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Original Article

Integration of Remote Sensing, Cellular Automata, and Carbon Modeling for Predicting Land Use Change and Carbon Stock Loss in Central Lampung Regency

Ery Amalia Ananda*[1], Alimudin Muchtar[1], Dedy Miswar[1], Hari Kaskoyo[1], Arif Darmawan[1]
[1] Universitas Lampung, Bandar Lampung City, Indonesia
*Cooresponding E-mail: eryaamalia@gmail.com

ABSTRACT
It was a quantitative research in which the data was compared using the logistic regression and the data were collected and documented through observation and documentation and MOLUSCE (Model For Land Use Change Simulation) model in QGIS Las Palmas 2.18.15. Landsat 7 imagery (2013), Landsat 8 imagery (2018, 2023), administrative, settlements, road network, soil type, and slope shapefiles are some of the data used. Based on the findings of the analysis, population growth and pressure on the land use resulted in the Central Lampung Regency experiencing significant landuse changes throughout the period of 2013- 2023. By 2023, the land area on dry agricultural land was reduced to 15162531 hectares, which was against 21662131 hectares in 2013. In fact, the developed land had expanded to a vast magnitude of 73,019.89 to 114,615.89 hectares within the same period signifying high needs of infrastructure and houses. It is projected that built-up land (29.06 percent) and bare land (28.72 percent) will be the biggest land covers in 2043 and this indicates high urbanization process and value of land renting strategy high. Such developments cause severe effects on the availability of land resources and the environment, and this is the reason why the effective and sustainable development can be ensured with the help of proper government policies.

KEYWORDS
land use change, prediction, control strategies, MOLUSCE model

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INTRODUCTION

The Law No. 24 of the year 2013 that applied amendments to the Law No. 23 of the year 2006 on the Population Administration defines population as the people of the Indonesian territory area that comprise the Indonesian citizens (WNI) and that of the foreign nationality (WNA) who live in Indonesia at least one year or have intentions to settle in Indonesia at least one year. The Indonesian statistical data shows that there is a

continuous increase in population in past three years. Indonesia is currently inhabited by 278.69 million and projected to have 281.60 million people in 2024. In 2020-24, the population growth rate was significantly greater 1.11. (BPS, 2024).

Lampung Province has a capital of Bandarlampung, which covers an area of 33,575.41 km2 and has 15 regencies/cities. The total land area of the Lampung Province is 3457.40 km 2 of the total land area, the capital of Central Lampung Regency and Gunung Sugih District occupies 13.55. The other town is Central Lampung Regency with a population of 1,525,189 comprising 16.19 per cent of the total population in Lampung Province. The population growth rate of the Central Lampung Regency 2020-2024 is transformed into moderate (1.10). The population of Central Lampung Regency currently stands at 1,508,331 individuals, with the total area of the locality being 4,559.57 km2 (2023). This led to the population density in Central Lampung Regency being 330.81 per km2 in 2023. This growth automatically leads to increased growth in development to meet the population (BPS, 2024).

This will certainly contribute to the enhancement of development to accommodate the population needs. Population growth and development will also have a bearing on land use. The impact of population growth is directly proportional to increasing demand of land that results to land-use change. These changes of land use involve the development of gardens, rice fields and swamps in Central Lampung Regency into settlements. Other than deforestation of farmlands and forests to residential areas, a majority of the water retention areas of Central Lampung Regency have been encroached and used as residential estates. It is possible to trace this to the sentiments of Cullingswoth (1997); Sari and Dewanti (2018) who note that land cover changes can occur due to a number of antecedent factors. The factors that influence the factors which lead to a land cover change have four factors which include population concentration and all the activities, access to activity centers and the city centers, road networks and transportation facilities, and orbritation. In addition, one can mention that topography, population, land value, accessibility, and facilities and infrastructure and environmental carrying capacity are some of the aspects that may influence the change in land cover (Chapin, 1979; Sari and Dewanti, 2019). The larger the population, the larger the land will be needed since the population increases with time to sustain housing and economy therefore changing the land cover (Miswar et. al., 2020).

It can be defined as land use of any type to meet material and spiritual needs (Arsyad, 2010; Hapsary, 2021). One kind of work involves the use of a piece of land in the past (Mulya et al., 2022). Meanwhile, the land-use change by Wahyunto (2001); Mulya et al (2022) is the expansion of one type of land use to another type of land use, and vice versa. The other definition of land change is the transformation of the role of a part or the whole of a piece of land of its initial role to another role, which has adverse impacts on the environment and the potential of the land itself (Prasetya, 2015).

The necessity or requirement of land resources will also increase with the increasing human activity in other arenas, specifically the economy. High competition of land-utilization arises due to the comparative permanency of land availability but eventually, the pressure of economic and social needs will prevail in the priority of land-use change. Land use competition also contributes to the transformation of Agricultural land into non-agricultural land hence an increase in land rent. The non-agricultural land use will surpass agricultural land use as it has higher value. The land management and use to execute agricultural practices must therefore be effective and efficient.

Setiyanto and Irawan (2015) argue that the mechanism of land allocation resources is normally dependent on the economic rent or the land rent value as compared to the rental value or the contract rent. An economic rent or land rent value land that is higher will displace the land use of a lower economic rent or land rent value. In most cases, the economic rent or land rent value that emerges in the market system is as follows industry > trade > settlement > intensive agriculture > extensive agriculture.

Among these technologies, remote sensing can be applied to monitor land-use change (Jaya, 2010) and it is efficient in providing specific and accurate information on spatial diversity. In the case whereby such technology is applied together with a computer based Geographic Information System (GIS), it can be utilized in the analysis of land use and land cover change. The characteristics of this combination of the two technologies include Cellular Automata (CA) which is a model that can be applied to many analysis combinations where one of them is the Logistic Regression (LR). Cellular Automata is a model of simple spatially distributed processes in GIS. The information is encoded as a set of cells (grid), and a cell can only be set in a state out of a finite number of possible states. This means that it is a method of modeling that can be applied

only to raster GIS (Baja, 2012; Fitriana et al., 2017). The advantage of this paradigm is that it applies simple patterns to explore simple patterns to create complex patterns based on simple principles (Singh, 2023). The vulnerability of Cellular Automata (CA) is that it focuses more on the growth process and forecast the growth of pixels although does not provide information about the causes of this growth in terms of how dependent variables are correlated with independent variables. Despite the fact that the land-use change is predetermined by a set of independent factors that should be taken into consideration, CA does not necessarily describe all these factors in detail. The model is therefore normally utilized together with other models to improve accuracy in prediction. (Peruge and Sakka, 2012).

METHOD

Research Method

This survey was conducted in 2024 in the Central Lampung Regency, Lampung Province, Indonesia. The research design is a quantitative research, and therefore data collection is by observation and document data collection techniques.

