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Integrated Economic and Land Evaluation of Cocoa Commodity in Pintu Rime Gayo District, Nanggroe Aceh Darussalam, Indonesia

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ABSTRACT: Bener Meriah Regency is known for its significant agricultural and plantation potential, particularly in horticultural commodities like vegetables and fruits. Arabica coffee is the primary crop, with 39,702 hectares dedicated to its cultivation. Cocoa has notable development potential, and locals in Pintu Rime Gayo District have begun cultivating it without scientific guidance. The study aimed to determine suitable areas for cocoa development using economic and land evaluation systems. The quantitative economic analysis included indicators such as Gross Margin (GM), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR), and Net Present Value (NPV). Land suitability was assessed by comparing the agricultural needs of cocoa with the area's land characteristics. The study found that the land in Pintu Rime Gayo is generally marginally suitable (S3) or not suitable (N) for cocoa. Several limiting factors for the development of cocoa commodities that can be identified in the analysis process are water availability (wa), rooting media (rc), nutrient availability (na), flood hazard (fh), and erosion hazard (eh). Financially, the price of dry cocoa beans is IDR 8,650 per kilogram, with a gross margin of IDR 1,652,922 per hectare per year and a BCR of 0.93, indicating that each unit of capital yields 0.93 times its value in revenue. The IRR was 15.33%, and the NPV was 684,848.

Keywords: Economic Evaluation, Land Evaluation, Land Suitability, Limiting Factor, Quantitative Analysis

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INTRODUCTION

The location of the Bener Meriah Regency area is bordered on the north by North Aceh Regency, on the east by East Aceh Regency, on the west by Bireuen Regency, and on the south by Central Aceh Regency. The area of Bener Meriah Regency is 1.888.70 km^2, which consists of 7 districts, one of which is Pintu Rime Gayo District. Bener Meriah Regency only has one entry route through Bireuen Regency. This limited in-and-out access is an inhibiting factor in accelerating regional development and isolates Bener Meriah from other districts. Apart from the relatively small regional income, lack of natural resources, increasingly depleting production forests, inadequate infrastructure, and restrictions on the authority to manage natural resources given by the central government make it difficult for Bener Meriah Regency to organize its area.

The Bener Meriah Regency, characterized by an elevation ranging from 100 to 2500 meters above sea level, experiences an annual precipitation of 1000 to 2500 mm and 143 to 178 rainy days per year. These environmental conditions have endowed the regency with abundant natural resources, which are the primary assets for fostering economic development, particularly through the agricultural sector. According to Anhar et al. (2024), the land use and cover in Bener Meriah district primarily consist of primary and secondary dryland forests, showing significant potential for agricultural development in the region. The agricultural and plantation potential in Bener Meriah has exhibited significant success and represents a notable resource for this particular administrative region. One of the farming products undergoing development is horticultural crops, including vegetables, fruits, and coffee plantations, considered high-value commodities spanning an area of 39,702 hectares. The cocoa plant shows promising development in Bener Meriah Regency. Recently, farmers in Pintu Rime Gayo District have begun cultivating this plant. However, the current cultivation methods used by the community have not been informed by scientific research, leading to suboptimal farming outcomes.

Pintu Rime Gayo District is characterized by its status as a district with the most extensive coffee plantation area within the administrative jurisdiction of Bener Meriah Regency. The prevailing climate conditions within the Pintu Rime Gayo District are not conducive for the cultivation of coffee plants. As a result, there is a necessity for innovative approaches in the cultivation of cocoa plants as a potential replacement for coffee crops. The community has initiated the establishment of a cocoa plantation, albeit at an experimental stage. The main problems with cocoa plantations, especially smallholder plantations, are low productivity and quality. However, there is significant potential for improvement. The productivity and quality of smallholder cocoa plantations are largely determined by the application of pre-harvest technology, such as plant materials, physical environment, and cultivation techniques, as well as post-harvest technology, such as harvesting, fermentation, drying, storage, and transportation (Hakim, 2023). The study aimed to identify appropriate regions for cocoa cultivation using economic and land evaluation systems.

