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RESEARCH ARTICLE

The Economic Valuation of Ricefield Conversion into Geothermal Plant Installation in Lahendong, North Sulawesi Province, Indonesia

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ABSTRACT

This research aimed to identify the impacts of rice fields conversion into geothermal plant installation, and the amount of lost economic benefits, in Lahendong, North Sulawesi Province, Indonesia. Quantitative data were obtained from questionnaires distributed to rice fields farmers to understand perceptions of the impacts of land conversion and determine the lost economic, environmental, and socio-cultural values. Meanwhile, the sample size was 65 individuals, comprising farmers and landowners. Interview methods were used to obtain information on land and rice prices, production, the amount and price of fertilizers, pesticides, labor and tractor power. Secondary data in the form of location and area of land converted as well as other supporting data were obtained from existing official agencies. This research found negative impacts on the environment and economy. Total economic value (TEV) lost reached IDR 4,912,057,684 which was distributed as direct use value (DUV) IDR. 4,145,682,000, indirect utility value (IUV) 58,457,520, optional utility value (OUV) 239,438,164, and existence utility value (EUV) 468,480,000. In addition, geothermal energy management provided extensive and comprehensive benefits for various aspects of the economy as well as contributing widely to comprehensive and sustainable economic development.

INTRODUCTION

Geothermal energy has been recognized as a potential renewable source to reduce dependence on fossil fuels and greenhouse gas emissions. Renewable energy source with great potential is geothermal (Idroes *et al*., 2024) produced from within the earth through heat generated by the core (Benti *et al*., 2023). The management has the potential to be a sustainable and environmentally friendly alternative to meeting energy needs (Liu *et al*., 2023). The area with significant geothermal energy is Geothermal Plant Lahendong which has an electricity generation capacity of 120 MW (Darma *et al*., 2021) in Lahendong, North Sulawesi Province, Indonesia. To use the potential of geothermal energy, productive agricultural land is converted into a reactor construction site.

Land-use change, which includes all development activities and the intentional use of land resources, is one of the primary forces behind economic development (Ren *et al*., 2019). During the expansion process, most agricultural land has been converted to industrial (Zhou *et al*., 2020). This land use change, specifically associated with negative impacts on living standards in agricultural and non-agricultural areas, has increased ecological damage (Xie *et al*., 2024). Conflicts arise between

maintaining agricultural land and achieving food security due to the increasing rate of land use change (Fienitz, 2023). Additionally, the complex relationship between global warming and the transition in agriculture shows a global problem. The sectors losing agricultural land produce higher carbon dioxide (CO_2) outputs while those with livestock land produce lower emissions (Sondakh *et al*., 2024).

The conversion can change land use, eliminate food production and income, as well as potentially disrupt the local economic balance (Mirzabaev *et al*., 2023). These functions can be lost when agricultural land is converted into non-agricultural (Fitri *et al*., 2022). Productive agricultural land provides a source of income as well as food security and supports local and regional economies (Sun *et al*., 2024). This land has an important role in supporting food sustainability, rural community life, and environmental sustainability (Achsanuddin *et al*., 2023). The existence of rice fields ensures a stable and affordable supply as the staple food for the majority of the population. Therefore, rice can meet the increasing consumption needs with population growth. This farming sector is also the main driver of the rural economy, providing employment and sources of income and promoting the development of related downstream businesses (Tono *et al*., 2023). Agricultural land, with a special focus on rice fields, plays an important role in ensuring food security and driving the rural economy (Rumawas *et al*., 2021). Rice fields agricultural land contributes to the maintenance of environmental sustainability. In addition, the fields can mitigate floods, conserve water resources, and recycle organic waste (Sumarno, 2012). There is also a significant carbon absorption capacity, acting as a carbon sink to mitigate the impacts of climate change (Svensson *et al*., 2021).

The existence of rice fields is closely related to the socio-cultural aspects of farming communities. The socio-cultural aspects of farming communities are reflected in Minahasa ethnic group where rice fields serve as a source of livelihood for rural communities as well as the basis of identity and cultural values (Eregae *et al*., 2021). The activities are accompanied by various traditional ceremonies, such as Tulude (rice planting), Kasamben (rice harvest), and Mapalus (cooperation) (Karundeng *et al*., 2022). As a social function, the existence shows that farmers' perceptions of the socio-cultural values of agricultural land are high, but the regeneration is relatively very low. Therefore, the perception has an impact on many farming households relating to labor from outside the hamlet or village during the planting and harvest seasons (Ega Agista & Rohmah, 2020). The process of transforming land into a geothermal project site requires a balance between economic benefits and environmental losses (Li *et al*., 2023).

