# UNDERSTANDING AND MANAGING THE LATE TIME OF RATOONING EFFECT ON CANE YIELD

By

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## Abstract

Each year growers are faced with the decision of when to harvest individual blocks of sugarcane throughout the harvest season. This decision influences the yield of the current crop and can affect the yield in the following season. Growers must therefore decide which blocks to harvest early and which to harvest later in the harvest season. Usually, the latest harvested cane is the lowest yielding the following year (the 'late harvest' effect). Block productivity data from Tully were used to determine the effects of harvest timing on cane yield of the current and subsequent crop. The results are tabulated to provide a ready reference to these time of harvest effects on the current and future crop in either a single year or over the full crop cycle for the Tully district.

## Introduction

Australian sugarcane is grown as a perennial monoculture that is usually harvested at approximately annual intervals between June and November. The harvesting of cane is highly organised, with growers harvesting a portion of their cane in 4 or 5 periods during the season. The amount of cane harvested in any one rotation may vary between harvesting contractors and farmer groups. Irrespective of the harvesting arrangements in place, the farmer must decide which block(s) of cane to harvest when the harvester arrives at the farm.

The time of ratooning (time when the crop was harvested in the previous year) influences the cane yield of the following crop. Yield reductions may occur when the crop is harvested after October, as was first identified by Chapman and Leverington (1976). The influence of timing and crop age on cane yield has been the subject of much research and discussion (e.g. McDonald *et al*., 1999; McDonald and Wood, 2001) and, in the normal commercial situation may influence the variation of cane yield more than variety or crop class (Lawes *et al*., 2002a). The magnitude of these influences on cane yield may vary between mill districts and between years, although in Tully the influence is remarkably consistent from one year to the next (Lawes *et al*., 2002b). Growers are often provided with information from local investigations into block productivity data on variety performance, the likely impact that succeeding crop classes have on cane yield, as well as information on district performance within a mill area. All of these factors are important and growers use this information to plan their farming operations. Additional information on the impact time of ratooning has on cane yield may also be useful in assisting growers to plan their harvesting operations.

The effect of the time of ratooning on cane yield provides a surrogate measure of the influence of factors such as incident radiation capture, rainfall and its distribution within the growing season (Rostron, 1972; Inman-Bamber, 1994; Muchow *et al*., 1997). These effects are captured by block productivity data and may therefore be used to give an indication of the likely impact that climatic conditions have on cane yield. In this study, we outline an analysis of block data that estimates these timing influences on cane yield. From the analysis, a Table is derived Table 1) to illustrate how the information might be used to plan the harvest of blocks in order to manage and minimise the impact of the late ratooning effect on cane yield. Alternatively, the information might be used to design a trial to investigate a the response to late ratooning over a number of years.

## Methods

### Block data

In the Tully Sugar Mill area, situated in the wet tropics of North Queensland, Australia, block productivity data from 1988 to 1999 have been digitally recorded and are available for analysis. Information such as month of harvest, month of ratooning (the month of harvest of the previous year's crop), farm of origin, crop class, variety, cane yield and CCS (commercial cane sugar content) is available for each block of cane harvested during this period. However, the date of planting at the start of each crop cycle (plant cane) was not recorded and was unavailable. Approximately 65 000 records from Tully block data were suitable for analysis.

### Statistical analysis

The effects of harvest timing on cane yield of both the present and subsequent crop were explored. In this study, we assumed that the harvester visits a farm four times during the harvesting season, at approximately six-week intervals. Therefore, the timing of harvest data was allocated into one of four six-weekly periods. The data for time of ratooning, which is the time when the crop was harvested in the previous year, were allocated into the same four, six-week periods. It was necessary to account for other random influences, including the farm of origin, the crop class and the variety of cane, which all potentially contribute to the variation in cane yield (Lawes and Fuelling, 2000) and should, therefore, be accommodated in the analysis. The model used to explain actual cane yield using the input data, where all effects were defined as random, is presented in equation (1):

