Cocunut Palm Replacement Model for Tanzanian Farming Systems

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Abstract

The major contributing factor to low and constantly declining productivity of coconut palm worlwide is senility. Over 75% of coconuts in Tanzania are more than 45 years old, and amongst these there are many above 60 years. This affects productivity negatively. It is possible to improve yield from coconut palm field by applying an appropriate replacement strategy. This paper presents results of a mathematical model aimed at determining the appropriate replacement time for coconut palms in coastal Tanzania. Data was collected from Tanga, Coast and Dar-es-Salaam Regions. A total of 592 palms were assessed and their yield estimated. Linear regression equations suggest a production pattern where there is a slow yield pick-up in the early ages (10 - 20 years), it increases at a fast rate in the intermediate age (20 - 40 years) and production declines beyond 50 years. Palms have highest yields at 42 and 38 years in Coast/Dar es Salaam and Tanga Regions respectively. A dynamic programming model indicates that the optimal replacement age is 66 years. Up to this plant age, the farmer is guaranteed some profit if he/she adheres to recommended palm stands husbandry practices.

1. Introduction

The total coconut palm (*Cocos nucifera*) population in Tanzania is about 22.6 million trees, growing on 240,000 hectares. Presently, a bigger proportion, i.e. about 95 percent of coconut acreage is grown by smallholder farmers. Plantations are estimated to cover only 3,500 hectares. The total area with potential for coconut production is estimated to be between 500,000 and 550,000 hectares (Vettickat, 1992). The importance of the crop in the agricultural sector and the national economy as a whole is based on its role as a cash crop to farmers and a source of edible oil to both the rural and urban population in the country. On a longer term perspective, coconut has a potential of earning foreign exchange through the export of copra, oil and other by-products.

Coconut tree plots play an important role in the farming systems along the coastal belt of Tanzania where about 70% of coconut is intercropped with food crops. On average, a farmer in the coconut growing area maintains about 225 palm trees.

In Dar-es-Salaam and Coast Regions farming land is still available and a large percentage of coconut is in the young age group, whereas in Tanga Region there is a low percentage of coconuts in the young age group. Replanting of coconuts is inevitable and a common practice by most coconut growers, however, small-scale coconut farmers do not normally cut down their old, non-bearing palms. Whenever it is done, replanting of aged coconut fields by small farmers is non-systematic and is done at any growth stage of the coconut palm regardless of whether the yield is economical or not. This situation leads to low productivity, stagnating output and is thus threatening the development of the coconut industry.

This paper presents preliminary findings of a coconut replacement model that aims at determining the right time for coconut replacement. Replacement of old coconut trees at the right time will ensure a stable level of coconut productivity and also enable farmers to raise their incomes.

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The analysis is governed by an understanding that with the present farmer's resource endowment, an optimal replacement age for coconut palms can help to ensure that farms longer higher productivity term.

2. Literature Review

One of the factors contributing to low income in coconut production systems is the declining productivity of coconut trees due to senility (Arancon, 1988). Other factors identified are unstable prices of coconut products, non adoption of recommended coconut husbandry practices, ineffective or weak support services and poor credit facilities (Mwinjaka *et al*, 1994, Aguilar and Benard, 1991). About 75% of coconuts in Tanzania are over 45 years old of which a significant number are above 60 years. In a number of other countries the picture is not different. In Fiji it is estimated that over 40% of palms are over 50 years of age and give very low yields (Manciot and Sivan, 1991). In the Southern Islands of Fiji, 70% of the coconut in large plantations are old whereas 90% of trees in the smallholder sector are over 40 years old (Ilalla, 1989). In western Samoa more than 50% of the coconut plantations are over 40 years of age (Opio, 1989), and in the Pacific over 60% of the palms are more than 50 years of age. According to Berges *et al* (1993), 62% of coconut palms in Vanuatu are more than 50 years old while in Indonesia 4.2% of coconut trees in Java are over 50 years of age (Amrizal, 1988).

The effect of senile palms in the coconut industry in Tanzania is not different from other countries. Bad crop husbandry practices and failure to adhere to optimal replanting strategies leads to a non optimal production, both in terms of quantity and quality. This, in turn, leads to an un-competitive production system and stagnating output and income for the whole sub-sector. It has been recorded that productivity and net economic returns of a coconut farm declines significantly with age, if trees are not optimally replaced.