Research Variables

The variables of the study will be the projected land use of Central Lampung Regency, and the land use changes in 2013, 2018 and 2023.

Tools and Materials

It operates a computer with Microsoft windows 10 (4GB of RAM), ArcGIS 10.4 and QGIS Las Palmas 2.18.15 (MOLUSCE plug-in), Microsoft office 2010, and a mobile phone camera. It will contain information about Landsat 7 and 8, 2013 and 2018 and 2023, administrative records of Landsat 7 and 8 and settlements, road networks, soil typology, and slope gradients in shapefiles. The additional data collection materials will include administrative, road, and settlement maps that were obtained via the Ina Geoportal platform; Landsat images of 2013, 2018, and 2023 that were retrieved on the USGS site; and slope data composed of DEMNAS.

Data Collection Techniques

The paper investigates the land cover dynamics of Central Lampung Regency over a period of 2013, 2018 and 2023, as well as giving future predictions that will reach 2043. The method of analysis is logistic regression.

Data Analysis Techniques

In the research, logistic regression is used as a statistic tool to determine the likelihood of binary results. The process of logistic regression application in MOLUSCE mapping includes data acquisition (shapefiles and satellite imagery provided by the corresponding institutions like Public works department), data preparation (preprocessing, cleaning and converting categorical variables in case of necessity) and model validation with the help of a specific test dataset.

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Table 1. Type and Source of Data

No.	Data	Source	Information
1	Landsat 7 imagery 2013	www.earthexplorer.usg.gov	Image interpretation and classification
2	Landsat 8 imagery 2018 and 2023	www.earthexplorer.usg.gov	Image interpretation and classification
3	Central Lampung Regency Administration	RBI Map, Lampung Province District Map, Lampung Province Village Boundary Map	Research location map
4	Shapefile of settlements, road networks, soil types, and slope	Public Works Department of Central Lampung Regency	Driving variables for land cover change

RESULTS AND DISCUSSION

Land Use in Central Lampung Regency (2013, 2018, and 2023)

The land use of Central Lampung Regency has undergone significant changes which have been majorly influenced by the increase in population and the competition among the land resources. These forces increase land rent which in turn directly influences land demand. The region has six major types of land use including open land, dryland agriculture, wetland agriculture, forested areas, built-up, and water bodies.

Land Use in 2013

Dryland agriculture was the leading land use in the year 2013 with total land use covered by it measuring 216, 621.31 hectares and this highlights its immense contribution to the local economy. Wetland agriculture occupied 50,704.65 hectares, which comprised primarily of rice. The area of bare land was 63,770.12 hectares, which showed untapped potential. The forest areas had an area of 52,485.78 hectares, which was a pillar to the ecological equilibrium and biodiversity. Water bodies, on the other hand, constituted 41,672.99 hectares, which were important in irrigation and fisheries.

Table 2. Land Use of Central Lampung Regency in 2013

Land Cover/Use	Area (ha)
Bare Land	63,770.12
Dry Agriculture	216,621.31
Wet Agriculture	50,703.65
Built-up Land	73,019.89
Forest	52,485.78
Water Bodies	41,672.99
Total Land Use Area	**498,273.74**

Source: Research Findings, 2025

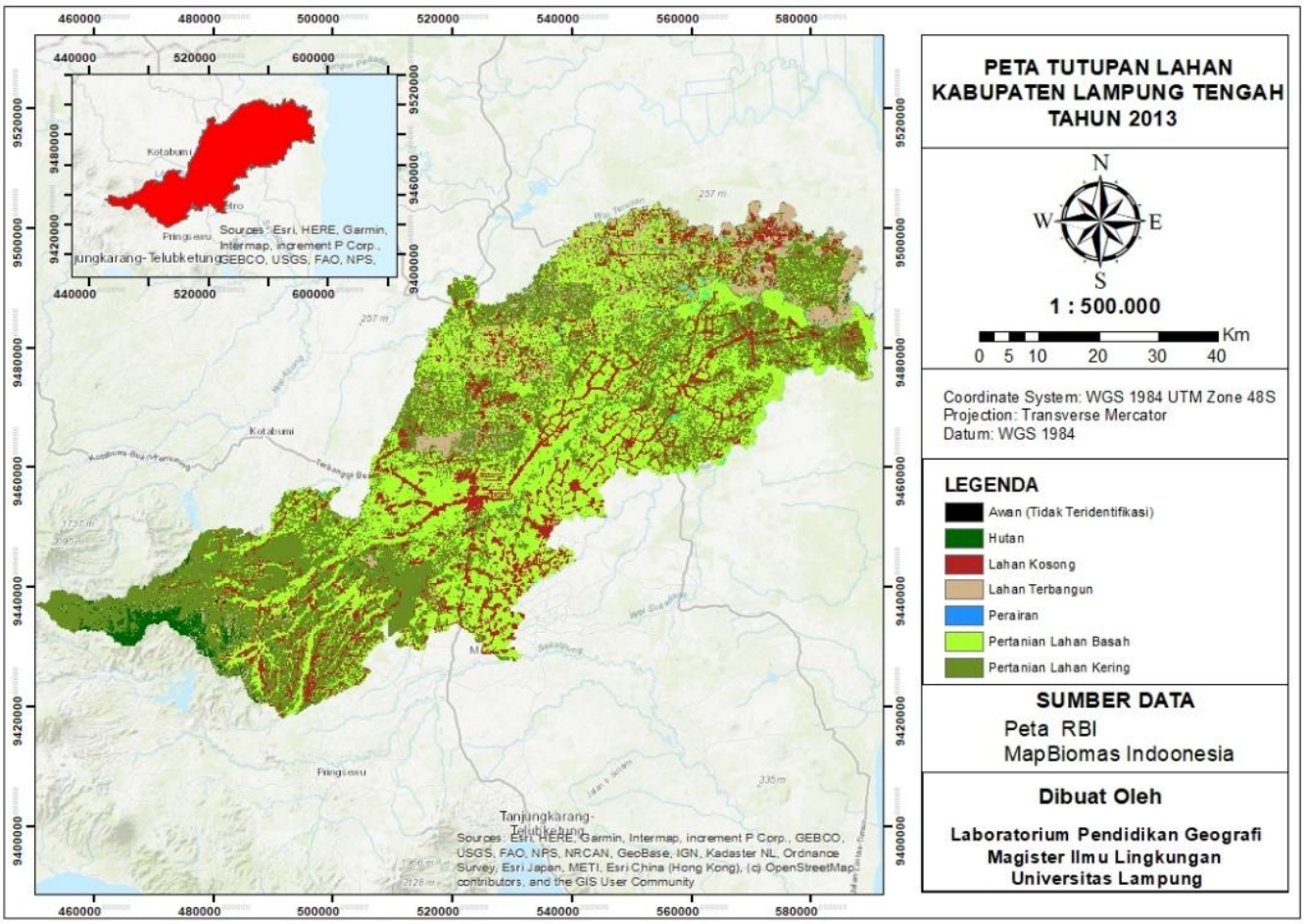

Figure 1. Land Cover Map Central Lampung Regency, 2013

Land Use in 2018

As of 2018, land use remained dominated by dryland agriculture but its area has decreased to 184,123.31 hectares. This industry continued to be at the center and grew major commodities like cassava, maize and rice. Constructed areas grew significantly to 89,317.89 hectares that reflected development in infrastructure and settlements. The bare land dropped marginally to 60,970.12 hectares that is used as other purposes, and the reason is that the rent value of the strategically located land is high. Wetland agriculture was raised to 62, 291.65 hectares, forest cover was raised to 62, 967.78 hectares whereas water bodies were reduced to 38, 602.99 hectares.