$$tch_{ijklmn} = \mu + year_i + farm_j + class_k + variety_l + tor_m + toh_{mn} + e_{ijklmn}$$

where $tch_{ijklmn}$ is the cane yield in tonnes per hectare for the $i^{th}$ year, $j^{th}$ farm of origin, $k^{th}$ crop class, $l^{th}$ variety, $m^{th}$ time of ratooning and $n^{th}$ time of harvest within the $m^{th}$ time of ratooning. $\mu$ is the mean; $year_i$ is the $i^{th}$ year when the crop was harvested; $farm_j$ is the $j^{th}$ farm of origin; $class_k$ is the $k^{th}$ crop class; $tor_m$ is the $m^{th}$ time of ratooning and $toh_{mn}$ is the effect of time of harvest $n$ within time of ratooning $m$; and $e_{ijklmn}$ is the error for the $i^{th}$ year, $j^{th}$ farm, $k^{th}$ crop class, $m^{th}$ time of ratooning and $n^{th}$ time of harvest within the $m^{th}$ time of ratooning.

The objective of this analysis was to obtain values of cane yield for every possible combination of time of harvest and time of ratooning. The nesting of time of harvest within time of ratooning effectively captures all timing influences on cane yield, including the influence of crop age. The nested model was adopted as the time of ratooning indicates when the new crop started to grow. Therefore, the time of harvest effect will be influenced by the time when the crop was ratooned. These effects plus the overall mean were used in the subsequent network analysis.

**Issues involved in deciding when to harvest**

Every year, each cane grower is faced with the decision of when to harvest each individual block of cane. This harvesting decision influences the cane yield and CCS of the existing crop as well as the cane yield of the following crop. It is therefore important to consider what impact a harvesting decision has on both the current and the following sugarcane crop, and ideally plan the harvesting of a block, or an experiment, for the whole crop cycle.

The sequence of events involved in the whole crop cycle, that is, the fallow prior to planting and the subsequent harvests of plant cane, 1$^{st}$ ratoon cane, 2$^{nd}$ ratoon cane, 3$^{rd}$ ratoon cane and ploughing out and fallowing the block can be described in dynamic programming terms as a network problem with a series of nodes (Chang and Sullivan, 1991). The origin and source of the network, node 1, indicates the point when the crop was planted (Figure 1) and is the beginning of the sequence of events that occurs with each block of cane. At each node, there are two options that can be exercised: to harvest or not to harvest. Any pair of nodes is designated *r* and *h* and the path connecting them is identified as a branch *(r,h)*, with a corresponding yield (*r*,*h*). The yield (*r*,*h*) is estimated as the sum of the time of ratooning effect, time of harvest and the overall mean, as estimated in equation (1) using the long-term data.

For the purposes of the exercise, all other effects (farm, variety, crop class and year) were ignored. Each vertical set of nodes in Figure 1 (a stage in dynamic programming terms) represents a year in the crop cycle of a single sugarcane crop, and each branch (*r*,*h*) represents a potential time of ratooning (*r*) and time of harvest (*h*). In the chosen scenario, there are four possible nodes (harvest times) in each stage of the sequential decision (year). For simplicity, a four-year crop cycle was chosen. The progression from one node to the next along the branch (*r*,*h*) equates to moving from one year to the next in the crop cycle.

A move from one node to the next indicates that the crop has been harvested and a cane yield results from that action. At nodes 14, 15, 16 or 17, the cane is ploughed out, the block fallowed and the cycle ended. There are 17 nodes with 52 possible node branches (*r,h*) and corresponding yields (*r*,*h*) (Figure 1). For each block of cane, there are 64 possible paths through the network, although clearly some would be impractical in normal farming circumstances. The potential total yield from a sequence of harvesting decisions is the sum of all yields (*r*,*h*) encountered on a particular path, which must consist of four branches (*r*,*h*).

