DETERMINING OPTIMAL REPLANTING CYCLES OF SUGARCANE

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Abstract

An alternative approach for determining optimal replanting cycles of sugarcane is suggested based on cane yield decline and corresponding break-even yield beyond which the cumulative return on investment tends to decline. Ratios of cumulative net returns to cumulative costs and yield declines in relation to reference yields are calculated to determine their functional relationship. The yield decline corresponding to the maximum cumulative return on investment is found using this relationship. The corresponding break-even yield is obtained by deducting this yield decline from the reference yield. The crop should be replanted when cane yields drop below the break-even yield. This method was applied to farm-level data collected from 1990-91 to 1994-95 in Sri Lanka. The results showed that rain-fed settler farms at Sevanagala and Pelwatte should be replanted after the eighth ratoon or when cane yields fall below 32 t/ha. In the out-grower situations at Pelwatte, crops should be replanted when cane yields fall below 21 t/ha which corresponds to the eleventh ratoon crop. In the irrigated settler farms at Sevanagala and Hingurana, a crop cycle with five ratoons was found to be optimum with break-even cane yields of 52 t/ha. In the out-grower farms at Hingurana, it was determined that crops should be replanted after the fourth ratoon or when the cane yields dropped below 75 t/ha.

Introduction

Ratoon cropping in sugarcane generates more profit because land preparation and planting costs are spread over a larger period (Blume, 1985; Chapman, 1988). However, cane yield tends to decline in successive ratoon crops due to a reduction in stalk population and stalk weight and an increase in stalk mortality (Midmore, 1979; Chapman, 1988). Some factors which may cause this yield reduction are: loss of soil tilth; soil compaction; mechanical, disease and pest damage to roots; and the build up of diseases such as ratoon stunting disease (Blume, 1985). Even though ratooning ability is a varietal character, yields of successive ratoon crops are also influenced by the growing environment and management practices employed (King et al., 1965; Chapman et al., 1992).

Since ratoon yields tend to decline over the years, maintenance of a ratoon crop after a certain level of yield may not be profitable (Chapman, 1988). Moreover, for a given variety, the yield after which the crop should be replanted is important not only to maximise the farmers' income but also to increase cane supplies to mills and insure their profitability. Replanting in an optimum crop cycle is also important to maximise the use of resources in cane production and sugar manufacture. Different methods have been suggested to determine optimum replanting cycles for sugarcane. Chinloy and Shaw (1969, 1973) suggested a criterion based on maximisation of profit per unit area per annum. Tonta et al. (1998) and Tonta and Smith (1996) used the same criterion but based their assessment of optimum replanting cycles on the maximisation of cumulative net present value per hectare per year. Determination of optimum replanting cycles based on this approach suffers from several shortcomings. Even when the profit per unit area per year is declining, the profit generated by individual ratoon crops can be higher than that of the plant crop. Hence, replanting after reaching the maximum profit per hectare per annum would not be rational from the point of view of maximising the farmers' total profit. Additionally, though this method can be applied to individual farm situations, it does not directly show the extent to which the cane yield should decline from the highest yield of either the plant crop or the first ratoon crop. It would be more practical if the recommendation for replanting is based on the decline of yield from its maximum level.

Simms (1982) suggested a criterion based on cumulative loss of revenue due to yield decline from its peak and replanting costs. Accordingly, replanting should be undertaken when the cumulative loss of gross revenue is equal to or greater than the replanting costs (costs of land preparation and crop establishment). Simms defines the cumulative yield loss as the sum of the difference between the peak yield and the individual crop yield. However, the actual cumulative decline from the peak is the summation of the yield difference between successive crops starting from the crop which gives the highest yield. In other words, the cumulative yield decline up to a given crop is the difference between the peak yield and the yield of that crop. With Simms' definition, the cumulative yield decline is overestimated. Further, when a decision on replanting is made by comparing cumulative loss of revenue with replanting costs, the distribution of land preparation and seed and planting costs among the plant crop and ratoon crops is not taken into account. When using

KEYWORDS: Cumulative Return On Investment, Ratoon Cropping, Reference Yield, Yield Decline.
profit per unit area per year, this aspect is taken into consideration to a certain extent, but maintenance costs of the plant and ratoon crops may not be the same. Thus, consideration of replanting costs only is not correct for the maximisation of profits.

Shaw (1988a,b) suggested a similar concept of accumulated yield decline and the criterion for determining the optimum replanting cycle through an index called the Ratoon Performance Index (RPI). The only difference in this method is the specification of a reference yield (the annualised yield of the most productive cane class) to determine the accumulated yield loss. Since this method is similar to the method suggested by Simms (1982), it is also fraught with the shortcomings mentioned above.

