



Analysis of Determining The Cost of Replanting for Smallholder Oil Palm Plantations Using Annuities Model with Python

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Abstract

Palm oil replanting is a necessary activity to enhance the productivity of aging oil palm trees. However, the high costs associated with replanting often create a financial burden for farmers. To address this issue, the study proposes the implementation of a contribution or levy system for smallholder farmers while their oil palm plantations are still productive, which would alleviate the financial burden of replanting. The research methodology employed includes a literature review and primary data collection through a survey of smallholder farmers, with the data being processed to create a mathematical model and simulated using the Python programming language. The results of this study include the development of a mathematical model for the levy and distribution of replanting costs, along with a simulation of the proposed system. This model could help smallholder farmers prepare for replanting costs, enhance the sustainability of palm oil production, and ultimately increase productivity.

Keywords: Oil palm replanting, mathematics model, annuity, Python

1. Introduction

Oil palm (*Elaeis guineensis*) is a vital oil-producing crop cultivated across Africa, Asia, and Latin America and has significant global demand (Qaim et al, 2020). According to the United States Department of Agriculture, the world's demand for imported crude palm oil (CPO) is predicted to reach 50.6 million tonnes for November 2021 to October 2022, representing an increase of 6.3% compared to the previous period (Mattson et al., 2004).

Indonesia is the world's largest producer and exporter of palm oil (Qaim et al., 2020), with small and medium-scale family plantations accounting for over 40% of total oil palm land in the country (Chrisendo et al., 2021; Euler et al., 2016).

Studies have shown that smallholder farmers benefit from oil palm cultivation in terms of higher household living standards, making it a profitable alternative to traditional crops such as rice or rubber (Euler et al., 2016; Krishna et al., 2017a; Kubitza et al., 2018). Despite the crucial contribution of smallholders in producing palm oil products, the yield of their production remains relatively low due to limited access to quality inputs, knowledge of good agricultural practices, and funding for replanting (Johnston et al., 2018).

To address this issue, the Indonesian government supports oil palm replanting through the Peremajaan Sawit Rakyat (PSR) program, which aims to increase oil palm productivity using superior seeds and good agricultural practices without the need for new land. However, financing remains a challenge for smallholders (Purba, 2009). Several financing models have been developed, including private sector, commercial banks, impact investors, development of financial institutions, and government schemes (Bronkhorst et al., 2017).

This study proposes a preventive measure to ensure smallholders can replant on time without waiting for financing, enabling them to be financially independent in rejuvenating their oil palm plantations. The proposed solution involves requiring contributions from each harvest, using a mathematical model based on the annuity principle to determine the amount of the contribution. The model will be simulated and analyzed using the Python programming language, with several case studies to assess its effectiveness.

In conclusion, the proposed solution has the potential to improve the financial independence of smallholders in oil palm replanting, ensuring they can contribute to the sustainable production of palm oil in Indonesia.

2. Literature Review

2.1. Annuity

2.1.1. Definition of annuity

Annuity is defined as the payment of payments made at equal intervals. Originally the term "annuity" was limited to annual payments, but has now been expanded to include payments made at other regular intervals such as semester payments and monthly payments (Kellison, 1991).

2.1.2. Types of annuities

a. Annuity-Immediate

Kellison (1991), direct annuity means a series of payments made at the end of each period for n periods. The present value $a_{\bar{n}|}$ must equal the sum of the present value of each payment, namely:

$$a_{\bar{n}|} = A \frac{1 - (1 + i)^{-n}}{i} \tag{1}$$

The total accumulated value $s_{\bar{n}|}$ must equal the total accumulated value of each payment, namely:

$$s_{\bar{n}|} = A \frac{(1 + i)^n - 1}{i} \tag{2}$$

b. Annuity-Due

Kellison (1991), annuity-due means a series of payments made at the beginning of each period for n periods. The present value $\ddot{a}_{\bar{n}|}$ must equal the sum of the present value of each payment, namely:

$$\ddot{a}_{\bar{n}|} = A \left(\frac{1 - (1 + i)^{-n}}{\frac{i}{1 + i}} \right) \tag{3}$$

