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Impact of agricultural infrastructure development on inequality and optimization equality of farmers' income in Indonesia-Timor Leste Border Area

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ABSTRACT
This research aims to analyze income inequality and the factors determining inequality, as well as the allocation of land resources that optimize income distribution. The research is a continuation of previous research that found production and income growth as a result of the construction of the Roticlot Dam in the border area of Indonesia and TimorLeste. The research used survey methods in Fatuketi Village, the location of agricultural infrastructure (Rotiklot Dam) in the Indonesia and Timor Leste Border Area. Data analysis uses Gini, Tobit ratios, and linear programming. The results of the Gini ratio analysis show that there has been a decrease in income inequality from medium (Gini Ratio = 0.44) to low (Gini Ratio = 0.26); and the results of the Tobit analysis state that the factor that has a significant positive effect on income inequality is land area, while farmer independence, the number of family dependents, and business capital have a significant negative effect. Furthermore, land resource factors that have a positive influence on income distribution are allocated appropriately and fairly so that income equality is achieved, namely IDR 3,732,692.81 (Gini Ratio = 0.00, which is a very low level of income inequality). It is recommended that agrarian reform through the distribution of additional land be adjusted to the existing conditions of land area, income, availability of water resources, and socio-economic factors.

Contribution/Originality: The originality of the research is the impact of production and income growth on the increasingly equal distribution of income and the factors that cause it. This year's research findings relate to reducing income inequality caused by technical and socio-economic factors so that appropriate land distribution can optimize income distribution.

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1. INTRODUCTION
The new development paradigm has changed the perspective of development, which is more directed at growth and equity (Rustiadi, Saefulhakim, & Panuju, 2011). Infrastructure development is an important aspect of spurring economic growth because it has an impact on expanding access, creating new jobs, and increasing income in a

sustainable manner. The development of agricultural infrastructure has an impact on the emergence of new economic growth locations, so that other regions will also grow and develop simultaneously according to the potential of their respective regions.

The characteristics of the Indonesia and Timor Leste Border region are dry land with a dry climate, which causes low agricultural production and makes it an underdeveloped area both in terms of infrastructure and human resources. The backwardness experienced is one of the causes of the high poverty rate, with an average of around 20%, according to the Central Bureau of Statistics (2023). The development of agricultural infrastructure, especially dams, aims to facilitate access to water resources so as to increase agricultural production and productivity as well as farmers' income.

The development of agricultural infrastructure, especially those related to water supply, is a priority in the Indonesia and Timor Leste border region. The establishment and enhancement of agricultural infrastructure can serve as a vaiable approach to address the differences in econmoic development across different regions. The Rotiklot Dam has been operating since 2019 with the aim of meeting the water needs of agricultural areas, which has an impact on increasing the productivity of rice and corn plants, which has implications for increasing farmers' income (Li, Cao, Qiu, & Li, 2020).

Increasing agricultural production through agricultural extensification with the use of marginal land and the availability of water resources can increase the cropping index, which was originally one growing season to two growing seasons (Sutrisno & Hamdani, 2019; Taena, Sipayung, Blegur,& Klau, 2023). Farmers who use water sources from dams have better technical efficiency than farmers who do not use water sources from dams (Shabanzadeh-Khoshrody, Azadi, Khajooeipour, & Nabavi-Pelesaraei, 2016). Alhader (2020) argues that farmers around the dam do not only use agricultural land for food crops but also aim for horticultural crops and animal husbandry so that their income becomes higher. Farmers who are near the dam are more empowered and tend to be more active, resulting in higher production and income (Cheruiyot & Nge'tich, 2022; Rasyid, Kristina, Wantara, & Jumali, 2023; Sipayung, Fobia, Taena, & Joka, 2021).

The production of food crops, horticulture, and livestock increases supply to the city of Atambua as one of the centers of national strategic activities because these commodities have a comparative advantage over the use of the Rotiklot Dam (Taena, Sipayung, Blegur, & Klau, 2023). In addition, it can be used for export because of its close proximity to Timor-Leste. Increased production and income have implications for increasing economic growth, but the consequences may not necessarily be felt by all people, as Adam, Nusantara, and Muthalib (2017) and Vo, Vo, and Le (2019) show that economic growth is positively correlated with income inequality. The findings are different from those (Sukmaadi & Marhaeni, 2021) in that if planning and resource allocation are carried out properly, economic growth can simultaneously reduce income inequality.