Coconut production especially declines at the age between 30 and 50 years. Coconuts commence full production at the age of 10 to16 years and go on producing at an increasing rate up to between 30 and 40 years. Over 40 years, coconut production starts to decline (Nelliat *et. al.* 1974). The useful bearing life of tall varieties is estimated at around the age of 60 years. In Samoa, Opio (1987) suggested that the yields of field having mature local tall varieties are not economically viable beyond 40 years, unless they are intercropped with other cash crops.

Different countries have adopted different strategies to combat the palm's ageing problem, however only a few models have been developed to aid the decision-making process. Furthermore available models are mainly for crop production practices rather than for farm enterprise management. There are, however, published accounts that bear systems simulation models that could address the management problem. A good example is a dynamic programming model for wheat as reported by Burt and Allison (1963). In the Phillipines, a major replanting programme was initiated in 1990 with the objective of reviving the coconut industry because 15% of the palms were by then senile (Magat, 1993). It was by then observed that unless replanting measures were promptly taken, there would have been a 2% decline per annum in coconut production due to senility.

A coconut farmer normally aims at maximizing his total returns from the farm enterprise over the years. Thus, it is necessary for the farmer to determine the optimal replacement time of old coconut palms in order to win both economies of scale and time. In essence, therefore, a replacement model for coconut will ensure the long-term viability of the coconut industry.

3. Methodology

A survey was carried out in Tanga, Coast and Dar-es-Salaam Regions. Coconut fields were visited and nut yields were assessed. On each farm a block of 15 palms appealing to be a representative of the plot were chosen to be subjects for data collection. The number of nuts per tree was counted. The counting of nuts was done from an oldest bunch (+1) to bunch six (+6). In total, 592 palms of different age categories i.e. 1-90 years old were assessed to estimate their yield. Additional information was collected regarding crop husbandry practices, type of vegetation in the farms left with bushes, labour inputs and prices o f other inputs and outputs. This information was necessary for determining whether and to what extent management practices (of the palm stands) affect yield. The data were then substituted in equations 1.1. to 1.5. The chosen dynamic programming model is based on Bellman's principle of optimality[6]and structure following as presented by

Burt and Allison (1963). Mathematically the method can be expressed as follows;

$$Fn(i) = \text{Max } k[\, Ri^{k} + b\Sigma m\ j{=}1\ \ Pij^{k}\ Fn - (j) \qquad 1.1$$

where;

Fn(i)=The discounted expected return from an n-stage decision process under an optimal policy, given a production level "i".

k =The decision variable, such that when k= R it indicates a point where a decision to replant or replace ought to be made, and k=M indicates where a decision to maintain the existing palms should be made.

Ri^k =The expected immediate returns under decision "k" given a production level "i". Under the decision to Replant or Replace (i.e. k=R), the returns are the negative of maintaing costs, and are the same regardless of the production level.

b =a discount factor which is the reciprocal of one plus the relevant interest rate.

Pij^k =Probability of moving from the'i'th to the'j'th state under decision "k".

The expected net returns over years were assessed for different coconut based production systems. The total returns were calculated using the following equation:

$$R(t) = \Sigma P_i * Y_i(t) \qquad 1.2$$

Where:

P_i and $Y_i(t)$ represent price and output from enterprise 'i' at time 't'.

The attendant total costs were calculated by the following equation:

$$C(t) = \Sigma\ W_j * X_j(t) \qquad 1.3$$

Where W_j and X_j (t) are input j's price and quantity at time 't'.

The estimated net returns over years were calculated as follows:

$$\pi(t) = R(t) - C(t) \qquad 1.4$$

$$\pi(t) = \Sigma[P_i * Y_i(t)] - \Sigma[Wj * Xj(t)] \qquad 1.5$$

4. Results and Discussion

4.1 Management practices

The most common husbandry practice in the coastal belt coconuts farming systems is intercropping, where 86.4% of the visited plots were intercropped with annuals or perennials. Slashing, which is not a common practice in the study area, is normally done when the palms are old, and very few farmers (4.9%) reported to be doing so. Overall more plots in Dar-es-salaam and Coast Regions have been left in the bush (not weeded) as compared to Tanga. This might be so because land is becoming more scarce in Tanga hence calling for better management, where as in Dar-es-salaam and Coast Regions land is currently less limiting. The most common intercrops are cassava, maize, citrus, mangoes, bananas and pineapples. The biological control of *P. wayi* (a pest) by *O. longinoda* commonly called "majimoto" (a natural predator) is a common practice in the surveyed plots.