An alternative approach for making replanting decisions may be based on the profit maximisation of a cropping cycle of sugarcane. When the criterion is maximisation of profit per unit area per year, as suggested by Chinloy and Shaw (1969, 1973), the shortcomings explained earlier will occur. Similarly, if the criterion is maximisation of profit of the individual crops, the ratoon crops would produce considerably higher profit than that of the crops raised before. On the other hand, cumulative profit reaches its maximum when a ratoon crop gives no profit. Thus, replanting when the cumulative profit is at its maximum is not rational. These shortcomings could be avoided by using total net return per unit expenditure of all crop classes, i.e. cumulative return on investment (CROI) in all crop classes in relation to the total decline of yield from the reference yield (peak) using either the plant crop or first or second ratoon crop as the basis. At the optimum level, the ratio of cumulative net return to cumulative cost should be at its maximum and greater than zero.

The total yield loss up to the ratoon crop beyond which the CROI starts to decline can be determined. The corresponding yield of the ratoon crop where CROI is at maximum, i.e. break-even yield can be determined by deducting cumulative yield decline from the reference yield. When the yield of a ratoon crop declines to this break-even yield, the crop should be replanted. This approach would be more rational and practical if used in average farm situations, i.e. at average levels of cane yields and costs on individual farms and can be expressed mathematically as shown in equations (1)–(4):

Equation (1) calculates the CROI:

$$\text{CROI}_i = \frac{n}{P} \sum_{i=1}^{n} \left[ Y_i - R + TM_i + HTMY_i \right]$$

where

- $\text{CROI}_i$ = cumulative net return per unit cost up to $i^{th}$ crop class
- $Y_i$ = cane yield of the $i^{th}$ crop class (t/ha) ($i = 1, 2, ..., n$); $i = 1$ for plant, $2$ for ratoon $1$, etc.)
- $R$ = replanting costs per ha (costs for land preparation and crop establishment)
- $M_i$ = maintenance costs per ha of the $i^{th}$ crop class
- $H$ = harvesting, loading and transport costs per tonne
- $P$ = price of cane per tonne

The total yield loss from the reference yield to the yield of ith crop class is calculated in equation (2):

$$\text{CYD}_i = Y_r - Y_i$$

where

- $\text{CYD}_i$ = cumulative yield loss up to $i^{th}$ crop class (t/ha)
- $Y_r$ = reference (peak) yield (t/ha)

To determine the CYD where CROI is at maximum, equation (3) can be used

$$\text{CROI} = \dot{f} (\text{CYD})$$

If the maximum point of the equation (3) is $\text{CYD}_m$, i.e. the maximum yield loss that can be allowed without reducing profitability, the yield of that ith ratoon crop ($i = m$), $Y_m$ is:

$$Y_m = Y_r - \text{CYD}_m$$

Thus, a field should be replanted after the $m^{th}$ ratoon for which the yield is $Y_m$ t/ha for the reference yield of $Y_r$ t/ha.

This alternative method was used to determine the near-optimal replanting cycles for sugarcane variety Co775 grown under different systems at sugar mill sites in Sri Lanka. The different sites were irrigated and rain-fed cultivation in settler and out-grower situations at Sevanagala, rain-fed cultivation in settler and out-grower situations at Pelwatte, and irrigated cultivation in settler and out-grower situations at Hingurana. Farm-level data used in the calculations were collected from a sample of 480 farms, 80 farms from each system between the 1990/91 to 1994/95 cropping years. Data could be collected up to the fifth ratoon crop. Cane yields and maintenance costs of further ratoon crops were estimated using these data. Monitory values were expressed in terms of 1991 prices by deflating them using GNP price deflator values reported by the Central Bank of Sri Lanka. The average cane yield to which the ratoon yield could attain before replanting was determined for each sugarcane production system by estimating equation (3) by the method of Ordinary Least Squares to determine $\text{CYD}_m$ and then by using equation (4). Data used for estimating the equation (3) for different sugarcane production systems are given in Appendix II.

1 Farmers who have been settled down in the sugar projects to grow sugarcane and they are provided with all inputs and services by the sugar company.

2 Independent growers who grow cane on their own land.
Appendix I—An example for calculating CROI using the Sevenagala irrigated data.