THEORETICAL REVIEW

The land analysis evaluates whether a parcel of land is suitable for cultivating specific agricultural commodities using two categories: Suitable (S) and Not Suitable (N). The S category includes three sub-categories: Highly Suitable (S1), Moderately Suitable (S2), and Slightly Suitable (S3). This classification is based on identifying the most limiting or inhibiting factors. The analysis process involves using geo-statistical and Geographic Information System (GIS) approaches to assess the land's suitability for crucial crops within a specific geographic area (Aldabaa, A. and Yousif, 2020). Effective land resource management also requires examining land suitability to determine the best use of existing land resources. This method uses multi-criteria evaluation and GIS techniques to assess specific areas' suitability for agriculture, urban development, and conservation (Kihoro et al., 2013).

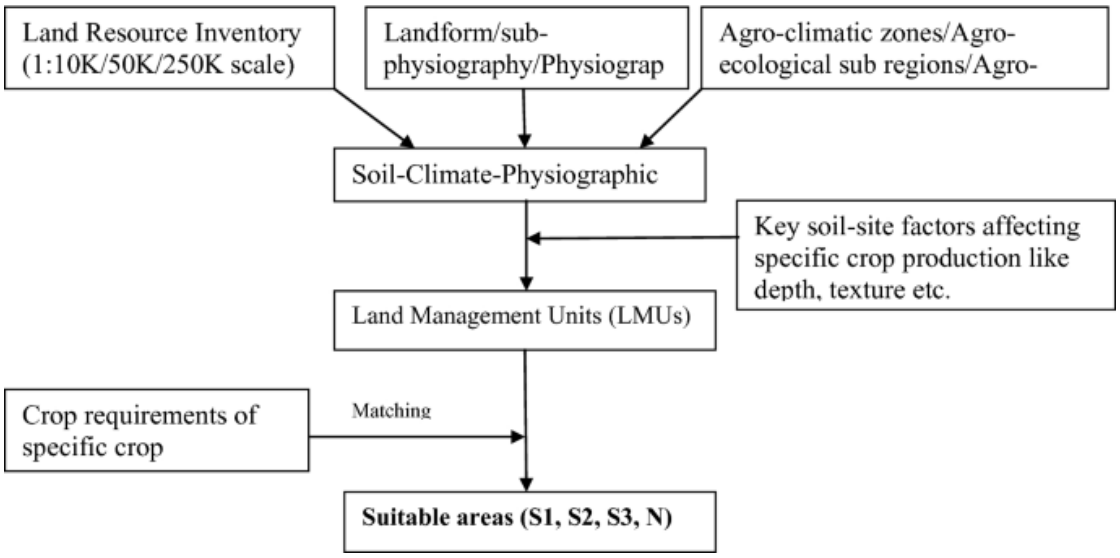

Figure 1. Land Evaluation Process (FAO, 1976)

METHODOLOGY

This study is based on a survey-oriented approach, incorporating direct field observations and the systematic collection of soil samples from designated agricultural and forestry areas outlined in work maps. The collected samples were subsequently subjected to thorough laboratory analysis.

Overlaying baseline maps is crucial for evaluating land suitability, and the outcome of this process is a map of land units. Land unit maps are created by overlaying various thematic maps, including soil, topography, land use, and climate (precipitation) maps.