4.2 Coconut palm distribution and yields

About 55% of the palms are at the age between 21 and 60 years, while 39% are between 1 and 30 years and 6% are between 61 and 80 years. Palm age distribution in the study areas is presented in Figure 1 Coconut yields vary significantly across age groups. Rainfall levels and patterns also contribute to yield levels and this was taken note of in the study area. Dar-es-Salaam, Coast and Tanga Regions have a bimodal pattern of rainfall, with the long rains (masika) falling from March to May and short rains (vuli) from November to December. The total annual rainfall is between 800 - 1200 mm. Soils are coarse and sandy in Dar-es-Salaam/Coast and are red sandy loam with moderate organic matter in Tanga. When coconuts are young i.e. from 10 to 20 years old, nut production in Dar-es-Salaam and Coast is higher than in Tanga, but the overall average palm yield across age in Tanga is higher. The coconut production pattern is such that palms start to bear nuts slowly in the early years (10 to 20). The production then increases at a fast rate in the intermediate age (20 to 40 years), and ultimately it declines towards the end of the life cycle, i.e. over 50 years, see Figures 2 a & b and 3a & b.

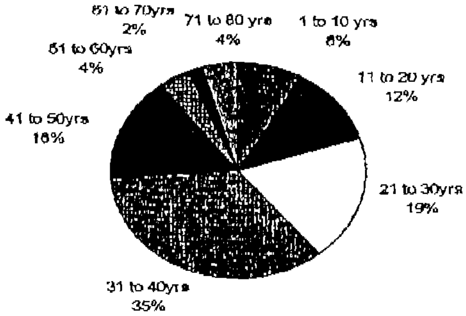

Figure 1: Palm age distribution in Tanga, Coast and Dar es salaam Regions Source: Survey 1997

The coconut production curve for Tanga, Coast and Dar-es-Salaam presents a nonlinear relationship. Shapes of the curves are described by polygons of the following equation: $Y=\beta_o + \beta 1x + \beta 2x^2$, Where Y is the dependent variable (Coconut yield), and X is the independent variable (cocon age). $\beta 1$ and $\beta 2$ are coefficients while β_o is the intercept. The R^2 indicates how much of the yiel variation is explained by the explanatory variables in the function. The regression equation for cocon production in Tanga, Coast and Dar-es-Salaam are presented graphically in Figures 2b and 3b, who quations are as follows:

$Y= -0.0369x^2 + 3.0619x - 15.929$ (R2=78.25%) Tanga

$Y= -0.0188x^2 + 1.422x + 8.1964$ (R2=76.25%) Coast and DSM

which can be optimimized as indicated below;

