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An Economic Analysis of the Commencement Time for Tapping Rubber by Smallholders in Imperata *Areas of Indonesia*

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A bioeconomic model for estate rubber is modified to apply to conditions facing Indonesian smallholders in low fertility Imperata *areas. The economic component of the model is updated using prices and costs prevailing in South Sumatra in 1995. The modifications to the model are briefly described, then used to analyse the decision of when tapping should commence. It is shown that smallholders who tap prior to recommended minimum tapping girths are acting logically. Early commencement of tapping is consistent with maximising economic returns over the life of the plantation, even though there is a sacrifice in terms of total rubber yield.*

Bioeconomic modelling is a powerful tool for analysing issues of this type, where the undertaking of long run biophysical experiments is prohibitively expensive.

Smallholder rubber production in many parts of Indonesia is characterised by poor growing conditions (low fertility soils and a high level of competition with weeds such as *Imperata*), and poor plant stock (genetic material). These poor growing conditions lead to low growth rates of trees planted by smallholders. The recommended rubber tree girth for tapping to commence is 45 cm[1] (under good growing conditions), but smallholders commonly commence tapping at girths around 40 cm, down to nearly 30 cm[2]. The preference for early tapping comes from the desire to obtain income as soon as possible. Due to their low income levels, smallholders are more likely than estates to have a preference for earlier tapping.

In this paper, an analysis is made of the economic trade-offs that are involved in the timing of the decision by smallholders to commence tapping. In undertaking this analysis, a modified version on the BEAM rubber agroforestry model is used. The designers of the BEAM model encouraged subsequent users to adapt and apply the model to particular situations of interest. This has been done with a focus on the smallholder rubber producing sector of Indonesia which is often characterised by low tree growth rates. The work reported is part of a broader ranging study on the prospects for tree growing in *Imperata* areas of Southeast Asia.

The BEAM Rubber Agroforestry Model

The BEAM rubber agroforestry model, RRYIELD[3], was developed by the University of Wales, Bangor. It is one of a series of bioeconomic agroforestry models[4]. The latex yield, timber and intercrop output can be determined for a number of bioclimatic, topographical and silvicultural regimes. The model was designed to represent conditions in rubber estates (*i.e.* it was not designed to represent smallholder conditions). The RRYIELD model is linked to an economic model RRECON[5], which determines the economic returns from the rubber plantation. These models are useful as extension tools — supplying farmers with information on the viability of rubber intercropping systems.

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The models can also provide information on the best combination of inputs for efficient use of resources such as labour and land. They are also useful for research — enabling 'experiments' to be conducted over both time and space. Such experiments would otherwise be prohibitively expensive.

The RRYIELD model was modified to represent smallholders in poor growing conditions (such as *Imperata* areas), and improve the model specifications. A summary of the modifications is given below. A full description of the modifications, and the reasoning behind them, is given in more detail elsewhere[6].

Modifications to the Model

The most pervasive variable within the model is tree girth. It provides a building block for many of the functions in the BEAM model. Girth features as a variable in equations for height, canopy width and wood volume (and also latex in the modified model).

Girth itself is a function of tree age, density and site conditions[4]. The function that relates these variables to girth is based on information from DeJonge[7] and Westgarth and Buttery[8] (referring to a *tapped* tree in an estate situation). Tree age and density provide the general shape of the function, while changing site conditions shift the girth function vertically[4].

Girth calculation. From the girth function, girth increment is calculated annually, then added to the previous year's girth. This allows *annual* changes in the parameters of the girth equation to be represented. (This was not possible in the original BEAM model).

Girth/tapping relationships. The girth at which tapping commences is a key element affecting the output of a rubber plantation. An assumption, underlying the girth equation in the original version of the BEAMR RYIELD model, is that tapping *will commence* at a girth of 45 cm (commonly recommended as the tapping commencement girth in estates).

The option to choose when tapping commences was added to the model. The approach taken in modifying the model was to subtract from, or add to, girth increment, according to whether tapping occurs before or after 45 cm. Tapping prior to 45 cm will reduce girth increment, compared to that determined in the original BEAM model. Tapping after 45 cm will increase girth increment compared to that determined in the original BEAM model.