The economic valuation of agricultural land conversion refers to the process of assessing or measuring the value associated with changing land use from agriculture to others (Raihan & Tuspekova, 2022). The purpose is to understand and estimate the economic impacts arising from changes in land use (Sauni H *et al*., 2022). The following are some crucial factors that must be taken into account when valuing agricultural land conversion economically: (a) Converting agricultural land may result in the loss of revenue streams for farmers, crops, or other natural resources whose market, production, or replacement values must be taken into account while evaluating the property's natural assets (Harini *et al*., 2022), (b) The short- and long-term economic effects of converting agricultural land into geothermal energy management installations can vary. The construction of infrastructure, the generation of jobs, and investment spending are examples of short-term effects (Fandani & Harini, 2020). Long-term benefits may include community income, economic growth, modifications to the regional economic structure, and multiplier effects (Fitri *et al*., 2022; Sourokou *et al*., 2023) and (c) Economic valuation must also take into account how the land use change will affect stakeholders, including farmers, local communities, geothermal energy companies, local governments, and other related sectors, and who will directly or indirectly benefit economically from the change (Nguyen *et al*., 2016).

The research specifically examining the economic valuation of agricultural land conversion into geothermal plant installation are very limited. This is because most analyses are focused on the economic valuation of rice fields land conversion for other uses, such as settlements (Liang & Li, 2020; Setyaningsih *et al*., 2023; Syahputra *et al*., 2023), industry (Z. Ahmed *et al*., 2022; Munir *et al*., 2023), airports (Halima *et al*., 2016; Utami *et al*., 2024), and roads (Jedlička *et al*., 2019; Makbul *et al*., 2021). In addition to the benefits of developing geothermal energy infrastructure, there are also drawbacks that impact local farmers. These developments can adversely affect agricultural land,

which is why it's crucial to research the potential impacts. Farmers are facing financial losses due to these projects and are actively opposing them. Research on this topic is essential for policymakers as well as the affected farmers to understand the implications and find solutions. This research is important since the output offers a comprehensive analysis of economic valuation considering the interests of stakeholders and socio-cultural aspects. Therefore, this research aims to identify the impacts of changes in the multifunctionality of agricultural or rice fields, as well as determine the amount of economic benefits lost.

1. METHOD AND MATERIAL

1.1. Research design and data collection

This research design is a descriptive analysis using quantitative and qualitative data to analyze the conversion of rice fields land into Lahendong geothermal energy management facilities using primary and secondary data. Quantitative data collection was carried out through questionnaires distributed to respondents to understand perceptions of the conversion of rice fields land and WTA (willingness to accept) compensation in exchange for the benefits lost from the process. The number of samples was 65 individuals, consisting of farmers and landowners whose land was converted for the construction of the Lahendong geothermal plant facility. Qualitative data were collected through interviews with selected informants who mastered matters regarding land prices, dry grain and rice production, rice market prices, as well as the amount of fertilizers, pesticides, farm labor and tractor power.

1.2. Data Analysis

Questionnaire data was analyzed using Kruskal Wallis Test (Chi-Square) and descriptive statistical analysis. This method analyzed farmers' perceptions of WTA on the conversion of rice fields. Meanwhile, economic valuation of land conversion was carried out using Contingent Valuation Method concept through WTA and Willingness to Pay (WTP) to estimate non-use or passive-use values (Bateman & G.Willis, 1999). Economic valuation based on market prices and replacement costs consists of the following:

a) Direct use value (DUV) is calculated based on the market price for marketable goods and services, such as agricultural production (rice and horticulture). The calculation is based on farmers' income from farming lost due to land conversion, as stated in Equation 1 (Bateman & G.Willis, 1999):

$$DUV = \sum_{i=1}^{n} \{(Q_i.P_r) - (A_i.C_i)\} \quad \textbf{(1)}$$

Where: *DUV* = *Direct use value* (IDR), Q_i = Rice quantity per converted land area (kg/ha), P_r = Rice price (IDR/kg) = IDR. 12,000, A_i = converted rice field area (ha) , C_i = Production cost (IDR/ha), i = No. cluster

b) Indirect use value (IUV) is the utilization value based on the function of the existence of rice fields. This value is calculated based on income from the sale of rice and horticultural waste for compost, according to Equation 2 (Azis *et al*., 2014):

$$IUV = \sum_{i=1}^{n} (Q_i.C_r.P_c) \quad \textbf{(2)}$$

Where: Q_i = Rice production for (kg), C_r = Compost production ratio per kg rice production = 0.06, P_c = Compost price (IDR/kg), i = No. cluster

c) Option use value (OUV) refers to the direct and indirect use of land resources with the potential to be produced in the future. This includes benefits stored or maintained for future interests when there is uncertainty about the availability of resources. The value of the optional benefits is the value of rice fields ecosystem acting as a carbon absorber. The absorption of CO_2 refers to the amount of carbon stock in rice fields of 5 tons/ha using Equation 3 (Harjana, 2010):

$$OUV = \sum_{i=1}^{n} (CS_{RF}.P_C.A_i) \quad \textbf{(3)}$$

Where: CS_{RF} = carbon sequestration from rice field = 6.1 ton/ha, P_C = carbon price (IDR/ton), A_i = converted rice field area (ha), i = No. cluster

d) Existance use value (EUV) is given by an individual because of natural resources and the environment. The value is based on the perception or assumption felt by the community from a social and cultural perspective. The existence value is calculated based on labor and tractor wages, such as Equations 4 and 5 (Bateman & G.Willis, 1999) :