$Y= -0.0369x^2 + 3.0619x - 15.929$ (R2=78.25%) Tanga

$\partial y/\partial x = - 0.0738x + 3.0619$

$x = 3.0619/0.0738$

$x = 41.48 \cong 42$

X = 42 years and,

$Y= -0.0188x^2 + 1.422x + 8.1964$ (R2=76.25%) Coast and DSM

$\partial y/\partial x = - 0.0376x + 1.422$

$x = 1.422/0.0376$

$x = 37.8 \cong 38$

X = 38 years

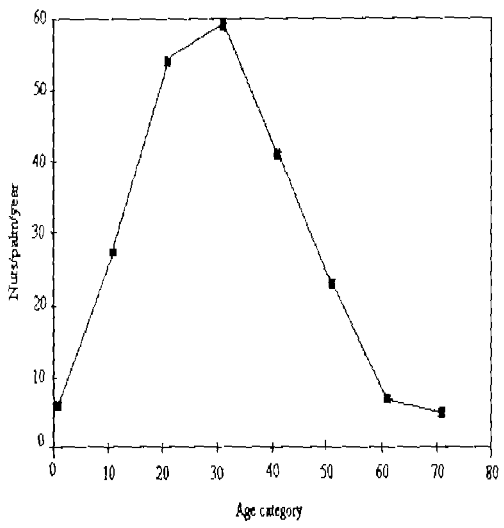

Figure 2a: Production of coconut with age in Tanga. Source: Survey 1997

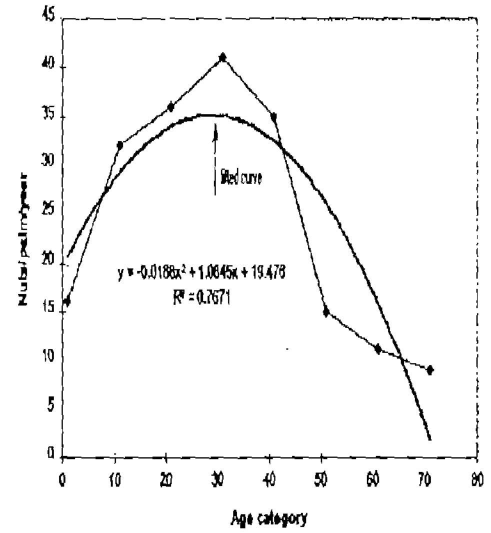

Figure 2b: Production of coconut with age in Tanga. Source: Survey 1997

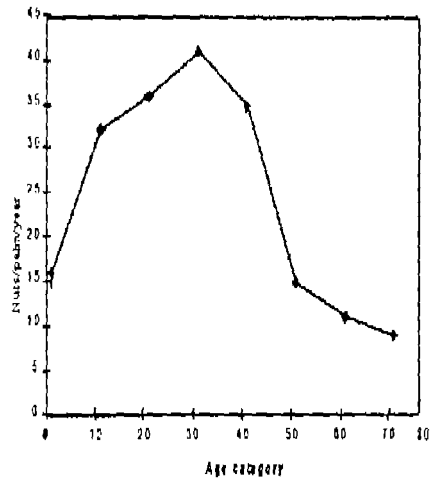

Figure 3a: Production of coconuts with age in DSM and Coast. Source: Survey 1997

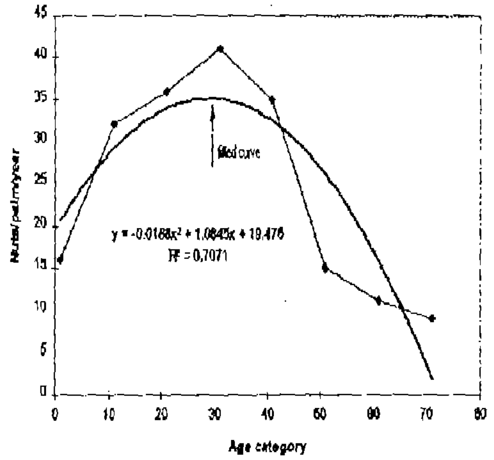

Figure 3b: Production of coconuts with age in DSM and coast

By setting the first derivative to zero, it is revealed that the optimum age for coconut production is about 42 years in Tanga Region and 38 years in Coast and Dar-es-salaam Regions. When the entire population is considered, the optimum age for coconut production is 40 years. From Figures 2b and 3b,

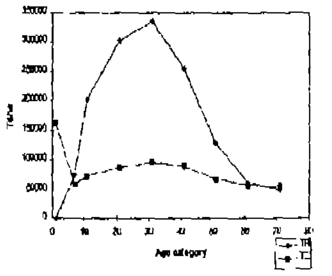

Figure 4a: Total revenue and total cost curve for coconut production in Tanga, Dar es salaam and Coast. Source: Survey 1997

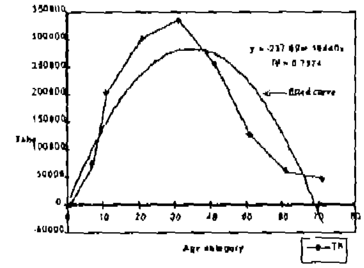

Figure 4b: Total revenue curve for coconut production in Tanga, Dar es salaam and Coast. Source: Survey 1997