The total accumulated value $\ddot{s}_{\bar{n}|}$ must equal the total accumulated value of each payment, namely:

$$\ddot{s}_{\bar{n}|} = A \frac{(1 + i)^n - 1}{\frac{i}{1 + i}} \tag{4}$$

c. Deferred annuity

Chan (2017), A deferred annuity is an annuity in which the first payment begins some time in the future. Consider an annuity with n units of payment whose first payment is due at time $m + 1$. The present value $m|a_{\bar{n}|i}$, namely:

$$m|a_{\bar{n}|} = A \left(\frac{(1 + i)^{-m} - (1 + i)^{-(m+n)}}{i} \right) \tag{5}$$

The total accumulated value $m|s_{\bar{n}|i}$, namely:

$$m|s_{\bar{n}|} = A \left(\frac{(1 + i)^{n+m}}{i} - \frac{(1 + i)^m}{i} \right). \tag{6}$$

d. Increasing annuity-immediate

Chan (2017), Direct annuity whose payments are tiered based on arithmetic progression. Suppose a direct annuity and the initial payment is P , the next payment is $P + D, P + 2D, \dots$ and so on until the j th payment is $P + (j - 1)D$. The present value $(Ia)_{\bar{n}|}$, namely:

$$(Ia)_{\bar{n}|} = A \left[\frac{\left(1 - \left(\frac{1+p}{1+i}\right)^n\right)}{i-p} \right] \quad (7)$$

The total accumulated value $(Is)_{\bar{n}|}$, namely:

$$(Is)_{\bar{n}|} = A \left[\frac{\left((1+i)^n - (1+p)^n\right)}{i-p} \right]. \quad (8)$$

2.2. Cost

According to Fernandes (2014), costs are sacrifices or expenses made by a company or individual with the aim of obtaining greater benefits from the activities carried out. The cost of fertilizer is a fairly large cost in managing oil palm plantations. Fertilization is the addition of nutrients through organic and inorganic fertilizers which aim to increase soil fertility in order to encourage healthy plant vegetative growth and optimal productivity (Woittiez et al., 2019). Fertilization is done within a certain period. In Gerendás & Führs, (2013) explained that plants tend to absorb more nutrients if fertilization is applied four times compared to twice a year.

2.3. Oil Palm

2.3.1. Oil Palm Plants

The oil palm plant (*Elaeis guineensis* Jacq) is a tropical plant belonging to the plasma group which is an annual plant. The oil palm plant originates from West Africa. This plant can thrive in Indonesia, Malaysia, Thailand and Papua New Guinea. Palm oil is one of the most important crops in national development. Oil palm plantations can provide greater employment opportunities and as a source of foreign exchange for the country. This plant began to be conserved and commercialized in 1991. Andrian Hallet was the person who first started the oil palm plantation business in Indonesia. He is a Belgian national who has learned a lot about oil palm plantations in Africa (Corley & Tinker, 2008).

2.3.2. Smallholder Plantations

Smallholder plantation is a plantation managed by smallholders, including small business groups of plantation crops and household plantation businesses. Smallholder plantations in Indonesia play an important role in producing palm oil (Central Statistics Agency, 2020). According to data from the Central Statistics Agency 2021, in 2019 smallholder plantations successfully produced 14.9 million tons of palm oil, accounting for around 35% of total crude palm oil production. However, the palm oil production yield from smallholder plantations is still relatively low. This is due to the lack of access to quality inputs, limited knowledge of good agricultural practices, and lack of funding, especially for replanting (Johnston et al., 2018).

In the study by Chrisendo et al. (2021), it is explained that more than 40% of the total oil palm land in Indonesia is cultivated by small and medium-sized family plantations, rather than large palm oil companies (Euler, et al., 2016). Several studies show that small farmers benefit from oil palm cultivation in terms of higher household living standards, as oil palm is more profitable than traditional crops such as rice or rubber (Euler, et al., 2016; Krishna, et al., 2017; Kubitza, et al., 2018). Oil palm is also an innovative crop that is labor-saving, meaning it requires fewer workers per hectare compared to most traditional crops (Feintrenie, et al., 2010; Chrisendo, et al., 2021).