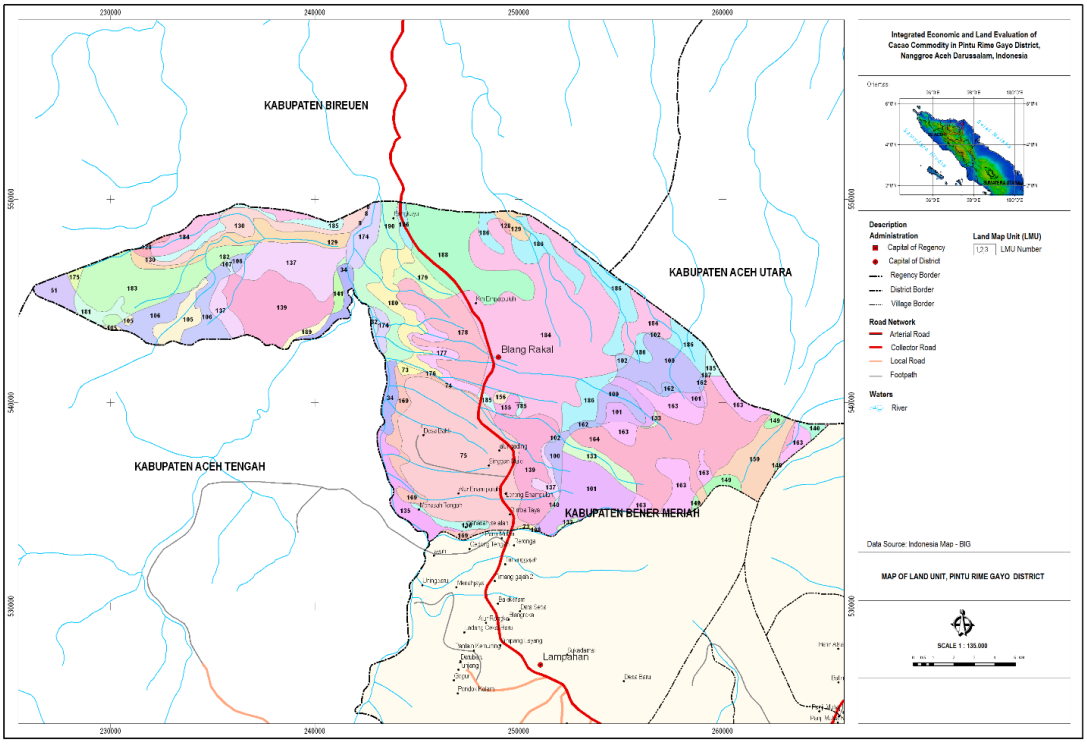

Figure 2. Land Unit Map of Pintu Rime Gayo District

Land Suitability Analysis

The land suitability assessment aims to evaluate how well a specific area can support the cultivation of particular agricultural commodities. This system classifies land into two main categories: Suitable (S) and Not Suitable (N). The Suitable (S) category is further divided into three sub-classes: Highly Suitable (S1), Moderately Suitable (S2), and Marginally Suitable (S3). The classification is determined based on the most significant limiting or restricting factors affecting land productivity.

The land suitability analysis employs geo-statistical techniques and Geographic Information System (GIS) tools to assess the potential of land for key crops within a designated region (Aldabaa & Yousif, 2020). Moreover, analyzing land suitability plays a crucial role in land resource management by identifying the most effective ways to utilize available land. This approach incorporates multi-criteria evaluation and GIS techniques to determine the suitability of specific areas for various applications, including agriculture, urban development, and conservation (Kihoro et al., 2013).

Economic Analysis

Quantitative Economic analysis was carried out to obtain information regarding the financial feasibility of cocoa farming. This analysis, which also includes a study and prediction of income and profits, underscores the crucial role of resource allocation in the success of cocoa farming. The success of managing a cocoa farming business is measured by the substantial income it can generate, resulting from efficient resource allocation.

The formulation method was run using a Microsoft Excel program. Gross Margin and BC-ratio values are calculated based on the highest production value of each commodity on S1 land. Each land is assumed to produce maximum production by referring to (Wood and Dent, 1983), where output in suitability class S1 is ≥ 80% of optimal production, land S2 is between 60% - 80%, land S3 is between 40% - 60%, and land N only produces 40% of optimal production on land S1. Thus, if the same TPL is determined on different SPTs with the same suitability class, the Gross Margin, BC ratio, IRR, and NPV values of the two SPTs will be the same. The assumptions used are at the same level as farm management.

