# Optimum replacement period for rubber plantation in Nigeria

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## Abstract

The study aimed to derive the optimum replacement period for rubber plantation in Nigeria. The analysis was carried out with the data collected from 30 randomly selected rubber estate holders in Nigeria using the profit maximization concept. Results revealed that the optimum period to replace rubber plantation in Nigeria should be at the 35th year. However, the result of the study suggests that the actual replacement period of rubber plantation in Nigeria may vary since factors such as price changes in inputs and outputs, changes in discount rate and income tax and the management ability of the plantation owner can either shift the replacement period upward or downward. The policy conclusions follow that farmers will have to keep accurate records of the right nature for management purposes and that research on market development and price forecasting should be improved.

**Keywords:** amortization factor, discount rate, rubber plantation, replacement period, profit maximization
**JEL:** Q 110

## 1. Introduction

Rubber plantations mainly consist of only one species, *Hevea brasiliensis*, a variety of plants of the genus Hevea (Euphorbiaceae family), native to Brazil. Commonly known as the rubber tree, Hevea brasiliensis is a tall erect tree with a straight trunk and bark which is usually fairly smooth and grey in colour. The plant, growing up to over 40 meters (m) in the wild, characteristically does not exceed 25 m in height when it is under cultivation. Whereas by nature the rubber tree is a perennial (lasting for over 100 years) plant, it is usually replanted after 25-40 years in plantations, when latex yields tend to decrease to an uneconomic level.

Rubber is produced on 154,000 hectares of the agricultural land in Nigeria (UDOFIA, 2006). Some of the rubber plantations in Nigeria are more than 50 years old and some of these plantations have been abandoned by the holders. They are growing below the rate that yield studies suggest might be expected on comparable sites elsewhere. Their age, the large capital investment represented by growing-stock, and the presence of trash hardwoods that pre-empt growing space in some stands have raised questions about when the ageing stands should be replaced with a new rubber crop. This study is therefore designed to develop a replacement model for rubber plantation in Nigeria in order to know the optimum period to replacement.

Replacement problems are generally optimization problems, which involve cost minimization and profit maximization as the case may be. This study focused on profit maximization which involves maximizing the future stream of net revenues from an existing rubber plantation.

## 2. Methodology

### 2.1 Data source

Primary and secondary data were used in this study. The secondary data were collected from Rubber Research Institute of Nigeria (RRIN). Data from the primary source were obtained through field surveys' using a set of structured questionnaires administered to rubber estate holder's selected from Delta, Edo, Bayelsa, Abia, Cross River and Ogun States. A total of 30 rubber estate holders were interviewed.

### 2.2 Analytical techniques

The principle underlying the replacement model that is adopted for this study is given by OLAYEMI and ONYENWAKU (1999). Intuitively it requires knowing when the running / maintenance cost of the plantation becomes so high that the discounted total cost is higher than the cost of establishing a new plantation.

The principle involved with optimal replacement of any durable asset is the maximization of the present value of the stream of future cash margins, which may, if needed, is computed over an infinite time period. This could be done by comparing gains from series of different possible strategies. This would be an inefficient procedure, and this recourse is taken to marginal criterion which involves comparing gains from holding the asset for one more period with the opportunity gain that could be realized by replacing the asset immediately (OLAYEMI and ONYENWAKU, 1999; FARIS, 1960; PERRIN, 1972; FARIS, 1961; FARIS and REED, 1962; GROENEWALD and DUTOIT, 1985). In other words, will it pay better to keep a rubber plantation one more year, or should it be replaced immediately? Any replacement decision therefore compares the presently expected cash balance with the present value of the future stream of cash balances should an asset be replaced immediately (CHISHOLM and DILLON, 1971). A discount rate, roughly equivalent to the present rate of inflation (10%) was used to access the viability of the assets.

The model used is based on the following assumptions:

i The entrepreneur is rational and expectation of profitability is assumed.