**Table 1**—The period of ratooning and period of harvest allocated to each branch (*r*,*h*) of the network solution, for a scenario assuming four main harvest periods in each year of a four-year crop cycle.

| Ratoon time (Year t) | Harvest time (Year t+1) | Branches (*r*,*h*) |
|---|---|---|
| 1 (wks 1–6) | 1 | (1,2), (2,6), (6,10), (10,14) |
| 1 | 2 | (1,3), (2,7), (6,11), (10,15) |
| 1 | 3 | (1,4), (2,8), (6,12), (10,16) |
| 1 | 4 | (1,5), (2,9), (6,13), (10,17) |
| 2 (wks 7–12) | 1 | (3,6), (7,10), (11,14) |
| 2 | 2 | (3,7), (7,11), (11,15) |
| 2 | 3 | (3,8), (7,12), (11,16) |
| 2 | 4 | (3,9), (7,13), (11,17) |
| 3 (wks 13–18) | 1 | (4,6), (8,10), (12,14) |
| 3 | 2 | (4,7), (8,11), (12,15) |
| 3 | 3 | (4,8), (8,12), (12,16) |
| 3 | 4 | (4,9), (8,13), (12,17) |
| 4 (wks 19–24) | 1 | (5,6), (9,10), (13,14) |
| 4 | 2 | (5,7), (9,11), (13,15) |
| 4 | 3 | (5,8), (9,12), (13,16) |
| 4 | 4 | (5,9), (9,13), (13,17) |

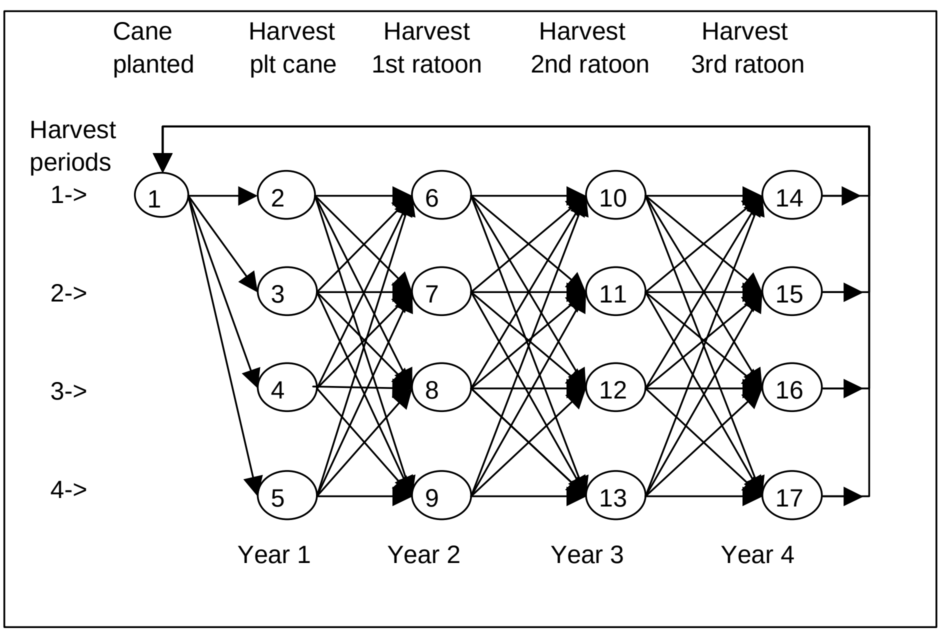


Fig. 1—Model describing harvest timing sequences in dynamic programming terms as a network problem with a series of nodes. Nodes are indicated by circles with the node number specified in the circle. The direction of flow and progression from one node to the next is indicated by the arrows.