Labor wage value:

$$EUV_L = \sum_{i=1}^{n} (L.P_L.A_i) \quad \textbf{(4)}$$

Where: L = Labors needs (person/ha), P_L = Labor wage (IDR/day), A_i = converted rice field area (ha), i = No. cluster

and tractor power value:

$$EUV_T = \sum_{i=1}^{n} (T.P_T.A_i) \quad \textbf{(5)}$$

Where: T = Tractors ops needs (person/ha), P_T = Tractor wage (IDR/day), A_i = converted rice field area (ha), i = No. cluster

e) Total Economy Value (TEV) is generated due to loss of multifunctional agricultural land and farming. This value is the sum of DUV, IUV, OV, and Existence Value (EV) of agricultural land and farming lost due to land conversion. TEV is calculated based on equation 6 (Bateman & G.Willis, 1999):

TEV = DUV + IUV + OV + EV **(6)**

RESULT AND DISCUSSION

Research Location

This research was conducted at villages of Lahendong, Pangolombian, Tondangow, Kasuratan, Leilem II (Fig. 1). Most of agricultural land has been converted for the construction of Lahendong geothermal energy management facilities.

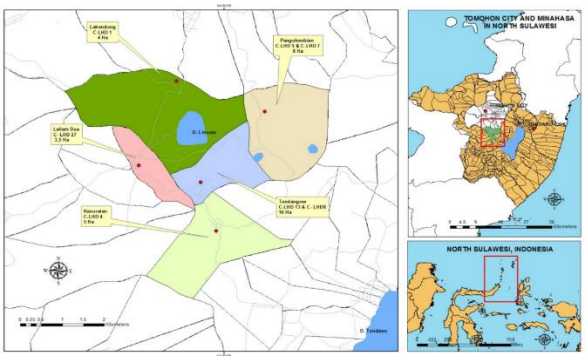

Figure 1: Location of Study

The condition of the population in the villages experienced faster changes. From an economic aspect, the population was relatively advanced and dynamic when compared to the conditions of the surrounding villages. In this context, the community was becoming increasingly heterogeneous, individualistic, and rationalistic. The community behavior increasingly shifted from socially oriented to economically oriented. Kinship-based relationships are gradually giving way to functional linkage-based relationships in terms of relationships and social solidarity. The demographic conditions as shown in Table 1.

Table 1. Demographic conditions

Villages	No. of Citizens	No. of Household	Gender		Working in the sector of		
			Men	Women	Agriculture	Government	Private
Lahendong	2,332	714	1,203	1,129	41%	10%	49%
Pangolombian	2,337	656	1,242	1,095	45%	20%	35%
Tondangow	1,138	617	638	521	40%	21%	39%
Leilem II	1,013	306	480	533	10%	8%	82%
Kasuratan	1,131	333	631	500	49%	23%	28%

The influence of cultural values rooted in sub-ethnicity still stands out, despite the fact that society is becoming increasingly heterogeneous as a result of accelerated development in various fields. The indigenous people of Lahendong, Pangolombian, and Tondangow villages belong to the Tombulu sub-ethnicity, while the Tontemboan sub-ethnicity is represented by the community of Leilem village. The Tolour sub-ethnicity is represented by the community of Kasuratan village in the Remboken sub-district. All of these sub-ethnicities are derived from the Minahasa ethnicity; however, they possess their own orientation values that influence the socio-economic conduct of their communities in a variety of fields, including their response to the management of Lahendong geothermal energy.

1.3. Impact of conversion of rice fields to geothermal energy management land in Lahendong

Based on data obtained from the Lahendong management, the converted rice fields, which have been permanently changed into a geothermal energy management area covering 30.5 hectare (Table 2).

Table 2. The area of rice land that has been coverted

Village	Land converted Area	Landowner (person)
Lahendong	4	8
Pangolombi	8	13
Tondangow	10	26
Kasuratan	5	13
Leilem II	3.5	5
Total	30.5	65

The concept of WTA is used to determine the perception of the farming community as owners or managers of rice fields. According to the average respondent perception, more than 50% stated that the conversion of agricultural land in Lahendong had a significant effect on the variables (Table 3),

Table 3. Farmers' perceptions of the impact of rice fields conversion and WTA in Lahendong

