Simulation of nitrogen management in trash-blanketed sugarcane systems

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Abstract

Sugarcane crop residues, known as trash, contain substantial amounts of nitrogen (N) and other nutrients. The availability of N in trash left in the field following harvest is complicated because most of the N cycles through the soil organic matter. To gain insights into the impacts of trash management on sugarcane production and the long-term fate of N contained in trash, a simulation study was conducted with the APSIM-Sugarcane cropping systems model. Long-term simulations were conducted for two different soil types combined with climatic data from three locations. Trash management and N fertiliser application rates were varied in the simulations. The simulation study showed that sugarcane yields have potential to respond positively to retention of trash in the field over the range of climates considered. However, achieving these higher potential yields will require that N applications not be reduced following the switch from trash burning to trash retention. This study also illustrates the potential negative, short-term impact of trash retention on sugarcane yields due to the immobilisation of N by the decomposing trash. The simulations also indicate that average environmental losses of N are likely to be greater where trash is retained and particular care should be exercised to avoid over-application of N in green cane trash blanket systems systems.

Media summary

Sugarcane yields have potential to respond positively to trash retention but average environmental losses of N are likely to be greater and care should be exercised to avoid over-application of N.

Keywords

Denitrification, fertiliser response, green cane harvesting, leaching, mineralisation, soil organic matter

Introduction

Sugarcane trash contains considerable quantities of dry matter and nutrients, particularly nitrogen (N) (Wood 1991; Ball-Coelho et al. 1993; Mitchell et al. 2000). When sugarcane is burnt either pre- or post-harvest, 70–95 % of the dry matter and N are lost from the system, with lower losses of other nutrients (Mitchell et al. 2000). Thus cane harvesting green and retaining the trash (a system know as 'GCTB') can have a considerable effect on organic matter conservation, nutrient cycling and N fertility of the soil (Wood 1991; Ball-Coelho et al. 1993; Thorburn et al. 2000, 2002). Trash retention is now the normal method of trash management in most parts of the Australian sugar industry. However, fertiliser recommendations in the industry have historically been based on burnt cane systems, as this was the dominant method of trash management when the recommendations were developed. Thus there is a need to examine whether new recommendations for management of nutrients are required for GCTB systems.

The complexity of the N cycle and the long time scales involved in soil organic matter cycling make simulation-based approaches to this N management problem attractive. Over the last 10 years there has been considerable progress made in our ability to simulate sugarcane production systems (Keating et al. 1999), including their response to variations in N and trash management (Thorburn et al. 2004a). In this paper, we take advantage of these advances and use a simulation approach to gain insights into the long-term fate of N contained in trash and identify the N fertiliser management implications of trash retention.

Materials and Methods

The general approach of this study was to conduct simulations of sugarcane yield and environmental losses of N at different rates of applied N to each of two trash management systems (trash burnt and trash retained at harvest). Details of methodology have been reported by Thorburn et al. (2004b) but a brief description follows. Simulations were undertaken with the APSIM cropping systems simulator. The model was configured to consist of modules for soil N and C (APSIM-SoilN; Probert et al. 1998), soil water (APSIM-SoilWat; Probert et al. 1998) and sugarcane residue (APSIM-Residue; Thorburn et al. 2001) dynamics, and sugarcane growth (APSIM-Sugarcane; Keating et al. 1999). Simulations were conducted using soil parameters (based on measured data) for two different soil types (Red Kandosol[1] and Brown Chromosol) and a range of climates in the industry, giving six contrasting soil type–climate combinations. Climate data were obtained for the Abergowrie, Burdekin and Mackay areas from the Queensland Department of Natural Resources, Mines and Energy SILO Patched Point Datasets (Jeffrey et al. 2001).