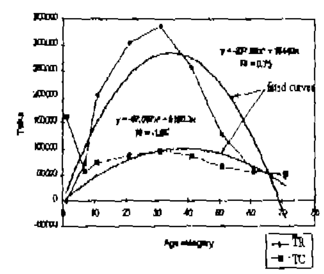

Figure 4c: Total revenue and total cost curves for coconut production in Tanga, Dar es salaam and Coast. Source: Survey 1997

the significant R^2 value, and the quadratic response fitted show that the model and the data present the function reasonably well. In our case, the peak production of coconuts in Tanga, Dar-es-salaam and Coast Regions is at the age of between 30 and 40 years, beyond which yields start to decline. The decline becomes more pronounced at the age of 50 years (Table 1, Figure 2b and 3b). So the remaining key question becomes: which is the best replacement age?.

Table: 1 Coconuts Yields in the Study Areas.

Age	DSM and Coast (nuts/palm/year)	Tanga (nuts/palm/year)	Average yield for entire population (nuts/palm/year)
1-10	16	6	11
11-20	32	27	30
21-30	36	54	45
31-40	41	59	50
41-50	35	41	38
51-60	15	23	19
61-70	11	7	9
71-80	9	5	7

Source: Survey 1997

5. Multi Period Analysis of Coconuts (84 Palms/ha)

Information collected on input and output data is here deployed to determine the appropriate replacement age for coconut palms. All inputs and outputs were valued at the prevailing market prices and the economic performance of a coconut plantation was computed and analysed. The time period for analysis is 80 years. Cash flow and gross margin analyses were undertaken to assess whether it is lucrative to invest in coconut farms and hence whether there is an incentive for the farmers to invest in the sub-sector. Gross margins differ significantly throughout the life span of the coconut palm. They are negative in the first 10 years, basically during the establishment period. During this formative stage, the most costly items are labour and seedlings. After establishment, labour requirement is reduced significantly. In cases where coconuts are intercropped with annual crops, then coconuts hardly require any additional labour. In the case of monocropping, the plots are slashed twice per year. Labour requirement increases again when palms reach the bearing stage. Gross margins are constantly increasing up to the age of 40 years. Gross margins remain relatively stable when palms are at the age between 20 and 50 years. From 50 years and beyond, gross margins fall significantly. At 70 year, gross margins are negative. Market prices are used to cost inputs such as seedlings and also outputs. Valuation of labour is difficult because a large component of itis from family labour, which is difficult to quantify with accuracy. Labour markets are also imperfect and off- farm work at a fixed rate is hardly available. Furthermore, it is difficult to calculate the opportunity cost for labour, since most of the important work can be carried out in seasons of low labour demand. In situations where a farmer hires labour, payment is made for piece-work or rated for a certain specific task and not on a per day basis. All these factors were considered and an estimated daily rate of Tshs1200 was adopted. The total cost of all required tools is estimated at Tshs 7,500, with a depreciation rate of 20% per year, where items are replaced after every 5 years.

A backward method dynamic programming was used here to determine the replanting time for a coconut field. The data in Table 2 is used and substituted in equation 1.1. The total revenue and costs from equation 1.2 to 1.5 form the basic parameters for estimating the replanting time. In equation 1.1, "k" is the decision variable, where k= **R**, and k=**M** indicates a decision whether to Replant (or Replace) or Maintain, respectively. When returns from replanting "R" are greater than returns from maintaining "M" then a recommendation to Replant (R) is made and vise versa.

Table 2: A Multiperiod Analysis of a Coconut Farm (1 hectare plot, 84 palms)

Item	Year / Unit costs (Tshs)	1 to 6	7to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80
OUTPUT										
Coconut (nuts)		0	11	30	45	50	38	19	9	7
Total revenues (Tshs)	80	0	73920	201600	302400	336000	255360	127680	60480	47040
FIXED COSTS										
Seedlings (per plant)	300	25200	0	0	0	0	0	0	0	0
Land preparation (Mandays)		102,200	0	0	0	0	0	0	0	0
Digging holes (Mandays)		4800	0	0	0	0	0	0	0	0
Planting (Mandays)		4800	0	0	0	0	0	0	0	0
TOTAL FIXED COST		136800	0	0	0	0	0	0	0	0
VARIABLE COSTS										
Climbing costs (per tree)	50	0	4200	4200	4200	4200	4200	4200	4200	4200
Dehusking (per nut), collect	10	0	9240	25200	37800	42000	31920	15960	7560	5880
Slashing		18000	36000	36000	38400	42000	44400	39600	36000	36000
Working tools	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
TOTAL VARIABLE COST		25500	56940	72900	87900	95700	88020	67260	55260	53580
TOTAL COSTS		162300	56940	72900	87900	95700	88020	67260	55260	53580
NET REVENUE (Tshs/ha)		-162300	16980	128700	214500	240300	167340	60420	5220	-6540