RESULTS AND DISCUSSION

Land Suitability

The land suitability evaluation conducted in this study encompasses the entire Pintu Rime Gayo District area, which includes several villages and has a total analyzed area of 140.01 hectares. The land suitability evaluation for the Cocoa commodity indicated that Pintu Rime Gayo District generally has a marginal land suitability (S3) level with varied limiting factors. The land suitability level for cocoa commodities in the Pintu Rime Gayo District is marginally suitable (S3) with varying limiting factors. Still, after being reassessed by overcoming the limiting factors, the potential suitability class becomes quite suitable (S2). For areas with value, the actual suitability is N1(temporarily not suitable); then, the land suitability class becomes marginally suitable (S3). Complete results for land suitability for cocoa commodities in the Pintu Rime Gayo District are detailed in Table 1 and Figure 3.

Table 1. Land Suitability of Cocoa in Pintu Rime Gayo District

Land Unit	Land Suitability		Land Unit	Land Suitability	
	Actual	Potential		Actual	Potential
3	S3 eh,rc,wa	S2: eh	130	S3: eh,rc,wa	S2: eh,rc
8	S3: rc,wa	S2: eh	133	N1: eh	S3: eh
12	S3: rc,wa	S2: eh	135	S3: eh,rc,wa	S2: eh,rc
21	S3: rc, wa	S2: eh	136	S3: eh,rc,wa	S2: eh,rc
25	N1: eh, rc	S3: rc	137	S3: eh,rc,wa	S2: eh,rc
26	S3: eh,rc,wa	S2: eh,rc	141	S3: eh,wa	S2: eh
27	S3: rc, wa	S2: rc	142	S3: eh,rc,wa	S2: eh,rc
28	S3: rc, wa	S2: rc	149	N1: eh,rc	S3: eh
32	N1: eh, rc	S3: rc	150	N1: eh	S3: eh
34	S3: eh,rc,wa	S2: eh,rc	155	S3: eh,rc,wa	S2: eh,rc
40	N1: eh, rc	S3 eh	156	S3: eh,rc,wa	S2: eh,rc
41	S3: eh,rc,wa	S2: eh,rc	157	S3: eh,rc,wa	S2: eh,rc
49	S3: eh,rc,wa	S2: eh,rc	162	S3: eh,wa	S2: eh
50	S3: eh,rc,wa	S2: eh,rc	163	S3: eh,rc,wa	S2: eh,rc
58	S3: eh,rc,wa	S2: eh,rc	169	S3: eh,rc,wa	S2: eh,rc
59	S3: eh,rc,wa	S2: eh,rc	170	S3: fh,rc,wa	S2: fh,rc
67	N1: eh,rc	S3: eh	173	S3: eh,rc,wa	S2: eh,rc

Land Unit	Land Suitability		Land Unit	Land Suitability	
	Actual	Potential		Actual	Potential
73	N1: eh	S3: eh	174	S3: eh,rc,wa	S2: eh,rc
74	S3: eh,rc,wa	S2: eh,rc	175	S3: eh,rc,wa	S2: eh,rc
75	S3: eh,rc,wa	S2: eh,rc	176	S3: eh,rc,wa	S2: eh,rc
76	S3: eh,fh,wa	S2: eh,fh	177	N1: eh	S3: eh
79	S3: eh,rc,wa	S2: eh,rc	178	S3: eh,rc,wa	S2: eh,rc
81	S3: eh,rc,wa	S2: eh,rc	179	S3: eh,rc,wa	S2: eh,rc
83	S3: eh,rc,wa	S2: eh,rc	180	S3: eh,rc,wa	S2: eh,rc
94	S3: eh,fh,na	S2: eh,fh	181	S3: eh,rc,wa	S2: eh,rc
100	N1: eh	S3: eh	182	S3: eh,rc,wa	S2: eh,rc
101	S3: eh,rc,wa	S2: eh,rc	183	N1: eh	S3: eh
102	S3: eh,rc,wa	S2: eh,rc	184	S3: eh,rc,wa	S2: eh,rc
103	N1: eh	S3: eh	185	S3: eh,rc,wa	S2: eh,rc
105	N1: eh,rc	S3: eh	186	S3: eh,rc,wa	S2: eh,rc
106	S3: eh,rc,wa	S2: eh,rc	187	S3: eh,rc,wa	S2: eh,rc
125	S3: eh,rc,wa	S2: eh,rc	188	S3: eh,rc,wa	S2: eh,rc
128	S3: eh,rc,wa	S2: eh,rc	189	S3: eh,rc,wa	S2: eh,rc
129	S3: eh,rc,wa	S2: eh,rc	190	S3: eh,rc,wa	S2: eh,rc

Source: Result of Analysis, 2024.

