

# Determinants of Cocoa Farming Sustainability in Polewali Mandar Regency

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## ABSTRACT

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Cocoa is one of Indonesia's main plantation export commodities and an important source of income for smallholder farmers in Sulawesi. However, cocoa farming sustainability at the farmer level faces multiple challenges, including ageing trees and declining productivity, land conversion, climate change risks, and weak farmer regeneration. This study aims to analyze the determinants of cocoa farming sustainability in Binuang District, Polewali Mandar Regency. A simple random sampling technique was used to select 40 cocoa farmers. Data were collected through observation and structured interviews using a questionnaire. Sustainability was measured by five dimensions: ecological, economic, social, technological, and institutional. Data were analyzed using multiple linear regression with a log-linear specification. The results show that the overall sustainability index of cocoa farming averages 29.29%, indicating a less sustainable category, with dimension scores of 26.67% (ecological), 31.17% (economic), 42.17% (social), 29.27% (technological), and 17.29% (institutional). Regression results indicate that cocoa productivity, cocoa price, farming experience, and education level significantly affect cocoa farming sustainability, while production costs are not statistically significant. Productivity has a negative effect, implying that higher productivity is associated with lower sustainability, whereas cocoa price has a positive effect, indicating that higher selling prices improve sustainability. Farming experience and farmer education have not yet translated into more sustainable practices. The findings highlight the need for policies that strengthen price incentives, promote environmentally friendly intensification, and improve farmer capacity building to support cocoa farming sustainability in Polewali Mandar.

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## 1. Introduction

Cocoa remains a strategic plantation commodity for Indonesia and a key driver of rural livelihoods, particularly in Sulawesi where smallholders contribute the majority of national production [1][2]. Despite its economic importance, the global cocoa sector has been widely criticized for persistent environmental degradation, low and volatile farmer incomes, and social issues such as child labor and weak farmer organization [1][3]. These challenges have triggered increasing pressure from governments, private companies, and civil society to transition toward more sustainable cocoa production systems.

In agricultural development discourse, sustainability is generally understood as the capacity of farming systems to maintain productivity, ecological integrity, and social functions over time, while reducing dependence on non-renewable inputs [4]. In the realm of smallholder cocoa, sustainability is typically viewed as a multidimensional construct that encompasses ecological, economic, social, technological, and institutional dimensions, reflecting the need to balance production, environmental conservation, livelihood security, and governance [5][6]. Approaches such as sustainable intensification promote yield enhancement alongside improvements in ecosystem services through practices like agroforestry, integrated nutrient management, and climate-smart innovations [4].

Cocoa agroforestry systems with diverse shade trees have been shown to support biodiversity, improve microclimate regulation, and enhance soil quality, thereby contributing to the ecological pillar of sustainability without necessarily reducing yields when appropriately managed [7][8]. Empirical studies in West Africa and other tropical regions indicate that farmers value tree diversity in cocoa for the provision of ecosystem services, including shade, soil fertility, timber, and non-timber products [8][9]. At the same time, the design of shade systems and management practices influences both productivity and ecological outcomes, creating potential trade-offs and synergies that must be considered in sustainability assessments [7][9].

Beyond ecological aspects, sustainability in cocoa farming is strongly shaped by economic conditions and value chain governance. Numerous studies highlight that low and unstable farmgate prices constrain farmers' ability to invest in rehabilitation, replanting, and adoption of good agricultural practices, thereby undermining long-term sustainability [10][11]. Initiatives such as certification schemes, price premiums, and improved market access have been promoted to enhance smallholder incomes and strengthen incentives for sustainable production, although their impacts remain uneven across contexts [12][6].

Climate change adds another layer of complexity to cocoa sustainability. Projections show that climatic suitability for cocoa is likely to shift in several major producer countries, including parts of Indonesia, with potential reductions in suitable area if adaptation measures are not widely adopted [13][14]. Without investments in climate-smart practices and risk management, smallholder cocoa farmers are expected to face increasing yield variability, pest and disease pressure, and income instability [13].