2.3.3. Replanting

Palm oil replanting is the activity of replacing old and unproductive palm oil plants with new ones. The main consideration for conducting palm oil replanting is that the age of the plant has exceeded its economic lifespan, which is around 25 years, resulting in low production and no longer profitable if maintained (Feintrenie et al., 2010). The regulation of the Ministry of Agriculture of the Republic of Indonesia number 18/permentan/KB/330/5/2016 on guidelines for palm oil replanting states that to achieve more efficient and sustainable palm plantation business development, one of the efforts is carried out through replanting of unproductive, old, and/or damaged plants. (Ministry of Agriculture of the Republic of Indonesia, 2016).

There are four general systems for palm oil replanting, namely simultaneous (conventional) system, underplanting system, gradual replanting system, and intercropping system. Each of these systems has its advantages and disadvantages (Ministry of Agriculture of the Republic of Indonesia, 2016).

2.4. Python

Python is a multipurpose interpreted programming language with a design philosophy that emphasizes code readability. Python is claimed to be a language that combines capability and power with a syntax that is very clear and is equipped with a large and comprehensive standard library functionality. Python also has a complete library, allowing programmers to create advanced applications using source code that appears simple (Perkovic, 2015).

According to the Python Software Foundation (2016), Python is an interpreted, object-oriented, and dynamically semantic programming language. Python has a simple syntax and is easy to learn, with an emphasis on ease of reading and reducing program repair costs. Python supports modules and packages to promote program modularity and code reuse. The Python interpreter and its standard library are available for free on all platforms and can be distributed freely. This programming language was created by Guido van Rossum from the Netherlands in 1992.

3. Materials and Methods

3.1. Materials

The object of this research is the cost of replanting of smallholder oil palm plantations for both those who have and have not rejuvenated their plantations. Population data for the research was obtained through literature studies and direct surveys in the Kuantan Hilir District, Kuantan Singingi Regency, Riau. There were 183 smallholder plantation populations obtained through the agriculture department where the survey was conducted in the Kuantan Hilir District, Kuantan Singingi Regency, Riau. From this population, a sample was selected for the survey using sampling techniques. Incidental sampling was used, which is a technique for determining a sample based on chance encounters with individuals who are deemed suitable as data sources (Sugiyono, 2018)

The survey was conducted on the sample obtained to determine the cost of rejuvenating oil palm, the area of oil palm plantations owned, income from oil palm per harvest, and the age of oil palm plantations. Data processing was then carried out to determine the replanting conditions and formulate a mathematical model. After formulating the mathematical model, it was simulated and analyzed using the Python programming language. The variables included in this study are the cost of rejuvenating oil palm plantations, the amount of replanting fee contributions, and the amount of distribution of oil palm replanting costs.

3.2. Methods

The research method used in this study is descriptive with a literature review through collecting and studying books, journals, and articles related to oil palm, replanting, annuities, and the cost of oil palm replanting. This research uses primary data with data collection techniques through a survey of a sample of smallholder oil palm farmers. The data is then processed and used to determine the model of the cost of oil palm rejuvenation for smallholder plantations using the Python programming language.

3.3. Research Steps

The steps taken in this research are as follows:

a. Literature Review

In this step, a literature review is conducted by collecting and studying books, journals, and articles related to oil palm rejuvenation, annuity, the cost of oil palm rejuvenation, as well as the Python programming language.

b. Questionnaire Development

In this step, a questionnaire is developed by identifying the required data for this research. Then, a questionnaire is prepared as a survey tool for a sample of smallholder oil palm farmers. The questionnaire contains questions designed to obtain the necessary data, such as the area of the plantation, gross income per harvest, plantation age, and the cost required for rejuvenation.

c. Data Collection

In this step, primary data is collected through a survey conducted on a sample of smallholder oil palm farmers. The survey is conducted by directly interviewing the respondents using the questionnaire prepared so that the data can be accountable.