Several limiting factors for the development of cocoa commodities that can be identified in the analysis process are water availability (wa), rooting media (rc), nutrient availability (na), flood hazard (fh), and erosion hazard (eh).

Land suitability for Cocoa cultivation is a complex issue influenced by various factors such as climate, soil properties, agronomic practices, and land management. Research emphasizes the importance of considering natural and anthropogenic factors to assess land suitability for Cocoa production (Scaccabarozzi et al., 2020). A practical example of this is seen in the adaptation strategies for cocoa in West Africa, which underscore the importance of factors like tolerance to high temperatures, promoting shade trees in cocoa farms, and intensifying cocoa production in suitable areas(Schroth et al., 2016). This practical application further reinforces the significance of understanding these factors for sustainable Cocoa cultivation. Soil properties and agronomic factors are also crucial in determining cadmium concentrations in Cocoa beans, highlighting the importance of understanding soil characteristics for sustainable Cocoa cultivation (Argüello et al., 2019).

Assessing land suitability for Cocoa is not just a theoretical exercise. It involves aligning land characteristics such as climate, slope, soil type, and fertility with the practical requirements for Cocoa cultivation (Malik et al., 2021). Studies have evaluated land suitability for Cocoa in specific regions, emphasizing the practical implications of optimizing land use based on potential land suitability levels and factors limiting Cocoa plant development (Stibis et al., 2022). Furthermore, evaluating land suitability for Cocoa includes considering the ecophysiological characteristics of different Cocoa varieties, which directly affects their suitability for cultivation in specific environments (Tezara et al., 2016).

Understanding the suitability of land for Cocoa cultivation is a multifaceted task. It requires a comprehensive comprehension of Cocoa's physiological reactions to its surroundings and its capacity to withstand the impacts of climate change. Our study focuses on the genotypic variation within Cocoa canopies and tree structure, elements that significantly influence the suitability of Cocoa cultivation under varying environmental conditions (Lahive et al., 2018). Agroforestry systems, particularly Cocoa agroforests, are not just a part of the solution, they are the solution. They play a critical role in conserving soil biota, preventing erosion, and promoting sustainable land use, all while maintaining viable yields. This underscores the significance of implementing sustainable land management methodologies in Cocoa cultivation (Possú et al., 2022).