In Indonesia, recent research points to persistent challenges in smallholder cocoa systems, including ageing trees, low and heterogeneous productivity, limited adoption of recommended technologies, and weak institutional support [3][15]. These issues are also evident in the cocoa landscapes of Sulawesi, where smallholder cocoa remains a primary livelihood source but is under pressure from land-use change and changing climatic conditions [15][6]. Polewali Mandar Regency in West Sulawesi is one of the important cocoa-producing areas, with Binuang District as a key production center, yet empirical studies that quantify the determinants of cocoa farming sustainability at the farm level in this specific realm are still limited. According to data from the Indonesian Ministry of Agriculture, in Polewali Mandar Regency, in 2024 the area of cocoa plantations reached 48,929.50 hectares, with a production of 36,589.88 tons.

Against this background, this study aims to analyze the determinants of cocoa farming sustainability in Binuang District, Polewali Mandar Regency. Specifically, the study (1) measures the sustainability status of cocoa farming across ecological, economic, social, technological, and institutional dimensions, and (2) examines the effect of cocoa productivity, cocoa price, production costs, farming experience, and formal education on overall sustainability. By integrating a multidimensional sustainability index with an econometric analysis of its determinants, this study contributes empirical evidence to the literature on sustainable cocoa production and provides insights for the design of targeted interventions in Polewali Mandar and similar cocoa-growing regions.

## 2. Method

### 2.1. Study Area and Sampling

This research was conducted in Binuang District, Polewali Mandar Regency, West Sulawesi, Indonesia, an area characterized by a strong dependence on smallholder cocoa farming and unique

constraints related to aging plantations, limited capital, and varying access to extension services. The target population consisted of 200 cocoa farmers actively managing their cocoa land in the district.

A simple random sampling technique was applied to select 40 cocoa farmers as respondents. The sample size was determined based on data availability, resource constraints, and the minimum requirements for multiple linear regression analysis. Data collection was conducted through field observations and structured interviews using a pre-tested questionnaire. The questionnaire collected information on farm characteristics, production and cost structures, farmers' socioeconomic characteristics, and indicators related to ecological, economic, social, technological, and institutional aspects of sustainability.

## 2.2. Variables and Measurement

The dependent variable in this study is cocoa farming sustainability (Y), which is constructed as a composite index derived from five dimensions: ecological, economic, social, technological, and institutional. Each dimension is measured through relevant indicators, normalized, and aggregated into a percentage score. The resulting sustainability index ranges from 0 to 100, where higher values indicate better sustainability status. For regression analysis, the sustainability index is transformed into natural logarithms (LNY) to stabilize variance and allow elasticity-based interpretation.

The independent variables are:

- X1: cocoa productivity (kg ha<sup>-1</sup>), transformed into natural logarithms (LNX1);
- X2: cocoa bean price received by farmers (IDR kg<sup>-1</sup>), transformed into natural logarithms (LNX2);
- X3: farming costs (IDR per season), including inputs and hired labor, transformed into natural logarithms (LNX3);
- X4: cocoa farming experience (years), transformed into natural logarithms (LNX4);
- X5: years of formal education completed by the farmer (years), transformed into natural logarithms (LNX5).

The selection of explanatory variables reflects the view that productivity, price incentives, cost structures, and human capital are key drivers of smallholder farm performance and sustainability [4][5][10]. Productivity and prices directly influence farm income, while costs and human capital proxies (experience and education) shape farmers' capacity and willingness to adopt sustainable practices [12][11].

## 2.3. Analytical Approach

Data were analyzed using multiple linear regression with a log-linear specification. The estimated model is:

$$\text{LNY} = C + \beta_1 \text{LNX1} + \beta_2 \text{LNX2} + \beta_3 \text{LNX3} + \beta_4 \text{LNX4} + \beta_5 \text{LNX5} + \varepsilon$$

where C is the intercept,  $\beta_1$ – $\beta_5$  are parameters to be estimated, and  $\varepsilon$  is the error term. The log-log specification allows coefficients to be interpreted as elasticities, i.e., the percentage change in sustainability associated with a one percent change in the explanatory variable, *ceteris paribus* [16].