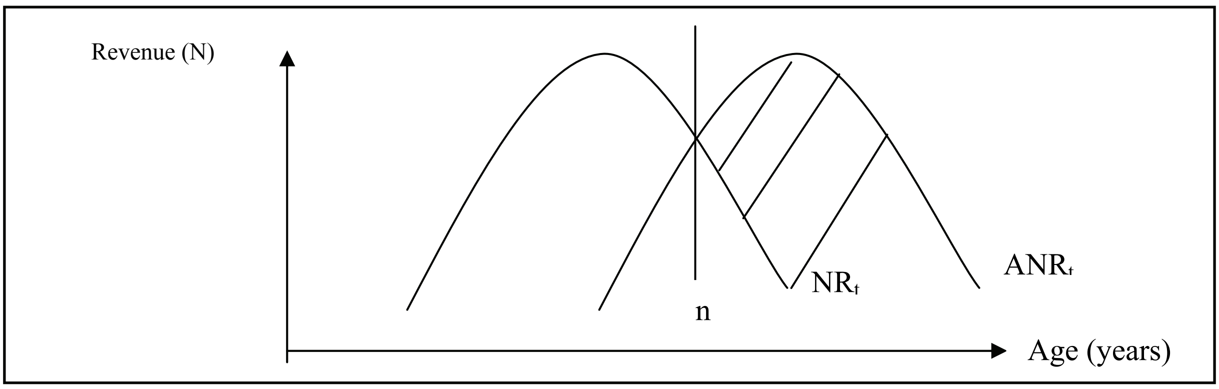
ii A rubber plantation when due for replacement could be replaced with identical variety or improved variety.

iii The rubber plantation is required for an indefinite number of future periods. This implies that the model is long–run net revenue maximization.

For cash crops enterprises which are capable of generating periodic incomes during their life spans, the optimum replacement period is given as the year when the highest amortized present value of Accumulated Net Revenue (ANR) from the incoming plantation just exceeds the anticipated Net Revenue (NR) from the existing plantation in the year following (year t + 1). Thus, as long as the anticipated net revenue in a following year t + 1 exceeds the amortized present value of Accumulated Net Revenue in year t (ANRt), it is profitable to continue with the enterprise. However, if the anticipated net revenue is less than the amortized present value of accumulated net revenue, long–run average net return would be maximized replacing the enterprise with a new but identical one.

Figure 1 shows the optimum replacement period 'n' for an enterprise with long production period and which is capable of generating income over a number of years.

**Figure 1. Optimum replacement period**




Source: OLAYEMI and ONYENKAWU (1999)

The penalty or opportunity cost of operating the existing enterprises beyond its optimum replacement period 'n' is the additional potential net revenue from a new one, which is forgone due to non – replacement. This penalty is represented by the shaded area in figure 1 and its magnitude increases with each additional year for which the existing enterprises is operated beyond the optimum replacement period ‘n’.

*The model*

$P_n$ = Accumulated present value of net revenue up to year n

$NR_t$= Annual Net Revenue in year t

N = optimum replacement period to be determined

C = Establishment Cost of plantation

Thus,

(1) $$P_n = \sum_{t=1}^{n} \frac{NR_t}{(1+r)^{t-1}}$$

$P_n$ for cost minimization is given as

(2) $$P_n = \sum_{t=1}^{n} \frac{R_t}{(1+r)^{t-1}}$$

But for profit maximization Pn is given in equation 1. This is because the cost has been taken care of in the calculation of net revenue.

(3) NR = TR – TC

Where,

NR = Net Revenue

TR = Total Revenue

TC = Total Cost

(4) But TC = EC + RC

Where, EC = Establishment Cost, RC= Maintenance/Running Cost

For planning purposes, it is clear that $P_n$ amount of money is required if the old rubber plantation is to be replaced with young rubber trees and if the new rubber trees used for replacement is to be maintained for another ‘n’ years. That is, $P_n$ takes care of establishment cost of a new plantation to replace the existing one in ‘n’ years and also takes care of Cost of running and maintaining the new plantation for another ‘n’ year. To ensure that we have $P_n$ amount of money at the end of the ‘n’ years (when we are ready to replant the rubber plantation), we should earn $NR_1$ in year 1, $NR_2$ in year 2 and so on until year ‘n’ when we would have earned $P_n$ amount of money. However, instead of earning these unequal amounts of money each year for ‘n’ years we can think of a fixed nominal amount of money (annuity) ‘a”, which if earned each year for n years, will be exactly equal in discounted value to $P_n$.