## Results

### Effect of harvest timing on cane yield

The time of ratooning and time of harvest both influenced cane yield, although the time of ratooning (previous harvest) was generally more important than the time of harvest (Figure 2). Crops ratooned in period 4 yielded between 8 and 10 t/ha less than crops ratooned in period 3 for all harvest times. Crops ratooned in period 3 yielded between 7.8 and 8.4 tonnes/ha less than crops ratooned in periods 1 and 2, when the crop was harvested in either period 1, 2 or 3. There was no difference in yield for crops ratooned in period 1, 2 or 3 when harvested in period 4.

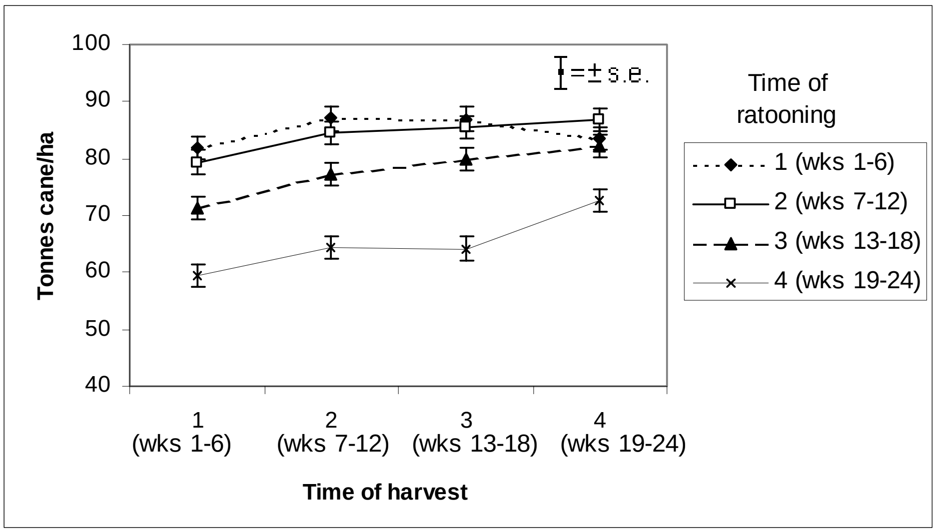


Fig. 2—Influence of time of ratooning and time of harvest on cane yield in the Tully district from 1988 to 1999, as estimated using harvest data from 65,000 block productivity records.

### Managing the crop over the life of a ratoon

The incorporation of the above effects calculated from the Tully block data into the dynamic programming routine for all combinations of period of ratooning and period of harvest during a four-year sequence generated a wide range in expectations for cane yield from a block of cane over the life of the crop. From the 64 possible harvesting sequences identified by the network, total cane yield ranged from 342 tonnes down to 301 tonnes per ha. This equates to an average cane yield per year of between 85.5 t/ha and 75.3 t/ha. An example of a high yielding harvesting sequence and a low yielding sequence are illustrated in Table 2. The crop from the high yielding sequence was planted in the first period (approximately June/July), and then harvested in the second period (August/September). In the following year the first ratoon crop was again harvested in the second period at twelve months of age. The second ratoon crop was also harvested in the second period. The third and final ratoon was then harvested in the final period and then ploughed out. In contrast the crop from the low yielding harvest sequence was planted in the 1$^{st}$ period (June/July) and harvested in the 4$^{th}$ period (Novmeber) at approximately 17 months of age. In the following year, the first ratoon crop was then harvested in the 4$^{th}$ period. The second and third ratoon crops were again harvested in the 4$^{th}$ period at 12 months of age.

