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Economic evaluation of shoot-grafting cocoa cultivation: a profitability study in the tropical zone of Indonesia

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Abstract: Cocoa output in Indonesia has greatly decreased in recent years due to climate changes, pest and disease outbreaks and limited empowerment of improved cultivation technologies. Using cost-benefit analysis (CBA), this study will assess the profitability of cocoa farming systems using shoot-grafting in the tropical regions of Indonesia. The research, conducted in Parigi Moutong Regency, using structured questionnaires along with focus group discussions to gather data from 80 cocoa farmers. The findings show that cocoa farming systems using shoot-grafting resulted in a gross margin of IDR 9,626,383/ha/year and net farm income of IDR 8,619,717/ha/year. Average NPV was IDR 8,374,245/ha/year, and BCR was 1.99 (so that IDR 1 invested provides a benefit of IDR 1.99). A 29.56% IRR indicates strong profitability and the need of investments from conventional credit sources at slightly higher interest rates. While the system requires substantial initial investment, the results clearly indicated that shoot-grafting is a cost-effective technology that can contribute to higher household income, improved financial risk bearing and sustainable agricultural intensification.

Keywords: Cocoa, shoot-grafting, financial feasibility, NPV, BCR, IRR
Abbreviations: BCR-Benefit cost ratio; GM-Gross margin; IRR-Internal rate of return; NFI-Net farm income; NPV-Net present value; TC-total costs; TFC-Total fixed costs; TR-Total revenue; TVC-Total variable cost.

Introduction

Cocoa (*Theobroma cacao*) is a highly significant tropical cash crop and an important component of rural livelihoods and exports. Indonesia is among the major producers of cocoa in the world. Most of its cocoa output, around 80%, is produced by smallholder farmers and the state-owned government plantations, with private plantations contributing the rest. However, despite its potential value, production of cocoa in Indonesia has been stagnate or declining during past decades, and national cocoa bean production has fallen sharply over the last five years, from 270,000 tons in 2017 to a mere 170,000 tons in 2021. As a result, Indonesia is no longer the world's fourth-largest producer of cocoa, having dropped to seventh place after such countries as Côte d'Ivoire, Ghana, Ecuador, Cameroon, Nigeria and Brazil.

One of the major factors contributing to this decline is the influence of global climate change (ICCO, 2023). Other factors leading to this decline are multi-faceted and include aging of plantations, susceptibility to pest and diseases, and low uptake of improved technologies (Effendy et al., 2019; Wessel and Quist-Wessel, 2015). Technology becomes indispensable to efforts to revive stagnating cocoa productivity. One of the promising technologies is shoot-grafting, where superior clones are grafted onto extant rootstocks to rejuvenate ageing trees without having to replant them from seedlings (Etienne et al., 2018; Somarriba et al., 2021; Warman et al., 2022).

Although shoot-grafting has shown agronomic potential to enhance cocoa yields and reduce the time to cropping (Tchapda et al., 2023), doubts persist about its financial sustainability for smallholder farmers. Scion production, technical labors and maintenance make this method more expensive. Without any sound financial analysis, many farmers might consider shoot-grafting too risky or not cost effective (Asiedu, 2024; Nadege et al., 2020).

This research assesses the financial viability of shoot-grafting in cocoa farming systems in the tropical region of Indonesia using strong financial metrics: Net Income, Net Present Value (NPV), the Benefit-Cost Ratio (BCR), and the Internal Rate of Return (IRR). The resulting estimates permit a quantitative, unbiased evaluation of profitability over the economic life of cocoa trees, which is key evidence for investment and policy decisions (Boardman et al., 2018; Kpenekuu et al., 2025).