That is,

(5) $\sum_{t=1}^{n} a_t = a_1 + a_2 + a_3 + \ldots + a_n = P_n$

Where,

$$a_1 = a_1$$

$$a_2 = \frac{a_1}{1+r}$$

$$a_3 = \frac{a_1}{(1+r)^2}$$

$$a_n = \frac{a_1}{(1+r)^{n-1}}$$

If $V = \frac{1}{1+r}$

Then,

(6) $\sum_{t=1}^{n} a_t = a_1 + a_1 v + a_1 v^2 + a_1 v^3 + \ldots + a_1 v^{n-1} = P_n$

(7) $P_n = \sum_{t=1}^{n} \frac{a_1(1-v^n)}{1-v}$

(8) $a_1 = \frac{\sum_{t=1}^{n} a_t (1-v)}{(1-v^n)}$

$a_1$, is therefore the nominal amount of money which could be earned every year so that, given an annual discount rate ‘r’, the accumulated sum after ‘n’ years would just be enough to establish a new rubber plantation and run it for subsequent period of ‘n’ years.

Since

(9) $P_{n=} \sum_{t=1}^{n} a_t$ and $\sum_{t=1}^{n} a_t = \frac{a_1(1-v^n)}{1-v}$

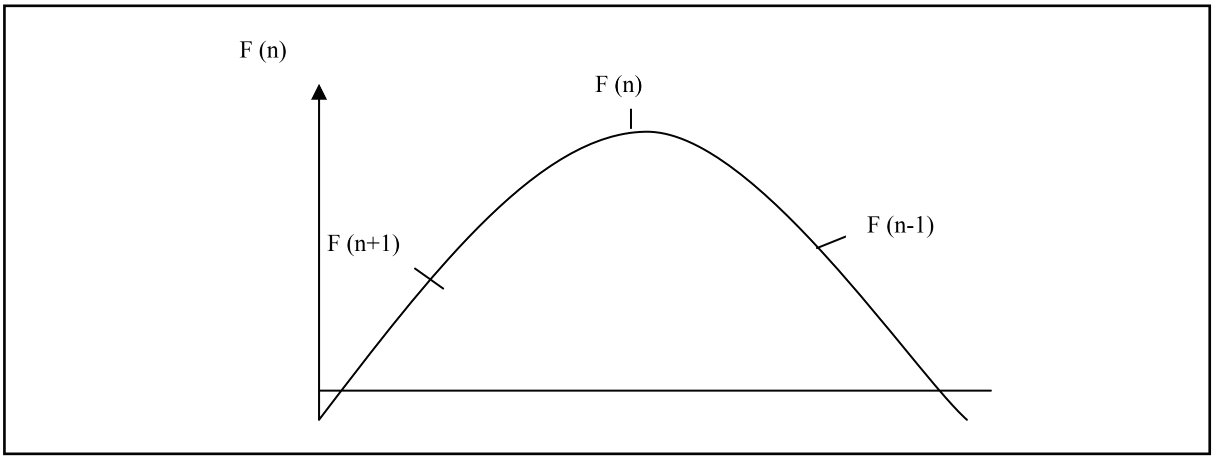
Therefore,

(10) $P_{n=} \frac{a_1(1-v^n)}{1-v}$

(11) $a_1 = \frac{P_n(1-v)}{(1-v^n)}$

This study is to obtain the maximum possible $a_1$, which can be earned annually such that its cumulated present value in 'n' years is equal to Pn. However, since 'n' is a discrete variable, the first order condition for a maximum is illustrated in figure 2.