The estimates of relative changes in girth increment, as a result of tapping, were derived from a study by Templeton[9]. For a small sample of RRIM 600 and RRIM 500 clones, Templeton calculated the girth increment of a tapped tree as a percentage of the girth increment of an untapped tree (58.7%). This is the only *direct* relationship between tapping and girth increment that was found in the literature.

However, support for the magnitude of this difference can be obtained by combining information from Simmonds[10] and Shorrocks *et al.*[11] Simmonds established, for tapped and untapped trees, the difference in annual dry shoot weight increment. Shorrocks *et al.* provided a relationship to translate this difference in annual dry shoot weight increment into a girth increment.

From Simmonds:

$$W = W_p\,(1\text{-}k) \qquad \dots 1$$

where: W = annual dry shoot weight increment in a tapped stand

W_p = annual dry shoot weight increment in an untapped stand

k = proportion of dry shoot weight increment partitioned towards latex

$1\text{-}k$ = dry shoot weight increment unrealised because some of the assimilates are partitioned towards latex.

Simmonds found the annual dry shoot weight increment of a tapped tree to be about half (*i.e.* $k = 0.49$) the annual dry shoot weight increment of an untapped tree.

In order to convert this difference in dry shoot weight increment to a difference in girth increment, the Shorrocks *et al.*[11] equation was used. Transposing this equation, such that girth is the dependent variable:

$$G = 8.51862\ W^{0.36} \quad \ldots 2$$

where: G = girth (cm)
W = dry shoot weight (kg).

By combining the above two relationships, the effect of tapping on tree girth was calculated. Annual girth increment was found to be reduced by 50% through tapping. This reduction approximates, and is thus supportive of the relationship found by Templeton, (*i.e.* the girth increment of a tapped tree is 58.7% the girth increment of an untapped tree). Thus the Templeton relationship was chosen for calculating changes in girth increment, as a result of commencing tapping at different times.

Inverting the Templeton relationship (*i.e.* 1/0.587 = 1.7), it is found that the girth increment of an untapped tree is 170% of the girth increment of a tapped tree. Thus for untapped trees the girth increment equation, in the modified BEAM model, is multiplied by 1.7. This is done every year that a tree is not tapped after reaching a girth of 45 cm.

Conversely, when a tree is tapped prior to reaching 45 cm, the reduction in girth increment (as a result of tapping) is 41.3% (*i.e.* 1 - 0.587 = 0.413) of the girth increment derived in the original BEAM model. This figure is subtracted from the girth increment in the original BEAM model for every year that a tree is tapped prior to reaching a girth of 45 cm.

These modifications to the model provide the option to choose tapping commencement time. Subsequently, the economic and biophysical consequences of various tapping commencement times can be assessed.

Latex Yield

The original BEAM latex yield equation has a constant factor of 2000. This is then converted into the latex yield per hectare *via* a series of indices. The key adjustment index is for planting material, altering the yield relative to the clone RRIM 600. The index for wildlings (trees from unselected seedlings used by smallholders) is expected to be significantly lower than the latex yield of trees used by estate farmers (such as RRIM 600). This conclusion is supported by Barlow and Murharminto[12], who suggest an average rubber yield of approximately 600 kg/ha/year for non-project smallholder producers in Indonesia. Thus, in calibrating the model to represent the smallholder situation, this index ('inadj' in the latex yield equation) was reduced to one third of the original value in BEAM.

Other factors which affect the latex yield include tree density, tree age and site condition. Changes in the density of the rubber plantation will effect both: the number of trees available to be tapped, thus the amount of latex collected, per hectare; and, the rubber yield per tree, due to the change in the level of competition between trees.

The age index reflects the relatively lower latex yields achieved in the early years of tapping. The site index reflects the effect of environmental factors on the growth rate of the tree and thus on latex yield. Full details are available in the original BEAM documentation[4].

The overall *shape* of the BEAM latex yield equation seems to accord with information from scientific literature and producer surveys. However, the equation did not explicitly represent yield as a function of girth and therefore cannot capture the effects of some important management practices. Many studies have shown that there is a strong relationship between latex yield and girth of rubber trees[1,13,14,15].