Questionnaire questions	..... %				
	SD	D	N	A	SA
1. Land conversion has an impact on decreasing farmers' income	0	0	2.1	46.8	51.1
2. Conversion of rice fields to non-agricultural land has the potential to bring economic losses to farmers and their families	0	0	9.7	39.4	50.9
3. Land conversion affects rice productivity	0	0	2.3	47.6	50.1
4. Land conversion affects the increase in land-selling prices	0	0	0	61.7	38.3
5. Willing to let go of this agricultural land if they obtain very profitable compensation.	0	0	0	51.9	48.1
6. Agricultural land or rice fields are a source of livelihood for farmers and their families	0	8.6	11.7	35.6	44.1
7. Conversion of rice fields also has the	0	0	9.3	47.6	43.1
8. Land conversion has an impact on reducing agricultural job opportunities	0	0	5.2	45.9	48.9

9. Land conversion affects changes in	0	0	9.7	56.8	33.5
10. Land conversion creates new business or job opportunities	0	0	1.5	25.6	72.9
11. This land conversion increases the difficulty of finding work or other equivalent	0	0	11.4	51.3	37.3
12. This agricultural land has Mapalus cultural heritage value, traditions, and the way of life of the community or farmers that are important for farmers and their families	0	10.4	17.3	31.7	48.1
13. Land conversion has an impact on the disruption of agricultural water supply	0	2.1	12.7	63.9	21.3
14. Land conversion causes disturbances in the form of sulfur odors	0	4.6	4.3	61.3	29.8

SD=Strongly disagree, D=Disagree, N=Neutral, A=Agree, SA=Strongly agree

Kruskal Wallis Test: Chi-Square 22.36, df= k-1=13, Sign. 0,03

Those impacts were that farmers have lost an average of 95.3% economic value (statements 1-3). Therefore, most farmers affected by the conversion have lost the economic value obtained from managing rice fields. Rice fields are the main source of livelihood for farming communities as a place for rice production and economic assets used to meet daily needs. The land conversion has removed the main livelihood, allowing farmers to lose source of income. This certainly has a major impact on the socio-economic conditions of farmers to obtain alternative sources of income. Careful consideration is needed in determining the policy of converting rice fields. The conversion of rice fields has significant economic consequences for farmers. The design of compensation and economic empowerment initiatives for farmers should be carefully crafted to mitigate any potential adverse effects. Furthermore, it is imperative to contemplate measures to preserve paddy fields as a viable option, enabling farmers to sustain their means of living. In summary, the results indicate that the transformation of paddy fields has substantial financial implications for farmers. This highlights the importance of giving careful consideration and adopting a comprehensive strategy to tackle this problem, in order to safeguard the welfare of the agricultural community.

From the perception of socio-cultural use value, 86.94% agreed with statements 6-12. In this context, the conversion of rice fields has implications for the economy and a significant impact on the socio-cultural aspect of the farming community. Rice fields are not only a source of economic livelihood, but also part of the identity and cultural heritage of the local community. The difference between the economic and socio-cultural aspects can be caused by priorities and perceptions among respondents. The economic aspect tends to be more visible and directly felt by farmers to obtain a higher percentage. Meanwhile, the socio-cultural aspect requires a deeper understanding of the values and identity of the farming community. Efforts to compensate, empower, and preserve the cultural values of farming communities are important to maintain the sustainability and welfare of the community. The potential for the development of new opportunities in the economic and employment sectors also needs to be optimized.

In terms of environmental value, 88.15% of respondents agreed with statements 13-14. Disruptions in agricultural water supply can be a serious problem for farmers. Rice fields are agricultural land highly dependent on the availability of sufficient and stable water. Land conversion disrupts the hydrological cycle and divert water sources used for irrigation purposes. This can have a negative impact on the productivity and sustainability of farming efforts carried out by the local community. Additionally, disturbances in the form of sulfur odor can cause environmental problems. The odor produced from geothermal energy management process pollutes the air around the operational area and affect the comfort and health of the surrounding community. This is a serious concern, specifically for people who live close to geothermal energy management area. Efforts such as modifying the arrangement, establishing more effective water management, and monitoring and controlling air quality become essential to uphold environmental equilibrium and safeguard the impacted farming communities. Moreover, involving the local community in the planning and

decision-making processes for geothermal energy management is a crucial measure to guarantee that mitigation actions are embraced and yield advantages to the local population.

Although the conversion of property has led to higher land values and the anticipation of receiving generous recompense, all respondents unanimously agree with points 4 and 5. This suggests that farmers can receive compensation that is proportional to the economic value they have lost from maintaining the paddy fields, also known as their Willingness to Accept (WTA). Therefore, the geothermal energy management firms that benefit from the land conversion must be prepared to pay the anticipated compensation sum, known as Willingness to Pay (WTP).

1.4. Economic Valuation of Rice Fields Resources

A quantitative (monetary) value is assigned to the goods or services that are created by natural resources and the environment through the process of economic valuation. This valuation is based on both market and non-market values. Several paddy fields have been converted as a result of the development of geothermal energy management facilities, which has had a direct impact on the total amount of rice produced as well as the aggregate value of rice output. The values consist of the Direct Use Value (DUV), the Indirect Use Value (IUV), the Option Use Value (OUV), and the Existence Value (EUV).

