76	0.20	Clayloam I
	82	0.30	Clay Loam II
	89	0.40	Silt
	100	0.50	Siltyloam I
	114	0.60	Siltyloam II
	133	0.70	Siltyloam III
	160	0.80	Sandyloam I
	163	a	Alluvial Loam (H.Hill)
	200	0.90	Sandyloam II
	254	b	Sandy-Loam (Jarvis F.)
	259	1.00	Sandyloam III
3.00	60	0.01	Heavy Clay
	64	0.10	Clay
	68	0.20	Clayloam I
	72	0.30	Clay Loam II
	76	0.40	Silt
	82	0.50	Siltyloam I
	90	0.60	Siltyloam II
	100	0.70	Siltyloam III
	113	0.80	Sandyloam I
	117	a	Alluvial Loam (H.Hill)
	130	0.90	Sandyloam II
	156	1.00	Sandyloam III
	185	b	Sandy-Loam (Jarvis F.)
3.50	56	0.01	Heavy Clay
	59	0.10	Clay
	62	0.20	Clayloam I
	65	0.30	Clay Loam II
	68	0.40	Silt
	72	0.50	Siltyloam I
	77	0.60	Siltyloam II
	83	0.70	Siltyloam III
	90	0.80	Sandyloam I
	93	a	Alluvial Loam (H.Hill)
	99	0.90	Sandyloam II
	114	1.00	Sandyloam III
	147	b	Sandy-Loam (Jarvis F.)

Burnt Cane: Soil Type Selector II

Slope 1/400 0r 0.25 %

Inflow Rate	Time to reach 300m	Soil Class	Soil Description
1.00	130	0.01	Heavy Clay
	161	0.10	Clay
	204	0.20	Clayloam I
	282	0.30	Clay Loam II
	438	0.40	Silt
	783	0.50	Siltyloam I
	1706	0.60	Siltyloam II
	6774	a	Alluvial Loam (H.Hill)
	x	0.70	Siltyloam III
	x	0.80	Sandyloam I
	x	0.90	Sandyloam II
	x	b	Sandy-Loam (Jarvis F.)
		1.00	Sandyloam III
1.50	103	0.01	Heavy Clay
	117	0.10	Clay
	133	0.20	Clayloam I
	156	0.30	Clay Loam II
	192	0.40	Silt
	249	0.50	Siltyloam I
	348	0.60	Siltyloam II
	523	0.70	Siltyloam III
	736	a	Alluvial Loam (H.Hill)
	854	0.80	Sandyloam I
	956	b	Sandy-Loam (Jarvis F.)
	1545	0.90	Sandyloam II
	3120	1.00	Sandyloam III
2.00	89	0.01	Heavy Clay
	97	0.10	Clay
	105	0.20	Clayloam I
	116	0.30	Clay Loam II
	132	0.40	Silt
	152	0.50	Siltyloam I
	183	0.60	Siltyloam II
	229	0.70	Siltyloam III
	295	a	Alluvial Loam (H.Hill)
	300	0.80	Sandyloam I
	415	0.90	Sandyloam II
	416	b	Sandy-Loam (Jarvis F.)
	608	1.00	Sandyloam III
2.50	78	0.01	Heavy Clay
	86	0.10	Clay
	91	0.20	Clayloam I
	98	0.30	Clay Loam II
	106	0.40	Silt
	116	0.50	Siltyloam I
	130	0.60	Siltyloam II
	149	0.70	Siltyloam III
	176	0.80	Sandyloam I
	180	a	Alluvial Loam (H.Hill)
	214	0.90	Sandyloam II
	268	b	Sandy-Loam (Jarvis F.)
	269	1.00	Sandyloam III
3.00	73	0.01	Heavy Clay
	78	0.10	Clay
	82	0.20	Clayloam I
	86	0.30	Clay Loam II
	91	0.40	Silt
	98	0.50	Siltyloam I
	105	0.60	Siltyloam II
	116	0.70	Siltyloam III
	128	0.80	Sandyloam I
	132	a	Alluvial Loam (H.Hill)
	146	0.90	Sandyloam II
	169	1.00	Sandyloam III
	200	b	Sandy-Loam (Jarvis F.)
3.50	69	0.01	Heavy Clay
	72	0.10	Clay
	75	0.20	Clayloam I
	78	0.30	Clay Loam II
	82	0.40	Silt
	86	0.50	Siltyloam I
	91	0.60	Siltyloam II
	98	0.70	Siltyloam III
	105	0.80	Sandyloam I
	108	a	Alluvial Loam (H.Hill)
	114	0.90	Sandyloam II
	120	1.00	Sandyloam III
	162	B	Sandy-Loam (Jarvis F.)

Slope 1/600 Or 0.166 %

Inflow Rate	Time to reach 300m	Soil Class	Soil Description
1.00	143	0.01	Heavy Clay
	175	0.10	Clay
	219	0.20	Clayloam I
	297	0.30	Clay Loam II
	453	0.40	Silt
	826	0.50	Siltyloam I
	1722	0.60	Siltyloam II
	x	0.70	Siltyloam III
	x	0.80	Sandyloam I
	x	0.90	Sandyloam II
	x	a	Alluvial Loam (H.Hill)
	x	b	Sandy-Loam (Jarvis F.)
		1.00	Sandyloam III
1.50	114	0.01	Heavy Clay
	129	0.10	Clay
	146	0.20	Clayloam I
	169	0.30	Clay Loam II
	205	0.40	Silt
	262	0.50	Siltyloam I
	363	0.60	Siltyloam II
	537	0.70	Siltyloam III
	745	a	Alluvial Loam (H.Hill)
	868	0.80	Sandyloam I
	967	b	Sandy-Loam (Jarvis F.)
	1559	0.90	Sandyloam II
	3136	1.00	Sandyloam III
2.00	99	0.01	Heavy Clay
	108	0.10	Clay
	117	0.20	Clayloam I
	128	0.30	Clay Loam II
	144	0.40	Silt
	165	0.50	Siltyloam I
	196	0.60	Siltyloam II
	242	0.70	Siltyloam III
	308	a	Alluvial Loam (H.Hill)
	313	0.80	Sandyloam I
	427	0.90	Sandyloam II
	428	b	Sandy-Loam (Jarvis F.)
	632	1.00	Sandyloam III
2.50	89	0.01	Heavy Clay
	95	0.10	Clay
	100	0.20	Clayloam I
	108	0.30	Clay Loam II
	117	0.40	Silt
	128	0.50	Siltyloam I
	142	0.60	Siltyloam II
	161	0.70	Siltyloam III
	187	0.80	Sandyloam I
	191	a	Alluvial Loam (H.Hill)
	226	0.90	Sandyloam II
	279	b	Sandy-Loam (Jarvis F.)
	281	1.00	Sandyloam III
3.00	82	0.01	Heavy Clay
	87	0.10	Clay
	91	0.20	Clayloam I
	96	0.30	Clay Loam II
	101	0.40	Silt
	108	0.50	Siltyloam I
	116	0.60	Siltyloam II
	126	0.70	Siltyloam III
	139	0.80	Sandyloam I
	143	a	Alluvial Loam (H.Hill)
	157	0.90	Sandyloam II
	180	1.00	Sandyloam III
	210	b	Sandy-Loam (Jarvis F.)
3.50	77	0.01	Heavy Clay
	81	0.10	Clay
	84	0.20	Clayloam I
	87	0.30	Clay Loam II
	91	0.40	Silt
	96	0.50	Siltyloam I
	101	0.60	Siltyloam II
	108	0.70	Siltyloam III
	115	0.80	Sandyloam I
	118	a	Alluvial Loam (H.Hill)
	125	0.90	Sandyloam II
	137	1.00	Sandyloam III
	172	b	Sandy-Loam (Jarvis F.)