The increase in income as a result of the roticlot dam is expected to be evenly distributed. The difference in income distribution results in income inequality for farmers. Kata and Wosiek (2020) states that income inequality can be caused by differences in production factors owned by farmers. In addition, Vo et al. (2019) stated that differences in labor participation and the implementation of socio-economic policies cause income inequality. Differences in technical production and socio-economic factors among farmers cause differences in production and income and have an indirect impact on inequality.

Agricultural production factors include agricultural technical factors (covering the planting area and number of types of businesses) and socio-economic factors (covering education, farmer independence, the ability to access information, group activity, cooperation, and venture capital). Technical factors of agricultural production and farmers' socio-economic influences on the empowerment of farmers in the Indonesia-Timor Leste border area. Research (Gushendri & Sentosa, 2023; Nugraha, Prayitno, Situmorang, & Nasution, 2020; Zolfaghari, Kabiri, & Saadatmanesh, 2020) states that the combination of economic infrastructure development and social infrastructure contributes to reducing income inequality. Another opinion from Nurdina (2021) and D'Onofrio and Giordani (2019) is that infrastructure development increases income inequality in society.

The different impacts generated by infrastructure development depend on the utilization of production factors including the social and economic capital of the people in a region (Vasilyeva, Bilan, Bagmet, & Seliga, 2020). Factors of agricultural production in border areas include: technical and socio-economic factors are used to utilize the agricultural infrastructure that has been built (Rotiklot Dam) so that there is an increase in income and equity, or income inequality. The novelty of this study is that itanalyzes income inequality and its causative factors as a result of the development of agricultural infrastructure in the Indonesia-Timor Leste border region, as well as an optimization model for equal distribution of farm income. The results of this study form the basis for recommending agricultural development policies in the Indonesia and Timor Leste border region.

2. RESEARCH METHOD

2.1. Research Locations

The research was carried out in the Indonesia-Timor Leste Border Area, specifically Fatuketi Village, KakulukMesak District, Belu Regency, which is shown in Figure 1, where the image data is obtained from Ina-Geoportal, which is a national geoportal in Indonesia that connects various ministries, institutions, provinces and regions that are the connecting partners for the National Geospatial Information Network node. Data collection was carried out in April-June 2023.

2.2. Data Collection

The research data uses primary data obtained from farmers in Fatuketi Village. Data obtained by conducting interviews and observations. The variables used in this study are the Gini ratio, technical factors, and socio-economic characteristics of farmers in Fatuketi Village. The population of this study was all farmers in Fatuketi Village, KakulukMesak District. The heads of farming families are 4,500. The number of samples is determined to be 300 households; the larger, the lower the error rate (Cuddeback, Wilson, Orme, & Combs-Orme, 2004; Hamed, 2017). The sample was determined using a purposive method with consideration of representing the diversity of ownership of the production factors of farmers in Fatuketi Village.