1) Direct use value (DUV)

The benefit value that can be directly received from the resources of the rice field is represented by the direct use value (DUV), which is the estimation of the economic worth of lost rice production. It was discovered, based on the summary of interviews that were carried out with farmers, that the total amount of paddy land that was transformed into geothermal energy management facilities was 30.5 hectares, and it was spread out throughout five different villages. In order to avoid making estimates that were influenced by bias, the DUV calculation was based on the prices that were prevalent in the market in 2012. This was done because the records of compensation payments for the land conversion to farmers were recorded in 2012. The information that was gathered for the computations was as follows, and it was obtained via the interviews with the farmers, as follows: total cost for one hectare of paddy field used for one rice planting season is IDR 1,250,000, which includes the costs of urea fertilizer, ponska fertilizer, and pesticides, but excludes labor costs, rice production per hectare for one harvest is 5.32 tons, farmers harvest rice twice a year and the market price of rice is IDR 6,500 per kilogram. The lost rice output resulting from land conversion was determined to be 324,764 kg/ha/year using equation (1). This loss corresponds to an economic value of IDR 4,145,682,000 per year. The village of Tondangow has the highest recorded value for lost rice production function, amounting to IDR 1,359,240,000 per year. On the other hand, the village of Leilem Dua has the lowest recorded value, which is IDR 475,734,000 per year.

2) Indirect use value (IUV)

IUV is the utilization based on the function of the existence of rice fields. The indirect function of rice fields ecosystem is waste (bran) used as animal feed (pigs). The production of agricultural waste varies and this is influenced by the amount and quality of milled rice, with an average ratio of 0.06 (Azis et al., 2014). Total rice production is 193,066 kg and the price of waste (compost) per kg is IDR 3,000. Meanwhile, the indirect benefit value as a waste producer is calculated using Equation 2, and IUV result is IDR. 58,457,520 for 1 year.

3) Option use value (OUV)

The value of the selected benefits is related to the ecosystem as a carbon absorber using Equation 3 and the assumption of a world price of US$ 79.38/ton CO_2e (Roaf *et al*., 2021). The exchange rate in May 2024 was IDR 16,200/US$, while the selling price of carbon was US$ 79.38/ton x IDR 16,200 = IDR 1,285,956/ton CO_2e. Therefore, OUV result is IDR. 239,438,164 per year.

4) Existance use value (EUV)

The existence of rice fields provides benefits or opportunities for the opening of employment opportunities for the community by obtaining wages. The value is the service obtained through farming activities. Land processing services using tractors and rice planting services are paid IDR.

300,000/person/ha and IDR. 150,000/person/ha, respectively. According to Equations 4 and 5, the results for Labor income are IDR 395,280,000 and tractor income IDR 73,200,000, hence, the total income from rice fields as a function of labor (EUV) is IDR 468,480,000.

5) Total Economy Value (TEV)

TEV of multifunctional rice fields is the sum of the economic function (rice production), social (labor), and environment (carbon absorption and waste processing) calculated using Equation 6 with the results as shown in Table 4.

Tabel 4. Total economy value (TEV) of converted ricefield

Village	DUV	IUV	OUV	EUV	TEV
Lahendong	543,696,000	7,666,560	31,401,726	61,440,000	644,204,286
Pangolombian	1,087,392,000	15,333,120	62,803,453	122,880,000	1,288,408,573
Tondangow	1,359,240,000	19,166,400	78,504,316	153,600,000	1,610,510,716
Kasuratan	679,620,000	9,583,200	39,252,158	76,800,000	805,255,358
Leilem II	475,734,000	6,708,240	27,476,511	53,760,000	563,678,751
Total	4,145,682,000	58,457,520	239,438,164	468,480,000	4,912,057,684

The results of the economic valuation calculation are the monetary value of WTA land conversion in Lahendong, which is IDR. 4,912,057,684 or IDR. 161,051,072/ha of rice fields ownership. This shows that the multifunctional economic value reflected in TEV needs to be an important consideration in conversion policies. In the context of WTA, TEV is the desire of the community to obtain compensation for the loss of the economic function. Meanwhile, OUV calculation shows that the loss has the potential to lose carbon absorption (CO_2) worth IDR. 239,438,164. The function of rice production (DUV) and employment provider (EUV) has the first and second largest values with a distribution of 84.40% and 9.54% of the total (Fig. 2).