The simulations were conducted over 100 years. The cropping cycle consisted of a 15 month plant crop plus four 13 month ratoons. The trash management systems simulated were 1) retention of trash at harvest and 2) removal of 95 % of trash at harvest, equivalent to trash burnt both pre- and post-harvest (Mitchell et al 2000). N fertiliser management systems were simulated by varying N fertiliser application rates from 0 to 300 kg/ha (in 30 kg/ha increments) on ratoon crops, with plant crops receiving 75 % of that applied to the ratoon crops (as is recommended N management). Irrigation was applied for simulations using Burdekin climate, as is customary for sugarcane production in this area. Potential sugarcane yields were predicted – there was no allowance made in the simulations for factors such as pests and diseases, lodging, water logging, stool damage during harvest, etc., which will limit yields in the field.

Results

In all simulations, the potential sugarcane yields varied markedly between each crop (in response to climatic differences) over the different growing seasons, as expected. This variability did not overshadow the consistent impacts simulated for different trash and N fertiliser managements systems. Thus for simplicity, simulated average N responses are presented (for example, sugarcane yield shown in Figure 1a).

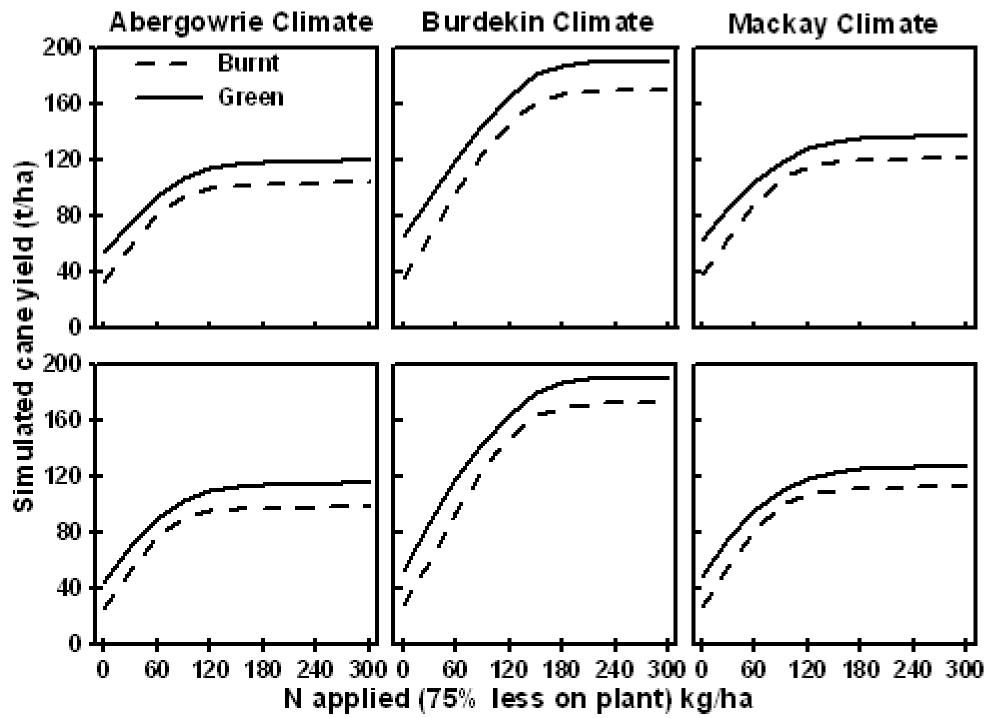
As expected, sugarcane yields are simulated to increase with increasing amounts of applied N until a yield plateau is reached, and no further response to N occurs. Maximum sugarcane yields are simulated to be highest for the Burdekin climate and lowest for the Abergowrie climate, as anticipated from the radiation and rainfall (and irrigation in the Burdekin) at these locations. Generally, sugarcane yields simulated in the GCTB systems are greater than those in the burnt systems at all rates of applied N (Figure 1a). The increases in yield in the GCTB systems are due to lower water stress in the simulations compared with the burnt system.

The N rates at which sugarcane yields are simulated to plateau in the burnt systems are approximately 160 kg/ha in all cases, except for the Burdekin climate where it is approximately 200 kg/ha (Figure 1a). These N rates are in accord with previous experience in the Australian sugar industry (Chapman 1994, Calcino et al. 2000). Interestingly, yields are simulated to plateau at similar rates in the GCTB systems, despite the N recycled in the trash blanket.

