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Agroecological Zoning and Financial Viability of Citronella (Cymbopogon nardus) Farming: Integrating Elevation, Economic Performance, and Farmer Welfare

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Abstract. *This study aims to analyze the effect of altitude on the performance of citronella farming and to evaluate its financial viability in supporting farmers' welfare. The study employs a quantitative approach using a survey design among citronella farmers across various elevation zones: 200–400 m asl, 400–600 m asl, 600–800 m asl, 800–1,000 m asl, 1,000–1,200 m asl, and >1,200 m asl The data were analyzed using income analysis, Break-Even Point (BEP), Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and sensitivity analysis. The research results indicate that elevation significantly affects the productivity and financial viability of citronella farming. The 800-1,000 m asl elevation zone offers the most optimal conditions, with an NPV of Rp.100,373,958, an IRR of 108%, and a payback period of 1.03 years. Conversely, at elevations of 200-400 m.a.s.l., the NPV is relatively low and indicates a higher level of risk. Analysis of minimum land requirements shows that at the optimal elevation, farmers need only about 0.21 ha of land to meet the Decent Living Standard (KHL), far less than the 1.96 ha required at lower elevations. Sensitivity analysis indicates that farming at optimal elevations is more resilient to rising costs and declining yields than farming at lower elevations. Therefore, the development of citronella farming should take agroecological zoning into account as a basis for policy-making and strategies to improve farmers' well-being.*
Keywords: C*itronella, Elevation, Financial Viability, NPV, IRR*

1. Introduction

Citronella (Cymbopogon nardus) is an essential oil-producing crop with high economic value and steadily increasing global demand, particularly in the pharmaceutical, cosmetic, and bio-based product industries. In recent decades, demand for essential oils derived from tropical plants has increased in line with the global trend toward natural and sustainable products (Isman, 2020; Pavela & Benelli, 2016). As one of the leading producers of essential oils, Indonesia possesses a comparative advantage in the cultivation of citronella, particularly in regions with specific agroecological characteristics such as highland areas.

The Gayo Highlands in Aceh Province are one of the regions with great potential for citronella cultivation, supported by favorable agroclimatic conditions such as temperature, rainfall, and elevation. However, the productivity and profitability of citronella farming are highly influenced by environmental factors, particularly elevation, which plays a role in determining vegetative growth, oil content, and production input efficiency (Karthik et al., 2024; Singh et al., 2021). Variations in elevation create heterogeneity within the production system, which ultimately impacts the financial performance of the farming operation.

In the context of economic evaluation, financial feasibility analyses such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) have become widely used approaches for assessing the viability of investments in the agricultural sector (Boardman et al., 2018; Gittinger, 1986). Recent studies indicate that a comprehensive financial approach can provide a more accurate picture of business viability, particularly when combined with risk and sensitivity analysis (Miaris et al., 2025). However, most previous studies have focused on profitability indicators without linking them to the dimension of farmer welfare.

The Decent Living Needs (KHL) approach is crucial for assessing whether income from farming can meet minimum living standards. The KHL reflects not only physiological needs but also social aspects such as education, health, and general well-being (Anker & Anker, 2017; Watts, 2020). In this context, an analysis of minimum land requirements serves as a key indicator for determining the scale of farming operations capable of ensuring the economic sustainability of farming households.

Nevertheless, there is a significant research gap. First, there are still few studies that integrate financial feasibility analysis with the KHL approach within a single comprehensive analytical framework. Second, empirical studies linking variations in elevation to minimum land requirements and the economic resilience of farming operations remain very limited, particularly for citronella in tropical regions. Third, most studies have not systematically included sensitivity analysis to test business resilience against uncertainties such as price fluctuations and changes in production (Hemani et al., 2023; Ivanova, 2023).

Various alternative solutions have been proposed in the literature, including increasing production efficiency through technology adoption, agricultural diversification, and value chain integration (Birthal et al., 2020; Porter & Kramer, 2011). However, an agroecological zoning-based approach particularly based on elevation combined with financial analysis and farmer welfare has not yet been widely developed. Therefore, this study offers an integrative approach that combines financial analysis (NPV, IRR, PBP), break-even point (BEP) analysis, minimum land requirement analysis based on KHL, and sensitivity analysis within a comprehensive evaluation framework.