Estimation was conducted using the least squares method with a sample of 40 observations. The main statistics reported include coefficients, standard errors, t-statistics, and p-values. Model goodness of fit is evaluated using R-squared, adjusted R-squared, F-statistic and its probability, as well as the Durbin–Watson statistic. Prior to estimation, the data were examined for basic econometric assumptions, including linearity and absence of perfect multicollinearity, following standard practices in applied agricultural economics [16].

### 3. Results and Discussion

#### 3.1. Sustainability Status of Cocoa Farming

The analysis indicates that cocoa farming sustainability in the study area is relatively low. The average sustainability index for cocoa farming is 29.29%, which falls into the “less sustainable” category. At the dimensional level, the indices are 26.67% for ecological, 31.17% for economic, 42.17% for social, 29.27% for technological, and 17.29% for institutional aspects. The relatively higher social dimension suggests that farmer organizations and social networks still function to some extent, whereas institutional support through formal organizations, policies, and services remains weak.

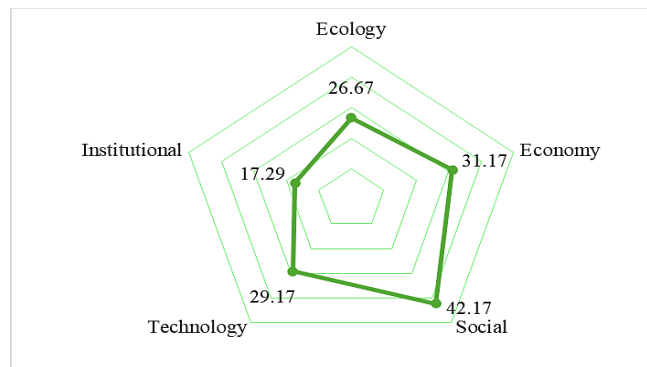


**Figure 1.** Sustainability of cocoa farming in Polewali Mandar Regency

These findings are consistent with studies in other smallholder cocoa regions that report persistent gaps in ecological and institutional dimensions despite ongoing interventions [6][17]. Similar patterns of low ecological sustainability due to limited adoption of shade management, organic fertilization, and soil conservation have been documented in Indonesian cocoa landscapes [15]. The low institutional score in this study reflects constrained access to extension, credit, and formal farmer groups, which has also been noted as a key bottleneck for sustainable cocoa intensification [11][10].

#### 3.2. Model Fit and Overall Significance

The goodness-of-fit statistics indicate that the model explains a substantial share of the variation in cocoa farming sustainability. The R-squared of 0.5788 show that the selected explanatory variables jointly account for more than half of the variation in the sustainability index, while the F-statistic of 9.34 ( $p < 0.01$ ) confirms that the model is statistically significant. The estimated coefficients and associated test statistics are presented in Table 1.

**Table 1.** Results of log-linear multiple regression of cocoa farming sustainability

| Variable                 | Coefficient | Std. Error | t-Statistic | p-value |
|--------------------------|-------------|------------|-------------|---------|
| Constant                 | -12.4018    | 3.7518     | -3.3055     | 0.0022  |
| Cocoa productivity       | -0.2612     | 0.0566     | -4.6185     | 0.0001  |
| Cocoa bean price         | 1.6166      | 0.3793     | 4.2616      | 0.0002  |
| Farming costs            | -0.0173     | 0.0394     | -0.4397     | 0.6629  |
| Cocoa farming experience | -0.1589     | 0.0587     | -2.7079     | 0.0105  |
| Formal education         | -0.2071     | 0.0752     | -2.7528     | 0.0094  |
| R-squared                | 0.5788      |            |             |         |
| F-statistic              | 9.3426      |            |             |         |
| Prob(F-statistic)        | 0.0000      |            |             |         |

Source: Primary data analysis, 2025.