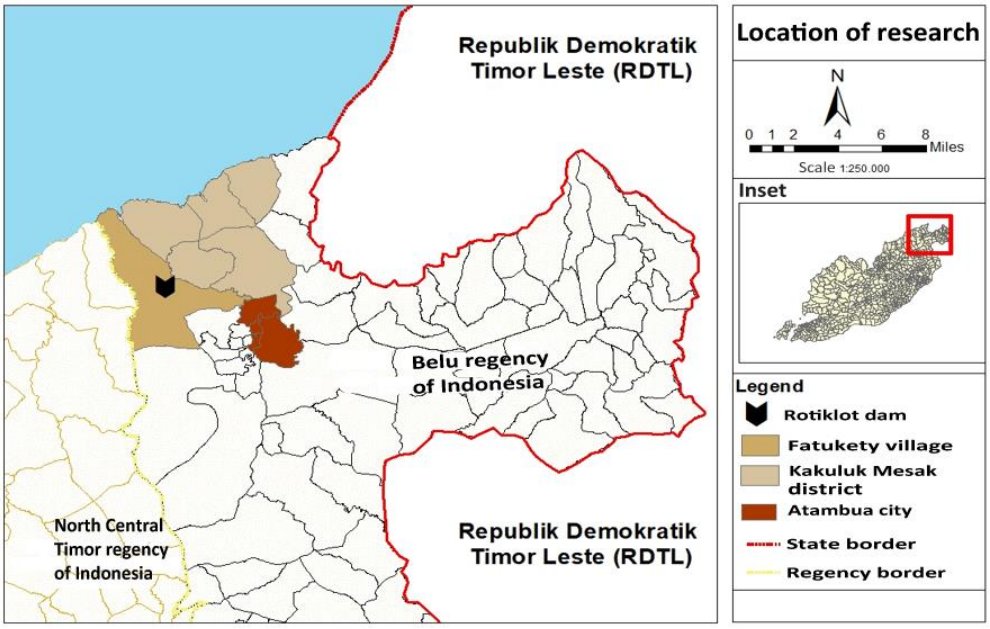

Figure 1. Map of research location.

Source: INA geoportal.

2.3. Data Analysis

Data analysis begins with an analysis of farmers' income from food crop, horticulture, and/or animal husbandry businesses. The results of the income analysis are grouped into five income groups for inequality analysis. Moreover, the examination of inequality includes the examination of both technical and socio-economic aspects. Additionally, one approach to understanding the reasons of inequality involves considering a specific causative element as a means of identifying restrictions that maybe addressed to enhance income equality. The data analysis framework is shown in Figure 2.

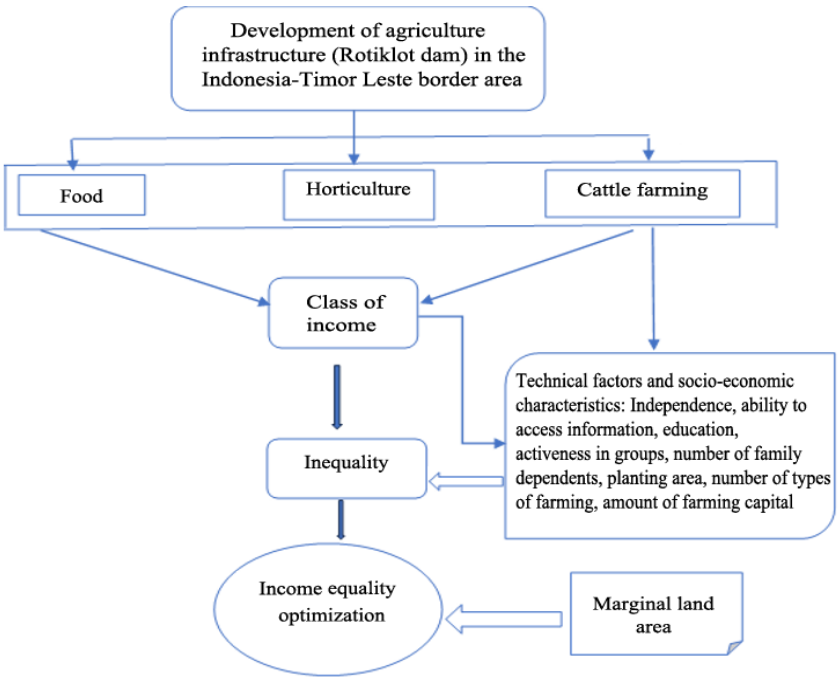

Figure 2. Flowchart of data analysis.

To analyze income inequality using the Gini ratio value with the following formula:

$$GR = 1 - \sum f_i (Y_i + Y_{i-1}) \quad (1)$$

Information:
GR = Gini ratio.
fi = Proportion of the total population.
Yi = proportion cumulatively the total income of the community up to class i.
Yi-1 = Cumulative percentage of income up to class i.
To analyze the factor of income inequality using Tobit regression analysis with the model used as follows:

$$P = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_9 X_9 + e \quad (2)$$

Information:
Q: The probability of the number of farmers with a certain income.
X1: Farmer independence.
X2: Planted area cultivated by farmers.
X3: Length of farmer's education.
X4: Farmers' ability to access information.
X5: Activeness of farmers in groups.
X6: Dummy number of farming sectors carried out by farmers (0= if farmers only cultivate food crops/horticultural crops; 1= if farmers cultivate food crops/horticulture and add livestock; 2; if farmers cultivate food crops, horticulture, and livestock).
X7: Number of dependents of the farming family.
X8: Amount of farmer's farming capital.
X9: The ability of farmers to cooperate.