The scope of this study includes an evaluation of citronella farming in the Gayo Highlands, taking into account variations in elevation as the primary variable affecting productivity, income, and the viability of the business. This study also examines the economic resilience of the farming business through simulations of changes in production costs and declines in crop yields as a representation of conditions of uncertainty in the agricultural sector.

Based on the above, this study aims to analyze the financial viability of citronella farming at various elevations, calculate the minimum land requirement to meet farmers' decent living standards (KHL), and analyze the sensitivity of the farming operation to changes in costs and production. This study is expected to provide a theoretical contribution to the development of an agroecology-based farm feasibility analysis model, as well as a practical contribution to the formulation of sustainable citronella commodity development policies oriented toward improving farmers welfare.

2. Method

This study employed a quantitative approach with a descriptive-analytical design to evaluate the financial viability of citronella (Cymbopogon nardus) farming and to determine the minimum land requirements based on the Decent Living Standard (KHL) at various elevations. The study was conducted in the Gayo Highlands, Aceh Province, which was selected through purposive sampling because it is a major production center for citronella with representative agroecological variations (Creswell, 2014).

The study population consists of all citronella farmers in the study area. Sampling was conducted using stratified random sampling based on elevation classes (200-1,200 m above sea level). From each stratum, respondents were selected randomly and proportionally to ensure representation of agroecological characteristics. The unit of analysis in this study is the farmer household, with observed variables including production costs, production, receipts, and farm income (Etikan, 2017; Hardani et al., 2020). The data used consists of primary and secondary data. Primary data was collected through structured questionnaires, face-to-face interviews, and field observations, while secondary data was obtained from the Central Statistics Agency (BPS), scientific literature, and reports from relevant agencies. The research instrument consisted of a questionnaire covering farmer characteristics, input use, production costs, crop yields, and selling prices (Badan Pusat Statistik, 2020).

Data analysis was conducted quantitatively through several stages. Farm income was calculated as the difference between total revenue and total costs. A Break-Even Point (BEP) analysis was used to determine the break-even point of the business in terms of production, price, and land area. The minimum land requirement is calculated by comparing the KHL value to net income per hectare. Financial feasibility is analyzed using the Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) indicators, with feasibility criteria of NPV > 0, IRR exceeding the interest rate, and PBP shorter than the business lifespan. Additionally, a sensitivity analysis is conducted to test the business's resilience to changes in economic conditions through scenarios involving a 10% increase in production costs and a 10% decrease in production (Boardman et al., 2018; Gittinger, 1986; Monde, 2008).

3. Results and Discussions

Minimum Land Requirements, Farmer Welfare, and Breakeven Point Analysis (BEP)

The analysis results indicate that the ability of citronella farming to meet the Decent Living Standard (KHL) is significantly influenced by elevation. Based on data from the Central Statistics Agency (2024), the KHL value in Aceh Province is Rp. 3,400,000 per capita per month, serving as the benchmark for determining the adequacy of farmers' income. At low elevations (200–400 m above sea level), farmers' net income is only Rp.1,728,078 per hectare, which is insufficient to meet the KHL standard, although it remains above the poverty line. Conversely, at medium to high elevations (400-1,200 m above sea level), farmers' income generally exceeds the KHL, with the highest value at 800-1,000 m above sea level at Rp.15,839,628 per hectare. Complete data are presented in Table 1 and Figure 1.

The implication is that the minimum land requirement (Lm) to achieve a decent standard of living varies significantly. At low elevations, farmers require up to 1.96 ha of land, whereas at the optimal elevation (800-1,000 m above sea level), only about 0.21 ha is needed. This underscores that increased productivity directly reduces the required land area, making it a crucial strategy for improving farmers' well-being.This section contains an objective description of the research results, including analysis and interpretation.