d. Uniformity Test of Data

In this step, if the data is declared uniform, the next step is taken. If the data is not uniform, then the non-uniform data is removed. Uniformity test of data using formula:

$$\begin{aligned} BKA &= \bar{x} + k(\sigma) \\ BKB &= \bar{x} - k(\sigma) \end{aligned} \tag{9}$$

e. Adequacy Test of Data

In this step, if the data is declared adequate, the next step is taken. If the data is inadequate, then it returns to the previous step. Adequacy test of data using formula:

$$N' = \left(\frac{\frac{k}{s} \sqrt{N(\sum x_i^2) - (\sum x_i)^2}}{\sum x_i} \right)^2 \tag{10}$$

f. Data Processing

The data obtained from the survey is then processed using descriptive statistics to calculate the mean, variance, and other descriptive calculations that need to be performed to support the research process using Python.

g. Assumptions

In this step, the assumptions that apply to this research are formulated. Assumptions are necessary for the research to be carried out optimally. Several assumptions needed are related to bank interest rates, inflation data, the price of oil palm seeds, and other factors that affect the research.

h. Mathematical Model Creation

In this step, a mathematical model is formulated that can be alternatives to the cost of smallholder oil palm rejuvenation. The model is formulated based on the assumptions and data known in the previous steps. The cost calculation model for oil palm rejuvenation comes from an annuity model, so the model created is in line with existing theories and studies. The creation of the mathematical model refers to equations (1), (2), (3), (4), (5), (6), (7), and (8).

i. Program Development Using Python Programming Language

In this step, the formulated model is implemented into a program using the Python programming language.

j. Mathematical Model Simulation

In this step, the model that has been designed in the Python program is simulated on various problems in this research. There are several case studies that can be simulated with the mathematical model created in the previous step. The existence of this model simulation proves that the created model can be applied under various conditions.

Interpretation of Results of Case Studies and Discussion

In this step, the simulation of the developed mathematical model is solved to obtain the results and recommendations of the research.

4. Results and Discussion

4.1. Palm Oil Replanting Plan

In this research, there are 65 respondents were chosen based on the criteria. Based on the palm oil replanting plan, the distribution of data describes that there are 64 respondents who do not have a palm oil plantation replanting plan. The respondents do not have a plan for replanting because the palm oil plantation is still young, so there is no need to plan currently. Note the following Tabel 1

Tabel 1: Descriptive statistics on the age of the oil palm trees (year(s))

Index	the age of the oil palm trees (year(s))
Count	65
Mean	6.31
Std	3.18
Min	2
25%	4
50%	6
75%	8
Max	20

Based on Table 1, the average age of the oil palm trees is around 6.3 years old. There are even plantations that are only two years old. Although there are respondents who already have replanting plans, the quantity is quite small. Only 1 out of 65 respondents have a replanting plan. This is because the palm oil plantation they own is already 20 years old.

Overall, based on the results of interviews with 65 respondents, it was found that the condition of palm oil plantation replanting among smallholders in Kuantan Hilir District, Kuantan Singingi Regency, Riau has not yet

entered the replanting phase. The main reason for this is that the palm oil plantations are still young and productive. Even planning for replanting has not yet been carried out. Therefore, the respondents still have enough time to prepare the costs for palm oil plantation replanting.

4.2. Simulation of a mathematical model to determine the cost of replanting smallholder oil palm plantations

The research results show that the total cost for replanting is IDR 37,500,000. This cost includes all operational and fertilizer costs during the four-year waiting period. Four models were used in this study, namely annuity-immediate, annuity-due, deferred annuity, and increasing annuity-immediate. The results of each calculation using Python programming are shown in Table 2.

Table 2: The results of the calculation of reinvestment fees using each annuity

Variable	Annuity-Immediate	Annuity-due	Deffered annuity	Increasing annuity-immediate
Future Value	37,500,000	37,500,000	37,500,000	37,500,000
Present Value	15,274,885.72	15,274,885.72	11,902,270.92	15,274,885.72
Contribution (A_i)	107,387.65	106,942.06	92,851.97	Minimum = 80,253.34 Maximum = 152,814.21

Based on Table 2, the contribution model using annuity-due has the lowest contribution amount of IDR 106,942.06 per month. This contribution lasts for 216 months or 18 years. Therefore, when it is time for plantation replanting, farmers already have the capital and fertilizer costs for the waiting period. For plantations that are less than 7 years old, the contribution calculation can be done using deferred annuity. In this study, it is simulated that plantations that are 2 years old will pay a contribution of IDR 92,851.97 with payment starting 5 years later.