**Figure 2. First-order condition for a maximum**




Source: OLAYEMI and ONYENKAWU (1999)

From figure 2, a new function is maximize as follow

(12) $F_n = \frac{P_n}{1-v^n}$

(13) $\Delta \boldsymbol{F_n} = \frac{P_{n+1}}{1-v^{n+1}} - \frac{P_n}{1-v^n}$

Which by expansion and re-arrangement

(14) $\Delta \boldsymbol{F_n} = \frac{P_{n+1} - P_n + V^{n+} P_n - V^n P_{n+1}}{(1-v^{n+1})(1-v^n)}$

But $P_n$= C + $NR_1$+ $VNR_2$+ $V^2NR_3$ + . . . +$V^{n-1}NR_n$

$P_{n+1}$= C + $NR_1$+ $VNR_2$+ $V^2NR_3$ + . . . +$V^{n-1}NR_n$+$V^nNR_{n+1}$

Therefore,

(15) $P_{n+1} - P_n = V^n NR_{n+1}$

Similarly,

$V^{n+1}\ P_n = V^{n+1}C + V^{n+1}NR_1 + V^{n+2}NR_2 + V^{n+3}NR_3 + \ldots + V^{2n}NR_n$ and

$V^nP_{n+1} = V^n\text{C} + V^nNR_1 + V^{n+1}NR_2 + V^{n+2}NR_3 + \ldots + V^{2n-1}NR_n + V^{2n}NR_{n+1}$

Therefore,

(16) $(V^{n+1}\,P_n - V^n P_{n+1}) = C(V^{n+1} - V^n) + (V^{n+1} - V^n)\sum V^{t-1}\,NR_t - V^{2n} NR_{n+1}$

Which by re-arrangement

$= [(V^{n+1} - V^n)\,(C + \sum_{t=1}^{n} V^{t-1}\,NR_t)] - V^{2n} NR_{n+1}$

(17) But $C + \sum_{t=1}^{n} V^{t-1}\,NR_t = P_n$

Therefore,

(18) $(V^{n+1}\,P_n - V^n P_{n+1}) = ((V^{n+1} - V^n)\,P_n - V^{2n} NR_{n+1}$

By substituting equations 15, 18 and re-arranging, we have:

(19) $\Delta \boldsymbol{F_n} = \frac{V^n NR_{n+1} + (V^{n+1} - V^n)P_n}{(1-v^{n+1})(1-V^n)} - V^{2n} NR_{n+1}$

Which by further simplification and re-arrangement gives

(20) $\Delta F_n = \frac{V^n}{1-v^{n+1}}\,(NR_{n+1} - \frac{1-V}{1-v^n}\,P_n)$

Referring back to condition in figure 2, we want

(21) $\Delta F_n = \frac{V^n}{1-v^{n+1}}\,(NR_{n+1} - \frac{1-V}{1-v^n}\,P_n) < 0$

Since V< 1, $\frac{V^n}{1-v^{n+1}}$ in equation 21 is always positive

(22) $\Delta F_n = NR_{n+1} - \frac{1-V}{1-v^n}\,P_n < 0$

(23) $\Delta F_n = NR_{n+1} < \frac{1-V}{1-v^n}\,P_n$

Or

(24) $\frac{1-V^n}{1-v}\,NR_{n+1} < P_n$

The optimum replacement period is therefore given at the year when the highest amortized present value of accumulated net revenue from the incoming plantation just exceeds the anticipated net revenue from the existing plantation in the year following (year t+1). That is we replace when

$P_n \frac{1-V}{1-v^n} > NR_{n+1}$ Or $P_n > NR_{n+1} \frac{1-V^n}{1-v}$

Where $\frac{1-V}{1-v^n}$ = the amortization factor

$NR_{n+1}$= anticipated net revenue in year (n+1)

$P_n$ and n are previously defined.

## 3. Result and discussion

This study discovered that the cost of land acquisition, perimeter and soil survey and the provision of irrigation water was ₦254, 000 as shown in table 1. Land preparation and planting cost at a wage rate of ₦500 per man day was ₦22, 000 (table 2). Material Component Cost for Land preparation and planting was ₦88, 436 as shown in table 3, while data in table 4 showed that the immature rubber maintenance cost was ₦157, 178 per year.