Burnt Cane: Soil Type Selector III

Slope 1/400 0r 0.25 %			
Inflow Rate	**Time to reach 300m**	**Soil Class**	**Soil Description**
1.00	153	0.01	Heavy Clay
	186	0.10	Clay
	230	0.20	Clayloam I
	309	0.30	Clay Loam II
	465	0.40	Silt
	815	0.50	Siltyloam I
	1734	0.60	Siltyloam II
	x	0.70	Siltyloam III
	x	0.80	Sandyloam I
	x	0.90	Sandyloam II
	x	a	Alluvial Loam (H.Hill)
	x	b	Sandy-Loam (Jarvis F.)
		1.00	Sandyloam III
1.50	123	0.01	Heavy Clay
	138	0.10	Clay
	155	0.20	Clayloam I
	179	0.30	Clay Loam II
	215	0.40	Silt
	272	0.50	Siltyloam I
	371	0.60	Siltyloam II
	547	0.70	Siltyloam III
	755	a	Alluvial Loam (H.Hill)
	878	0.80	Sandyloam I
	978	b	Sandy-Loam (Jarvis F.)
	1569	0.90	Sandyloam II
	3146	1.00	Sandyloam III
2.00	106	0.01	Heavy Clay
	116	0.10	Clay
	125	0.20	Clayloam I
	137	0.30	Clay Loam II
	153	0.40	Silt
	174	0.50	Siltyloam I
	205	0.60	Siltyloam II
	252	0.70	Siltyloam III
	317	a	Alluvial Loam (H.Hill)
	322	0.80	Sandyloam I
	438	b	Sandy-Loam (Jarvis F.)
	443	0.90	Sandyloam II
	624	1.00	Sandyloam III
2.50	96	0.01	Heavy Clay
	102	0.10	Clay
	109	0.20	Clayloam I
	116	0.30	Clay Loam II
	125	0.40	Silt
	136	0.50	Siltyloam I
	150	0.60	Siltyloam II
	170	0.70	Siltyloam III
	196	0.80	Sandyloam I
	200	a	Alluvial Loam (H.Hill)
	234	0.90	Sandyloam II
	288	b	Sandy-Loam (Jarvis F.)
	290	1.00	Sandyloam III
3.00	88	0.01	Heavy Clay
	93	0.10	Clay
	98	0.20	Clayloam I
	103	0.30	Clay Loam II
	109	0.40	Silt
	116	0.50	Siltyloam I
	124	0.60	Siltyloam II
	135	0.70	Siltyloam III
	148	0.80	Sandyloam I
	152	a	Alluvial Loam (H.Hill)
	165	0.90	Sandyloam II
	189	1.00	Sandyloam III
	219	b	Sandy-Loam (Jarvis F.)
3.50	82	0.01	Heavy Clay
	87	0.10	Clay
	90	0.20	Clayloam I
	94	0.30	Clay Loam II
	98	0.40	Silt
	103	0.50	Siltyloam I
	109	0.60	Siltyloam II
	115	0.70	Siltyloam III
	123	0.80	Sandyloam I
	126	a	Alluvial Loam (H.Hill)
	133	0.90	Sandyloam II
	145	1.00	Sandyloam III
	180	b	Sandy-Loam (Jarvis F.)

Soil Class **0.1: Non Cracking Heavy Clay**

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	GCTB	0.06	8000	3200	78	28.8	2.6	9.03
		Burnt	0.06	8000	3309	78	28.8	2.4	8.68
	350	GCTB	0.09	8000	3090	77	43.2	4.1	11.58
		Burnt	0.08	8000	3330	78	38.4	3.4	8.68
	500	GCTB	0.12	8000	3175	77	57.6	5.6	9.03
		Burnt	0.12	8000	3340	78	57.6	5.0	9.08
	600	GCTB	0.15	8000	3118	77	72.0	7.2	11.14
		Burnt	0.14	8000	3340	78	67.2	6.1	9.64
	700	GCTB	0.17	8000	3147	77	81.6	8.3	10.66
		Burnt	0.16	8000	3376	78	76.8	7.0	9.64
	1000	GCTB	0.25	8000	3100	76	120.0	13.0	10.00
		Burnt	0.24	8000	3400	78	115.2	10.3	9.55
1/200	**250**	GCTB	0.06	8000	2960	76	28.8	3.2	11.11
		Burnt	0.06	8000	3310	78	28.8	2.5	8.68
	350	GCTB	0.09	8000	3160	77	43.2	3.9	9.03
		Burnt	0.08	8000	3363	78	38.4	3.4	8.85
	500	GCTB	0.12	8000	3097	77	57.6	6.2	10.76
		Burnt	0.12	8000	3235	77	57.6	5.6	9.72
	600	GCTB	0.15	8000	3093	77	72.0	7.6	10.56
		Burnt	0.14	8000	3300	76	67.2	6.5	9.67
	700	GCTB	0.17	8000	3140	78	81.6	8.7	10.66
		Burnt	0.17	8000	3362	76	81.6	7.4	9.07
	1000	GCTB	0.25	8000	3090	77	120.0	13.9	11.58
		Burnt	0.24	8000	3400	76	115.2	11.0	9.55
1/400	**250**	GCTB	0.06	8000	2960	76	28.8	3.2	11.11
		Burnt	0.06	8000	3310	78	28.8	2.5	8.68
	350	GCTB	0.09	8000	3160	77	43.2	3.9	9.03
		Burnt	0.09	8000	3363	78	43.2	3.4	9.11
	500	GCTB	0.12	8000	3097	77	57.6	6.2	10.76
		Burnt	0.12	8000	3235	77	57.6	5.6	9.72
	600	GCTB	0.15	8000	3093	77	72.0	7.6	10.56
		Burnt	0.14	8000	3300	76	67.2	6.5	9.67
	700	GCTB	0.17	8000	3140	78	81.6	8.7	10.66
		Burnt	0.17	8000	3362	76	81.6	7.4	8.85
	1000	GCTB	0.25	8000	3090	77	120.0	13.9	11.58
		Burnt	0.24	8000	3400	76	115.2	11.0	9.55
1/600	**250**	GCTB	0.06	8000	2960	76	28.8	3.2	11.11
		Burnt	0.06	8000	3310	78	28.8	2.5	8.68
	350	GCTB	0.09	8000	3160	77	43.2	3.9	9.72
		Burnt	0.08	8000	3363	78	38.4	3.4	7.87
	500	GCTB	0.12	8000	3097	77	57.6	6.2	10.83
		Burnt	0.12	8000	3235	77	57.6	5.6	9.72
	600	GCTB	0.15	8000	3093	77	72.0	7.6	10.56
		Burnt	0.14	8000	3300	76	67.2	6.5	8.33
	700	GCTB	0.17	8000	3140	78	81.6	8.7	10.17
		Burnt	0.16	8000	3362	76	76.8	7.4	9.07
	1000	GCTB	0.25	8000	3090	77	120.0	13.9	10.56
		Burnt	0.24	8000	3400	76	115.2	11.0	9.55
1/800	**250**	GCTB	0.06	8000	2990	76	28.8	3.2	9.49
		Burnt	0.06	8000	3312	78	28.8	2.5	9.67
	350	GCTB	0.09	8000	3200	77	43.2	3.9	10.22
		Burnt	0.08	8000	3650	78	38.4	3.4	9.56
	500	GCTB	0.12	8000	3121	77	57.6	6.2	10.66
		Burnt	0.12	8000	3250	77	57.6	5.6	9.67
	600	GCTB	0.15	8000	3093	77	72.0	7.6	10.76
		Burnt	0.14	8000	3321	76	67.2	6.5	8.85
	700	GCTB	0.17	8000	3150	78	81.6	8.7	9.03
		Burnt	0.16	8000	3380	76	76.8	7.4	8.94
	1000	GCTB	0.26	8000	3120	77	124.8	13.9	10.76
		Burnt	0.24	8000	3580	76	115.2	11.0	8.85