<table>
<thead>
<tr>
<th>Cane yield (t/ha)</th>
<th>Gross revenue (Rs/ha)</th>
<th>Cost of land preparation (Rs/ha)</th>
<th>Cost of crop establishment (Rs/ha)</th>
<th>Total cost of replanting (Rs/ha)</th>
<th>Cost of cropping maintenance (Rs/ha)</th>
<th>Cost of harvesting and loading</th>
<th>Total cost (Rs/ha)</th>
<th>Cumulative cost (Rs/ha)</th>
<th>Net return (Rs/ha)</th>
<th>Cumulative net return (Rs/ha)</th>
<th>CROI**</th>
</tr>
</thead>
<tbody>
<tr>
<td>152.16</td>
<td>115015</td>
<td>13755</td>
<td>10404</td>
<td>24159</td>
<td>12833</td>
<td>22219</td>
<td>592111</td>
<td>55804</td>
<td>55804</td>
<td>101122</td>
<td>0.94</td>
</tr>
</tbody>
</table>

* Gross revenue = Cane yield x Price of cane
** Transport cost was not added as it was paid by the sugar company
*** CROI = Cumulative net return/cumulative cost

PC = plant crop; R1, R2, etc. = ratoon 1, ratoon 2, etc.

Appendix II—Data used for estimating the relationships between CROI and CYD for each mill site in Sri Lanka.

<table>
<thead>
<tr>
<th>PC</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>R7</th>
<th>R8</th>
<th>R9</th>
<th>R10</th>
<th>R11</th>
<th>R12</th>
</tr>
</thead>
</table>

1. Sevanagala (Irrigated):
- Cane yield (t/ha): 152.16, 102.48, 86.58
- CROI: 0.94

2. Sevanagala (Rainfed):
- Cane yield (t/ha): 66.67, 66.53
- CROI: 0.16

3. Pelwatte (Settler):
- Cane yield (t/ha): 79.66, 75.10
- CROI: 0.16

4. Pelwatte (Out-grower):
- Cane yield (t/ha): 58.75, 68.85
- CROI: 0.05

5. Hingurana (Irrigated):
- Cane yield (t/ha): 99.33
- CROI: 0.27

6. Hingurana (Out-grower):
- Cane yield (t/ha): 100.27
- CROI: 0.49

Table 1—Near optimal number of ratoon crops for sugarcane in several areas in Sri Lanka.

<table>
<thead>
<tr>
<th>Farm condition/Situation</th>
<th>Reference yield (t/ha)</th>
<th>When to replant</th>
<th>No. of ratoons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sevanagala (settler)</td>
<td>152.2 (1)</td>
<td>100.0</td>
<td>34</td>
</tr>
<tr>
<td>Irrigated</td>
<td>152.2 (1)</td>
<td>100.0</td>
<td>34</td>
</tr>
<tr>
<td>Rain-fed</td>
<td>152.2 (1)</td>
<td>100.0</td>
<td>34</td>
</tr>
<tr>
<td>Pelwatte (rain-fed)</td>
<td>79.7 (1)</td>
<td>47.4</td>
<td>32.3</td>
</tr>
<tr>
<td>Setter*</td>
<td>79.7 (1)</td>
<td>47.4</td>
<td>32.3</td>
</tr>
<tr>
<td>Out-grower*</td>
<td>68.8 (2)</td>
<td>48.1</td>
<td>20.7</td>
</tr>
<tr>
<td>Hingurana (irrigated)</td>
<td>99.3 (1)</td>
<td>48.9</td>
<td>52.4</td>
</tr>
<tr>
<td>Setter*</td>
<td>99.3 (1)</td>
<td>48.9</td>
<td>52.4</td>
</tr>
<tr>
<td>Out-grower*</td>
<td>100.3 (1)</td>
<td>25.2</td>
<td>75.1</td>
</tr>
</tbody>
</table>

1 Numbers in parentheses denote the crop which produced the reference (peak) yield. These values should be determined and inserted in the table.
2 *Settler:* These are farmers who have been settled down in sugar projects for the purpose of growing sugarcane exclusively for the relevant mill areas.
3 *Out-grower:* These are independent farmers who grow sugarcane as well as other crops. The former receive inputs from the mills while the latter do not receive any inputs.
Results and discussion

The relationship between CROI and cumulative yield decline (CYD) in the square root form for the Sevanagala irrigated farms is shown in equation (5):

\[
\text{CROI} = 0.9424 - 0.0022\text{CYD} + 0.0400\text{CYD}^{0.5}
\]

\[R^2 = 0.95\] (5)

According to equation (5), CROI reaches its maximum when the yield decline is 100 t/ha (Table 1). Profitability decreases when the total yield decline of a ratoon crop is greater than this amount. Thus, in average farm situations (reference yield is 152.2 t/ha) ratoon crops yielding at least 52.2 t/ha are profitable. This corresponds to the expected yield of a fifth ratoon crop is greater than this amount. Thus, in an average rain-fed farm situation (reference yield is 152.2 t/ha) ratoon crops beyond a cane yield of 36.1 t/ha are profitable. Hence, in an average settler farm at Pelwatte, replanting should start when the cane yield drops to 20.7 t/ha or 30% of the reference yield (68.8 t/ha) (Table 1). Thus, at this yield level, 11 ratoon crops can be profitably raised in an average out-grower farm at Pelwatte.