Table 1 shows that cocoa productivity has a negative and highly significant coefficient, indicating that higher yields are associated with lower sustainability scores when other factors are held constant. In contrast, cocoa price exerts a strong and positive effect, suggesting that better price incentives are crucial for improving farm-level sustainability. Farming experience and formal

education both have significant negative coefficients, implying that existing experience and schooling have not yet been translated into more sustainable management practices. Production costs are not statistically significant, which indicates that differences in total expenditures do not clearly distinguish more sustainable from less sustainable farms.

### 3.3. Effects of Productivity and Price

The coefficient for cocoa productivity is negative and statistically significant at the 1% level ( $\beta_1 = -0.2612$ ;  $p = 0.0001$ ). In the log-log specification, this means that a one percent increase in cocoa productivity is associated with a 0.2612 percent decrease in the sustainability index, *ceteris paribus*. At first glance, this finding appears counter-intuitive because higher productivity is often assumed to be synonymous with improved farm performance. However, the negative and significant elasticity of sustainability with respect to cocoa productivity suggests that yield gains in the study area are not yet aligned with sustainable intensification pathways.

In many smallholder cocoa systems, higher yields are often achieved through input-intensive practices—such as increased use of synthetic fertilizers and pesticides, excessive pruning, and shade reduction—that may boost short-term production but degrade soils, reduce biodiversity, and increase vulnerability to pests, diseases, and climatic shocks [4]. Consistent with this view, studies on cocoa agroforestry show that removal of shade trees and simplification of canopy structure can undermine key ecosystem services, including microclimate regulation and natural pest control, thereby weakening the ecological pillar of sustainability even when yields temporarily rise [7][8].

Similar trade-offs between productivity and sustainability are reported in other cocoa-growing countries, where intensification without adequate soil and shade management has led to declining long-term yields and increased production risks [12][9]. The negative coefficient on productivity in this study therefore indicates that current intensification trajectories in Polewali Mandar are likely dominated by practices that prioritize short-term yield maximization over ecological resilience. In line with the concept of sustainable intensification, raising productivity in this context should be coupled with the wider adoption of climate-smart and ecologically sound practices—such as cocoa agroforestry, integrated nutrient management, and organic soil amendments—so that yield improvements reinforce, rather than erode, the multidimensional sustainability of cocoa farming [4][15].

In contrast, the coefficient for cocoa price is positive and highly significant ( $\beta_2 = 1.6166$ ;  $p = 0.0002$ ). This indicates that a one percent increase in cocoa prices received by farmers increases the sustainability index by approximately 1.62 percent, holding other factors constant. The strong and positive elasticity of sustainability with respect to cocoa prices highlights the central role of economic incentives in shaping farmers' capacity and willingness to invest in sustainable management.

When farmgate prices are low and volatile, smallholders often lack the financial resources and risk-bearing ability required for long-term investments such as replanting, shade tree enrichment, and adoption of improved agronomic practices [10][11]. Empirical evidence from West African cocoa shows that higher and more predictable cocoa prices are associated with greater uptake of certification schemes, better farm maintenance, and higher likelihood of replanting ageing plantations, all of which contribute to improved economic and ecological outcomes [12][6].

In this study, the large and significant price coefficient suggests that improved price transmission and market access can act as powerful levers to enhance cocoa farming sustainability in Polewali Mandar. Farmers who receive better prices are more likely to invest in yield-enhancing and risk-reducing technologies, to participate in farmer organizations, and to engage with extension services, thereby strengthening multiple dimensions of sustainability simultaneously [10][11]. This is consistent with broader analyses of global cocoa value chains, which argue that addressing structural price and income issues is a precondition for scaling up sustainable cocoa production, rather than treating sustainability solely as a matter of technical practice change at the farm level [1][2].