As expected, losses of N to the environment (Figure 1b) were simulated to increase with increasing rates of applied N fertiliser at all sites and soil types. The increase was greatest at N rates where yields ceased to respond to additional N fertiliser. Total N lost was most affected by climate with Burdekin climate producing the lowest losses. The impact of climate in the simulations is largely due to differences in sugarcane yields – climates resulting in higher yields have lower N losses. However, it is also affected by rainfall with the Abergowrie climate simulated to have higher losses relative to its yield. Although the two soil types have similar total loss of N the Brown Chromosol had lower leaching and higher denitrification than the Red Kandosol (Thorburn et al. 2004b).

In all soils and for all climates, N losses (Figure 1b) are simulated to be higher under the GCTB system than the burnt system. This indicates that not all of the additional N recycled in the GCTB systems is taken up by the crop. Soil organic matter concentrations are higher in GCTB soils, both experimentally (Wood 1991, Thorburn et al. 2000) and in the simulations (data not shown). This increased soil organic matter results in higher soil N mineralisation rates and a greater probability that nitrate is in soil solution during times when conditions are favourable for N losses.

a)



b)

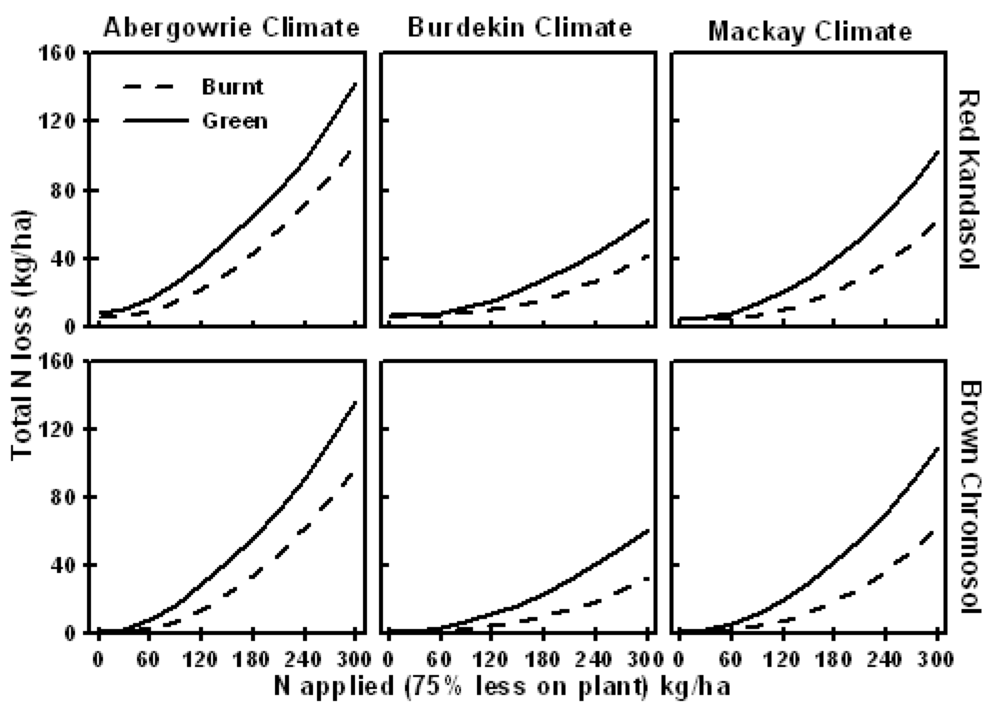


Figure 1. Simulated long-term average a) sugarcane yield and b) nitrate leaching response to applied N for GCTB and trash burnt systems in a Red Kandosol (top row) and Brown Dermosol (bottom row).