The NPV reports the discounted value of future net cash flows in present terms and the IRR is the implicit rate of return on the investment (Boardman et al., 2018, Akinyi et al., 2022). BCR is estimated by comparing total benefits with total costs, and marginal net revenue represents the annual revenue to farmers in monetary terms (Kpenekuu et al., 2025). Taken altogether, these approaches give the most comprehensive overview of the economics of shoot-grafting being justified under field conditions. Moreover, this research frames the financial analysis in the social-economic setting of cocoa smallholders in Indonesia. Such farmers often have restricted access to credit, extension officers, and improved seed (Effendy et al., 2019). The profitability of shoot-grafting under such conditions becomes crucial in designing support programs to stimulate sustainable cocoa intensification (Neilson, 2016; ICCO, 2023). The wider applicability of this study corresponds with national development objectives, including the improvement of productivity for agriculture, rural competitiveness in global markets, and rural welfare. This research concentrates on the economic analysis of shoot-grafting cocoa systems under actual smallholder farm circumstances in the tropics of Indonesia, an area lacking in empirical data. Although previous studies have looked at agronomic intensification of cocoa or the macroeconomic value of certification of cocoa (Ingram et al., 2018; Fountain and Hütz-Adams, 2020; Somarriba et al., 2021; Meilani et al., 2023; Wahyudi et al., 2023), very few have used holistic financial analysis to quantify the cost-benefit trade-offs of shoot-grafting to farmers. This study addresses a key literature gap by providing local evidence for linking agronomic innovation and economic decision-making, especially at the small-scale cocoa level.

Results and Discussion

Characteristics of the respondents

The average outputs of cocoa farmers are presented in Table 1. It is evident that the majority of cocoa farmers in the study area are small scale farmers, 65% of the farms being between 1-2 hectares and only 35% of the farms being larger than 2 hectares. Since cocoa production started, most of the farmers (55%) have had experience with cocoa for 39–54 years, which is evidence of a solid base of operational experience. Only 5% of the respondents have had 23–38 years of experience farming cocoa and 40% have had between 7 and 22 years of experience. In the case of age distribution, 70% of the respondents are 53 years old or more, in that 40% and the 30% of them are in the age ranges of 53–60 and 61–68 years old, respectively. The remaining 30% represents farmers in the age bracket 45–52. This demographic distribution implies that the population of cocoa farmers in the area consists of older and more experienced farmers with access to small sizes of land. These variables could affect the decision-making process of farmers and their receptiveness to adopting sustainable agriculture. However, more qualitative research is required to confirm these commonalities. Characteristics analysis shows that farm size and experience are among the primary factors that influence the adoption of technology in the production of cocoa in the study area. Previous studies support our contention. For instance, Fred et al. (2022) identified farm experience as a major socioeconomic determinant for the adoption of technology in cocoa farming. A previous report by Djokoto et al. (2016) reported that farm size, among other factors, influenced adoption of organic cocoa production. The level of farming experience of the respondents in light of their ages shows an excellent maturity, indicating that most of their knowledge is experience based.

Production cost

The total variable costs, fixed costs and costs of shoot-grafting cocoa are presented in Tables 2, 3 and 4.

In terms of cocoa farming production costs, the total variable costs (TVC) and total fixed costs (TFC) were separately estimated per hectare per year (Tables 2 and 3). The data represent cost components: material/equipment depreciation (fixed costs), and operation expenditures (variable costs). The cost data (variable) included the costs of fertilizers, pesticides, hired and family labor, transporting, drying, and packing of harvest materials, all being inputs with the life of a year or less. These results are presented in Table 2 which shows that the average TVC that cocoa farmers face is the total TVC at IDR 4,252,147 per year per hectare.

Fixed costs were estimated based mainly on equipment depreciation (like the knapsack sprayers, tarpaulins) and annual tax. Depreciation of equipment was calculated by dividing the current cost of equipment (IDR) by the duration of expected useful life (years). Summarized output is laid out in Table 3, and the average TFC amounting to 1,006,667 IDR per hectare per annum is observed.

By adding the two cost elements together, Table 4 shows the total costs (TC) of production incurred by cocoa farmers. The findings show that the average TD cost per hectare per annum is IDR 5,258,813 which includes variable and fixed costs. These cost approximations will form the basis for subsequent profitability analysis which shall include gross margin and net farm income determination. This costing method is consistent with the methods used in smallholder agricultural economics, where the separation and categorization between fixed and variable costs are considered essential elements for economic performance analysis (Yahaya et al., 2016).