To analyze the optimization of the distribution of income of farmers using the distribution of marginal land based on the initial income of farmers. The available marginal land is 300 ha. Palayukan (2021) stated that optimizing income distribution with limited resource allocation (such as: increasing planting area) uses linear programming. The linear programming model is solved using LINGO software.

The objective function of the linear program (Z) is to determine the maximum income for each farmer after managing marginal land as agricultural land. The constraint functions of the linear program are: (1) the addition of planting area for each farmer originating from marginal land does not exceed the available marginal land area, (2) the amount of initial income and the additional income from increasing planting area must be evenly distributed for each farmer, (3) non-negative constraints for all variables to ensure that there is no reduction in planted area and farmer income. The Linear Program Model is:

$$\begin{aligned} &\max Z = z \\ &\sum_{i=1}^{300} X_i \leq 30{,}000 \\ &AVGI \cdot X_i + I_i^{-1} = z, \forall i = 1, 2, \ldots, 300 \\ &X_i \geq 0, \forall i = 1, 2, \ldots, 300 \\ &z \geq 0 \end{aligned} \quad (3)$$

Information:
i :Farmer index (i=1,2,…,300).
X_i :Additional planting area from marginal land for farmer i (are).
I_i^{-1}:Initial income of farmer i (IDR).
AVGI:Average income of farmers from each acre of planted area (IDR 16,266.38).

3. RESULTS AND DISCUSSION

3.1. Income Inequality and Factor Causing Analysis

3.1.1. Income Inequality Analysis

The Rotiklot Dam, which was built in the Indonesia-Timor Leste border area, has an impact on the distribution of infrastructure provision in the border areas, which are classified as lagging, backward, and frontier areas. An equal distribution of infrastructure development is also expected to reduce income inequality. After the dam, farmers generally carry out farming for two growing seasons, with more diversified farming (food, horticulture, and/or animal husbandry). Decision-making in farming affects agricultural production and productivity as well as farmers' income (Jha & Gupta, 2021), which in turn has an impact on decreasing or increasing income inequality.

Todaro and Smith (2009) provide a limitation that countries with high inequality have a Gini coefficient of 0.51-0.70, and are classified as very high when the coefficient value is 0.71-1; while countries with relatively low inequality or evenly distributed Gini coefficients, namely 0.21-0.35; and very low inequality with a coefficient of 0.00-0.20 and inequality is classified as medium if the Gini ratio coefficient is 036-0.50. Based on the results of the Gini ratio analysis for farmers in the Indonesia-Timor Leste border region in 2021, a Gini ratio index value of 0.44 is obtained, so the income inequality level of farmers in border areas is categorized as medium. This condition occurs because farmers generally do farming specifically for food crops, and a small number of farmers do cattle farming in large quantities.

The results of the analysis state that the Gini coefficient has decreased in 2022 to 0.28, which means that the level of income inequality is categorized as low or that there is a tendency for income distribution among farmers in

the Indonesia-Timor Leste border region. This is in line with research (Molebila, Latuan, & Lutang, 2022; Zega, Mursalin, & Yudhistira, 2022), which states that the level of inequality in farmer income is low. After 3 years of operation of the dam, farmers adapted well so that the type of farming began to experience an increase from seasonal food crops to 2 seasons of food crops or 1 season of food crops and 1 season of horticultural crops. Income inequality will drop to a very low category (<0.20) if the inequality factor is analyzed properly so that the allocation of resources is carried out correctly.

3.1.2. Analysis of Factors Causing Income Inequality

The results of the analysis of factors that influence income inequality in the Rotiklot Dam service area are shown in Table 1.

Table 1. Results of analysis of factors influencing inequality in the Indonesia-Timor leste border area.

Variabel	Margin effect	Standard error	Prob.
X_1	-0.014	0.009	0.108[c]
X_2	0.015	0.005	0.002[a]
X_3	-0.001	0.001	0.70
X_4	-0.000	0.004	0.226
X_5	-0.003	0.010	0.76
X_6	0.003	0.003	0.985
X_7	-0.004	0.000	0.099[b]
X_8	-0.006	0.010	0.081[b]
X_9	-0.006	0.003	0.555

Note: a, b, and c significant on α: 5% ,10%, and 20%.