Table 3. Land Use of Central Lampung Regency, 2018

Land Cover/Use	Area (ha)
Bare Land	60,970.12
Dry Agriculture	184,123.31
Wet Agriculture	62,291.65
Built-up Land	89,317.89
Forest	62,967.78
Water Bodies	38,602.99
Total Land Use Area	**498,273.74**

Source: Research Findings, 2025

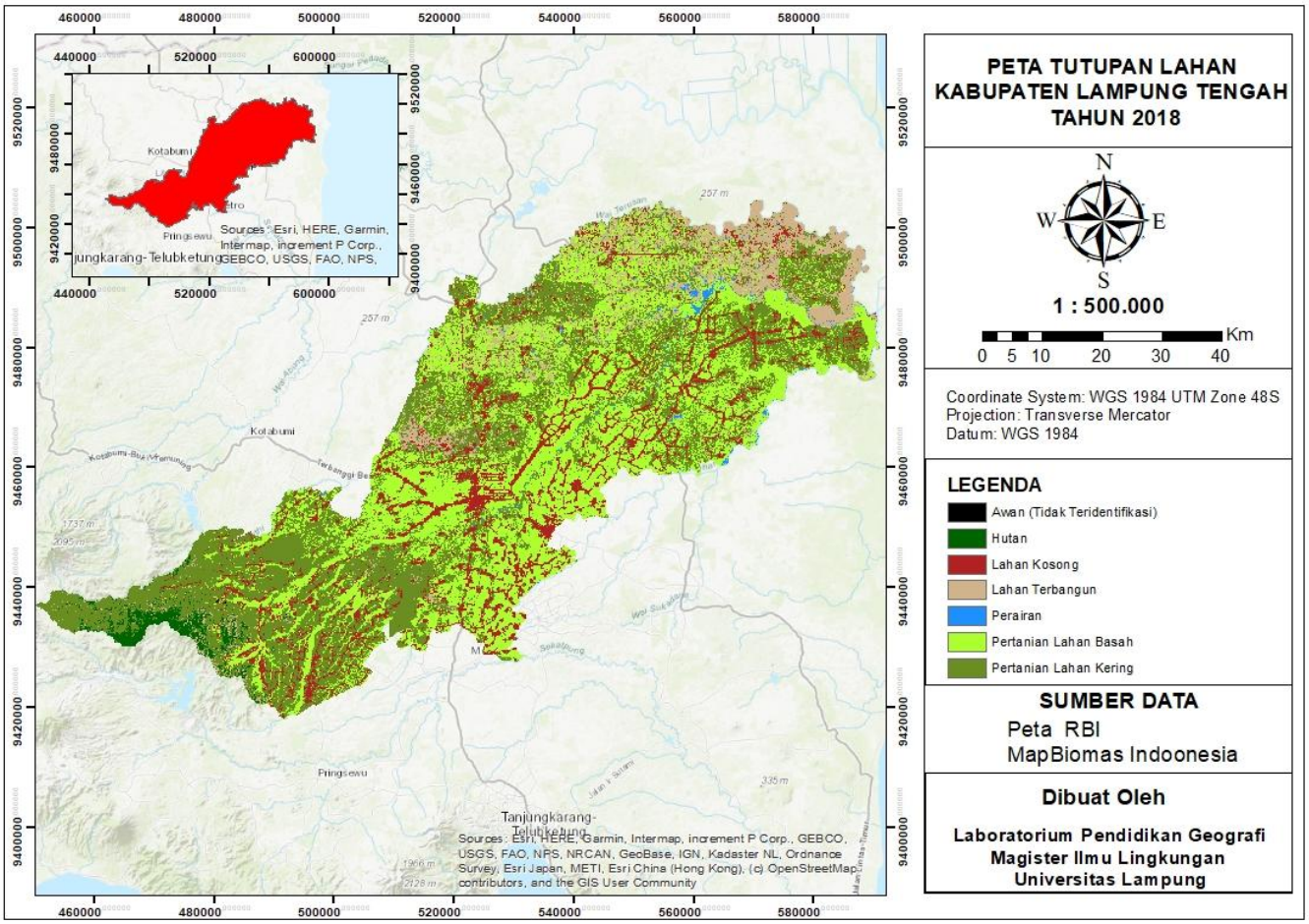

Figure 2. Land Cover Map Central Lampung Regency, 2018

Land Use in 2023

As of 2023, the size of dryland farming was again shrinking to 151,625.31 hectares. On the contrary, the wetland agriculture increased significantly to 73,879.65 hectares, indicating that it has the ability to boost food production. There was a resultant increase in built-up areas of 114,615.89 hectares due to population, increased housing demand, increased demand on social facilities and economic development that promoted the transformation of agricultural land. The bare land also dwindled to 53,170.12 hectares which is in the form of more intensive use. Forest areas have increased to 68,449.78 hectares whereas the water bodies have reduced to 36,532.99 hectares which is a significant decline which needs to be addressed because of the importance they play in irrigation activities, fisheries and the provision of clean water.