Soil Class **0.1: Clay**

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	250	GCTB	0.25	2000	927	76	30.0	3.4	8.33
		Burnt	0.24	2000	978	77	28.8	2.9	10.38
	350	GCTB	0.34	2000	937	76	40.8	5.0	13.06
		Burnt	0.34	2000	995	78	40.8	4.2	10.59
	500	GCTB	0.50	2000	935	75	60.0	7.6	12.25
		Burnt	0.48	2000	1015	77	57.6	6.1	10.37
	600	GCTB	0.60	2000	939	75	72.0	9.4	12.76
		Burnt	0.58	2000	1027	77	69.6	7.4	11.11
	700	GCTB	0.70	2000	945	74	84.0	11.1	13.42
		Burnt	0.68	2000	1037	77	81.6	8.7	10.78
	1000	GCTB	1.03	2000	950	74	123.6	17.7	14.72
		Burnt	0.97	2000	1070	77	116.4	12.8	10.94
1/200	250	GCTB	0.25	2000	929	75	30.0	2.5	6.50
		Burnt	0.24	2000	993	77	28.8	3.0	10.29
	350	GCTB	0.35	2000	941	75	41.5	5.3	13.52
		Burnt	0.34	2000	1018	77	40.8	4.2	10.63
	500	GCTB	0.51	2000	943	74	61.1	8.3	13.10
		Burnt	0.48	2000	1042	77	58.0	6.3	10.47
	600	GCTB	0.61	2000	947	74	73.4	10.3	14.08
		Burnt	0.58	2000	1058	76	70.0	7.6	10.91
	700	GCTB	0.72	2000	954	73	86.2	12.5	15.35
		Burnt	0.68	2000	1074	76	82.0	9.0	11.04
	1000	GCTB	1.06	2000	967	72	127.2	20.3	16.16
		Burnt	0.98	2000	1116	76	117.5	13.3	11.32
1/400	250	GCTB	0.25	2000	931	75	30.0	19.1	43.57
		Burnt	0.24	2000	1004	77	28.8	3.1	10.80
	350	GCTB	0.35	2000	944	75	42.0	5.5	13.21
		Burnt	0.34	2000	1033	77	40.8	4.3	10.66
	500	GCTB	0.52	2000	949	73	61.8	8.7	13.89
		Burnt	0.49	2000	1060	77	58.2	6.4	10.54
	600	GCTB	0.62	2000	953	73	74.4	11.0	14.62
		Burnt	0.59	2000	1079	76	70.2	7.7	11.13
	700	GCTB	0.73	2000	961	72	87.6	13.5	15.41
		Burnt	0.69	2000	1099	76	82.2	9.2	11.10
	1000	GCTB	1.08	2000	978	71	129.6	22.1	18.02
		Burnt	0.99	2000	1147	76	118.2	13.7	11.59
1/600	250	GCTB	0.25	2000	933	75	30.0	13.1	13.67
		Burnt	0.24	2000	1014	77	28.8	3.1	10.59
	350	GCTB	0.35	2000	946	74	42.5	5.7	14.07
		Burnt	0.34	2000	1048	77	40.8	4.3	10.83
	500	GCTB	0.52	2000	954	72	62.5	9.1	14.52
		Burnt	0.49	2000	1078	76	58.4	6.5	10.97
	600	GCTB	0.63	2000	959	72	75.4	11.6	15.35
		Burnt	0.59	2000	1099	76	70.4	7.8	11.22
	700	GCTB	0.74	2000	967	71	89.0	14.4	16.28
		Burnt	0.69	2000	1123	76	82.4	9.3	11.30
	1000	GCTB	1.10	2000	989	69	132.0	23.8	19.47
		Burnt	0.99	2000	1177	76	118.9	14.1	12.17
1/800	250	GCTB	0.25	2000	935	74	30.0	4.1	12.67
		Burnt	0.24	2000	1029	77	28.8	3.2	10.42
	350	GCTB	0.36	2000	950	73	43.2	6.0	14.32
		Burnt	0.34	2000	1070	76	40.8	4.3	11.00
	500	GCTB	0.53	2000	962	71	63.6	9.8	15.97
		Burnt	0.49	2000	1105	76	58.8	6.6	11.36
	600	GCTB	0.64	2000	967	70	76.8	12.5	17.32
		Burnt	0.59	2000	1130	75	70.8	8.0	11.59
	700	GCTB	0.76	2000	976	69	91.2	15.8	17.01
		Burnt	0.69	2000	1160	75	82.8	9.6	11.82
	1000	GCTB	1.13	2000	1005	67	135.6	26.4	1.24
		Burnt	1.00	2000	1223	75	120.0	14.6	9.72

Soil Class **0.2: Clayloam I** (Lower Infiltration)

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	GCTB	0.47	1050	489	76	29.6	4.0	14.04
		Burnt	0.46	1100	530	74	30.4	3.7	13.70
	350	GCTB	0.66	1050	497	75	41.6	5.8	14.38
		Burnt	0.64	1050	547	77	40.3	4.5	12.54
	500	GCTB	0.96	1050	504	74	60.5	8.6	14.92
		Burnt	0.92	1050	555	77	58.0	6.7	12.69
	600	GCTB	1.17	1050	506	74	73.7	11.0	15.29
		Burnt	1.11	1050	565	77	69.9	8.2	12.89
	700	GCTB	1.37	1050	509	73	86.3	135.0	15.80
		Burnt	1.30	1050	576	77	81.9	9.7	11.79
	1000	GCTB	2.01	1050	514	71	126.6	22.4	16.54
		Burnt	1.87	1050	604	76	117.8	14.2	12.13
1/200	**250**	GCTB	0.48	1050	495	75	30.0	4.2	13.16
		Burnt	0.46	1100	543	74	30.6	3.8	11.16
	350	GCTB	0.68	1050	503	74	42.5	6.3	4.96
		Burnt	0.65	1050	563	77	40.7	4.6	11.73
	500	GCTB	0.98	1050	513	73	62.0	9.7	17.69
		Burnt	0.93	1050	579	77	58.3	6.9	11.60
	600	GCTB	1.20	1050	519	73	75.6	12.0	10.99
		Burnt	1.12	1050	593	76	70.5	8.4	11.95
	700	GCTB	1.42	1050	524	72	89.5	99.9	17.26
		Burnt	1.31	1050	607	76	82.7	10.0	12.13
	1000	GCTB	2.08	1035	542	70	129.1	24.4	56.53
		Burnt	1.89	1050	644	75	119.3	14.9	12.51
1/400	**250**	GCTB	0.48	1050	499	75	30.2	4.4	14.73
		Burnt	0.47	1100	551	74	30.7	3.9	11.56
	350	GCTB	0.69	1050	508	73	43.2	6.6	15.23
		Burnt	0.65	1050	574	77	41.0	4.7	11.84
	500	GCTB	1.00	1050	519	72	63.0	10.4	15.86
		Burnt	0.93	1050	596	77	58.6	7.0	11.78
	600	GCTB	1.22	1050	528	73	76.9	12.7	18.47
		Burnt	1.13	1050	612	76	70.9	8.6	12.10
	700	GCTB	1.46	1050	534	71	91.7	76.5	4.13
		Burnt	1.32	1050	628	76	83.2	10.3	12.29
	1000	GCTB	2.13	1025	560	69	130.7	25.7	5.60
		Burnt	1.91	1050	671	75	120.3	15.4	12.79
1/600	**250**	GCTB	0.48	1050	502	74	30.5	4.5	14.77
		Burnt	0.47	1100	559	73	30.8	3.9	11.35
	350	GCTB	0.70	1050	512	72	43.8	6.9	15.57
		Burnt	0.65	1050	585	76	41.2	4.8	11.97
	500	GCTB	1.02	1050	525	71	64.0	11.1	16.46
		Burnt	0.93	1050	612	76	58.8	7.1	12.33
	600	GCTB	1.24	1050	537	72	78.1	13.3	11.13
		Burnt	1.13	1050	630	76	71.3	8.8	12.33
	700	GCTB	1.49	1050	544	70	93.8	53.0	0.34
		Burnt	1.33	1050	648	76	83.7	10.5	12.53
	1000	GCTB	2.17	1015	578	68	132.2	27.0	0.58
		Burnt	1.93	1050	697	74	121.3	15.8	13.43
1/800	**250**	GCTB	0.49	1050	508	73	30.9	4.7	15.21
		Burnt	0.47	1100	572	73	31.0	4.0	11.48
	350	GCTB	0.71	1050	518	71	44.7	7.4	16.43
		Burnt	0.66	1050	601	76	41.6	4.9	12.05
	500	GCTB	1.04	1050	534	69	65.5	12.1	83.40
		Burnt	0.94	1050	636	76	59.2	7.3	12.48
	600	GCTB	1.27	1050	550	71	80.0	14.3	18.45
		Burnt	1.14	1050	658	75	71.8	9.0	12.76
	700	GCTB	1.54	1050	559	69	97.0	17.9	19.67
		Burnt	1.34	1050	679	75	84.4	10.8	13.03
	1000	GCTB	2.24	1000	606	67	134.4	29.0	14.80
		Burnt	1.95	1050	737	73	122.9	16.5	10.07