Since decomposing trash blankets have the potential to immobilise considerable amounts of N (Ng Kee Kwong et al. 1987, Basanta et al. 2003), there may be a possibility of N stress developing and limiting sugarcane yields following the switch from burning to retaining trash. To investigate this through the simulations, yields with N applied at optimum rates in the burnt system were compared to those in the GCTB system at various N rates. In the example shown in Figure 2, the cumulative difference (increase or decrease) between simulated yields in the GCTB (at various rates of N) and burnt (at optimum N) systems are shown through time. The cumulative differences are shown as they remove the impacts of large year-to-year variability on depiction of the results. In both examples the optimum N application rates in the burnt system was approximately 150 kg/ha on ratoon crops (Figure 1a). At the rates of N applied to GCTB shown in Figure 2, simulated yields tend to be lower (i.e., the cumulative difference is increasingly negative) immediately following the switch from trash burning to trash retention. The duration of this period of yield depression varies depending on the rate of N and it may take some time (5-15 years as in Figure 2) for the cumulative yield benefit of the GCTB system to be positive.

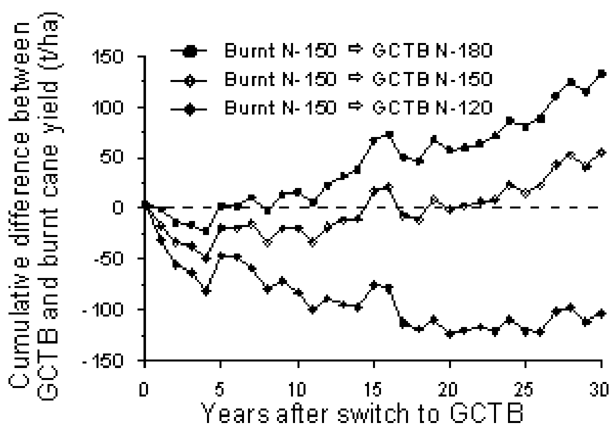


Figure 2. Simulated change in cumulative difference in sugarcane yield between GCTB (at three different rates of N fertiliser) and trash burnt (at 150 kg/ha application of N fertiliser) systems with increasing time after changing from the burnt to the GCTB system for Mackay climate and Brown Chromosol soil.

Discussion

This simulation study, and that of by Thorburn et al. (2004b), has shown that sugarcane production has the potential to respond positively to trash retention in a range of environments (Figure 1a), provided soils have good internal drainage. This is widely recognised from both experiments (Wood 1991, Chapman et al. 2001) and anecdotal accounts. However, this study also shows that achieving these production benefits (i.e. higher potential yields) makes use of the trash N that is recycled in the soil-crop system. Therefore, N application rates should not be reduced following the switch from a burnt to GCTB system, provided there is an expectation that cane yields will be higher. Previous recommendations have implicitly assumed a similar target yield in both burnt and GCTB systems and so, logically, suggested N applications be reduced. Where there is an expectation that yields will not be higher under GCTB, such as in areas with poor drainage or early harvested crops in NSW, the recommendation to reduce N application rates is sound.

This study has also illustrated the potential negative, short-term impact of trash blanketing on sugarcane yields (Figure 2) due to the immobilisation of N by the decomposing trash. Following the change to trash blanketing both soil organic matter concentrations and soil N mineralisation rates increase. Eventually the system comes into a new equilibrium with sufficient N supply in the soil-crop system to allow the trash blanket to decompose without immobilisation creating N deficits. The results of these simulations suggest that it takes at least 5 years for this equilibrium to be reached at conventional N fertiliser application rates, possibly longer at lower rates.

The results of the simulations also indicate that average environmental losses of N are likely to be greater from GCTB systems at all rates of N applications (Figure 1b). Despite the lack of experimental experience to support the simulation results in this area, this study suggests that even more caution should be exercised to avoid over-application of N in GCTB systems.

One limitation of this study is that field yields are usually lower than the potential yields presented because of lodging, water logging, pests and diseases, and other factors. It may be that these factors prevent the yield advantages of the GCTB system being realised in the field to the extent indicated by the simulations. If so, the need to reduce N fertiliser rates following the change to trash blanketing may be more widespread than indicated by this study. Nevertheless, an important implication of this study is that extension officers and growers should consider the likely yields in a GCTB system relative to those in a burnt system when deciding whether modifications are needed to N fertiliser management regimes.

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[1] All soils are described according to the Australian soil classification (Isbell 1996).