Table 4. Land Cover/Land Use of Central Lampung Regency, 2023

Land Cover/Use	Area (ha)
Bare Land	53,170.12
Dry Agriculture	151,625.31
Wet Agriculture	73,879.65
Built-up Land	114,615.89
Forest	68,449.78
Water Bodies	36,532.99
Total Land Use Area	**498,273.74**

Source: Research Findings, 2025

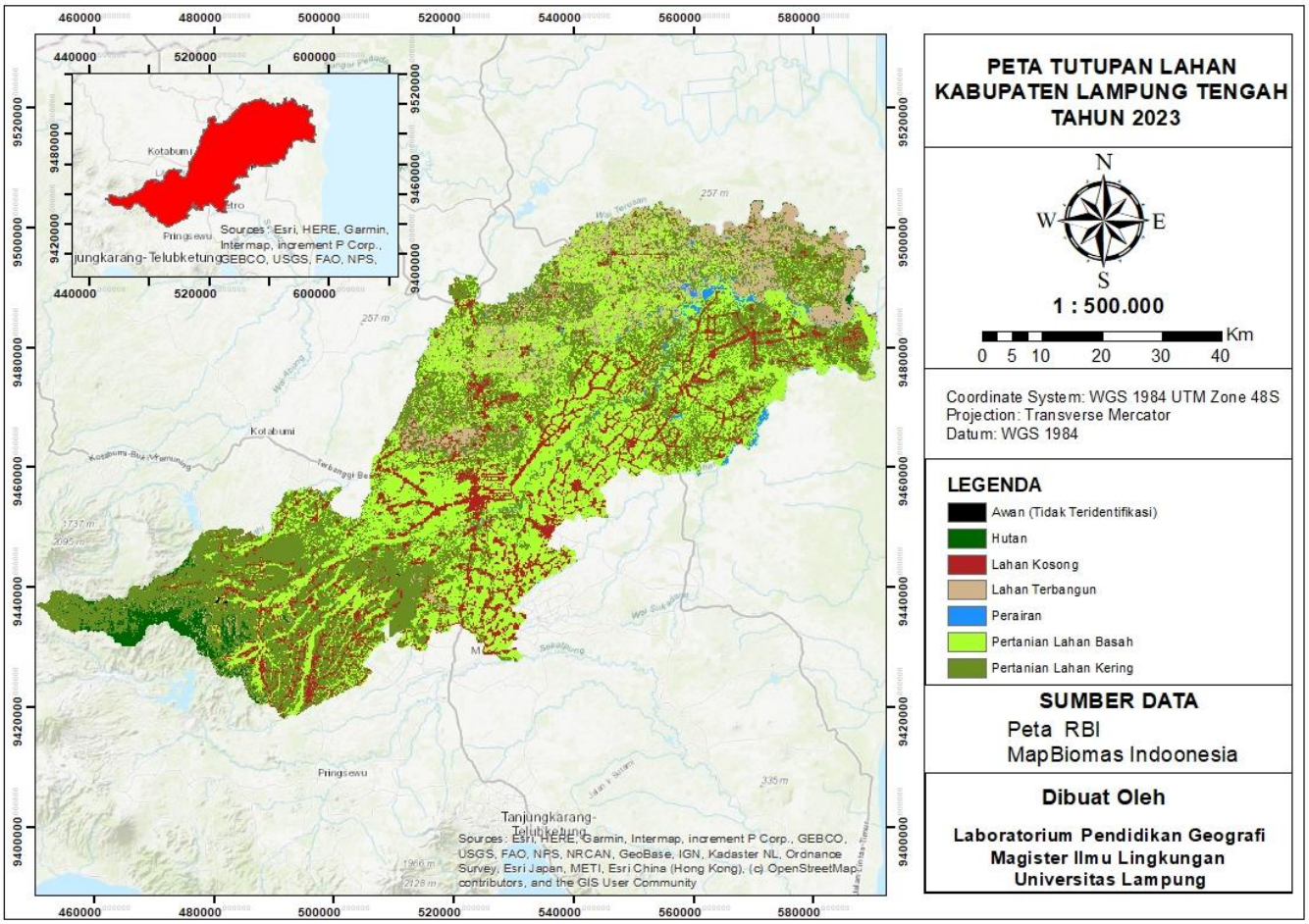

Figure 3. Land Cover Map Central Lampung Regency in 2023

Land Cover/Use Changes (2013-2018 and 2018-2023)

2013-2018 Changes

The intensive land use change that took place in Central Lampung Regency took place in the period of 2013 to 2018. The result of the growing population and transformation of the land into built-up land or wet agriculture was a reduction by 32,498.00 hectares of the dry agricultural land. The loss of bare land was 2,800.00 hectares meaning that it was turned into better economic activities of settlements, industry or intensive agriculture. The built up land became 16,293.00 hectares, wet agricultural land became 11,588.00 hectares, forest area became 10,482.00 hectares. Loss in water bodies was 3,070.00 hectares. These transformations highlight the complexity of human relationships and environmental related processes that require sustainability of land management.

Table 4. Land Cover/Land Use Change in Central Lampung Regency (Ha) in 2013 and 2018

Land Cover/Use	2013 Area (ha)	2018 Area (ha)	Change (ha)
Bare Land	63,770.12	60,970.12	-2,800.00
Dry Agriculture	216,621.31	184,123.31	-32,498.00
Wet Agriculture	50,703.65	62,291.65	11,588.00
Built-up Land	73,019.89	89,317.89	16,293.00
Forest	52,485.78	62,967.78	10,482.00
Water Bodies	41,672.99	38,602.99	-3,070.00

Source: Research Results, 2025

2018-2023 Changes

The major shifts in land use did not stop after 2018 and proceeded until 2023. Dry land agriculture area of 32,498.00 hectares fell and this could be due to low productivity or fall in the demand. Conversely, wetland agriculture increased by 11580.00 hectares, which is likely to be supported by the enhanced irrigation system or easier access to markets. The area built, which experienced the rise in housing, industrial and infrastructure demands, was augmented considerably by 25,298.00 hectares to augment land rent and the conversion of farmland. The forest cover was increased by an increment of 5,482.00 hectares that could possibly have been reforestation or conservation. Over time, the water bodies began to dwindle by the year 2,070.00 hectares by sedimentation, climatic change or human activities. More land was further converted with a total bare land of 7,800.00 hectares. These developments directly affect rent of lands and converted lands to wet agriculture or wetlands converted to development would attract high rents compared to bare lands or dry land farming.

Table 5. Land Cover/Land Use Change in Central Lampung Regency (Ha) in 2018 and 2023

No	Land Cover/Use	2018 Area (ha)	2023 Area (ha)	Change (ha)
1	Bare Land	60,970.12	53,170.12	-7,800.00
2	Dry Agriculture	184,123.31	151,625.31	-32,498.00
3	Wet Agriculture	62,291.65	73,879.65	11,588.00
4	Built-up Land	89,317.89	114,615.89	25,298.00
5	Forest	62,967.78	68,449.78	5,482.00
6	Water Bodies	38,602.99	36,532.99	-2,070.00

Source: Research Results, 2025

The analysis considers the land cover and land use change dynamics in Central Lampung Regency in a 10-year period, i.e. from 2013 to 2023. The results highlight the great variability of the different land cover and land use categories, which indicates the interaction between utilization of natural resources and modernization of the local people. The above changes can be explained in terms of a land rent concept since, the more productive or accessible a piece of land is, the greater will be its rental value. Table 6 and 7 provide specific data of land cover and land use changes in Central Lampung Regency in 2013, 2018 and 2023 and data of land use transition among land use types.