Soil Class **0.3: Clayloam II** (Higher infiltration)

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	GCTB	0.73	725	328	71	31.8	4.6	15.95
		Burnt	0.71	725	350	73	30.9	4.0	14.36
	350	GCTB	1.03	700	333	70	43.3	6.9	15.53
		Burnt	0.99	725	364	73	43.1	5.6	12.68
	500	GCTB	1.51	700	339	71	63.4	10.1	16.42
		Burnt	1.43	700	380	75	60.1	7.6	11.55
	600	GCTB	1.82	700	343	70	76.4	12.9	12.03
		Burnt	1.72	700	390	74	72.2	9.1	12.79
	700	GCTB	2.15	690	347	71	89.0	14.8	17.47
		Burnt	2.01	700	400	74	84.4	10.8	14.04
	1000	GCTB	3.18	690	353	68	131.7	25.7	2.86
		Burnt	2.90	700	425	74	121.8	16.1	15.04
1/200	**250**	GCTB	0.74	725	333	71	32.2	5.0	15.65
		Burnt	0.71	725	364	73	30.9	4.0	13.00
	350	GCTB	1.05	725	339	69	45.7	7.5	16.88
		Burnt	1.00	725	382	72	43.4	5.7	12.60
	500	GCTB	1.54	700	347	69	64.7	11.3	12.74
		Burnt	1.43	700	400	74	60.1	7.7	12.79
	600	GCTB	1.88	700	360	69	79.0	13.2	16.43
		Burnt	1.73	700	410	72	72.7	10.2	12.73
	700	GCTB	2.22	690	362	70	91.9	15.1	16.95
		Burnt	2.03	700	415	72	85.3	11.0	12.61
	1000	GCTB	3.29	690	372	68	136.2	25.0	18.83
		Burnt	2.93	700	445	71	123.1	16.5	14.35
1/400	**250**	GCTB	0.75	725	497	69	32.7	4.9	13.95
		Burnt	0.72	735	348	71	31.6	4.4	12.63
	350	GCTB	1.08	700	409	69	45.3	7.9	8.03
		Burnt	1.01	700	391	74	42.2	5.4	13.43
	500	GCTB	1.59	678	625	69	64.5	9.6	16.52
		Burnt	1.45	735	376	71	63.9	9.5	12.65
	600	GCTB	1.94	700	450	72	81.5	14.6	14.99
		Burnt	1.75	700	342	71	73.5	9.9	14.06
	700	GCTB	2.30	665	717	69	91.8	13.0	113.33
		Burnt	2.06	725	395	70	89.4	13.6	13.95
	1000	GCTB	3.40	625	412	72	127.4	24.8	6.31
		Burnt	2.99	680	496	73	122.0	16.5	13.83
1/600	**250**	GCTB	0.76	700	451	70	32.0	4.8	14.53
		Burnt	0.71	700	372	75	29.8	3.8	13.29
	350	GCTB	1.10	700	352	70	46.1	7.9	19.52
		Burnt	1.01	700	413	79	42.4	5.4	14.04
	500	GCTB	1.62	681	672	68	66.3	9.6	5.84
		Burnt	1.46	700	392	74	61.5	8.3	15.25
	600	GCTB	1.99	650	381	71	77.5	14.6	13.20
		Burnt	1.77	700	460	73	74.2	9.9	13.24
	700	GCTB	2.34	663	592	68	93.0	15.6	21.58
		Burnt	2.07	700	413	73	87.0	12.2	14.98
	1000	GCTB	3.41	625	449	71	127.9	24.6	17.92
		Burnt	3.03	680	524	73	123.6	17.1	12.19
1/800	**250**	GCTB	0.77	700	448	71	32.3	4.8	19.24
		Burnt	0.70	700	361	75	29.6	4.0	12.95
	350	GCTB	1.11	700	362	70	46.6	7.9	1.50
		Burnt	1.02	700	420	79	42.8	5.4	14.98
	500	GCTB	1.64	700	548	66	69.0	11.8	17.87
		Burnt	1.46	700	397	73	61.5	8.6	12.82
	600	GCTB	2.01	650	391	71	78.4	14.6	17.26
		Burnt	1.78	700	472	73	74.8	9.9	13.53
	700	GCTB	2.35	658	626	68	92.6	15.3	14.40
		Burnt	2.09	700	421	72	87.9	13.2	13.22
	1000	GCTB	2.86	625	453	71	107.3	24.6	17.07
		Burnt	3.06	680	531	73	124.8	17.1	12.40

Soil Class **0.4: Silt**

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	GCTB	1.01	500	236	74	30.3	4.6	16.59
		Burnt	0.98	500	259	76	29.4	3.7	14.81
	350	GCTB	1.44	500	243	73	43.2	6.8	14.08
		Burnt	1.37	500	269	76	41.1	5.2	14.23
	500	GCTB	2.11	500	250	71	63.2	10.7	14.76
		Burnt	1.97	500	285	75	59.1	7.5	14.06
	600	GCTB	2.56	480	254	73	73.7	12.6	17.76
		Burnt	2.38	500	294	75	71.4	9.2	11.74
	700	GCTB	3.03	480	258	72	87.3	15.5	5.48
		Burnt	2.79	500	304	75	83.7	10.9	13.66
	1000	GCTB	4.48	480	273	70	129.0	25.4	13.77
		Burnt	4.03	500	326	74	120.9	16.4	15.77
1/200	**250**	GCTB	1.03	500	246	75	30.9	4.4	16.94
		Burnt	0.98	500	261	76	29.4	3.8	13.66
	350	GCTB	1.47	500	282	72	44.1	5.9	14.60
		Burnt	1.38	500	306	75	41.4	4.6	13.91
	500	GCTB	2.17	500	300	73	65.1	8.4	18.92
		Burnt	1.99	500	318	74	59.7	6.3	13.85
	600	GCTB	2.65	490	267	73	77.9	10.8	2.63
		Burnt	2.40	500	295	75	72.0	8.5	14.15
	700	GCTB	3.13	490	325	70	92.0	13.9	14.72
		Burnt	2.82	500	361	73	84.6	10.2	13.39
	1000	GCTB	4.62	490	278	70	135.8	18.7	2.60
		Burnt	4.09	500	316	74	122.7	13.2	12.10
1/400	**250**	GCTB	1.05	500	326	72	31.5	4.7	14.49
		Burnt	0.99	500	258	75	29.6	4.0	12.59
	350	GCTB	1.57	500	350	74	47.1	6.0	15.70
		Burnt	1.32	500	350	73	39.6	5.0	12.95
	500	GCTB	2.24	500	398	68	67.1	11.6	13.38
		Burnt	2.01	500	286	74	60.3	8.5	13.49
	600	GCTB	2.74	500	282	70	82.2	12.0	21.13
		Burnt	2.44	500	305	74	73.2	10.0	10.99
	700	GCTB	3.21	485	454	69	93.3	15.9	12.93
		Burnt	2.38	500	304	73	71.5	12.6	13.02
	1000	GCTB	4.05	500	470	68	121.5	19.0	13.51
		Burnt	4.18	500	460	69	125.4	18.0	13.35
1/600	**250**	GCTB	1.07	500	339	70	32.0	5.0	15.93
		Burnt	0.99	500	265	74	29.7	4.0	14.39
	350	GCTB	1.55	500	262	68	46.5	9.0	11.46
		Burnt	1.40	500	315	74	42.0	5.4	10.76
	500	GCTB	2.27	500	427	71	68.2	9.7	14.74
		Burnt	2.03	500	297	74	60.8	8.6	12.46
	600	GCTB	2.78	450	301	71	75.1	14.2	13.65
		Burnt	2.46	485	358	75	71.6	9.0	12.00
	700	GCTB	3.00	488	538	72	87.8	9.8	18.88
		Burnt	2.90	500	317	72	86.9	13.0	10.47
	1000	GCTB	3.47	600	575	72	124.9	7.0	20.44
		Burnt	4.25	500	415	70	127.5	19.1	12.90
1/800	**250**	GCTB	1.08	500	351	69	32.3	5.1	0.51
		Burnt	0.99	500	271	74	29.8	3.9	14.57
	350	GCTB	1.57	500	400	70	47.1	6.3	8.44
		Burnt	1.41	500	290	74	42.3	6.0	12.89
	500	GCTB	2.29	463	451	70	63.5	9.2	22.94
		Burnt	2.04	500	306	73	61.3	8.5	14.10
	600	GCTB	2.79	500	520	69	83.7	9.2	111.56
		Burnt	2.48	500	316	73	74.4	9.0	14.96
	700	GCTB	2.62	600	696	69	94.1	5.5	14.14
		Burnt	2.92	500	327	71	87.7	13.3	13.47
	1000	GCTB	3.45	800	1181	54	165.6	6.0	11.11
		Burnt	4.30	500	435	70	129.0	19.4	13.41