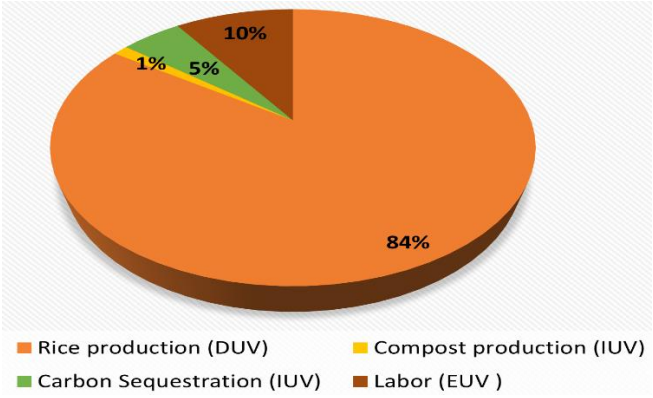

Fig 2. Distribution of total economic value by function

The benefits of the environmental economic value are related to carbon absorber and rice waste management (compost), which has not shown a significant percentage based on functions, namely 0.48% and 1.23%, respectively (Fig. 2). However, rice fields have an important role in maintaining environmental balance, such as carbon absorption and waste processing. The conversion into geothermal energy processing land has negative impacts on the environment, such as decreasing ecosystem quality.

Interpretation of descriptive statistical analysis shows a fairly large variation in TEV values between villages, with the highest and lowest in Tondangow and Leilem II at IDR. 1,610,510,716 and IDR. 563,678,751, respectively. This suggests differences in the characteristics and economic potential of multifunctional rice fields. The largest component of TEV value is DUV representing the economic value of rice production, with an average of IDR 829,136,400 per village. Other components, such as IUV, OUV, and EUV also provide significant contributions of IDR. 11,691,504, IDR. 47,887,633, and IDR. 93,696,000, respectively.

Table: 5 Descriptive statistical analysis

Statistic value	DUV (000)	IUV (000)	OUV (000)	EUV (000)	TEV (000)
Minimum	475,734	6,708.2	27,476,511	61,440,000	563,678,751
Maksimum	1,359,240	19,166.4	78,504,316	153,600,000	1,610,510,716
Mean	829,136.4	11,691.5	47,887,633	93,696,000	982,411,537
Std.deviation	339,538.1	4,787.8	19,610.4	38,369.3	402,305.5

The high variation in TEV values between villages requires a location-specific method for assessing and managing rice fields, as well as determining fair compensation for communities affected by land conversion. This is stated in Table 3, statement 5, namely "Willing to let go of this agricultural land if they obtain very profitable compensation". A total of 98.5% of respondents agreed with the statement, where matters relating to losses will be replaced when farmers receive compensation of at least IDR. 281,422,672/ha. The 65 farmers affected by land conversion received a compensation value of IDR. 4,329,580/ha/person. TEV value can be interpreted as the minimum amount of compensation that the community is willing to accept (WTA) when rice fields are converted into geothermal energy processing land. This reflects the multifunctional economic value of rice fields lost due to land conversion. Therefore, the community does not experience economic losses but receives compensation equal to TEV. Compensation equal to the value can reduce economic losses due to land conversion.

WTP is value imposed on the party causing the consequences, namely geothermal energy management company, PT. Pertamina Geothermal Energy Area Lahendong, which is a subsidiary of PT. Pertamina Tbk. Based on the data, this company has made compensation payments for the conversion of agricultural land (Table 6)

Table 6. The amount of WTP (compensation for land use transfer)

Village	Converted Land Area (ha)	WTP (IDR)
Lahendong	4	1,400,000,000
Pangolombia	8	2,800,000,000
Tondangow	10	3,500,000,000
Kasuratan	5	1,75,000,000
Leilem Dua	3.5	1,225,000,000
Total	30.5	10,675,000,000

The compensation value with TEV shows that WTA < WTP. The total economic value of the area conversion is 30.5 ha (WTA) = IDR. 4,912,057,684 (Table 4) and calculating TEV after 2012 is important. The calculation is carried out by obtaining the present value of TEV lost between 2012 to 2017, which is a period to recover newly pioneered businesses. This concept refers to the principle of the time value, where money received has a higher value. To obtain the present value (2017), TEV reported after 2012 should be discounted using the appropriate interest or discount rate. The formula NPV (Net present value) = Σ TEV x $[(1 + i)^t]^{-1}$ reported 17,948,633,503 or IDR. 17,948,633,503 as the total economic value lost due to land conversion for 5 years. Even though the total WTP value of IDR.10,675,000,000 has been paid by the company, the value is still inadequate for farmers to restore new businesses pioneered as a replacement for converted land. According to a literature review, a newly pioneered business can become stable in 5 years.

When managing public goods that are natural resources, the community's optimal decision is reached when the willingness to pay (WTP) is equivalent to the willingness to accept (WTA). This indicates that each recipient is willing to assume the financial responsibility, and every one who is exposed to the potential financial loss must be compensated with the corresponding advantage. The condition where the Willingness to Accept (WTA) is less than the Willingness to Pay (WTP) is a result of the community's compensation being assessed solely based on the value of the surface land and its agricultural/paddy function. Furthermore, the company offers a higher price for the land due to its inclusion of not just the surface area and its intended use, but also the valuable natural resources

it contains, specifically the geothermal energy. This economic worth, sometimes overlooked by the landowner, is taken into consideration by the company.