**Table 2—**Tabulation of the ratoon and harvest period and expected cane yield from plant cane to third ratoon for a high yielding harvest sequence and a low yielding harvest sequence.

| | High yielding harvest sequence | | | Low yielding harvest sequence | | |
|---|---|---|---|---|---|---|
| | Period of ratooning | Period of harvest | Cane yield t/ha | Period of ratooning | Period of harvest | Cane yield t/ha |
| Plant cane * | 1 | 2 | 87 | 1 | 4 | 84 |
| 1st ratoon | 2 | 2 | 84 | 4 | 4 | 73 |
| 2nd ratoon | 2 | 2 | 84 | 4 | 4 | 73 |
| 3rd ratoon | 2 | 4 | 87 | 4 | 4 | 73 |
| Total yield | | | 342 | | | 303 |

*The period of ratooning of plant cane equates to the period when the crop was planted.

A simple table of the yield expected from a given time of ratooning and time of harvest is presented below, and can be used as a ready reference for the impact harvest time has on cane yield of both current and future crops (Table 3). For example during the first round, a grower may consider harvesting cane that was ratooned in the 1st, 2nd, 3rd or 4th round in the previous year. The crop ratooned in period 1 yields 3 t/ha more than the crop ratooned in period 2, 11 t/ha more than the crop ratooned in period 3 and 22 t/ha more than the crop ratooned in period 4.

**Table 3—**Tabulation of period of ratooning effects with corresponding period of harvest effects on cane yield.

| Period of ratooning | Period of harvest | Tonnes cane/ha |
|---|---|---|
| 1 (wks 1–6) | 1 | 82 |
| 1 | 2 | 87 |
| 1 | 3 | 87 |
| 1 | 4 | 84 |
| 2 (wks 7–12) | 1 | 79 |
| 2 | 2 | 84 |
| 2 | 3 | 86 |
| 2 | 4 | 87 |
| 3 (wks 13–18) | 1 | 71 |
| 3 | 2 | 77 |
| 3 | 3 | 80 |
| 3 | 4 | 82 |
| 4 (wks 19–24) | 1 | 60 |
| 4 | 2 | 65 |
| 4 | 3 | 64 |
| 4 | 4 | 73 |

## Potential applications

Information on variety performance is regularly tabulated and used to improve production. Like varieties, the time of ratooning has an impact on the yield of the crop and, as for varieties, decisions need to be made on which blocks to harvest in particular harvesting rounds. The decision may also be influenced by the expected CCS, which varies through out the year (e.g. Rostron, 1972) and is dependent on variety selection and its interaction with time of year (Cox *et al.,* 1990). Obviously, the decision of when to harvest a block is potentially affected by a wide range of additional factors such as trafficability under wet conditions, the crop class and maybe whether the block is high yielding or otherwise. There are many competing reasons for harvesting a block at a given time and, from the evidence presented here, we suggest that the impact that a late ratooned crop has on the yield of the following crop also be considered.

Similarly, the time of planting and age of the crop at harvest should be considered by researchers and perhaps accommodated in the experimental design. It is common practice to evaluate the varietal response to a treatment, and it may therefore be worth evaluating the interaction between harvest time and the time of ratooning, as a crop planted or ratooned early is exposed to a different climatic regime to a crop planted or ratooned late. These climatic differences may influence the crop's response to the treatment.

As we show elsewhere (Lawes *et al.,* 2002a), the information presented here can be used to optimise the decision pathways shown in Figure 1 to determine an ideal harvesting rotation across the farm. Higher yields are generally obtained by avoiding late ratooning and ensuring the crop is harvested at 12 months of age (see Table 2). Crops that are to be ploughed out may then be harvested in the last round. This action would minimise the amount of cane that must be ratooned late. Higgins and Muchow (1998) previously optimised harvesting across the whole of mill to exploit geographical differences in CCS. Although both this study and that of Higgins and Muchow (1998) used block data, the purpose here was to provide growers and researchers with additional information to aid in the decision of when to harvest cane for an individual farm or trial site.

To date, little information has been collected on the time of planting although McDonald and Lisson (2001) found that crops planted early (May, June or July) are identifiably more productive than those planted later. It is possible to plan harvesting and planting operations to ensure crops are given an adequate amount of time to grow, while minimising the effect of late ratooning on cane yield.

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