Soil class: **0.5 Siltyloam I** (Lower infiltration)

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	250	GCTB	1.32	400	187	71	31.7	5.0	11.79
		Burnt	1.26	400	203	74	30.2	4.1	14.13
	350	GCTB	1.88	400	192	70	45.1	7.6	16.59
		Burnt	1.78	400	216	74	42.7	56.0	14.06
	500	GCTB	2.76	375	198	73	62.1	10.3	14.23
		Burnt	2.56	400	228	73	61.4	8.5	12.69
	600	GCTB	3.36	375	203	72	75.6	13.3	18.20
		Burnt	3.08	400	238	73	73.9	10.1	15.07
	700	GCTB	3.98	375	208	71	89.6	16.3	12.52
		Burnt	3.61	400	246	72	86.6	12.0	15.64
	1000	GCTB	5.84	375	225	69	131.4	26.3	15.84
		Burnt	5.24	400	268	71	125.8	18.1	12.65
1/200	250	GCTB	1.34	575	212	72	46.2	4.6	18.95
		Burnt	1.27	400	206	74	30.5	4.1	10.11
	350	GCTB	1.93	315	237	71	36.5	6.1	11.91
		Burnt	1.79	400	210	71	43.0	31.2	13.71
	500	GCTB	2.85	400	236	73	68.4	7.3	15.18
		Burnt	2.58	388	290	71	60.0	8.3	14.18
	600	GCTB	3.47	375	238	73	78.1	9.3	21.90
		Burnt	3.12	378	280	72	70.7	11.1	12.69
	700	GCTB	4.11	375	264	71	92.5	10.6	13.86
		Burnt	3.60	378	224	69	81.5	15.1	13.11
	1000	GCTB	5.95	375	252	70	133.9	18.7	14.18
		Burnt	5.33	390	382	69	124.7	14.4	13.13
1/400	250	GCTB	1.38	400	223	68	33.0	5.9	20.02
		Burnt	1.28	400	226	73	30.8	4.2	12.35
	350	GCTB	1.99	400	382	69	47.7	6.3	18.62
		Burnt	1.81	400	244	72	43.4	6.0	13.85
	500	GCTB	2.92	380	269	68	66.5	12.7	19.69
		Burnt	2.62	400	264	71	62.8	8.9	13.39
	600	GCTB	3.57	380	496	66	81.3	10.7	14.82
		Burnt	3.17	400	278	71	76.2	11.1	15.71
	700	GCTB	4.08	375	405	71	91.9	12.2	17.45
		Burnt	3.73	400	248	70	89.5	14.0	15.14
	1000	GCTB	3.70	800	1123	50	177.6	2.2	3.62
		Burnt	5.47	400	327	68	131.3	20.7	15.15
1/600	250	GCTB	1.40	381	280	70	32.0	4.9	13.38
		Burnt	1.29	400	213	72	30.9	4.2	13.85
	350	GCTB	2.04	375	213	70	45.9	8.7	5.21
		Burnt	1.82	400	257	72	43.7	5.9	14.22
	500	GCTB	2.95	375	371	69	66.3	9.7	18.35
		Burnt	2.64	400	240	71	63.5	9.6	13.84
	600	GCTB	3.56	350	259	72	74.8	13.4	5.34
		Burnt	3.21	375	298	75	72.2	9.0	17.62
	700	GCTB	4.25	375	433	67	95.7	14.1	14.92
		Burnt	3.79	385	261	72	87.5	12.9	12.76
	1000	GCTB	4.30	500	504	68	129.0	6.4	14.22
		Burnt	5.57	375	352	72	125.3	18.0	12.57
1/800	250	GCTB	1.42	375	294	71	32.0	4.6	3.66
		Burnt	1.29	400	216	72	31.0	4.4	13.10
	350	GCTB	x						
		Burnt	1.83	400	263	71	43.9	6.0	14.20
	500	GCTB	2.90	375	403	70	65.3	8.0	13.25
		Burnt	2.67	400	249	70	64.1	9.7	14.35
	600	GCTB	2.74	500	411	67	82.2	6.6	19.47
		Burnt	3.24	400	309	70	77.8	11.3	12.86
	700	GCTB	4.26	371	466	67	94.9	12.3	15.64
		Burnt	3.82	375	270	74	86.0	12.2	13.24
	1000	GCTB	4.36	500	536	68	130.8	5.4	17.04
		Burnt	5.65	375	373	72	127.1	16.9	14.91

Soil Class**: 0.6 Siltyloam II** (Medium Infiltration)