Table 2 shows that the average TVC cost of cocoa farmers using shoot-graft techniques was IDR 4,252,147 per year per hectare. In the case of systems using shoot-grafting methods, this rather high value would indicate the existence of a heavy cost of these high inputs. Cost of fertilizers and labor also are major causes of higher TVC, as these inputs tend to be significantly more expensive for shoot-grafted cocoa farming than for standard systems (Manolova and Ganev, 2013; Sodr and Gomes, 2019).

Shoot-grafting methods generally require higher levels of field management, such as fertilization, pruning, pest control and post-graft care. These operations need heavier inputs of agrochemicals and result in a heavier human work load, especially during establishment and 'juvenile growth' stages. As noted by Jaza et al. (2021), the implementation of shoot grafting technique, despite its many agronomic advantages, is possibly associated with hidden, undisclosed and/or unexpected labor requirements and continuous monitoring. In labor hiring, the extra costs of these things add to the cost of production, making the cost structure steep.

Table 1. Characteristics of the respondent.

Items	Frequency	Percentage (%)
Land area (ha)		
1-2	52	65.00
>2-3	28	35.00
Farming experience (Years)		
7-22	32	40.00
23-38	4	5.00
39-54	44	55.00
Respondent age (years)		
45-52	24	30.00
53-60	32	40.00
61-68	24	30.00

Table 2. Total variable costs of shoot-grafting cocoa farming per hectare per year.

Items	Cost per ha per year
Fertilizer	1,918,297
Pesticides	974,040
Labor	1,033,723
Transportation (cocoa)	126,812
Drying	181,159
Packaging	18,116
TVC	4,252,147

In addition, the required skilled labor in the shoot-grafting systems increases costs even more, because they frequently use more expensive workers based on the specific tasks involved in shoot grafting. These cost trends make it clear that farmers should not assess profitability based on just yield results, but instead, analyze the efficiency and sustainability of input use. This is corroborated by evidence from analogous agro-ecological systems that suggest that better cocoa farming technologies, though promising in terms of productivity, will often have higher short-run operational costs which may compromise smallholders' returns to the extent that these are beyond what can be managed with quality extension service and affordable inputs (Yahaya et al., 2016, Afele et al., 2024).

Gross margins

The GM was estimated as the difference between the average total revenue per hectare and the average total variable cost on an annual basis. For this, we totaled the revenues of all respondent cocoa producers then divided by the number of respondents, and subtracted the average total variable costs, which was derived by summing up the individual costs of variables and then dividing by the number of producers. The outcome is an annual gross margin per hectare.

Table 5 shows the per hectare per year equivalent of the estimated GM for cocoa producers. The output in Table 5 shows a positive GM condition on average for the producers of cocoa, with IDR 9,626,383 per ha per year. This margin represented a significant difference between the value of sales and variable costs, indicating that cocoa production, especially under shoot-grafting systems, is feasible. The positive gross margins for all treatments show the profitability of the improved cultivation practices (Oladoyin and Aturamu, 2022). Shoot-grafting increases productivity, improving growth, disease tolerance and bean quality, to obtain higher market returns (Jaza et al., 2021).

Net farm income (NFI)

NFI was obtained by subtracting the average total cost per hectare per year from the average total revenue per hectare per year (Table 6). It was calculated by dividing the total sales of all cocoa producers by the number of the respondents and deducting the mean total cost (arrived at by dividing the total cost spent by each respondent by the total number of producers).

Moreover, Table 6 indicates a positive NFI of IDR 8,619,717 per hectare per year, confirming good financial performance above total production cost (including variable and fixed costs). Osarenren et al. (2016) reported that this level of profitability is practically useful for resource-poor farmers to earn income and to turn the profit into expansion of farming, purchase of inputs (fertilizer, improved seeds, agrochemicals, and others), and repayment of debt. Positive NFI indicates that cocoa farmers employing shoot grafting are in a better position to increase their financial solvency and productivity in the future.

Table 3: Total fixed costs of shoot-grafting cocoa farming per hectare per year.