**Table 1. Land acquisition, survey and irrigation for 1 hectare of land**

| **Details** | **Cost (₦)** |
|---|---|
| Land acquisition | 100,000 |
| Perimeter survey | 2,000 |
| Soil survey | 2,000 |
| Water source for irrigation | 150,000 |
| **Total** | **254,000** |

Source: field survey (2008)

**Table 2. Land preparation and planting cost at N500 per man day per hectare**

| **Field operation** | **Man days** | **Cost (₦)** |
|---|---|---|
| Clearing and filling | 10 | 5,000 |
| Burning, packing and re-burning | 6 | 3,000 |
| Marking out and pegging | 4 | 2,000 |
| Holing | 4 | 2,000 |
| Carrying of seedlings to the field | 3 | 1,500 |
| Planting | 5 | 2,500 |
| Watering | 5 | 2,500 |
| Mulching | 4 | 2,000 |
| Miscellaneous | 3 | 1,500 |
| **Total** | **44** | **22,000** |

Source: field survey (2008)

**Table 3. Material component costs for land preparation and planting per hectare**

| Material components | Unit cost | Quantity | Cost (₦) |
|---|---|---|---|
| Budded stump | 70 | 450 | 31,500 |
| Supplying vacancies (5%) | 70 | 23 | 1,610 |
| Fertilizer (in 50kg bags) | 2,700 | 3 | 8,100 |
| Matchet | 400 | 2 | 800 |
| Hoe | 300 | 2 | 600 |
| Spade | 600 | 1 | 600 |
| Wheel barrow | 7,000 | 2 | 14,000 |
| Transportation cost of seedling (depending on distance) | | | 23,650 |
| Termicide (5kg at 1,000/kg) | 50 | 473 | 5,000 |
| Sub total | 1,000 | 5 | 85,860 |
| 3% contingencies | | | 2,576 |
| **Total** | | | **88,436** |

Source: field survey (2008)

**Table 4. Maintenance of immature rubber trees at ₦500 per man day per hectare**

| Field operation/materials | Man days | Cost (₦) |
|---|---|---|
| Ring and inter-row weeding | 20 | 10,000 |
| Supplying vacancies | 2 | 1,000 |
| Pruning | 1 | 500 |
| Fertilizer application | 4 | 2,000 |
| Watering 2 men/day for 120 days | 240 | 120,000 |
| Pesticide application | 2 | 1,000 |
| Fertilizer (3x50kg) | | 8,100 |
| Termicide (furadan at N1000 per kg) | | 10,000 |
| Sub total | | 152,600 |
| 3% contingencies | | 4,578 |
| **Total** | | **157,178** |

Source: field survey (2008)

The rubber tree is considered tappable when the plantation is between 5 and 7 years old depending on the planting material used. For this study, 7 years is considered as the tappable age. The mature rubber plantation maintenance / running costs with the materials required is shown in table 5. This was found to be ₦348, 243 annually. Cost items like project vehicles, equipments, project building and extensive staff salaries were not included in this report because one hectare of rubber plantation does not required these cost items and as such are treated as fixed (constant) costs, which according to FARIS (1960) could be deleted from the cost calculations without changing the solution for the optimum replacement pattern. Operators with different fixed cost would have the same optimum replacement pattern when fixed costs are deleted provided other inputs and output profiles are the same (FARIS, 1960; CHISHOLM, 1966). A supervision cost of ₦300, 000 was built in as part of maintenance cost. The total cost for the enterprise is assumed to increase by ₦100, 000 for every 5 years, with effect from the $10^{th}$ year in order to meet additional costs.

**Table 5. Maintenance of mature rubber plantation (7 years and above) at N500/man day/hectare/year**

| **Field operation/materials** | **Man days** | **Cost (₦)** |
|---|---|---|
| Ring and inter-row weeding | 10 | 5,000 |
| Fertilizer application | 2 | 1,000 |
| Fertilizer in 50kg (4 bags at N 2700/bag) | | 10,800 |
| Pruning | 4 | 2,00 |
| Pest control | 2 | 1,000 |
| 6 tapping knives at N1300 each | | 7,800 |
| 3 bundles of cup hanger at N3000/bundle | | 9,000 |
| 500 unit of spouts at N3/unit | | 1,500 |
| Supervision cost | | 300,000 |
| Sub total | | 338,100 |
| 3% contingencies | | 10,143 |
| **Total** | | **348,243** |

Source: field survey (2008)

The actual yield and marketed quantities were computed from field data. Findings revealed that the farm gate price of rubber latex is ₦160 per litre. Table 6 shows the optimum replacement period for rubber plantation in Nigeria. The optimum period to replace the existing rubber trees with new ones is at the $35^{th}$ year when the conditions $P_n \frac{1-V}{1-v^t} > NR_{t+1}$ is satisfied.