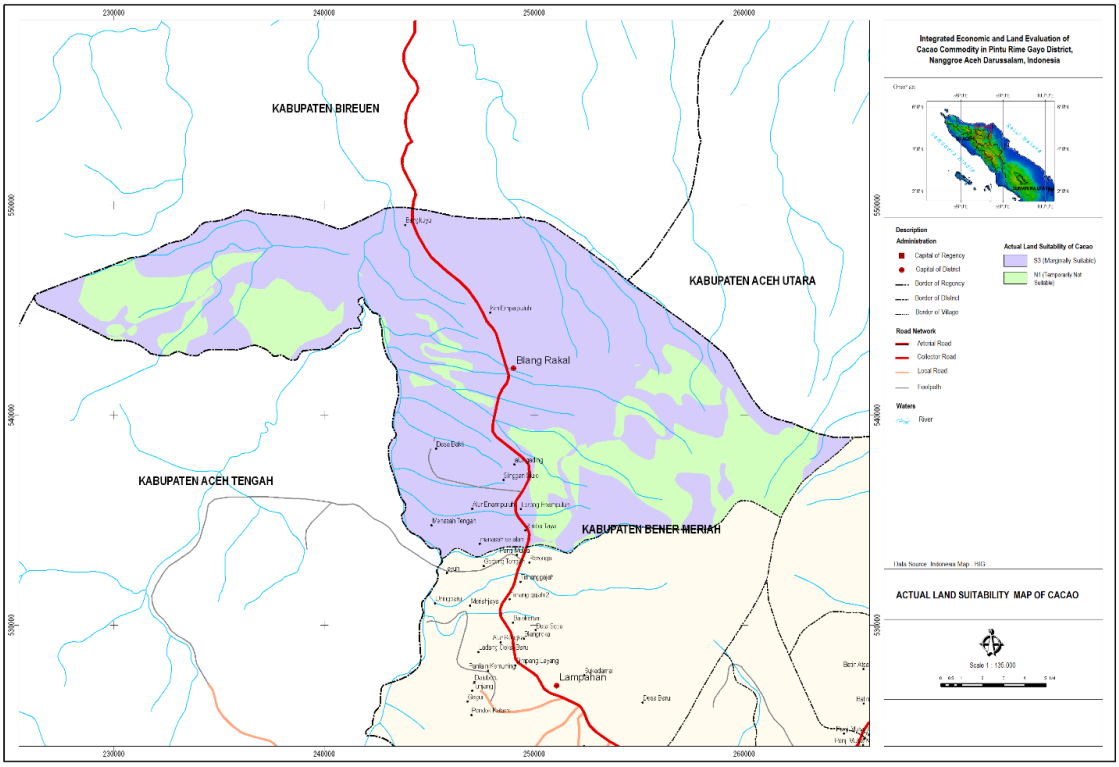

Figure 3. Actual Land Suitability of Cocoa in Pintu Rime Gayo District

Economic Analysis

The land use for annual cocoa crops in the study location generally has a suitability level of S3 (marginally suitable) and N1 (Temporarily Not Suitable). A description of the quantitative economic analysis results for cocoa cultivation is presented below. Importantly, the complete quantitative analysis results (S1 to N) are readily available in tabular form in Table 2.

Land Suitability Class S1

The price of dry cocoa beans per kilogram at the study location is IDR 8,650. Based on calculations, IDR's gross margin or profit can be obtained with this price level: IDR 4,849,962/ha/year, and a BC ratio of 2.48. A BC ratio of 2.48 means that for every use of one unit of capital, you will receive revenue of 2.48 times the initial capital. Based on quantitative analysis, an IRR value of 26.04 was obtained and an

NPV value of 20,254,402. The IRR value of 26.04 indicates that land use for cocoa is worth cultivating on land with a suitability level of S1 because the value is > 15% (interest rate). Meanwhile, the NPV value of 20,254,402 shows that land use for cocoa plants is profitable, which can be seen from the positive NPV results. The assessment of gross margin, BC ratio, IRR, and NPV above shows that the land in the study area in the S1 suitability class is suitable for cultivating cocoa plants.

Land Suitability Class S2

The price of dry cocoa beans per kilogram is IDR 8,650, resulting in a gross margin or profit of IDR 3,251,442/ha/year, and a BC ratio of 1.68. A BC ratio of 1.68 means that for every use of one capital unit, you will receive a revenue of 1.68 times the initial capital. The IRR value obtained is 21.22, while the NPV value is 6,088,692. These figures not only demonstrate the financial feasibility of cocoa cultivation but also indicate a profitable venture. The NPV value of 6,088,692, in particular, shows that land use for cocoa plants is quite profitable because it has a positive value. From the assessment of gross margin, BC ratio, IRR, and NPV, it is clear that the land in the study area, which has suitability class S2, is an excellent choice for cultivating cocoa plants.

Land Suitability Class S3

The price of dry cocoa beans on the market is IDR 8,650 per kilogram, a gross margin or profit of IDR 1,652,922/ha/year, and a BC ratio of 0.93. A BC ratio of 0.93 means that you will receive a revenue of 0.93 times the initial capital for every use of one unit of capital. The IRR value obtained was 15.33, while the NPV value was 684,848. From this review, the IRR value of 15.33 shows that using brownfield land is quite feasible to cultivate because the value is > 15% (interest rate). Meanwhile, the NPV value of –684,848 shows that land use for cocoa is not profitable because it has a negative value. Based on the overall analysis results, only the calculation of the BC Ratio and NPV values is less profitable; however, if the gross margin and IRR values are assessed, it can still be feasible. Overall, it can be concluded that the land at the study location with a suitability class of S3 is less suitable for cultivating cocoa plants.