The analysis results in Table 1 can be written in the following equation, and described in the following section.

$$Y = 0.2255 - 0.01382X_1 + 0.01505X_2 - 0.00007X_3 + 0.00348X_4 - 0.00294X_5 - 0.00008X_6 - 0.00134X_7 - 0.00612X_8 - 0.00599X_9 \quad (4)$$

Table 1 presents an analysis of several factors that influence the income gap between farmers in the border areas of Indonesia and Timor Leste as a result of the rotiklot dam. Factors that significantly affect income inequality are farmer independence, land area, the number of family dependents, and business capital. First, farmer independence. The independence of farmers in the Indonesia-Timor Leste border region has a significant negative effect on income inequality. The independent attitude of farmers who are in the dam service area reduces the chance that the number of farmers with higher incomes is 1.38%, so that the percentage of farmers with lower incomes is higher, causing income inequality. Traditional farmers in the Indonesia-Timor Leste regionare still bound by very strong customs. They have some difficulties working independently because they do not have the technology that requires agricultural labor. Groups of farmers provide agricultural labor, allowing farming to be managed with group assistance. Sudarko, Sumardjo, Fatchiya, and Tjitropranoto (2020) have a different opinion in the case of coffee farmers, the independence of farmers supports increased income from their farming. Groups or institutions owned by farmers support the independence of farmers.

Second, land area. The increase in the area of agricultural land due to the availability of better water resources from dams has a positive and significant effect on the Farmers have the chance to earn a 1.5% increase in income.Farmers residing in border regions employ adaptive strategies to enhance water availability, primarily through the expansion of land area, hence leading to amplified agricultural output and income. It impacts the increase in agricultural land area and income. An increase in farmer income with an unbalanced percentage can cause inequality. Abdul - Salam and Phimister (2017) and Sugiarto, Nur, Djatmiko, Wakhidati, and Einstein (2019) stated that the addition of land area causes differences in the technical efficiency of farming due to differences in the ability to access agricultural information and intellectual abilities of farmers, so that it affects the income of the resulting farming.

Third, the number of family dependents. The number of family dependents has a negative and significant effect on the opportunities for the number of farmers with better incomes in border areas. The number of family dependents reduces the probability that the number of farmers with better incomes is 0.4%, which means that the percentage of farmers with low incomes is increasing, resulting in income inequality. Increasing family dependents increases the expenditure costs of farming families in border areas. The number of large families is a potential source of farm labor if productivity is high, and vice versa, it becomes a burden if productivity is low. Farming families in border areas have strong socio-cultural attachments, so social activities are higher than efforts to increase production and productivity, resulting in income inequality for farmers who have a small number of family dependents but focus on developing their farming businesses. Sasmi, Susanto, Mula, and Alatas (2022) argue that the number of dependents of the farming family, which is a source of labor, has a negative effect on farm production and income due to the inefficiency of farming.

Fourth, the amount of farming capital. The amount of farming capital has a significant and negative effect on the opportunities for the number of farmers with high incomes. The amount of farming capital reduces the probability of high number of high-income farmers by 0.5%, thereby contributing to income inequality. The capital farming issues in the service area of the roticlot dam in the border area are inversely proportional to the profits they get. Low

technological adaptation causes the use of capital that does not produce high production and productivity. Low financial management ability is also one of the causes, according to the opinions of Wang, Ma, Li, and Xue (2022) and Suh, Njimanted, and Thalut (2020) that good farmer management capabilities increase the adaptability and technical efficiency of agriculture so that it has implications for increasing agricultural production and farmer income. The factor that significantly increases the income of farmers is land area, on the other hand, the factor thatsignificantly decreases the income is the independence of farmers, the number of family dependents, and business capital. Therefore, an optimization analysis is needed to increase income by increasing the land area proportionally so that there is an equal distribution of income for farmers in the Indonesia-Timor Leste border area. Lin, Ma, Zhu, and Cui (2022) stated that the allocation of land resources with the socio-economic transformation of the community will produce effective innovations, thereby realizing an equal distribution of income.

3.2. Income Equality Optimization

The addition of agricultural land area due to an increase in the availability of water resources will increase the production and income of farmers, as is the opinion of Campenhout (2021) that the allocation of resources must take into account the equity and efficiency of farming, also agreements between farmers. The equitable and balanced allocation of land resources is conducted by considering land area, while income distribution is enhanced through several approaches to achieve a more equal distribution of revenue. The results of the analysis state that the initial income of farmers is around IDR 150,000 to IDR 3,200,000. The existing land area ranges from 15 to 200 acres with an average of 80.23 acres.