### 3.4. Effects of Production Costs, Experience, and Education

The coefficient for farming costs is negative but statistically insignificant ( $\beta_3 = -0.0173$ ;  $p = 0.6629$ ). This implies that within the observed range of variation, higher production costs do not have a clear effect on the sustainability index. One plausible explanation is that cost levels across

the sample are relatively homogeneous and dominated by routine expenditures on labor and basic inputs, with limited variation in investments directly related to sustainable practices such as organic fertilizers, shade management, or soil conservation [18]. In such conditions, total cost levels may not differentiate sustainable from less sustainable farms, particularly if the composition of costs does not reflect adoption of sustainability-enhancing technologies [4].

Farming experience has a negative and statistically significant coefficient ( $\beta_4 = -0.1589$ ;  $p = 0.0105$ ). This result indicates that a one percent increase in years of cocoa farming experience is associated with a 0.1589 percent decrease in the sustainability index, *ceteris paribus*. The negative association suggests that more experienced farmers in the study area tend to maintain conventional management strategies that may not align with contemporary sustainability principles. Studies on technology adoption in smallholder agriculture similarly report that older or more experienced farmers can be more risk-averse and less inclined to adopt new or unfamiliar sustainability-oriented innovations [18][5].

The coefficient for formal education is also negative and significant ( $\beta_5 = -0.2071$ ;  $p = 0.0094$ ). This implies that longer formal schooling years do not automatically translate into higher cocoa farming sustainability; instead, farmers with more years of general education may have alternative livelihood options outside agriculture, reducing their incentives to invest in sustainable cocoa management, or they may not have been exposed to agricultural sustainability content during their schooling [19]. Evidence from sustainable agriculture adoption studies underscores that general education needs to be complemented by targeted, context-specific extension and training to effectively change farming practices [4][5].

Taken together, these findings emphasize that general human capital indicators such as experience and schooling alone are insufficient to promote sustainability without deliberate efforts to reshape knowledge systems, attitudes, and incentives. Strengthening the relevance and quality of extension programs—particularly those addressing ecological management, climate change adaptation, and market linkage—could help transform existing experience and education into more sustainable practices in Polewali Mandar [15][6].

The observed low sustainability index and the identified determinants are particularly concerning in light of climate change projections. Studies indicate that climatic suitability for cocoa is expected to shift, with some current production areas facing increased heat and water stress, while new areas may become suitable [13][14]. Without proactive adaptation and sustainable land-use practices, smallholder cocoa farmers will be increasingly exposed to yield variability, pest and disease outbreaks, and income instability [13].

In this case, the negative relationship between productivity and sustainability in the study area can be interpreted as a signal that current intensification pathways are not sufficiently climate-smart. Sustainable intensification strategies that integrate shade tree management, soil and water conservation, and diversification can improve resilience to climate shocks while maintaining or improving yields [7][4]. Coupled with improved price incentives and institutional support, such strategies could enable cocoa farmers in Polewali Mandar to better navigate climate-related risks and move toward more resilient and sustainable production systems.

#### 4. Conclusion

The results show that the overall sustainability index of cocoa farming is 29.29%, categorized as less sustainable, with particularly low scores in ecological and institutional dimensions. Regression analysis reveals that cocoa productivity, cocoa price, farming experience, and formal education significantly influence sustainability, while production costs do not have a statistically significant effect. Productivity exerts a negative impact, suggesting that current intensification patterns may undermine ecological and social aspects of sustainability. In contrast, higher cocoa prices contribute positively to sustainability by improving farmers' capacity and incentives to invest in their farms. Farming experience and education, however, have not yet translated into more sustainable practices, indicating a need for more effective extension and capacity-building efforts.

The findings imply that policy interventions should focus on promoting sustainable intensification, improving price incentives and market access, and strengthening institutional support and farmer capacity. Aligning productivity enhancement with ecological management, expanding access to premium markets, and providing targeted sustainability training can help move

cocoa farming in Polewali Mandar toward a more sustainable trajectory. Given the additional pressures posed by climate change, integrated strategies that combine technical, economic, and institutional measures are essential to safeguard the long-term viability of smallholder cocoa systems.

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