Table 1. Results of the analysis of the break-even point (BEP) for production volume, the break-even point (BEP) for production price, and the minimum land area required to meet the minimum living standard (KHL) at each elevation in the Gayo Highlands

Elevation (m asl)	Total Production Cost (Rp)	Selling Price (Rp)	Total Production (kg/ha)	BEP for Production Volume (kg/year)	BEP for Production Cost (Rp/kg)	KHL (Rp)	Net Income (Rp/ha)	Lm (ha)
1	2	3	4	5 (2/3)	6 (2/4)	7	8	9 (7/8)
200-400	13.175.922	135.000	110,40	97,60	119.347,11	3.400.000	1.728.078	1,96
400-600	13.175.922	135.000	137,03	97,60	96.153,55	3.400.000	5.323.128	0,64
600-800	13.175.922	135.000	192,30	97,60	68.512,7	3.400.000	12.784.578	0,27
800-1.000	13.175.922	135.000	214,93	97,60	61.299,0	3.400.000	15.839.628	0,21
1.000-1.200	13.175.922	135.000	205,53	97,60	64.102,5	3.400.000	14.570.628	0,23
>1.200	13.175.922	135.000	145,76	97,60	90.388,3	3.400.000	6.501.678	0,52

Notes:
KHL = Basic Living Needs
Lm = Minimum land area required for a decent standard of living

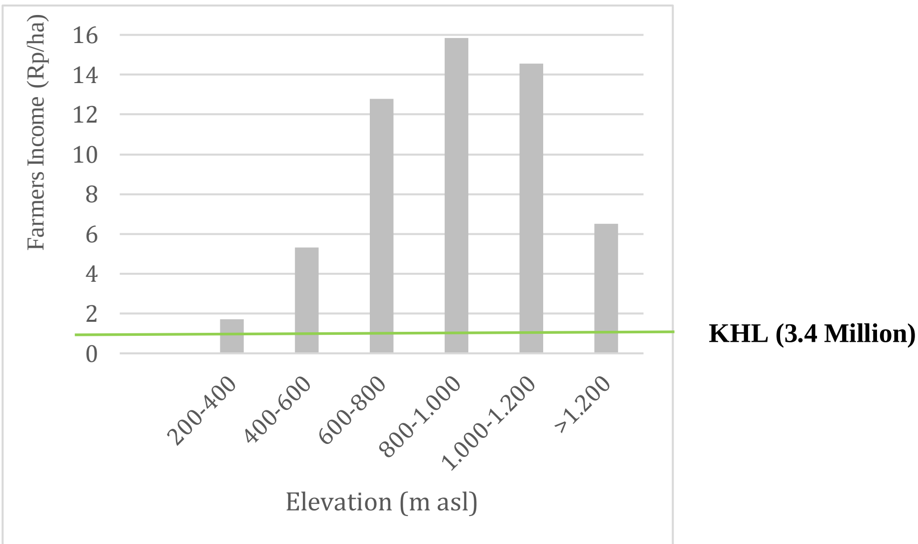

Figure 1. Income trends for citronella farmers in the Gayo Highlands in millions of rupiah

The BEP analysis results indicate that all citronella farming operations are in a relatively stable economic condition. The BEP production volume of 97.60 kg/year remains below the lowest actual production level (110.40 kg/ha), meaning the operations are still able to cover production costs.

Additionally, the production cost BEP ranges from Rp. 61,299 to Rp. 119,347/kg, which is still lower than the market price of Rp. 135,000/kg. This indicates a fairly stable profit margin, meaning citronella farming operations are classified as having a low risk of loss under normal conditions. However, the smaller profit margin at lower elevations indicates higher vulnerability to price and production fluctuations, making production efficiency a key factor in this zone.

Sensitivity and Resilience Analysis of Farming Operations

The sensitivity analysis shows that elevation plays a crucial role in determining the economic resilience of farming operations to external changes. In a scenario involving a 10% increase in operating costs and a 10% decrease in production, elevations between 600 and 1,200 meters above sea level still demonstrate strong financial performance. Specifically at elevations of 800–1,000 m.a.s.l., the NPV reaches Rp. 91,650,939 with an IRR of 99% and an extremely short payback period (1.11 years), even under economic stress. Conversely, at elevations of 200-400 m asl, the NPV becomes negative under sensitivity analysis, indicating that the venture is no longer viable. is presented in detail in Table 2.