Table 6. Matrix of Land Use Area Changes in Central Lampung Regency in 2013, 2018, and 2023 (Ha)

No.	Land Cover/Land Use	2013 (Ha)	2018 (Ha)	2023 (Ha)
1	Empty Land	63,770.12	60,970.12	53,170.12
2	Dryland Agriculture	216,621.31	184,123.31	151,625.31
3	Wetland Agriculture	50,703.65	62,291.65	73,879.65
4	Built-up Land	73,019.89	89,317.89	114,615.89
5	Forest	52,485.78	62,967.78	68,449.78
6	Water Bodies	41,672.99	38,602.99	36,532.99

Source: Research Results, 2025

Table 7. Land Cover/Land Use Change in Central Lampung Regency, 2013-2023 (Ha)

From Land Cover/Land Use	To Land Cover/Land Use	Area of Change (Ha)
Dryland Agriculture	Wetland Agriculture	16,236.00
Dryland Agriculture	Built-up Land	32,596.00
Dryland Agriculture	Forest	15,964.00
Empty Land	Built-up Land	9,000.00
Empty Land	Wetland Agriculture	1,600.00
Water Bodies	Wetland Agriculture	5,140.00

Source: Research Results, 2025

Alterations in the coverage of the bare lands, agricultural lands, built-up lands, forests, and water bodies also show change in relative rentality of the land uses. A fall in the hectares of dryland farming 216,621.31 of 2013 to 151,625.31 hectares of 2023 signifies a reduction in the rental worth of dryland farming. This trend is explained by factors such as low productivity due to climate change, high cost of production or change in the market demand. Quite on the contrary, the fact that wetland agriculture has risen to 73,879.65 hectares as opposed to 50, 703.65 hectares reveals that in any manner, its rental value can be enhanced through increased productivity either through increased irrigation, availability of the markets, or overall demand of agricultural products produced in wetlands.

There was also a significant increase in the number of hectares developed, with 73, 019.89 hectares of land becoming developed in 2013 and rising to 114, 615.89 hectares in 2023, meaning an increase in the value of land that has been rented out to be developed. The trend shows that more land is demanded in residential, industrial, and infrastructure in Central Lampung Regency. Strategic positioning and good accessibility coupled with high economic potential have contributed to the increase in value of the built-up areas. Such magnifications in land rent tend to determine how agricultural land can be developed into an area that is developed which has an impact on spatial planning and generates less farmland.

The rise of forest cover of 52,485.78 hectares in 2013 to 68,449.78 hectares in 2023 can be regarded as the rise in the land rent value as a result of environmental functions. It is also evidence of a better comprehension of how the conservation of forests can assist in ensuring an ecosystem balance, minimizing the probability of natural catastrophes, and enhancing the level of environment. Increased land rent of forests can initiate reforestation activities, conservation activities and introduction of sustainable forest management activities.

Quite the opposite, the decline of the water bodies area of 41,672.99 hectares to 36, 532.99 hectares shows that the value of the land rent of the water related activities is on the downward trend. This trend may be connected with the aggravation of the water quality, sedimentation, or the impact of climate changes that cause the unproductiveness of water resources.

Prediction of Land Use in Central Lampung Regency in 2043

The land cover and land use change are projected using Logistic Regression to land model and MOLUSCE (Model for Land Use Change Simulation) as the predictive

model. A statistical tool known as Logistic Regression compares two variables and uses them to approximate one of the variables based on the others, with MOLUSCE, a Quantum GIS plug-in, being a 6-stage process that involves data input, correlation analysis, area change analysis, transition potential modeling, cellular automata simulation, and validation. Before the process of modeling and prediction, the land cover/use datasets and driving variables are processed with ArcGIS 10.4.

Stages of Prediction using MOLUSCE:

Inputs: There are 2013 (baseline), 2018, and 2023 (final) land cover and land use maps along with driving variables, which include the soil type, slope, settlements, and road networks. Maximum likelihood approach is used to carry out the classification of land cover. Euclidean distance analysis is done on supporting variables in order to quantify how close their measures are to the factors.