The amount of contributions that respondents are willing to pay, the average is IDR 144,950.40 per month. When compared to the results of the annuity calculation, the contribution amount from respondents is higher. Therefore, the contribution model for palm oil plantation replanting costs using annuity can be applied because it is still below the respondents' expected cost.

Furthermore, the model for distributing the replanting costs is also determined using annuities. This is aimed at ensuring that the accumulated costs are not immediately depleted during the early stages of replanting, leaving no funds for fertilizer costs during the waiting period. The results of each calculation using Python programming are shown in Table 3.

Table 3: The results of the calculation of distributing fees using each annuity

Variable	Annuity-Immediate	Annuity-due	Deffered annuity	Decreasing annuity-immediate
Future Value	45,745,858.04	45,745,858.04	45,745,858.04	45,745,858.04
Present Value	37,500,000	37,500,000	37,500,000	37,500,000
Distributing values (B_i)	2,600,502.08	2,757,242.26	2,699,244.97	Min =1,392,524.38 Maks =3,005,721.44

The research results show that the mathematical model for distributing replanting costs using decreasing annuities is suitable for use in the case of oil palm plantation replanting. This is because the costs required during the early period of replanting are higher compared to the waiting period. Using decreasing annuities, the initial distribution is made for IDR 3,005,721.44. Then, the subsequent payment period continues to decrease over 16 periods with one payment period of 3 months. Meanwhile, using annuity-immediate and annuity-due, the respective distribution values are IDR 2,600,502.08 and Rp2,757,242.26. Although this result is less than using decreasing annuities, the distribution of costs using constant annuity-immediate and annuity-due continues until the end of the period. Meanwhile, the costs required during the waiting period are only for fertilizer costs, which amount to IDR 1,250,000 with a one-time payment every three months. Thus, using upfront and regular annuities becomes less effective for this case.

5. Conclusion

The replanting condition of smallholder oil palm plantations in Kuantan Hilir District, Kuantan Singingi Regency, Riau, has not yet entered the replanting phase. The main cause of the lack of replanting is due to the young and productive oil palm plantations. Even for replanting planning, there has not been any effort made. Therefore, the

respondents still have a sufficient amount of time to prepare for the cost of rejuvenating their oil palm plantations. One of the ways is by contributing to a fund.

The cost of oil palm plantation funding was determined in this research using annuities and supported by Python programming. Based on the research results, the total cost of replanting is IDR 37,500,000, which includes all operational costs and fertilizer expenses during the four-year waiting period. According to the research, the annuity-due contribution model has the lowest contribution amount, which is IDR 106,942.06 per month. The contribution lasts for 216 months or 18 years. Therefore, when rejuvenating the plantation, the farmers will have enough capital and fertilizer funds during the waiting period. For plantations that are less than seven years old, the annuity calculation can be done with a deferred annuity. In this research, it was simulated that a two-year-old plantation would pay a contribution of IDR 92,851.97, with payments starting five years later.

The average monthly contribution they are willing to pay is IDR 144,950.40. Compared to the annuity calculation results, the contribution amount from respondents is higher. Therefore, the oil palm plantation funding annuity model can be applied because it is still below the respondents' expected contribution amount.

Furthermore, the model for distributing the replanting costs is also determined using annuities. This is done to ensure that the funds collected will not be immediately depleted during the initial phase of replanting, so there is no remaining fund for fertilizer expenses during the waiting period. The research results show that the mathematical model for distributing replanting costs using a decreasing annuity is best suited for oil palm plantation replanting. This is because the costs required during the initial replanting period are higher than during the waiting period. Using a decreasing annuity, the initial distribution is IDR 3,005,721.44. Then, the subsequent period's payments continue to decrease over 16 periods, with a one-payment period every three months. Meanwhile, using a constant annuity-due and an annuity-immediate, the values are IDR 2,600,502.08 and IDR 2,757,242.26, respectively. Although these values are lower than using a decreasing annuity, the distribution of costs using a constant annuity-due and annuity-immediate continues until the end of the period. Meanwhile, the cost required during the waiting period is only for fertilizer expenses, amounting to IDR 1,250,000 for a one-time three-month period. Therefore, using a constant annuity-due and annuity-immediate is less effective for this case.