Table 2. Sensitivity analysis of citronella farming at different elevations (m asl) in the Gayo Highlands

Elevation (m asl)	Sensitivity Analysis	Assumption		
		No fluctuations	Operating Costs are Rising 10%	Production volume has decreased 10%
200-400	NPV (Rp)*	1.183.267	-7.539.752	-9.291.579
	Net B/C	1,07	0,54	0,43
	IRR (%)	15	5	3
	PBP	6,53	8,82	9,35
400-600	NPV (Rp) *	26.456.766	17.733.747	13.454.571
	Net B/C	2,62	2,09	1,82
	IRR (%)	41	32	28
	PBP	2,70	3,55	4,11
600-800	NPV (Rp) *	78.900.403	70.177.384	60.653.844
	Net B/C	5,83	5,30	4,71
	IRR (%)	89	80	72
	PBP	1,25	1,38	1,53
800-1.000	NPV (Rp) *	100.373.958	91.650.939	79.980.043
	Net B/C	7,14	6,61	5,90
	IRR (%)	108%	99	90
	PBP	1,03	1,11	1,23
1.000-1.200	NPV (Rp) *	91.430.160	82.707.141	71.930.625
	Net B/C	6,60	6,06	5,40
	IRR (%)	100	92	82
	PBP	1,11	1,21	1,34
>1.200	NPV (Rp) *	34.734.982	26.011.963	20.904.964
	Net B/C	3,13	2,59	2,28
	IRR (%)	49	40	35
	PBP	2.29	2,76	3,11

Note: NPV: Net Present Value; PBP: Payback Period
IRR: Internal Rate of Return; * Diskonto 14%

These findings suggest that the optimal elevation zone not only enhances profitability but also boosts the economic resilience of farming operations, making them more resistant to uncertainties such as price and climate fluctuations. This is also consistent with previous research stating the importance of selecting a location at the appropriate elevation to minimize financial risks resulting from fluctuations in costs and prices (Karthik et al., 2024; Mwithiga et al., 2024).

Financial Feasibility Analysis

The financial feasibility evaluation indicates that all citronella farming operations at various elevations are generally viable for development (NPV > 0, IRR > interest rate, and relatively short payback period), except under certain extreme conditions. Elevations of 800–1,000 m above sea level constitute the most optimal zone, with an NPV of Rp. 100,373,958, an IRR of 108%, and a PBP of 1.03 years. Conversely, at elevations of 200–400 m above sea level, the NPV is only Rp. 1,183,267 with an IRR of 15% and a PBP of 6.53 years, indicating low profitability and higher investment risk. The results of the financial analysis for each elevation in the Gayo Highlands are shown in Table 3.

Table 3. The feasibility of citronella farming at different elevations in the Gayo Highlands

Elevation (m asl)	Feasibility Indicators			
	NPV (Rp)*	Net B/C	IRR (%)	PBP
200-400	1.183.267	1,07	15	6,53
400-600	26.456.766	2,62	41	2,70
600-800	78.900.403	5,83	89	1,25
800-1.000	100.373.958	7,14	108	1,03
1.000-1.200	91.430.160	6,60	100	1,11
>1.200	34.734.982	3,13	49	2,29

Note: * Diskonto 14%

These differences confirm that agroecological factors, particularly elevation, have a significant influence on production efficiency, operating costs, and the rate of return on investment. The policy implication of these findings is the importance of an agroecological zoning approach in the development of citronella. Additionally, technological interventions and efforts to improve production efficiency should be focused on low-altitude areas to enhance competitiveness and farmers' well-being.

4. Conclusions

This study indicates that elevation is a key factor determining the agronomic performance and financial viability of citronella farming. The medium to high altitude zone (600-1,200 m asl), particularly in the 800-1,000 m asl range, proved to be the optimal condition capable of yielding the highest productivity, maximum income, and the best financial viability indicators, as evidenced by high NPV and IRR values and a relatively short payback period. Conversely, at low elevations (200-400 m asl), the farming operation exhibits suboptimal performance, both in terms of productivity and profitability, and has a higher level of vulnerability to changes in costs and production. The minimum land requirement to meet the Decent Living Standard (KHL) is also greater in this zone, implying low operational efficiency.

The results of the sensitivity analysis confirm that farming at optimal elevations exhibits greater economic resilience to external fluctuations, such as increases in production costs and decreases in yield. Thus, an agroecological zoning-based approach is a critical strategy for the development of the citronella commodity.

This study recommends that the development of citronella farming should be focused on areas with optimal elevations, and supported by appropriate technological and policy interventions in non optimal areas to improve efficiency and farmer welfare.

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