The results of the optimization analysis using LINGO software stated that the allocation of land resources ranging from 32.75 acres to 220.25 acres, with an average of 153.06 acres will increase revenue from IDR 532,692.79 to IDR 3,582,693.47 so that there is an equal distribution of income at IDR 3,732. 692.81. The average income of farmers increased by 200.31%, from IDR 1,242,940.41 to IDR 3,732,692.81. Chen, Restuccia, and Santaeulàlia-Llopis (2022) the effect of land relocation increases agricultural productivity and income. The results of the analysis are shown in Table 2 and Figure 3.

Table 2. Optimization results for equal income.

No	Initial income (IDR)	Increased allocation of planting area (Are)	Increased income due to additional planting area (IDR)	Equitable income (IDR)
1	1,800,000.000	118.815	1,932,693.466	3,732,693.466
2	800,000.000	180.292	2,932,692.091	3,732,692.091
3	2,600,000.000	69.634	1,132,692.777	3,732,692.777
⋮	⋮	⋮	⋮	⋮
299	2,000,000.000	106.520	1,732,693.416	3,732,693.416
300	1,150,000.000	158.775	2,582,693.223	3,732,693.223
Average	1,242,940.408	153.061	2,489,752.404	3,732,692.813

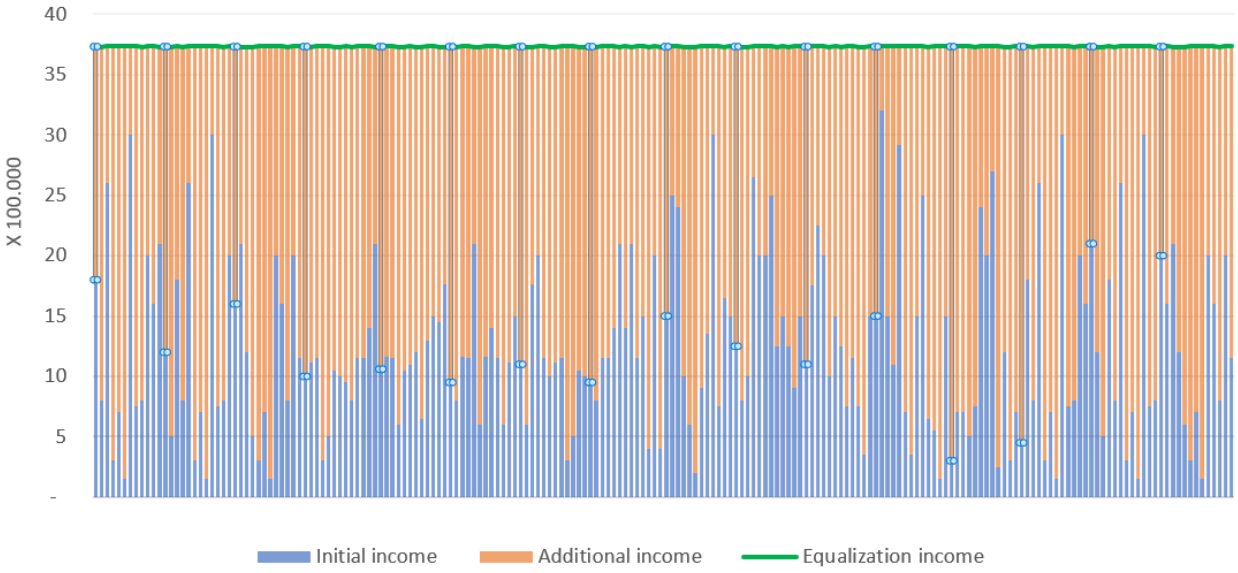

Figure 3. Results of income equality analysis.

4. CONCLUSIONS

Income inequality has decreased from medium to low as a result of the use of the Roticlot Dam. Factors that have a significant positive effect on income inequality are land area, while the independence of farmers, the number of family dependents, and business capital are significantly negative. Therefore, the addition of land area proportionately increases farmers' income until it reaches equal distribution of income at IDR 3,732. 692.81. The

study recommends land distribution in a balanced proportion with the availability of socio-economic factors, and further studies are needed on institutional and environmental aspects.

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Institutional Review Board Statement: The Ethical Committee of the Timor University, Indonesia has granted approval for this study on 17 April 2023 (Ref. No. 03/UN60.60/PP/2023).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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