Assumptions

1 Labour is costed at Tshs 1,200 per manday .

2 Farmers slash their plots twice per year, mainly before the rain seasons i.e. the long and short rains.

3. Coconut trees start to bear nuts in year seven.

Source: Survey 1997

From the results in table 3, it shows that a coconut field can be replanted when the palms are at the age between 60 and 80 years. Based on this analysis it is suggested that a coconut field be replaced when the palms are 60 years old. To establish the exact and specific age for replanting, a further analysis was conducted and this incorporated the Total cost (TC) and Total revenue (TR) curves. The adopted criteria to determine the exact replanting age of a coconut palm is the point where the TR=TC. The Total Revenue (TR) and Total Costs (TC) curves for coconut production in Tanga, Coast and Dar-es-Salaam Regions are presented by the following equations :

Total revenue $TR = -237.89x2 + 16440x$

Total cost $TC = -67.067\ x2 + 5190.3x$

The coconut farmer will make profit by growing coconuts if TR>TC. Therefore the two equations presented above are used to determine the exact replanting age.

TR=TC, we can solve for x if

$$-237.89x^2 + 16440x = -67.067x^2 + 5190.3x2.1$$

Therefore

$X = 65.8 \cong 66$YEARS

$X = 66$ YEARS

Table 3: Costs, Returns and Replanting Time of a Coconut field

Time (yrs)	Returns Fn(1) (Tshs)	Costs (Tshs)	Return age(t) (Tshs)	K (decision R/M)
80	47040	53580	-6540	R
70	60480	55260	5220	R
60	127680	67260	60420	R
50	255360	88020	167340	M
40	336000	95700	240300	M
30	302400	87900	214500	M
20	201600	72900	128700	M
10	73920	56940	16980	M

Source: Survey 1997

As is shown in figures 3a and 3b, the output from a coconut palm at exactly 66 years barely covers both variable and fixed costs, and thus there is no profit realized. Beyond 66 years when TC>TR, any development on the coconut plantation is uneconomical. Therefore replanting should be done at the age of 66 years. Moreover, at the age of 66 most of the coconut palms are tall and allow over 50% of solar radiation to pass through to the planted seedlings and therefore the growing of coconut seedlings is possible. Another advantage of old coconuts is that, at above 60 years its wood can be used for timber and therefore farmers will have an added value. It should also be noted that farmer's plots in the study area are small in size, .e. 1.5 ha in Tanga and 2.9 ha in Dar-es-Salaam and Coast. These plots also have small numbers of coconut trees per hectare, i.e. 84 in Tanga and 63 in Dar-es-Salaam and Coast. It is therefore difficult for such farms to provide farmers with adequate returns and earnings and effective replanting programme and adhering to the recommended appropriate timing to do so. Therefore, so as to ensure a stable income over years, farmers ought to be made aware of the optimal replanting age. Agricultural extension officers should also emphasize the replanting time.

6. Conclusion

Coconut growers in Tanzania are recommended to replant their coconut fields when the palms are 66 years old. The gradual replacement of existing coconut palms should be undertaken at planting densities of 15-17 x10m. This density if maintained will allow for various intercropping systems to be established with other crops. In general, there is a need to educate small farmers and strongly advice them regarding the need for adhering to the replanting age and the benefits accruable from intercropping. There is sufficient evidence that returns from coconut fields can be increased by intercropping with other crops and also by intergrating crop production with livestock production.

End notes

[1] an optimal policy has the property that, whatever the initial decisions are, the remaining decisions must constitute an optimal policy with respect to the state resulting from the first decision.

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