Items	Cost per ha per year
Tax	50,000
Depreciation of equipment	956,667
TFC	1,006,667

Table 4. Total costs (TC) of shoot-grafting cocoa farming per hectare per year.

Items	Cost per ha per year
TVC	4,252,147
TFC	1,006,667
TC	5,258,813

Table 5. Gross margin of shoot-grafting cocoa farming per hectare per year.

Items	Cost per ha per year
TR	13,878,530
TVC	4,252,147
GM	9,626,383

These results correspond to the results of Jaza et al. (2021) who reported the same profitability trends among cocoa farmers in Cameroon. They demonstrate that despite the greater monetary input of this technology, in terms of fixed and operational costs, shoot-grafting can be cost-effective for cocoa producers through increased yields and cost premiums. Furthermore, a positive NFI enables producers to increase their working capital, replace worn-out equipment, and absorb income fluctuation due to seasonal price differentials (Yahaya et al., 2016). From a more general development point of view, profitable agricultural technologies such as shoot-grafting can be a driver for rural development, particularly for stimulating farmer investment capacity, alleviating poverty, and promoting adoption of other technologies.

Cost-benefit of shoot-grafting cocoa production

Several mechanisms of CBA, such as NPV, BCR and IRR, have been used in such studies to measure the net profitability of farms and to analyze the tradeoff between costs and benefits (Akinyi et al., 2022; Oladoyin and Aturamu, 2022). For all types of farms, the NPV per farm category was determined by taking the average of the total discounted revenues of all respondents and subtracting the average discounted total costs per ha/yr (over the life of the tree). We used a constant interest rate of 7.5% to calculate both discounted revenues and costs (Table 7).

The findings of this research validate the fact that shoot-grafting cocoa systems are profitable, considering the major investment appraisal variables (Net Present Value (NPV), Benefit-Cost Ratio (BCR), and Internal Rate of Return (IRR) presented in Table 7. The mean NPV per ha is IDR 8,374,245, indicating that there is a present value of return which is higher than the total cost of investment in the production period. This implies that the capital invested in shoot-grafted cocoa comes in the form of very high long-term financial returns. As noted by Oluyole et al. (2023), it is likely that investments in higher yielding and/or better-quality producing technologies for cocoa production will generate greater economic returns. The Benefit Cost Ratio (BCR) is also documented at 1.99, implying that for each 1 IDR spent, farmers can attain IDR 1.99. This implies a high level of cost-effectiveness, and clearly demonstrates the financial feasibility of promoting shoot-grafting as a sustainable intensification tool in cocoa cultivation. BCRs in the range of near to 2.0 are frequently viewed as a strong signal in agricultural economics that a project may be successfully scaled up.

In addition, the IRR was calculated at 29.56%, much higher than the average interest rate of 7.5% used in the analysis. This high IRR demonstrates that farmers using shoot-grafting techniques can repay the agricultural loan and still earn a large profit, enhancing their financial resilience. This cushion gives producers significant flexibility in loan repayment, investment ability, and risk bearing. The IRR also suggests that the venture could tolerate moderate rises in the cost of financing and remain a viable proposition. For example, even if informal interest cost is as high as 20% per year, the net return goes in favor of the producer by 9.56%.

This adaptability indicates that shoot-grafting systems can deal with higher capital costs without affecting profits. However, in an informal credit model like its "Ten Born Ten" kin where interest rates can go up to 50 percent per annum, the IRR will not match with the cost of borrowing. It is not commercially viable as an investment if solely funded from such mediums. Thus, even though the system is very profitable, affordable credit is essential for its financial success. These results underscore the rationale for policy measures to diminish the reliance of farmers on expensive informal credit (e.g., through cooperative loans, microfinance, or input subsidies), which would greatly increase the potential for scale-up of shoot-grafting adoption (Lescuyer and Bassanaga, 2021; Jaza et al., 2021). Our results confirm earlier empirical work that improved cocoa technologies increase both cocoa output and capital productivity, the return per unit of capital, so their adoption is particularly beneficial to resource-limited smallholder cocoa farmers (Oluyole et al., 2023).