The disparity in the perception of the worth of land resources between the community and the company stems from the unequal access to information between the farmers and the company. Typically, farmers lack information or awareness regarding the economic worth of the geothermal energy present in their property, whereas the managing firm possesses comprehensive expertise and understanding of this economic value. The society perceives the distinction between WTP (willingness to pay) and WTA (willingness to accept) as an economic incentive offered by the corporation, primarily due to the insufficient information available. The corporation has successfully capitalized on this situation by presenting the WTP as a beneficial remuneration publication. For the corporation, this value is utilized as a means of promoting their support for the community.

Nevertheless, the current reality is that the corporation has an outstanding debt of IDR 7,273,633,503 to the farmers, which is a substantial sum for them. The disparity between the actual worth of the land resources and the amount of compensation provided by the firm can be attributed to the presence of unequal information and the corporation's exploitation of the community's limited understanding regarding the genuine economic value of geothermal energy.

In practice, the implementation stage of payments does not necessarily mean that the compensation value can be directly received by the entitled party. There are complicated bureaucratic mechanisms or procedures deliberately created by certain parties since the process is unclear. This condition causes the community to be affected in obtaining the rights according to the actual ownership value. The community experiences various difficulties in realizing the sale and purchase transaction. The consequence will be several new costs that should be borne by farmers.

This finding further corroborates other prior research (Y. Ahmed *et al*., 2022; Chen *et al*., 2021; Pretty *et al*., 2003) indicating that the majority of farmers in developing nations do not adequately attain their entitlements in proportion to the relinquishment of their land. They are adapted for different project objectives.

The benefits of Lahendong Geothermal Power Plant existence

Lahendong geothermal plant management provides benefits seen from the supply, distribution, and demand sides. Therefore, the management has become an economic multiplier effect for the surrounding community and has functioned as a coordination tool. This refers to the presence of Lahendong geothermal energy management as the center of activity for all related businesses. Based on the in-depth interviews with existing stakeholders, various benefits can be obtained, as follows:

1. Primary sector: The benefits obtained by the primary sector (agriculture, livestock, fisheries and mining) are land compensation value, *Corporate Social Responsibility* (CSR) assistance, Partnership and Community Development Program (PKBL). Benefits obtained from sand and stone excavations are needed in the physical development of Lahendong geothermal energy management. CSR initiatives encompass activities such as training, provision of production facilities, and finance for business development projects in the domains of agriculture, animal husbandry, fisheries, and mining. In addition to providing compensation for land and engaging in corporate social responsibility (CSR), the corporation is also implementing a partnership and environmental development (PKBL) program that involves stakeholders in the primary sector. This program offers several options such as business partnership schemes, cash aid, and technical help to enhance the capacity and productivity of the primary sector. The demand for construction materials, such as sand and stone, for geothermal power plants has stimulated excavation and trading operations in the mining industry. This creates supplementary revenue prospects for small and medium-sized mining enterprises in the vicinity of the power generation site. In general, the presence of a geothermal power plant in Lahendong has yielded many economic advantages that directly help the primary sector. These benefits include compensation, development initiatives, and chances to exploit natural resources to facilitate the growth of the plant.

2. Secondary sector: Electrical energy is the driving force for household industries, and small, medium, and large industries both in sub-districts and villages around the operational area and in areas that can be reached by Lahendong geothermal electricity services. Trade supports

materials for geothermal operational needs. The electricity generated by the Lahendong geothermal power plant has become a catalyst for many industries inside and accessible from its operational vicinity. Home industries, small industries, medium industries, and large industries can access cost-effective and dependable electrical energy from this facility to enhance the efficiency of their production operations. The presence of sufficient electricity supply enables the industrial sector in the vicinity of the Lahendong geothermal power plant to flourish and expand its production operations. This generates fresh economic prospects, not only for the industry itself but also for ancillary sectors like trade, logistics, and services. In addition to electrical energy, the presence of the Lahendong geothermal power plant has also stimulated commerce in the necessary materials for the facility's operation and maintenance. This presents lucrative economic prospects for the commerce industry, including enterprises of all sizes, including small, medium, and large-scale operations, that cater to the demand for essential spare parts, equipment, and other supplies.

3. Tertiary sector: Lahendong geothermal energy management triggers the development of transportation service businesses such as car rentals, banking, and other service businesses. The demand for increased mobility in relation to operating activities and maintenance of the Lahendong geothermal power plant has stimulated the expansion of transportation service enterprises in the vicinity. This encompasses the provision of automobile rental, taxi services, and freight transportation services to facilitate and assist in the operations of generator activities. Transportation service enterprises can capitalize on the economic prospects generated by the presence of power plants. The expanding economic activity surrounding the Lahendong geothermal power plant, encompassing the primary, secondary, and service sectors, has resulted in a heightened demand for banking services. This presents prospects for banks to establish branches or services in the region to cater to the financial, savings, and other transactional requirements of business entities and the local populace. In addition, it has also stimulated the growth of several service industries, including lodging, dining, retail, telecommunications, and professional services. The growing economic activity in the region has generated a rising demand for diverse sorts of support services.