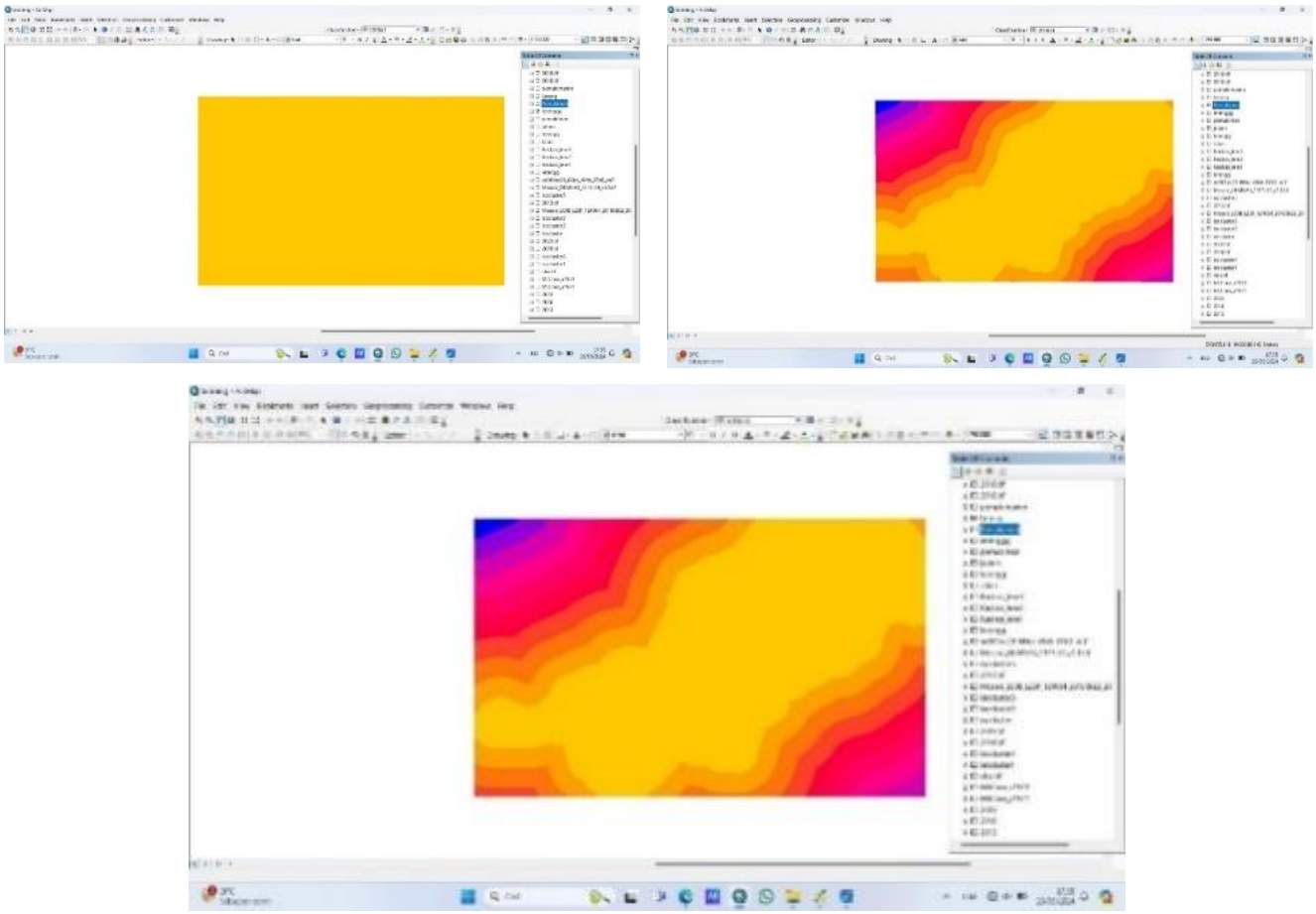

Figure 4. Driving Factors of Land Cover Change

1. **Evaluating Correlation**: Pearson correlation test was used to statistically test all the driving variables. It was found that settlements had the most impact on land cover and land use change with a correlation value of 0.99. This implies that closeness to road networks and settlement areas hastens the process of land use transformation, a fact that is similar in the case of Central Lampung Regency where large parts of land have been turned into built-in regions.

Pearson's Correlation

	lerenggg1	pemukimannn1	Jalan
lerenggg1	--	nan	nan
pemukimannn1		--	0.993160182901
Jalan			--

Figure 5. Correlation Test Results

2. **Area Change**: This step underlines the extent of land cover and land use alterations. The most remarkable change in Central Lampung Regency was the decline in dryland agriculture by 64,996 hectares then the decline in bare land by 10,600 hectares. The need to increase population is a major cause of these conversions, especially the conversion of the dryland agriculture to built-up regions and the wetland agriculture.

Table 8. Land Area Change Model for 2013 and 2023

No	Land Cover/Use	2013 Area (ha)	2023 Area (ha)	Change (ha)
1	Bare Land	63,770.12	53,170.12	-10,600.00
2	Dry Agriculture	216,621.31	151,625.31	-64,996.00
3	Wet Agriculture	50,703.65	73,879.65	23,176.00
4	Built-up Land	73,019.89	114,615.89	41,596.00
5	Forest	52,485.78	68,449.78	15,964.00
6	Water Bodies	41,672.99	36,532.99	-5,140.00

Source: Research Results, 2025

3. **Transition Potential Modeling**: The training of the model at this phase is done based on the Logistic Regression method with a maximum of 100 iterations and a 1 pixel neighborhood. The pseudo R-squared (Count) was 0.67800, which indicated the extent of impact of the driving factors on the variables. Darmawan (2015) defines an R-squared of 0.75 as strong, 0.50 as moderate, and 0.25 as weak. Thus, the (relatively good) impact of the driving factors is observed through the obtained value of 0.67800, and it is possible to proceed to the next stage of the process.

4. **Cellular Automata Simulation**: It is a step that aims at predicting land cover and land use. The prediction will be made depending on the model, and it will be compared to the real land use data in 2023. It also gives a projection to 2043. Validation led to high differences between the predicted and observed land cover types in 2023 with the greatest number in built-up land (40.96%), barren land (22.31%), and dryland agriculture (16.85%). The discrepancies can be attributed to the accuracy of the kappa of 0.67 (67 percent) which can be classified as good but it cannot be considered as excellent (80-100 percent) either.

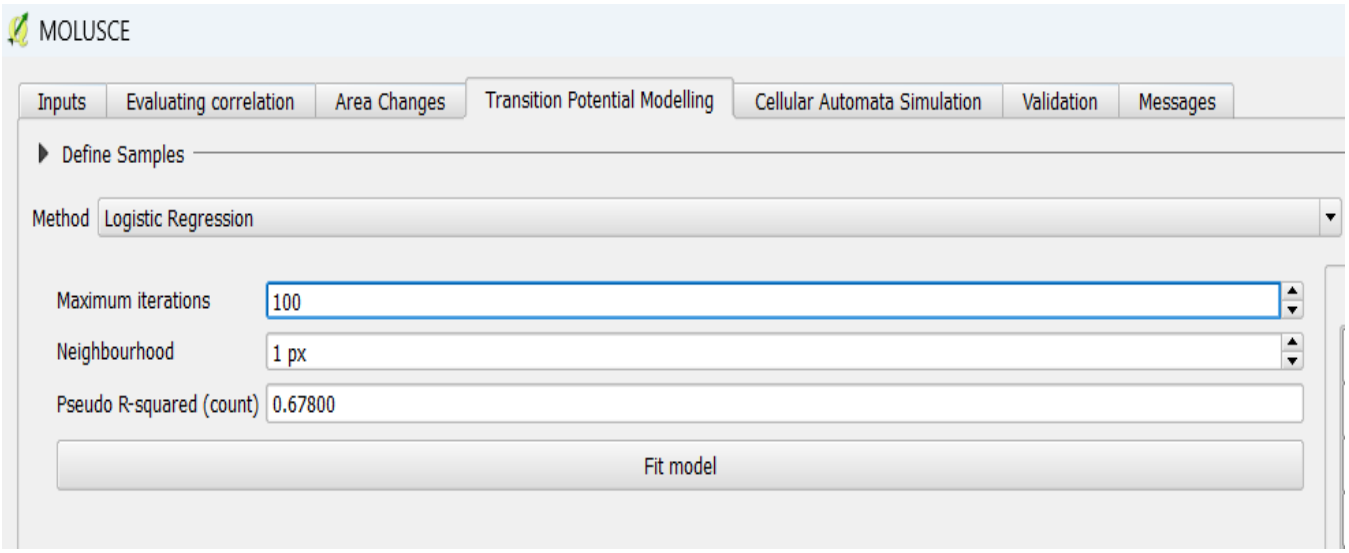

Figure 6. Results of the Transition Modelling Phase.