Table 6. Net farm income of shoot-grafting cocoa farming per hectare per year.

Items	Cost per ha per year
TR	13,878,530
TC	5,258,813
NFI	8,619,717

Table 7. Cost-benefit analysis of shoot-grafting cocoa farming.

No	Investment Criteria	Value
1	Net Present Value (NPV); IDR	8,374,245
2	Benefit Cost Ratio (BCR)	1.99
3	Internal Rate Of Return (IRR); %	29.56%

Materials and Methods

The current study was based on a cross-sectional data gathering survey research design. Data were collected by structured questionnaires and group discussions in the cocoa-producing area of Parigi Moutong Regency. By applying the Taro Yamane sampling formula (Yamane, 1973) for statistical sample size calculation, 80 respondents were sampled to take part in the study.

Realization of main objectives in the study was through financial feasibility analysis. GM, NFI, NPV, BCR, and IRR are the indicators used in the study. GM was calculated as the difference between total revenue (TR) and total variable cost (TVC):

GM = TR − TVC (1)

NFI was estimated as the difference between total revenue and total costs:

NFI = TR − TC (2)

TR = P*Q (3)

TC = TVC + TFC (4)

The Net present value (NPV) calculation assumes the data of an estimated investment cost, data of operating and maintenance costs and estimated benefits/drawbacks of the planned business, and it depends on the discounted cash flow methods. The decision to invest will be based on net present value and that will be calculated as follows:

$$Net\ Present\ Value\ (NPV) = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} \quad (5)$$

Where:

Bt = Benefit (project benefit) at year - t (IDR)

Ct = Cost in year – t (IDR)

n = Number of years n = Period (years)

i = Rate of interest applicable (%)

P = Price

Q = Quantity

NPV assessment criteria are:

a. NPV > 0, the firm should be continued

b. NPV < 0, firm does not add value, should cease the operation.

BCR is the proportion of the present value of benefits by the present value of costs. This BCR is an example of how many worths can benefit the costs (costs) made. BCR > 1 means the project or the business idea is doable. Conversely, if BCR < 1, the project or business idea does not prove feasible to implement. The BCR is the extra net benefit that the project realizes for each $1 of cost invested. The value of BCR can be expressed by the following formula:

$$BCR = \sum_{t=1}^{n} \frac{\frac{B_t}{(1+i)^t}}{\frac{C_t}{(1+i)^t}} \quad (6)$$

IRR is a profitability measure (not an interest rate of the bank) that provides a funding break-even point for business profit which helps in determining the level of business profit up to which the present value of all business investment costs (cash outflows) is equal to zero. IRR is a rate at which NPV = 0. Exercise: IRR can be calculated by the formula:

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} \times (i_1 - i_2) \quad (7)$$

Where:

i_1 =interest rate 1 (discount rate with NPV 1)

i_2 = interest rate 2 = discount rate yielding NPV 2

NPV_1 = net present value 1

NPV_2 = net present value 2.

If the IRR is greater than the interest rate of the loan, then we accept it. We reject it if the IRR is less than the interest rate of the loan.

Conclusion

It is concluded that shoot-grafting cocoa farming systems are economically feasible and profitable for smallholders in the humid tropics of Indonesia. The positive GM and NFI indicate that farmers obtained large net incomes after all production costs. The findings for NPV, BCR and IRR also substantiate that the system is economically viable and provides long-term profit. While the investment costs in skilled labor and premium-quality inputs were initially higher, the results demonstrated that shoot-grafting can be a worthwhile option for agricultural intensification. An IRR of 29.56% gives a good cushion, ensuring farmers can still be profitable even at moderate borrowing rates of interest (≈20%). However, it will not be economical to borrow informally at high interest, say "Ten-Born-Ten" at 50%, because the borrowing cost would exceed the project IRR. Hence, dissemination of shoot-grafting technology may be followed by supportive policies which enhance access to subsidized credit, technical training and lower priced inputs. These results are crucial for the implementation of national programs for increasing cocoa productivity and the well-being of farmers in the face of adverse climatic conditions and falling farm yields.

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