For the settler farms at Hingurana, the relationship between CROI and CYD in cubic form is given in equation (9):

\[
\text{CROI} = 0.2723 - 0.0196\text{CYD} + 0.0015\text{CYD}_2 - 0.000018\text{CYD}_3
\]

\[R^2 = 0.99\] (9)

The maximum allowable yield decline for obtaining the highest return was 46.9 t/ha. Thus, replanting should start when the cane yield drops to 52.4 t/ha or 53% of the reference yield of 99.3 t/ha (Table 1). This yield level corresponds to the fifth ratoon crop.

Equation (10) gives the square root form of the relationship between CROI and CYD for the out-grower farms at Hingurana.

\[
\text{CROI} = 0.4859 - 0.0214\text{CYD} + 0.2145\text{CYD}_0.5
\]

\[R^2 = 0.98\] (10)

Under these conditions, a ratoon crop should not be maintained beyond a yield decline of 25.2 t/ha or when the ratoon crop yield reaches 75.1 t/ha or 75% of the reference yield of 100.3 t/ha (Table 1). Thus, the near-optimal replanting cycle occurred with fewer ratoons. The authors thank the Sevanagala, Hingurana and Pelwatte Sugar Companies and their cane growers for providing the necessary information.

REFERENCES


UNE METHODE DE DETERMINATION DU CYCLE OPTIMAL DE LA CANNE A SUCRE

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Résumé

Une méthode alternative basée sur la chute du rendement de la canne à sucre en repousse et celui au seuil de la rentabilité, est proposée pour déterminer le nombre optimal de repousses avant la replantation. Ainsi la relation entre les revenus net accumulés, les coûts cumulatifs et les chutes de rendements encourues, est établie en fonction d’un rendement référentiel. Le coefficient ainsi obtenu représente la relation fonctionnelle entre les revenus et les coûts qui permet de déterminer un déclin de rendement maximal acceptable équivalent à un revenu cumulatif optimal. Ainsi, une repousse ayant atteint le déclin maximal doit être replanté. La différence entre le rendement référentiel et le déclin maximal représente un rendement qui est au seuil de la rentabilité. Cette méthode a été appliquée sur les données pour la période 1990–91 à 1994–95 provenant plantations (var. Co 775) irriguées et non-irriguées des régions de Sevanagala, de Pelwatte et de Hingura du Sri Lanka. Les résultats ont indiqué que les champs non-irrigués des sucreries de Sevanagala et de Pelwatte devraient être replantés après la huitième repousse ou quand le rendement descendrait à 32 t ha⁻¹. Pour les planteurs de Pelwatte, le cycle de la canne pourrait être maintenu jusqu’à la onzième repousse, soit avec un rendement de 21 t ha⁻¹. Les champs irrigués des sucreries de Savanagala et de Hingura devraient être replantés après la cinquième repousse, soit à un rendement minimal de 52 t ha⁻¹. Les planteurs de Hingura auraient à replanter leurs champs après la quatrième repousse quand le rendement serait de 75 t ha⁻¹.

Mots clés: revenu cumulatif, repousse, rendement de référence, baisse de rendement.

DETERMINACIÓN DE LOS CICLOS ÓPTIMOS DE RENOVACIÓN

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Resumen

Se sugiere un método alternativo para determinar los ciclos óptimos de resiembra de la caña, el cual está basado en la disminución de la producción y el correspondiente punto de equilibrio por encima del cual, los retornos acumulados de las inversiones tienden a disminuir. La relación entre los retornos netos acumulados, los costos acumulados y la disminución en la producción en comparación con las producciones de referencia, son calculados para determinar sus relaciones funcionales. La reducción en producción que corresponde al mayor valor de retorno acumulado se encuentra utilizando estas relaciones. El valor correspondiente al punto de equilibrio se obtiene al deducir la reducción de producción de la producción de referencia. El cultivo debe ser renovado cuando la producción de caña es inferior a la producción de referencia. Este método fue utilizado con información comercial de los años 1990–1991 y 1994–1995 EN Sri Lanka. Los resultados muestran que en las zonas sin riego de Sevanagla y Pelwatte se debe renovar después de la octava soca o cuando la producción sea inferior a 32 t/ha. En la situación de los proveedores de Pelwatte los cultivos se deben renovar cuando la producción sea inferior a 21 t/ha, lo cual corresponde al ciclo de cinco socas que es equivalente a una producción de referencia de 52 t/ha. En la zona de proveedores de Hingurana, se encontró que la renovación se debe programar después de cuatro socas y cuando la producción sea inferior a 750 t/ha de caña.