Table 9. Predicted and Existing Land Cover/Land Use Area (Ha)

No	Land Cover/Use	2023 (Existing) (ha)	2023 (Predicted) (ha)	Difference (ha)	Difference (%)
1	Bare Land	53,170.12	41,307.78	11,862.34	22.31%
2	Dry Agriculture	151,625.31	126,083.36	25,541.95	16.85%
3	Wet Agriculture	73,879.65	65,000.74	8,878.91	12.02%
4	Built-up Land	114,615.89	161,567.89	-46,952.00	-40.96%
5	Forest	68,449.78	69,380.99	-931.20	-1.36%
6	Water Bodies	36,532.99	34,932.99	1,600.00	4.38%

Source: Research Results, 2025

5. **Validation**: The validation of the 2023 prediction results indicates that the model demonstrates a satisfactory level of accuracy and reliability. This is reflected in the overall Kappa value of 0.67622, which falls into the "good agreement" category. The Kappa statistic measures the level of agreement between the predicted results and the reference data while accounting for agreement that may occur by chance. In addition, the percentage of correctness (83.37%) suggests that a large proportion of the model's classifications are consistent with actual conditions, highlighting its strong performance in capturing general patterns of change.

Figure 7. Kappa Value and Validations

Predicted Land Use Change in 2043

An analysis of the land use projection of Central Lampung Regency in 2043 indicates that the types and the proportion of land cover vary significantly. Throughout the 20-year period (20232043), each category of land cover is likely to experience a large increase or decrease. It is estimated that by 2043, the built areas will become the leading type, comprising 161,567.89 hectares (29.06%), and the next largest occupy the bare land with 41,307.78 hectares (28.72%). Dryland farming will consume 126,083.36 hectares (20.26%), and wetland farming will be 65,000.74 hectares (13.66%). The least extensive land use is expected to be a forest, 69,380.99 hectares, (1.34%), with water bodies expected to be the most extensive, 34,932.99 hectares (4.58%).

The increase in built-up (29.06) and bare land (28.72) is associated with the high growth of the property market and the existence of unexploited land potential (both of which directly affect land rent values). The land is likely to experience a significant change in terms of rental value due to the presence of strategic locations with high accessibility. The development of urban cities is an indication to the serious urbanization process, which is fueled by the increase in housing and business infrastructure demand, making land prices and rental costs rise in urban areas.

Changes in agricultural practices are reflected by the change in agricultural land use which showed 13.66% growth wetland farming and 20.26% decline in dryland farming. Dryland farming will be changed to wetlands or urbanized, which will lead to a decrease in agricultural production and will increase the prices of commodities. However, the development of wetland agriculture also provides the interest of the modern agricultural development.

Increase in bare land (28.72) indicates that there is underutilization of land resources, which can boost property speculation. Meanwhile, the increase in forest area at 1.34 percent indicates the continuation of environmental conservation efforts, as forests play a very critical role in ensuring a balance in the ecosystem. However, the decrease in the number of water bodies by 4.58% is worrying since water bodies are vital, particularly in fisheries and marine-based tourism.

The land use projections by 2043 have great implications on the land rent making the government policies on land use very essential to support efficient, fair and sustainable development. The challenges to be faced through these projections also include the over-exploitation of natural resources due to the increase in population and the demand in food and clothes. Moreover, the growth of urbanized districts can contribute to the rise of air and noise pollution, the rise in crime rates due to the unacceptability of communal

demands. The solutions to these problems should be regarded attentively and with the interscenic solutions that require the government and the local people to jointly apply their efforts to enact solutions to these issues, with the local government taking the lead in applying solutions like family planning, job creation, and healthy development.

Table 10. Predicted Land Cover/Land Use Area Changes in 2043

No	Land Cover/Use	2043 (ha)	Change (%)
1	Bare Land	41,307.78	28.72%
2	Dry Agriculture	126,083.36	20.26%
3	Wet Agriculture	65,000.74	13.66%
4	Built-up Land	161,567.89	29.06%
5	Forest	69,380.99	1.34%
6	Water Bodies	34,932.99	4.58%

Source: Research Results, 2025

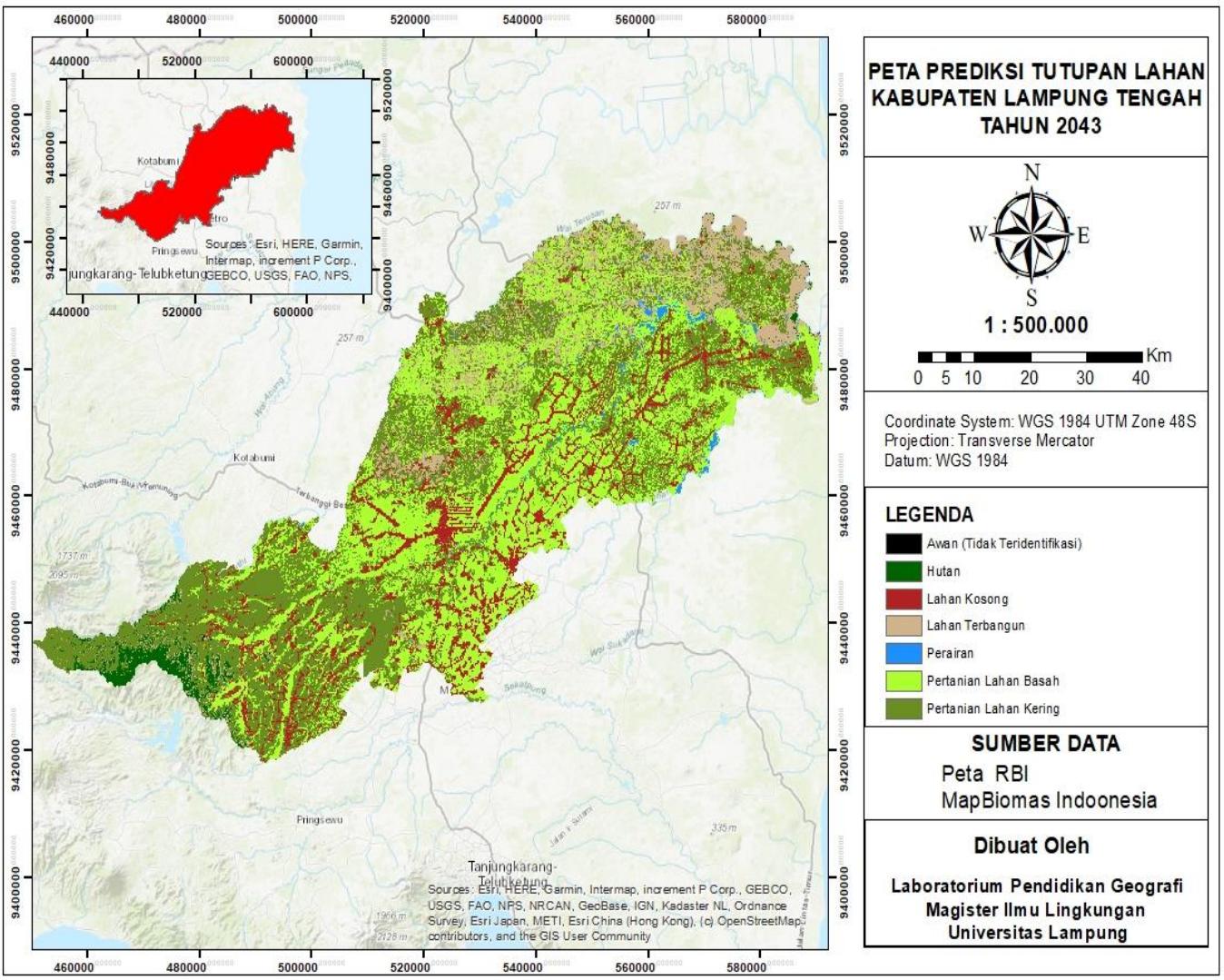

Figure 8. Predicted Land Cover/Land Use Map of Central Lampung Regency in 2043.