**Table 6. Profit maximization replacement model for rubber plantation in Nigeria**

| Age | Latex yield (litre) | NR | $v^t$ | $P_n$ | $(1-v)/(1-v^t)$ | $P_n(1-v)/(1-v^t)$ | $NR_{t-1}$ |
|---|---|---|---|---|---|---|---|
| 1 | - | (521,614) | 0.9091 | (521,614) | 1.0000 | (521,614) | (157,178) |
| 2 | - | (157,178) | 0.8264 | (664,505) | 0.5236 | (347,935) | (157,178) |
| 3 | - | (157,178) | 0.7513 | (794,397) | 0.3655 | (290,352) | (157,178) |
| 4 | - | (157,178) | 0.6830 | (912.485) | 0.2868 | (261,701) | (157,178) |
| 5 | - | (157,178) | 0.6209 | (1,019,838) | 0.2398 | (244,556) | (157,178) |
| 6 | - | (157,178) | 0.5645 | (1,117,430) | 0.2087 | (233,208) | 803,757 |
| 7 | 7,200 | 803,757 | 0.5132 | (663,709) | 0.1867 | (123,914) | 803,757 |
| 8 | 7,500 | 803,757 | 0.4665 | (226,587) | 0.1704 | (38,610) | 931,757 |
| 9 | 8,000 | 931,757 | 0.4241 | 208,078 | 0.1578 | 31,888 | 1,571,757 |
| 10 | 12,000 | 1,571,757 | 0.3855 | 874,660 | 0.1479 | 129,362 | 1,631,757 |
| 11 | 13,000 | 1,631,757 | 0.3505 | 1,503,702 | 0.1400 | 210,518 | 1,711,757 |
| 12 | 13,500 | 1,711,757 | 0.3186 | 2,103,679 | 0.1334 | 280,631 | 1,791,757 |
| 13 | 14,000 | 1,791,757 | 0.2897 | 2,674,533 | 0.1280 | 342,340 | 1,871,757 |
| 14 | 14,500 | 1,871,757 | 0.2633 | 3,216,781 | 0.1234 | 396,951 | 1,951,757 |
| 15 | 15,000 | 1,951,757 | 0.2394 | 3,730,679 | 0.1195 | 445,816 | 2,011,757 |
| 16 | 16,000 | 2,011,757 | 0.2176 | 4,212,294 | 0.1162 | 489,469 | 2,171,757 |
| 17 | 17,000 | 2,171,757 | 0.1978 | 4,684,863 | 0.1133 | 530,795 | 2,331,757 |
| 18 | 18,000 | 2,331,757 | 0.1779 | 5,146,085 | 0.1108 | 570,186 | 2,331,757 |
| 19 | 18,000 | 2,331,757 | 0.1635 | 5,565,568 | 0.1087 | 604,977 | 2,331,757 |
| 20 | 18,000 | 2,331,757 | 0.1468 | 5,946,810 | 0.1068 | 616,090 | 2,231,757 |
| 21 | 18,000 | 2,231,757 | 0.1351 | 6,278,449 | 0.1051 | 642,285 | 2,231,757 |
| 22 | 18,000 | 2,231,757 | 0.1228 | 6,579,959 | 0.1036 | 681,684 | 2,231,757 |
| 23 | 18,000 | 2,231,757 | 0.1117 | 6,854,019 | 0.1023 | 701,166 | 2,071,757 |
| 24 | 17,000 | 2,071,757 | 0.1015 | 7,085,434 | 0.1012 | 717,046 | 1,911,757 |
| 25 | 16,000 | 1,911,757 | 0.0923 | 7,279,477 | 0.1001 | 728,676 | 1,651,757 |
| 26 | 15,000 | 1,651,757 | 0.0839 | 7,431,934 | 0.0992 | 737,248 | 1,331,757 |
| 27 | 13,000 | 1,331,757 | 0.0763 | 7,543,668 | 0.0984 | 742,297 | 1,331,757 |
| 28 | 13,000 | 1,331,757 | 0.0639 | 7,645,281 | 0.0977 | 746,944 | 1,331,757 |
| 29 | 13,000 | 1,331,757 | 0.0630 | 7,737,572 | 0.0970 | 750,544 | 1,331,757 |
| 30 | 13,000 | 1,331,757 | 0.0573 | 7,821,473 | 0.0964 | 753,990 | 1,071,757 |
| 31 | 12,000 | 1,071,757 | 0.0521 | 7,882,885 | 0.0959 | 755,969 | 1,071,757 |
| 32 | 12,000 | 1,071,757 | 0.0474 | 7,938,724 | 0.0954 | 757,354 | 911,757 |
| 33 | 11,000 | 911,757 | 0.0431 | 7,986,109 | 0.0950 | 758,680 | 831,757 |
| 34 | 10,500 | 831,757 | 0.0391 | 8,021,958 | 0.0946 | 758,877 | 831,757 |
| **35** | **10,500** | **831,757** | **0.0356** | **8,054,480** | **0.0943** | **759,537** | **651,757** |
| 36 | 10,500 | 651,757 | 0.0323 | 8,077,683 | 0.0939 | 758,494 | |