4. Center and Upstream Business: Benefits that arise in the process of operating a company include company profits and employee welfare. Benefits are obtained from investment and supporting factors, hence, Lahendong geothermal energy management operations can operate.

5. Downstream business and community: Benefits that follow the flow of energy production with the chain. Benefits of residual hot steam with the chain. All economic sectors are connected from the back side starting from investment, labor, and land value. All benefits obtained by businesses connected to the output side of Lahendong geothermal energy management. Job opportunities, increased community income, educational assistance, and use of infrastructure as a positive externality.

6. Government and other business actors: Company taxes, business permits and levies. Other types of businesses related to Lahendong geothermal energy management receive benefits such as buying and selling supporting materials for geothermal energy management.

7. Cooperatives: Financial support from the company in the form of *revolving funds* for cooperatives in the local community. The Lahendong geothermal power plant's management business offers financial assistance to cooperatives in the plant's vicinity through a revolving fund. Cooperatives can utilize this revolving fund for many purposes such as company capital, member loans, infrastructure development, and other operational operations. By utilizing revolving funds provided by the corporation, local communities' cooperatives can achieve more convenient access to capital. Cooperatives can enhance their business capacity, broaden their service offerings, and foster the growth of productive economic activities for their members through this. Providing ongoing financial assistance to local cooperatives can help to enhance the economic empowerment of communities surrounding the Lahendong geothermal power plant. Cooperatives serve as a platform for individuals to establish enterprises, enhance their earnings, and obtain affordable financial services. The collaboration between the Lahendong geothermal power plant management business and local cooperatives can generate mutually advantageous

synergies. Companies have the ability to enhance the capability of cooperatives, while cooperatives can serve as collaborators in the development of economic activity in the surrounding area.

2. CONCLUSION

In conclusion, the conversion of agricultural land to non-agricultural use for geothermal plant installation construction project had a negative impact on the environment and economy. This could worsen ecological damage and reduce the standard of living of the community in agricultural and non-agricultural areas. This changed land use, eliminated food production land, and disrupted the balance of the local economy. Therefore, the process of land transformation from agriculture to geothermal projects required a balance between economic benefits and environmental losses.

The valuation of land conversion showed the value of rice fields to the surrounding community. TEV reached IDR 4,912,057,684 or around IDR 161,051,072/ha. This figure reflected TEV of the lost rice fields relating to production functions, employment providers, and ability to absorb carbon. The value was an important consideration in land conversion policies since the concept showed WTA and obtain adequate compensation. In addition, the calculation showed that the loss of rice fields had the potential to eliminate absorption worth IDR 239,438,164. The benefits of carbon absorbers and rice waste management did not show a significant percentage based on functions, which were 0.48% and 1.23%, respectively. Even though the total WTP of the community to maintain rice fields reached IDR 10,675,000,000, this amount was considered insufficient to restore new businesses pioneered by farmers as a replacement for converted land. The results showed that farmers lost IDR 7,273,633,503, and the economic compensation considered the aspects of economic value.

The Lahendong geothermal plant management provided comprehensive benefits for different aspects of the economy. In terms of supply, distribution, and demand, this project met the need for sustainable and well-distributed energy. In addition, the activities were closely related to other economic upstream and downstream sectors. This created mutually reinforcing backward and forward linkages. The existence of the project provided benefits felt by various parties, such as the government, community, companies, and cooperatives. Geothermal energy management became a center of economic activity to provide a multiplier effect. This project functioned as an economic coordination tool for connecting various related sectors and contributing to sustainable economic development.

However, there are several limitations to this study that need to be continued in future studies, including those related to changes in prices, costs, productivity in the future, and the economic impact on society's income as a whole, which have not been examined in this study.

Author's contribution

Welky Karauwan led the research design and methodology, responsible for data collection and analysis. She also coordinated the entire research process to ensure the suitability and accuracy of the information obtained, including ensuring a clear understanding of DUV (Direct Use Value), EUV (Existence Use Value), IUV (Indirect Use Value), OUV (Option Use Value), TUV (Total Economic Value), WTA (Willingness to Accept), and WTP (Willingness to Pay). **Daniel Stefanus Imanuel Sondakh** and **Joula Silvana Kalangi** were instrumental in conducting interviews and collecting quantitative data from farmers, as well as ensuring the validity of the survey instruments. **Deisy Agnes Juita Pratiwi Pangkey** and **Elsje Hanna Lintong** focused on the economic valuation aspect, including the calculation of Total Economic Value (TEV) and interpretation of results. **Stanss L. H. V. Joyce Lapian** and **Joni Kutu' Kampilong** contributed to the socio-cultural analysis, highlighting the impacts of land conversion on local communities. All authors collaborated in the drafting and revision of the manuscript, ensuring that this article reflects a comprehensive understanding of the complex interactions between geothermal energy development and agricultural land use.

Conflict of Interest Statement

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare absence of conflicting interests with the funders.

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