



A Calculus Based Rice Production Scenario for Farm Planning in Deli Serdang

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ABSTRACT

This study examines a calculus-based production scenario intended to support discussion of rice-farm planning in Deli Serdang, Indonesia. A deterministic simulation integrates an assumed accumulation rate of $20 + 3t$ over a 120-day crop cycle, where time is measured in days. The resulting function is $Q(t) = 20t + 1.5t^2$, giving a modeled cumulative quantity of 24,000 kg at day 120. At an assumed price of IDR 5,500 per kg, this quantity corresponds to gross revenue of IDR 132,000,000. The positive second derivative describes a convex quadratic trajectory; it does not demonstrate exponential growth, increasing returns to farm inputs, or improvements in soil fertility. The coefficients were not calibrated against documented field measurements, and the cultivated area, production costs, and conversion from biomass to marketable grain were not specified. Consequently, the calculation is an illustrative scenario rather than a validated harvest forecast or a profitability assessment. Extending the same trajectory across successive harvest cycles is not justified. The example can help explain accumulation and the distinction between revenue and profit, while practical application requires local yield measurements, explicit area and grain-quality definitions, cost records, and evaluation with participating farmers.

Keywords: rice production; definite integral; farm planning; simulation; Deli Serdang

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INTRODUCTION

Farm planning requires a clear distinction between expected output, sales revenue, production costs, and the uncertainty surrounding each quantity. Organic production adds questions about management, certification, market access, and environmental outcomes. A review of organic agriculture treats productivity, environmental impacts, economic viability, and social wellbeing as separate dimensions of sustainability (Reganold & Wachter, 2016). A production curve alone cannot establish performance across those dimensions.

The performance of organic agriculture varies with the setting and the outcomes being assessed (Seufert & Ramankutty, 2017). Evidence from smallholder rice systems in India also shows the importance of comparing costs, prices, and household circumstances alongside crop output (Eyhorn et al., 2018). These findings provide context for farm-

planning exercises, but do not establish the profitability of a particular farming group in Deli Serdang. In Indonesia, market access, certification, and farmer organization have also been discussed as constraints on organic-agriculture development (Mayrowani, 2012).

This study evaluates the internal mathematical consistency and interpretation of a simple production scenario. Its objectives are to derive cumulative output from an assumed rate, calculate conditional gross revenue, and identify the information required before applying the result to farm decisions. Deli Serdang is the intended application setting; no local field experiment, farmer training evaluation, or measured empowerment outcome is reported. The contribution is an educational calculation whose assumptions and limits are explicit.

METHODS

The study uses a deterministic simulation with a 120-day scenario horizon. The supplied model assumes an accumulation rate of $20 + 3t$. Although the original formulation referred to secondary biological information, no identifiable measurement series or coefficient-estimation procedure was supplied. The coefficients are therefore treated as assumptions, not empirical estimates for organic rice in Deli Serdang.

Let t denote days from the start of a modeled crop cycle, and let $Q(t)$ denote a hypothetical accumulated production quantity in kilograms for the modeled farming unit. The unit's cultivated area is unspecified. Accordingly, Q is a total quantity, not a yield expressed in kilograms per hectare. The model adopts $Q(0) = 0$ and the rate function in Equation (1), restricted to $0 \leq t \leq 120$.

$$Q'(t) = 20 + 3t, \quad Q(0) = 0, \quad 0 \leq t \leq 120 \quad (1)$$

For dimensional consistency, the intercept has units of kg per day and the coefficient of t has units of kg per day squared. This rate is an assumed mathematical input. It does not demonstrate that soil fertility, root development, or grain filling follows the same trajectory. Integrating the rate gives Equation (2).

$$Q(t) = \int_0^t (20 + 3x) dx = 20t + 1.5t^2 \quad (2)$$

The model does not distinguish plant biomass from harvestable grain. To calculate revenue, an additional scenario assumption is required: the day-120 total represents saleable unhusked rice. Moisture content, quality, post-harvest losses, and milling conversion are not modeled. The price of IDR 5,500 per kg is retained as an assumed input from the supplied scenario; it has not been verified as a local market observation.

$$R = pQ(120), \quad \Pi = R - C \quad (3)$$

In Equation (3), R denotes gross revenue, p the assumed unit price, C total production and marketing costs, and Π net profit. Costs were not supplied, so only gross revenue can be calculated numerically. A positive revenue figure is insufficient to establish financial feasibility. No comparison with household income or regional wages is undertaken.

Calculations comprise exact integration, substitution at specified times, and differentiation to interpret the curve. The analysis also checks the consequence of extending the function beyond its stated horizon. Such an extension is examined as a mathematical extrapolation, not as a forecast of repeated rice harvests. No statistical prediction interval is reported because neither parameter uncertainty nor a stochastic error model is available.

RESULT AND DISCUSSION

Integrating the assumed rate produces $Q(t) = 20t + 1.5t^2$. The day-120 total is $2,400 + 21,600 = 24,000$ kg. The constant-rate component contributes 2,400 kg, and the time-dependent component contributes 21,600 kg. These are algebraic components of the model, not experimentally separated biological effects.

Table 1 presents the within-cycle calculations. The day-60 quantity is 6,600 kg and the day-120 quantity is 24,000 kg. The monetary value at day 60 is a hypothetical valuation of modeled accumulation at the assumed price, not evidence that a saleable harvest exists at that date.

Table 1. Within-cycle production and conditional valuation

Time (days)	Modeled quantity (kg)	Conditional value (IDR)
60	6,600	36,300,000
120	24,000	132,000,000

Note. Calculated from the assumed model; values are not observed harvests.