DISCUSSION

Central Lampung Regency Land Use Change (2013-2023)

Land cover and land use change dynamics in Central Lampung Regency in the decade that has passed (20132023) demonstrates that the changes have been immense with far-reaching development implications in the area. Agricultural industry is significant because the most common is dryland agriculture that covers 216,621.31 hectares (43.47%). However, infrastructure and access were not good at that time, and this constrained the development of built-up areas.

The increase of the built up land is enormous and the land area has increased to 114,615.89 hectares as opposed to 73,019.89 hectares implying a vast development of infrastructures and settlements. This aligns with the study conducted by Hapsary and Subiyanto (2021) and Rijal and Barkey (2017), who found that the proximity to roads/settlement and the rapid conversion of land (primarily agricultural land) into residential units along road networks were strongly correlated. This fact underscores the powerful aspect of spatial dynamics in formulating good policies and also sustainable policies in relation to the regional development.

Despite the fact that the urbanized areas have boosted agricultural activities of the drylands, the reduction of the drylands to the wetlands, forests and urban areas has been experienced in a great proportion. Wetland type agriculture like rice paddies can be said to be a more profitable crop as it is guaranteed of water, good soil, and commerciality as a result of constant irrigation thus being more enticing to farmers compared to dry land rain derivation agriculture. These changes reveal the way farmers react to the environment and market and to the reaction of farmers to the government policies in agriculture sector.

Land rent can be used to analyze the land cover change processes, which took place on the land cover of Central Lampung Regency during 2013-2023. According to Rustiadi, et al. (2011), land rent is merely a definition of an economic excess that is the net income/benefit that is yielded by a piece of land after an activity is undertaken on the piece of land in terms of the number of square meter/year. One of the factors of the land production is land rent, which has high production thereby raising land rent. The result of land competition is that an agricultural land is a non-agricultural use, which boosts land rent. The non- agricultural purposes will always increase compared to the agricultural purposes because their economic value is higher. Setiyanto and Irawan (2015) opine that the allocation of land resources is normally influenced by economic rent or land rent where land with high economic rent replaces land use with low economic rent. The conventional grouping of economic rent used in market mechanisms is industry, trade, residential, intensive agriculture, and extensive agriculture.

Business central lampung regency (2023-2043): Future land change use.

The land use land cover projection of the Central Lampung Regency in 2043 indicates that nature and area of the land cover of Central Lampung regency has transformed a lot and the prediction has a good accuracy of 0.67. The 30 years will witness great losses or gains in all the forms of land cover.

Urbanization will occupy most of the land area (161.567.89 hectares) by the year 2043 (161.567.89 hectares/32.43 of the total area). The hectares of dryland agriculture is estimated as 126,083.36 (25.30%), whereas the wetland farming will be 13.05. The smallest are water bodies that have an estimated cover of 7.01. The active population growth and the growth in the housing and infrastructure demands are directly related to the increased urbanization of land, especially the sub-district (Selagai Lingga). This is a manifestation of spatial changes that are necessitated by population pressures and economic development.

The rent change of the land is related directly to the expected transformation of agricultural lands to the developed ones. As population and the rate of economic growth increase, the demand of the urban land also increases and the value of the land rent also increases. This compels the land owners into transforming the farmland into another economic benefit which is even more costly through infrastructure development. In addition to this, other policy frameworks like the Central Lampung Regency Spatial and Regional Plan 2043 whereby the development of good infrastructures is given priority are also a key force behind the dynamics of land rent.

The projected growth of wetland agriculture and forestlands meets the economic growth and environmental sustainability targets of the RTRW. Land rent is directly affected by conversion of dry-land

agriculture to wetlands or forests. The wetland agriculture should be productive and hence the renting value will be higher to wetlands than that of forest conversion but this is bound to be mixed depending on the contribution to the economy in terms of timber or in conservation. As a result, the decisions regarding land use change should be a trade off between the economic and environmental factors. The analysis of the previous studies has revealed that one of the key factors that contributes to the land conversion as the aspect is the land value determined based on the strategic location and spatial planning policy so that the urban use of the land will always yield high rent as compared to the agricultural use of the land.

Based on previous research, conversion of the land is based on the land value. The choices made by farmers to convert agricultural land to other purposes are often dictated by economic considerations as Saputra and Budhi (2015) found. According to Mahardika and Muta'ali, as also highlighted by them (2018) the relatively large sale value/price of land is the most-significant factor, which greatly relies on the location, and whether the land falls under the policies of RTRW as an industrial or conservation land. Likewise, Erwin and Bockstael (2017) also explained that high rent in urban land use is steady compared to the rural agricultural land use.

CONCLUSSION

The results of the research indicate that the land cover and land use of Central Lampung Regency experienced significant changes between 2013 and 2023, both positive and negative. The emergence of the built up and wetland agriculture increased at an alarming rate at the expense of bare land and dry land agriculture. There was also a growth in forest areas but by a smaller percentage than the growth of built-up land. On the other hand, water bodies were always declining over the time. These transformations denote land use conversion to development and wetland farming, as well as to enhance forest cover in the area.

The land use changes projections of the Central Lampung Regency up to the year 2043 provide some significant trends. Building areas are expected to have the highest growth rate of 29.06 with a second place of 28.72 and 20.26 increasing by bare land and dryland agriculture. Wetland agriculture is also expected to grow by 13.66. Forests and water bodies on the contrary are forecasted to record smaller increases, at 1.34% and 4.58% respectively. These projected changes point to a growth in built-up lands and transformation of dryland agricultural lands and bare land and a relatively low growth in forest cover and water body cover.

On the basis of this study the following recommendations are presented: (1) Accuracy and precision at the digitization of the stages of land cover/land use types is key to producing quality classifications; (2) The presence of driving factors of change significantly affects the quality of prediction results; the more the factors are taken into account, the better results of the predictions are achieved.

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