Ownership of critical resources like land and labor significantly impacts efficiency in agricultural production (Rahman and Rahman, 2009), highlighting the importance of resource ownership in economic farming analysis. Assessing land suitability for Cocoa cultivation by matching land characteristics such as climate, soil type, and fertility with Cocoa cultivation requirements is crucial for optimizing production (Malik et al., 2021). Understanding farmers' economic and ecological adaptation based on land resources and climate change risks is essential for sustainable economic resilience in agriculture (Jumiyati et al., 2021).

Table 2. Quantitative Economic Analysis of Cocoa Based on Land Suitability Class in Pintu Rime Gayo District

Description	Land Suitability Class		
	S1	S2	S3
Dry Bean Price (IDR/kg)	8,650	8,650	8,650
Gross Margin (IDR/ha/year)	4,849,946	3,251,442	1,652,922
BC ratio	2.48	1,68	0.93
IRR	26.04	21,22	15.33
NPV	20,254,402.5	6,088,692.4	- 684,848.4

Source: Result of Analysis, 2024

Additionally, incorporating livelihoods in biodiversity conservation, such as promoting Cocoa agroforestry systems, can serve as a viable livelihood strategy while conserving biodiversity (Dahlquist et al., 2007). Furthermore, the economic viability of Cocoa farming is influenced by factors such as soil fertility, nutrient uptake, and using fertilizers to enhance sustainable cultivation practices (Dogbatse et al., 2021). The minimum land size required for sustainable Cocoa cultivation to meet family needs and develop farming sustainably has been identified as 2.47 hectares (Murniati et al., 2022). Moreover, promoting biodiversity-friendly Cocoa farming practices and expanding protected areas not only enhance the economic sustainability of Cocoa farming but also contribute to conservation efforts, emphasizing the benefits of sustainable farming practices.

CONCLUSIONS AND RECOMMENDATIONS

The land suitability evaluation for the Cocoa commodity indicated that Pintu Rime Gayo District generally has a marginal land suitability (S3) level with varied limiting factors. The land suitability level for cocoa commodities in the Pintu Rime Gayo District is marginally suitable (S3) with varying limiting factors. Several limiting factors for the development of cocoa commodities that can be identified in the analysis process are water availability (wa), rooting media (rc), nutrient availability (na), flood hazard (fh), and erosion hazard (eh).

The price of dry cocoa beans on the market is IDR. 8,650 per kilogram, a gross margin or profit of IDR 1,652,922/ha/year, and a BC ratio of 0.93. A BC ratio of 0.93 means that you will receive a revenue of 0.93 times the initial capital for every use of one unit of capital. The IRR value obtained was 15.33, while the NPV value was 684,848. From this review, the IRR value of 15.33 shows that using brownfield land is quite feasible to cultivate because the value is > 15% (interest rate). Meanwhile, the NPV value of –684,848 shows that land use for cocoa is not profitable because it has a negative value. Based on the overall analysis results, only the calculation of the BC Ratio and NPV values is less profitable; however, if the gross margin and IRR values are assessed, it can still be feasible. Overall, it can be concluded that the land at the study location with a suitability class of S3 is less suitable for cultivating cocoa plants.

FURTHER STUDY

The study on the Integrated Economic and Land Evaluation of Cocoa Commodity in Pintu Rime Gayo District Nanggroe Aceh Darussalam Indonesia explores the feasibility of cocoa cultivation in Bener Meriah Regency particularly in Pintu Rime Gayo District, suggesting that further improvements in land management and agricultural practices are required future research should focus on overcoming these limiting factors through soil enhancement water management and improved farming techniques as well as exploring policy support to enhance the economic sustainability of cocoa cultivation in the region.

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