The day-120 gross revenue is $24,000 \times 5,500 = \text{IDR } 132,000,000$. This result is conditional on all modeled output being marketable at the stated price. Without land area, the output cannot be compared with per-hectare rice yields. Without costs and the number of participating households, the revenue cannot be interpreted as household earnings or evidence of economic superiority.

Equation (4) establishes the shape of the trajectory. The first derivative increases linearly with time, and the second derivative is a positive constant. Hence Q is a convex quadratic function. Neither the rate nor the accumulated quantity is exponential.

$$Q'(t) = 20 + 3t, \quad Q''(t) = 3 > 0 \quad (4)$$

Figure 1 plots the function only over its stated 120-day horizon. The curve becomes steeper because the assumed rate rises with time. This is a consequence of the model specification, not independent confirmation of biological growth or organic-management benefits.

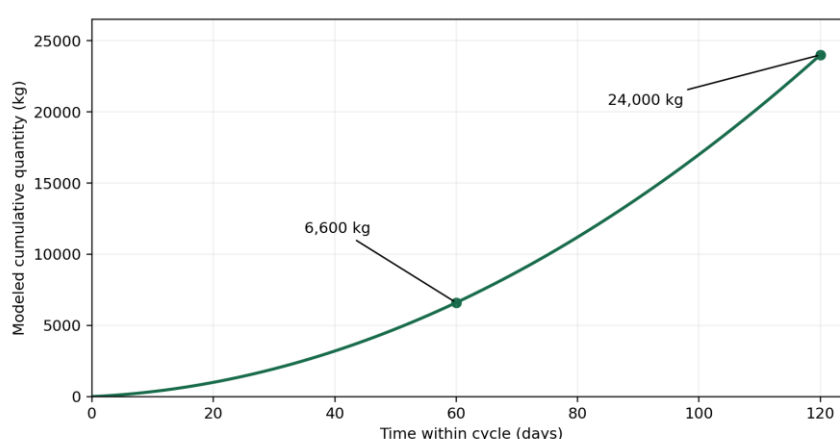


Figure 1. Assumed cumulative quantity over one 120-day cycle.

The increase between days 60 and 120 is 17,400 kg in the simulation. This does not establish that farmers should delay harvest, because maturity, grain quality, weather exposure, and harvest losses are absent from the model. Similarly, a derivative with respect

to time is not a marginal product with respect to fertilizer, labor, or capital. The curve therefore cannot demonstrate increasing returns to those inputs.

Table 2 separates unrestricted extrapolation from a repeated-cycle illustration. Substitution of $t = 240$ gives 91,200 kg, but this assumes uninterrupted accumulation beyond the first harvest. At $t = 365$ the exact polynomial value is 207,137.5 kg. Neither value is a validated annual harvest forecast.

Table 2. Continuous extrapolation and repeated-cycle illustrations

Scenario	Quantity (kg)	Interpretation
Q(240)	91,200	Outside the 120-day domain
Q(365)	207,137.5	Outside the 120-day domain
Two identical cycles	48,000	Hypothetical sum of two harvests
Three identical cycles	72,000	Hypothetical sum of three harvest

Note. Calculated from the assumed model; values are not observed harvests.

If two identical 120-day cycles were assumed independently, their combined end-of-cycle quantity would instead be $2 \times 24,000 = 48,000$ kg. Three identical completed cycles would give 72,000 kg. These calculations reset the within-cycle clock at each planting and illustrate why repeated harvests must be distinguished from continuous plant growth. They do not establish that two or three crops per year are locally feasible; water availability, turnaround time, seasonality, and management would need to be documented.

The financial interpretation also depends on omitted quantities. Under the stated output and price assumptions, the break-even total cost is IDR 132,000,000: costs below this amount yield a positive modeled profit, and costs above it yield a loss. This threshold is an identity derived from revenue minus costs. It is not an estimate of actual farm costs or a recommendation to invest.

Organic-agriculture research assesses more than the curvature of output over time. Productivity, environmental performance, and economic outcomes require different measurements (Reganold & Wachter, 2016; Seufert & Ramankutty, 2017). The Indian rice comparison considered production costs and sales prices in assessing farm performance (Eyhorn et al., 2018). Applying the present scenario to Deli Serdang would likewise require a defined farming unit and locally documented inputs and outputs, rather than transferring findings from another production system.

For an educational application, facilitators could ask farmers to distinguish assumed values from recorded observations, identify costs missing from the calculation, and compare output and price scenarios. Such an activity is proposed here; it was not implemented or evaluated in this study. Claims of improved financial literacy, access to credit, or economic empowerment would require participant information, a documented intervention, and an appropriate outcome assessment.

The principal limitations are the absence of calibrated coefficients, cultivated area, grain-quality definitions, cost records, and independent validation. A practical extension should collect dated observations from identified fields and crop cycles, distinguish biomass from

marketable grain, and evaluate prediction errors on data not used for model fitting. Sustainability claims would additionally require relevant environmental and social indicators. Until those data are available, the model should remain an illustrative planning exercise.

CONCLUSION

The assumed accumulation rate yields a quadratic function with a day-120 quantity of 24,000 kg and conditional gross revenue of IDR 132,000,000. The arithmetic is internally consistent, but the result is not a validated harvest forecast. Positive curvature does not prove exponential growth, increasing returns to farm inputs, profitability, or ecological sustainability. Repeated cropping also requires a cycle-based formulation rather than unrestricted extension of the same curve.

The example offers a transparent way to explain integration and the difference between revenue and profit. Its use in Deli Serdang should begin with local data collection and a clearly defined educational or farm-planning purpose. Evidence of economic empowerment would need to come from an evaluated intervention, not from the size of a simulated revenue figure.

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