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	250	GCTB	1.64	325	150	70	32.0	5.4	12.85
		Burnt	1.57	325	167	73	30.6	4.2	14.65
	350	GCTB	2.36	300	155	74	42.5	7.0	15.17
		Burnt	2.21	325	177	73	43.1	5.9	14.26
	500	GCTB	3.47	300	162	72	62.5	11.3	14.12
		Burnt	3.18	325	190	72	62.0	8.7	14.48
	600	GCTB	4.23	300	167	71	76.1	14.4	15.36
		Burnt	3.84	325	198	72	74.9	10.7	12.85
	700	GCTB	5.01	300	173	70	90.2	17.8	18.89
		Burnt	4.51	325	206	71	87.9	12.7	13.45
	1000	GCTB	7.33	275	192	74	120.9	22.9	16.84
		Burnt	6.56	325	226	76	127.9	15.8	13.83
1/200	250	GCTB	1.69	325	158	71	33.0	5.0	18.09
		Burnt	1.58	325	170	73	30.8	4.2	12.11
	350	GCTB	2.43	300	188	73	43.7	6.1	18.93
		Burnt	2.23	325	209	71	43.5	5.3	13.77
	500	GCTB	3.58	300	168	71	64.4	9.9	10.88
		Burnt	3.22	325	198	72	62.8	7.5	14.29
	600	GCTB	4.36	300	178	73	78.5	11.6	14.08
		Burnt	3.89	325	199	72	75.9	9.8	15.58
	700	GCTB	5.13	300	303	69	92.3	12.6	2.11
		Burnt	4.58	325	258	71	89.3	12.7	13.46
	1000	GCTB	5.48	275	240	74	90.4	19.8	9.31
		Burnt	6.69	325	218	73	130.5	15.6	14.97
1/400	250	GCTB	1.74	306	226	71	31.9	5.1	4.35
		Burnt	1.59	325	169	72	31.0	4.4	13.63
	350	GCTB	2.50	300	174	70	45.0	8.5	14.78
		Burnt	2.25	325	205	71	43.9	6.2	14.44
	500	GCTB	3.65	300	402	69	65.7	5.6	12.21
		Burnt	3.27	310	192	74	60.8	8.8	11.74
	600	GCTB	4.39	300	287	73	79.0	16.7	2.72
		Burnt	3.97	325	210	69	77.4	15.3	72.51
	700	GCTB	5.17						
		Burnt	4.68	325	208	72	91.2	13.3	12.07
	1000	GCTB	5.40	450	413	63	145.8	9.2	14.19
		Burnt	6.88	300	287	73	123.8	16.7	13.84
1/600	250	GCTB	1.70	325	252	67	33.2	4.9	13.97
		Burnt	1.57	325	174	72	30.6	4.5	12.98
	350	GCTB	x						
		Burnt	2.27	325	218	72	44.3	5.8	11.92
	500	GCTB	3.71	300	326	68	66.7	9.8	15.00
		Burnt	3.31	325	201	70	64.6	10.1	14.17
	600	GCTB	x						
		Burnt	4.03	325	255	69	78.6	11.7	13.51
	700	GCTB	5.26						
		Burnt	4.75	300	220	73	85.5	12.8	13.22
	1000	GCTB	5.34						
		Burnt	7.01	300	308	71	126.2	17.8	14.53
1/800	250	GCTB	1.78	300	253	70	32.1	4.6	17.09
		Burnt	1.61	325	178	71	31.5	4.6	8.26
	350	GCTB	x						
		Burnt	2.28	325	220	71	44.5	6.2	6.01
	500	GCTB	3.79	281	344	71	64.0	7.7	16.63
		Burnt	3.34	325	208	69	65.1	10.3	14.54
	600	GCTB	x						
		Burnt	4.05	325	261	68	79.0	11.7	14.72
	700	GCTB	5.26						
		Burnt	4.83	300	109	71	86.9	57.7	14.27
	1000	GCTB	x						
		Burnt	7.06	300	318	71	127.0	17.6	13.56

Soil Class: **0.7 Siltyloam III** (Higher Infiltration)

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	250	GCTB	1.99	250	126	75	29.9	4.7	16.76
		Burnt	1.88	275	141	72	31.0	4.3	12.46
	350	GCTB	2.86	250	130	73	42.9	7.3	14.93
		Burnt	2.65	275	151	72	43.7	6.2	13.10
	500	GCTB	4.22	250	138	71	63.3	11.9	18.24
		Burnt	3.83	275	164	71	63.2	9.1	14.62
	600	GCTB	5.14	250	143	70	77.1	15.2	12.25
		Burnt	4.65	275	171	71	76.7	11.2	12.07
	700	GCTB	6.08	250	149	70	91.2	18.5	20.02
		Burnt	5.43	275	179	71	89.6	13.3	13.53
	1000	GCTB	8.79	250					
		Burnt	7.90	275					
1/200	250	GCTB	2.04	260	134	73	31.8	4.8	17.70
		Burnt	1.89	275	145	72	31.2	4.3	12.40
	350	GCTB	2.95	250	163	72	44.3	6.3	18.91
		Burnt	2.68	260	181	73	41.8	5.0	13.32
	500	GCTB	4.35	250	138	71	65.3	11.9	19.71
		Burnt	3.88	275	171	71	64.0	7.8	14.60
	600	GCTB	x						
		Burnt	4.70	275	172	71	77.6	10.2	13.90
	700	GCTB	6.16	250	149	70	92.4	18.5	16.89
		Burnt	5.53	260	229	71	86.3	11.0	12.82
	1000	GCTB	x						
		Burnt	8.11	260	210	74	126.5	9.6	19.76
1/400	250	GCTB	2.10	250	200	71	31.5	4.9	17.59
		Burnt	1.91	275	144	71	31.6	4.6	13.79
	350	GCTB	x						
		Burnt	2.72	275	178	70	44.9	6.4	14.49
	500	GCTB	x						
		Burnt	3.98	260	166	73	62.1	9.1	12.94
	600	GCTB	x						
		Burnt	4.80	250	210	74	72.0	9.6	7.59
	700	GCTB							
		Burnt	5.66						
	1000	GCTB	x						
		Burnt	8.36	250	254	72	125.4	18.0	14.89
1/600	250	GCTB	2.09	250	220	72	31.3	4.1	71.09
		Burnt	1.93	260	149	74	30.1	4.1	13.27
	350	GCTB	x						
		Burnt	2.74	275	188	69	45.2	6.5	13.76
	500	GCTB	4.46	231	298	73	61.9	6.9	12.83
		Burnt	4.00	250	174	74	60.1	8.6	14.69
	600	GCTB	x						
		Burnt	4.88	250	225	73	73.2	9.6	13.52
	700	GCTB	6.27						
		Burnt	5.76						
	1000	GCTB	x						
		Burnt	8.47						
1/800	250	GCTB	2.11	250	232	71	31.6	3.9	7.51
		Burnt	1.94	275	153	70	32.0	4.7	13.55
	350	GCTB	x						
		Burnt	2.77	275	196	69	45.7	6.4	11.86
	500	GCTB							
		Burnt	4.05	250	182	74	60.8	8.7	14.33
	600	GCTB	x						
		Burnt	4.94	250	237	72	74.1	9.5	13.66
	700	GCTB							
		Burnt	5.81						
	1000	GCTB	x						
		Burnt	8.63						

Soil Class: **0.8 Sandyloam**

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	GCTB	2.34	225	108	71	31.6	5.4	14.51
		Burnt	2.20	225	123	75	29.7	3.9	13.72
	350	GCTB	3.37	225	112	77	45.5	6.6	19.92
		Burnt	3.10	225	132	75	41.9	5.5	13.92
	500	GCTB	4.95	225	122	75	66.8	10.5	15.75
		Burnt	4.48	225	146	74	60.5	8.2	13.48
	600	GCTB	6.07	200	127	74	72.8	13.7	17.04
		Burnt	5.42	225	152	73	73.2	10.1	12.28
	700	GCTB	7.15	200					
		Burnt	6.37	225					
	1000	GCTB	8.07	200					
		Burnt	9.30	225					
1/200	**250**	GCTB	2.41	225	116	72	32.5	4.9	22.28
		Burnt	2.22	225	126	75	30.0	3.9	13.19
	350	GCTB	3.49	213	145	76	44.5	5.5	20.29
		Burnt	3.14	225	161	73	42.4	4.9	15.57
	500	GCTB	x						
		Burnt	4.55	225	152	74	61.4	7.0	13.80
	600	GCTB	x						
		Burnt	5.52	225	153	73	74.5	9.2	14.75
	700	GCTB	x						
		Burnt	6.51	225					
	1000	GCTB	7.53	200					
		Burnt	9.55	225	189	71	128.9	11.0	14.03
1/400	**250**	GCTB	2.47	206	181	73	30.5	4.3	15.78
		Burnt	2.25	225	125	74	30.3	4.2	12.85
	350	GCTB	x						
		Burnt	3.19	225	158	73	43.1	5.8	14.08
	500	GCTB	x						
		Burnt	4.66	225	172	72	62.9	8.7	13.56
	600	GCTB	x						
		Burnt	5.65	225	189	71	76.3	11.0	8.53
	700	GCTB							
		Burnt	6.68	225					
	1000	GCTB	x						
		Burnt	9.86	225					
1/600	**250**	GCTB	2.49	225	199	68	33.5	4.8	15.40
		Burnt	2.26	225	130	74	30.5	4.3	13.68
	350	GCTB	x						
		Burnt	3.22	225	168	72	43.5	5.8	14.30
	500	GCTB							
		Burnt	4.73	225	188	71	63.8	8.8	14.42
	600	GCTB	x						
		Burnt	5.75	225	203	69	77.6	11.0	13.56
	700	GCTB							
		Burnt	6.88						
	1000	GCTB	7.30						
		Burnt	10.06						
1/800	**250**	GCTB	2.49	225	210	67	33.5	4.2	9.95
		Burnt	2.28	225	134	73	30.8	4.3	14.02
	350	GCTB	x						
		Burnt	3.25	225	175	71	43.9	5.7	13.69
	500	GCTB							
		Burnt	4.78	225	161	70	64.5	10.0	13.32
	600	GCTB	x						
		Burnt	5.83	225	214	69	78.7	10.9	131.09
	700	GCTB							
		Burnt	6.88						
	1000	GCTB	7.30						
		Burnt	10.18						