Source: field survey (2008)

However, there are other factors that could affect this optimum replacement period. These factors are as follows.

*a. Price changes*

Prices of products as well as inputs change over time. Increases in product prices relative to price of inputs have the effect of shifting upwards the annual net income from present trees and the amortized discounted future income of replacement trees. If prices of inputs rise relative to those of products, both annual net income from the present trees and the amortized discounted future income of replacement trees shift downward (GROENEWALD and DUTOIT, 1985). The effect on optimum replacement age is rather slight (FARIS and REED, 1962).

*b. Discount rates*

Higher discount rates have the effect of decreasing present value of future incomes but increasing annuities from an income stream. The effect on present values is the larger of the two, with the result that a net decrease in amortized value of future earnings is associated with an increase in the discount rate. According to GROENEWALD and DUTOIT (1985), appropriate discount rate are influence by the following considerations:
**Inflation:** The higher the rate of inflation, the higher should be the discount rate used, and the lower will be amortized present values of future earnings. Consequently, replacement should normally be postponed during time of accelerating inflation. They may be speeded up as inflation rates decline.
**The grower's financial situation:** The optimal replacement pattern can vary considerably according to the solvency and liquidity positions of growers. A farmer with a low level of liquid assets may have to borrow money to finance replacement. In this case, the loan rate in excess of 20%, rather than the inflation rate of 10%, will be the appropriate discount factor. The result will be replacement at a later age. In addition, if the farmer has a high degree of indebtedness, he may be in a situation of having to pay a higher rate of interest on borrowed funds. This will once again lead to a higher optimum replacement age.

*c. Income tax rates*

If income tax rates are expected to increase over time, future earning of replacement trees will decline relative to present earnings of existing trees. Therefore, if income tax rates are expected to increase over time, replacement should be postponed. Earlier replacement will be appropriate should tax rates be expected to decline over the long run.

## 4. Conclusion and recommendation

The study has shown that many factors obviously determine optimum replacement period of rubber plantation in Nigeria. It is, therefore, rather obvious that no clear prescription exists. It is rather the job of the plantation manager to apply the tools presented by the model in this study to the vexing problem of rubber plantation replacement. Any "rule of thumb" procedure is likely to be very costly as farms vary in terms of yield potential, costs, financial position, asset structure, plantation composition and managerial ability. The policy conclusions follow that farmers will have to keep accurate records of the right nature for management purposes. Research on market development and price forecasting should be improved. Finally, extension efforts should be directed towards raising the annual net returns of farmers.

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