The BEAM latex yield equation was modified to directly include the *girth variable*. While maintaining the original shape of the latex yield function, a relationship between latex yield and *girth* was estimated. All other components of the latex yield equation remain the same. Thus, a variable expression (30 × girth, where girth is in cm) was substituted for the original constant value (2000). The new latex yield equation became:

$$\text{Latex Yield} = 30 * \text{girth} * \frac{\exp(\text{tapping year}/0.5)}{1 + \exp(\text{tapping year}/0.5)} * \frac{(\text{site index})}{100} * \text{inadj} * \frac{(\text{density})^{0.7}}{400} \quad \ldots 3$$

where: girth = tree girth in cm
tapping year = number of years since tapping commenced
site index = an index of the climate and soil characteristics and their impact on latex yield, for a given site
inadj = index of planting stock
density = number of trees per hectare.

Experiments with the Model

Using the modified model, described above, and in more detail elsewhere[6], a number of simulation experiments were performed. These involved changing tapping commencement girth (and by implication, the year that tapping commenced). The corresponding changes to the monetary present value of income streams were noted. In arriving at the present value figures, different discount rates were used. This enabled a test of sensitivity of the conclusions to these changes in discount rates. The planting density in all experiments was 400 trees/ha. A site index of 75 was used to represent an average site index for smallholders in *Imperata* areas of Indonesia. Cost and revenue factors, necessary to calculate economic returns in the model, were obtained from the Palembang region of South Sumatra in 1995.

RESULTS

Tree Girth at Tapping Commencement

The presentation of results begins with outputs from model runs, using a real discount rate of five percent (*Figure 1*). From an economic viewpoint, the optimal girth for commencement of tapping was found to be 35 cm,

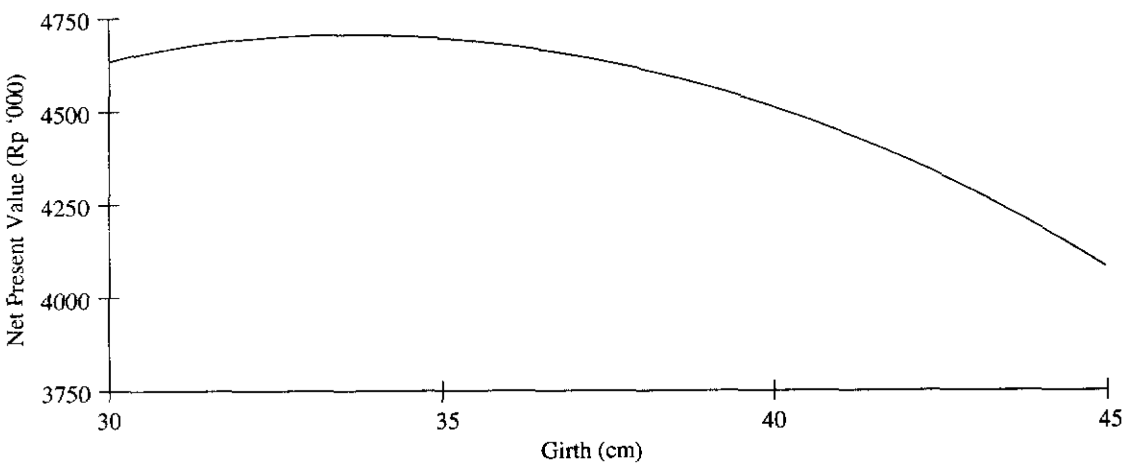

Figure 1. NPV from different tapping commencements (5% discount rate).

which for the smallholders under consideration here is equivalent to a tree age of 10 years. With commencement of tapping at 35 cm girth, total income (in present value terms) is maximised. If tapping commences at less than 35 cm, tree growth, and latex flows are reduced, outweighing the early returns from latex. Alternatively, if tapping commences after 35 cm, the faster tree growth, and increased latex yields, are insufficient to offset delays in the receipt of income.

The balance of revenue flows is influenced by the choice of discount rate. As discount rates increase, optimal tapping commencement is at lower girths. This is in line with the intuitive result — higher discount rates enhance the value of income flows in early years. The net effect of these forces on the girth at tapping commencement is shown in *Figure 2*.