Soil Class: **0.9 Sandyloam**

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	GCTB	2.71	180	95	76	29.3	4.6	18.12
		Burnt	2.53	200	109	74	30.4	4.0	66.40
	350	GCTB	3.91	180	99	74	42.2	7.4	19.02
		Burnt	3.57	200	118	73	42.8	5.8	13.13
	500	GCTB	5.77	180	108	72	62.3	12.0	17.09
		Burnt	5.16	200	129	73	61.9	8.7	12.96
	600	GCTB	7.02	180	114	71	75.8	15.1	14.37
		Burnt	6.24	200	137	72	74.9	10.7	13.07
	700	GCTB							
		Burnt	7.30						
	1000	GCTB							
		Burnt							
1/200	**250**	GCTB	2.79	180	99	74	30.1	5.2	17.52
		Burnt	2.55	200	118	73	30.6	4.1	13.54
	350	GCTB	4.04	180	107	72	43.6	8.3	19.26
		Burnt	3.61	200	129	72	43.3	6.0	14.05
	500	GCTB	x						
		Burnt	5.25	200	143	72	63.0	9.1	14.57
	600	GCTB	x						
		Burnt	6.37						
	700	GCTB							
		Burnt	7.51						
	1000	GCTB							
		Burnt							
1/400	**250**	GCTB	2.85	185	222	71	31.6	22.5	17.73
		Burnt	2.58	200	111	73	31.0	4.4	14.89
	350	GCTB	x						
		Burnt	3.68	200	142	76	44.2	4.6	13.46
	500	GCTB							
		Burnt	5.37	80	55	31	25.8	3.5	12.94
	600	GCTB	x						
		Burnt	6.55	180	172	76	70.7	8.9	13.15
	700	GCTB							
		Burnt	7.72						
	1000	GCTB	x						
		Burnt	11.40						
1/600	**250**	GCTB	3.02	173	233	72	31.3	2.4	6.11
		Burnt	2.60	200	116	72	31.2	4.5	14.94
	350	GCTB	x						
		Burnt	3.72	200	152	70	44.6	6.1	11.40
	500	GCTB							
		Burnt	5.46						
	600	GCTB	x						
		Burnt	6.67	180	186	74	72.0	8.7	14.38
	700	GCTB							
		Burnt	7.91						
	1000	GCTB	x						
		Burnt	11.65						
1/800	**250**	GCTB	2.97	180	187	69	32.0	3.8	13.95
		Burnt	2.62	188	116	73	29.6	4.4	12.98
	350	GCTB	x						
		Burnt	3.80	200	166	67	45.6	5.9	13.72
	500	GCTB							
		Burnt	5.53						
	600	GCTB	x						
		Burnt	6.85	180	208	73	74.0	7.7	15.78
	700	GCTB							
		Burnt	7.96						
	1000	GCTB							
		Burnt	11.70						

Soil Class: **1.0 Sandyloam**

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	250	GCTB	3.08	170	84	72	31.4	5.5	16.77
		Burnt	2.85	170	99	77	29.1	3.6	14.55
	350	GCTB	4.45	170	89	77	45.4	6.8	15.72
		Burnt	4.03	170	107	76	41.1	5.3	13.18
	500	GCTB	6.56	150	98	76	59.0	10.9	17.26
		Burnt	5.84	170	118	75	59.6	7.9	13.40
	600	GCTB	7.97						
		Burnt	7.07						
	700	GCTB	x						
		Burnt	8.33						
	1000	GCTB	x						
		Burnt	12.20						
1/200	250	GCTB	3.18	150	89	78	28.6	4.8	14.98
		Burnt	2.88	170	107	76	29.4	3.7	12.89
	350	GCTB	4.60	150	98	76	41.4	7.5	18.46
		Burnt	4.08	170	117	75	41.6	5.4	13.26
	500	GCTB	x						
		Burnt	5.95	170	131	74	60.7	8.3	13.14
	600	GCTB	x						
		Burnt	7.24						
	700	GCTB	x						
		Burnt	8.55						
	1000	GCTB	9.65						
		Burnt	12.66						
1/400	250	GCTB	3.18	160	154	74	30.6	3.9	16.48
		Burnt	2.91	180	99	72	31.5	4.6	13.18
	350	GCTB	x						
		Burnt	4.16	170	130	74	42.4	5.5	14.02
	500	GCTB	6.75						
		Burnt	6.08						
	600	GCTB	x						
		Burnt	7.45	170	160	71	76.0	10.7	15.09
	700	GCTB							
		Burnt	8.70						
	1000	GCTB	9.47						
		Burnt	13.00						
1/600	250	GCTB	3.23	160	170	72	31.0	3.4	19.74
		Burnt	2.95	168	105	75	29.7	3.9	12.60
	350	GCTB	x						
		Burnt	4.22	170	139	73	43.0	5.5	14.46
	500	GCTB							
		Burnt	6.21						
	600	GCTB	x						
		Burnt	7.59	170	173	70	77.4	10.5	13.44
	700	GCTB							
		Burnt	8.95						
	1000	GCTB	x						
		Burnt	13.34						
1/800	250	GCTB	4.54						
		Burnt	2.97	180	113	69	32.1	4.8	14.34
	350	GCTB	x						
		Burnt	4.27	170	146	72	43.6	5.4	13.56
	500	GCTB							
		Burnt	2.56						
	600	GCTB	x						
		Burnt	7.73						
	700	GCTB							
		Burnt	9.08						
	1000	GCTB	x						
		Burnt	13.30						

Soil Class: **Alluvial Sandyloam**, Jarvis Field, Burdekin.