Explain what has been done, and draw conclusions in accordance with the objectives of the research that has been determined. The conclusions are delivered narratively, do not contain equations, tables, and figures.

References

- Badan Pusat Statistik (2021) *Indonesia Palm Oil Statistics 2020*. Jakarta: Badan Pusat Statistik
- Bronkhorst, E., Cavallo, E., van Dorth tot Medler, M., Klinghammer, S., Smit, H. H., Gijsenbergh, A., & van der Laan, C. (2017). *Current practices and innovations in smallholder palm oil finance in Indonesia and Malaysia: Long-term financing solutions to promote sustainable supply chains* (Vol. 177). CIFOR.
- Chrisendo, D., Siregar, H., & Qaim, M. (2021). Oil palm and structural transformation of agriculture in Indonesia. *Agricultural Economics*, 52(5), 849-862.
- Corley, R. H. V., & Tinker, P. B. (2008). *The oil palm*. John Wiley & Sons.
- Euler, M., Schwarze, S., Siregar, H., & Qaim, M. (2016). Oil palm expansion among smallholder farmers in Sumatra, Indonesia. *Journal of Agricultural Economics*, 67(3), 658-676.
- Feintrenie, L., Chong, W. K., & Levang, P. (2010). Why do farmers prefer oil palm? Lessons learnt from Bungo district, Indonesia. *Small-scale forestry*, 9, 379-396.
- Fernandes, N. (2014). *Finance for Executives: A practical guide for managers*. NPVPublishing.
- Gerendás, J., & Fühns, H. (2013). The significance of magnesium for crop quality. *Plant and Soil*, 368, 101-128.
- Johnston, D., Smit, H. H., Bronkhorst, E., Dorth, M. M., Adjaffon, I., & Cavallo, E. (2018). Innovative replanting financing models for oil palm smallholder farmers in Indonesia. Potential for upscaling, improving livelihoods and supporting deforestation-free supply chains.
- Kellison, S. G. (1991). *The Theory of Interest*, Richard D. Irwin. INC., Burr Ridge: Illinois.
- Krishna, V., Euler, M., Siregar, H., & Qaim, M. (2017). *Differential livelihood impacts of oil palm expansion in Indonesia*. *Agricultural Economics*, 48(5), 639-653.
- Kubitza, C., Krishna, V. V., Alamsyah, Z., & Qaim, M. (2018). The economics behind an ecological crisis: livelihood effects of oil palm expansion in Sumatra, Indonesia. *Human Ecology*, 46, 107-116.

- Mattson, J. W., Sun, C., & Koo, W. W. (2004). *Analysis of the world oil crops market* (No. 1187-2016-93849).
- Ministry of Agriculture of the Republic of Indonesia. (2016). MOA Number 18 of 2016. Jakarta: Ministry of Agriculture of the Republic of Indonesia
- Ministry of Trade of the Republic of Indonesia. (2013). *Market Brief Palm Oil and its Processes*, ITPC Hamburg: July, pp. 1–35.
- Perkovic, L. (2015). *Introduction to computing using python: An application development focus*. John Wiley & Sons.
- Purba, J. H. V. (2019). Replanting policy of Indonesian palm oil plantation in strengthening the implementation of sustainable development goals. In *IOP Conference Series: Earth and Environmental Science* (Vol. 336, No. 1, p. 012012). IOP Publishing.
- Qaim, M., Sibhatu, K. T., Siregar, H., & Grass, I. (2020). *Environmental, economic, and social consequences of the oil palm boom*.
- Sugiyono, P. D. (2018). Quantitative, qualitative, and R&D research methods. *Bandung:(ALFABETA, Ed.)*.
- Woittiez, L. S., Turhina, S. R. I., Deccy, D., Slingerland, M., Van Noordwijk, M., & Giller, K. E. (2019). Fertiliser application practices and nutrient deficiencies in smallholder oil palm plantations in Indonesia. *Experimental Agriculture*, 55(4), 543-559.