The difference in economic returns between tapping commencement at a girth of 35 cm and other girths such as 30 cm and 40 cm (equivalent to years 8 and 13 respectively) is in the order of 5%, as shown in *Figure 1*. Although not shown here, the model results were consistent in this regard over a range of discount rates (*i.e.* the sensitivity of the present value of income streams to changes in the girth at tapping commencement is not great and is usually under 10%). Given this low sensitivity, short term demands for cash are likely to speed up commencement of tapping.

Economic *versus* Physical Optimum

Choosing the best girth for tapping commencement involves a trade-off between tree growth and commencement of income receipts. Maximum revenue (in present value terms) occurs when tapping commences at 35 cm, but maximum *latex yield* occurs when tapping commences at 45 cm. Faster tree growth, resulting from delayed tapping, will provide a greater total latex yield over the life of the tree. A comparison of the total latex yield from different girth at tapping commencement is presented in *Table 1*.

The sensitivity of total latex yield to different tapping commencement girths, is substantial, but the resulting net present values of income flows do not differ as much. For example, total latex yield increases 30% by allowing tree girth to increase from 30 cm to 45 cm prior to commencement of tapping. Thirty percent is well above the corresponding percentage change in net present value of income (*Figure 1*).

The difference between the total latex yield and its present monetary value is embodied in the discount factor applied to future income

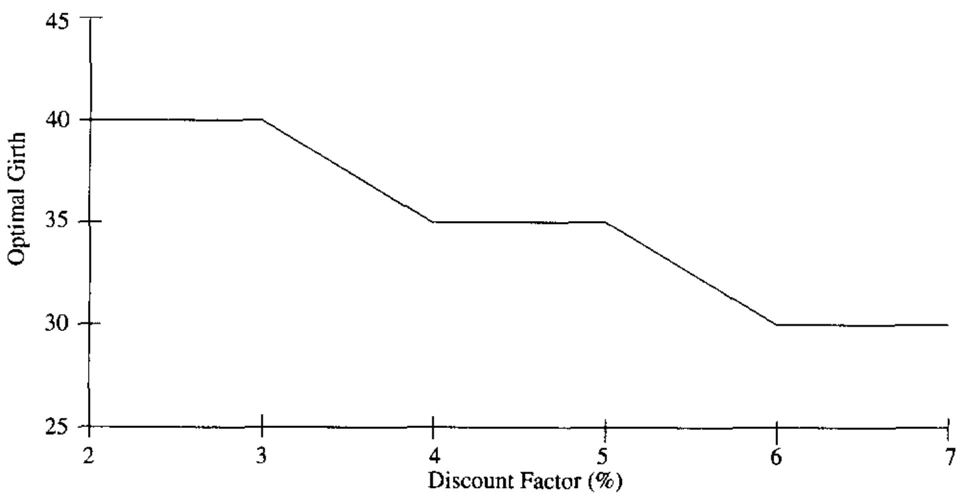

Figure 2. Optimal girth for tapping to commence (various discount rates).

TABLE 1 AGE, NPV AND LATEX YIELD FOR VARIOUS TAPPING COMMENCEMENTS

Age (years)	Girth of tree at tapping commencement (cm)	Latex yield over the life of the plantation ('000 ka/ha)	NPV (Rp '000 @ 5%)
8	30	10 2	4600
10	35	11 6	4700
13	40	12 9	4500
16	45	13 3	4100

streams In the case examined here, cash costs are assumed to be negligible Therefore present value is simply total latex yield multiplied by its per unit value, then discounted

CONCLUSION

For trees managed under a low intensity small holder regime commencement of rubber tapping at 45 cm girth gives the maximum latex yield over the life cycle of the plantation However advice to smallholders to delay tapping to 45 cm in order to increase total latex yields will be contrary to their economic interests Earlier tapping at 35 cm, gives a greater economic return in today's dollars and is consistent with the short term demands for cash flow typical of smallholders

Bioeconomic modelling is a powerful tool for analysing issues of this type, where the undertaking of long run biophysical experimentation is prohibitively expensive Indeed maintenance of appropriate treatment controls for an experiment of this type would be virtually impossible, irrespective of cost The BEAM rubber agroforestry model is a convenient and efficient tool for analysing relatively complex bioeconomic issues The modified BEAM model and documentation is available from the authors

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