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	250	GCTB	3.08	175	120	69	32.3	5.5	15.71
		Burnt	2.85	175	135	75	29.9	3.6	13.54
	350	GCTB	4.36	175	129	69	45.8	7.8	16.84
		Burnt	4.05	175	142	74	42.5	5.3	10.42
	500	GCTB	4.50	230	227	72	62.0	2.7	12.18
		Burnt	5.89	175	152	72	61.8	8.1	9.90
	600	GCTB	4.29	380	359	55	97.8	2.8	16.72
		Burnt	7.14	175	158	72	75.0	10.0	13.47
	700	GCTB	6.07	280	260	62	102.0	7.1	3.23
		Burnt	8.44	175	164	71	88.6	12.2	13.74
	1000	GCTB	8.50						
		Burnt	12.20						
1/200	250	GCTB	3.11	175	130	69	32.7	5.5	17.02
		Burnt	2.89	175	143	74	30.3	3.7	14.44
	350	GCTB	3.20	230	220	71	44.2	2.3	13.17
		Burnt	4.12	175	151	72	43.3	5.5	14.18
	500	GCTB	4.33	250	261	69	65.0	2.1	19.35
		Burnt	6.02	175	164	71	63.2	8.4	13.77
	600	GCTB	5.12	250	280	70	76.8	1.7	3.73
		Burnt	7.30	175	173	70	76.7	10.3	13.15
	700	GCTB	5.90	270	296	66	95.6	3.5	11.11
		Burnt	8.59	175	180	70	90.2	12.2	12.61
	1000	GCTB	8.16						
		Burnt	12.40						
1/400	250	GCTB	3.40	153	234	72	31.1	1.9	10.60
		Burnt	2.94	175	135	73	30.9	4.2	14.29
	350	GCTB	3.04	270	259	64	49.2	2.7	17.92
		Burnt	4.20	175	164	71	44.1	5.6	13.30
	500	GCTB	4.06	331	547	56	80.6	0.3	17.11
		Burnt	6.11	170	155	72	62.3	8.4	13.72
	600	GCTB	4.97	270	319	66	80.5	1.7	15.11
		Burnt	7.43	170	193	71	75.8	8.9	14.10
	700	GCTB	5.70						
		Burnt	8.56						
	1000	GCTB	7.90						
		Burnt	10.65						
1/600	250	GCTB	3.40	154	269	72	31.4	0.8	19.02
		Burnt	2.97	180	139	70	32.1	4.6	13.44
	350	GCTB	2.98	270	280	65	48.3	1.8	15.38
		Burnt	4.26	175	172	70	44.7	5.4	12.58
	500	GCTB	4.15	294	582	52	73.1	0.4	16.80
		Burnt	6.15						
	600	GCTB	4.88	270	352	67	79.0	0.4	17.13
		Burnt	7.47	170	208	71	76.2	7.7	10.41
	700	GCTB	5.58						
		Burnt	7.34						
	1000	GCTB	7.75						
		Burnt	7.58						
1/800	250	GCTB	3.40	165	280	67	33.6	0.9	2.21
		Burnt	3.00	175	143	71	31.5	4.2	12.19
	350	GCTB	2.95	270	294	66	47.8	1.3	14.24
		Burnt	4.29	160	179	76	41.2	3.4	14.84
	500	GCTB							
		Burnt	6.16						
	600	GCTB	4.81	300	371	62	86.6	1.3	14.68
		Burnt	7.45	160	222	75	71.5	4.3	18.52
	700	GCTB							
		Burnt	6.02						
	1000	GCTB	7.60						
		Burnt	8.74						

Soil Class: **Alluvial Loam**, Home Hill, Burdekin

Slope	Furrow Length (m)	Burnt GCTB	Inflow Rate (l/s)	Cutoff Time (min)	Time to Reach End (min)	Efficiency (%)	Inflow per Drill (m^3)	Runoff per Drill (m^3)	Runoff % of Inflow
1/100	**250**	Burnt	2.19	225	128	75	29.5	3.9	13.2
		GCTB	2.32	200	114	79	27.8	4.0	14.4
	350	Burnt	3.09	225	138	75	41.7	5.5	13.2
		GCTB	3.34	200	119	78	40.0	6.3	15.7
	500	Burnt	4.47	225	150	74	60.3	8.1	13.4
		GCTB	4.91	200	127	76	58.9	10.1	17.1
	600	Burnt	5.40	225	157	74	72.9	10	13.7
		GCTB	5.98	200	134	75	71.7	12.7	17.7
	700	Burnt	6.30	225	164	73	85.0	11.9	14
		GCTB	7.02						
	1000	Burnt	9.20						
		GCTB	7.40						
1/200	**250**	Burnt	2.21	225	137	75	29.8	3.9	13.1
		GCTB	2.38	200	119	78	28.5	4.4	15.4
	350	Burnt	3.12	225	149	74	42.1	5.6	13.3
		GCTB	3.43	200	127	76	41.1	6.9	16.8
	500	Burnt	4.53	225	164	73	61.1	8.4	13.7
		GCTB	x						
	600	Burnt	5.49	225	174	73	74.1	10.4	14
		GCTB	x						
	700	Burnt	6.46	225	182	72	87.2	12.5	14.3
		GCTB	5.22	275	260	72	86.1	4.6	5.3
	1000	Burnt	9.40						
		GCTB	7.20						
1/400	**250**	Burnt	2.20	200	152	83	26.4	2.6	9.9
		GCTB	2.46	200	242	75	29.5	2.8	9.3
	350	Burnt	3.17	225	163	73	42.7	5.7	13.3
		GCTB	x						
	500	Burnt	4.61	220	182	73	60.9	8.1	13.3
		GCTB	4.96	200	262	75	59.5	6.1	10.3
	600	Burnt	5.62	225	194	71	75.8	10.7	14.1
		GCTB	x						
	700	Burnt	6.41	220	175	74	84.6	11.3	13.4
		GCTB	5.53						
	1000	Burnt	9.75						
		GCTB	x						
1/600	**250**	Burnt	2.25	225	135	74	30.3	4.3	14.0
		GCTB	2.39	225	210	70	32.3	4.1	12.7
	350	Burnt	3.21	225	173	72	43.3	5.7	13.2
		GCTB	x						
	500	Burnt	4.68						
		GCTB							
	600	Burnt	5.70	225	209	70	76.9	10.6	13.8
		GCTB	x						
	700	Burnt	6.68						
		GCTB	5.67						
	1000	Burnt	9.91						
		GCTB	x						
1/800	**250**	Burnt	2.26	220	139	75	29.9	4.0	13.4
		GCTB	2.41	220	220	70	31.8	3.4	10.7
	350	Burnt	3.23	225	180	72	43.6	5.5	12.6
		GCTB	x						
	500	Burnt	4.72	220	167	72	62.4	9.14	14.6
		GCTB							
	600	Burnt	5.77	225	220	69	77.8	10.3	13.2
		GCTB	x						
	700	Burnt	6.79						
		GCTB	1.09						
	1000	Burnt	9.99						
		GCTB	x						

DEFINITION OF TERMS

Trash Management: whether the trash is retained after harvest or burnt in the field. This is a surrogate for furrow roughness.

GCTB: If trash or weeds are present in the furrow causing an impedance or roughness to flow. Cultivated soils with or without trash retention may be considered to behave like GCTB.

Burnt: When there is little or no trash or weeds in the furrow. ie occurs before the first harvest or after the first harvest when the trash has been burnt either in the field or after harvest.

Inflow Rate (L/s): The inflow rate measured in litres per second is the amount of water entering the furrow, ie the amount of water coming from a single outlet, not the pumping capacity.

Cutoff Time (min) The cutoff time is the duration of the irrigation or the time between turning the pump on and switching it off.

Time to Reach End (min): the time to reach the end or final advance time is the amount of time it takes for the water in the furrow to reach the end of the furrow, ie the time when runoff starts. The time to reach the end of the furrow is usually different to the cutoff time.

Efficiency (%): The measure of efficiency presented in the tables represents application efficiency. It is a simple volume balance measure of the amount of water infiltrated into the root zone (above the target application depth) divided by the total inflow volume. Ie
Application efficiency = water stored in root zone / total inflow
Application efficiency = Inflow Volume – deep drainage – runoff.

Requirement Efficiency (%): The requirement efficiency is a measure of how well the root zone or target application depth has been filled.

Inflow per Drill (m^3): The total volume of water applied to each drill measured in cubic meters, ie inflow rate (l/min) x cutoff time or pumping duration (min).

Runoff per Drill (m^3): Is the final volume of water that ran out the end of the drill.

Runoff % of Inflow (%). Is the amount of water that ran out the end of the furrow as a percentage of the input volume.

Target Application Depth (Zreq): The target application depth (irrigated rooting zone) is the amount of water which infiltrates into the soil which is available for crop growth, usually expressed as a depth.

UNIT CONVERSIONS

Slope

Fraction	**1/100**	**1/200**	**1/400**	**1/600**	**1/800**
Decimal	0.01	0.005	0.0025	0.00166	0.00125
Percent	1	0.5	0.25	0.166	0.125
Inch/chain	8 inch to a chain	4 inch to a chain	2 inch to a chain	1&1/3 inch to a chain	Half inch to a chain

Length

Meters	**250**	**350**	**500**	**600**	**700**	**1000**
Chain	12.5	17.5	25	30	35	50
Yards	274	383	547	656	766	1094

Volume

Convert from	**Convert to**	**Action**
Liters L	Cubic meters m^3	Divide 1000
Liters L	Megaliters Ml	Divide 1000000
Cubic meters m^3	Megaliters Ml	Divide 1000

REFERENCES

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