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Projected land use change and impact in South Seluma Sub-district, Bengkulu

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Abstract The results of the study showed that land use in the three periods was analyzed using satellite imagery with appropriate resolution and multitemporal data taken in 2013, 2018, and 2023, released by the United States Geological Survey (USGS). The rice fields in those years covered an area of 846.78 ha, 727.95 ha, and 555.42 ha, respectively, while the oil palm plantations covered an area of 3,879.10 ha, 4,087.97 ha, and 4,045.89 ha, respectively. The area of rice fields in South Seluma District has decreased dramatically by around 34.41% over the past decade, while the area of oil palm plantations managed by local farmers has increased slightly by around 4.29%. The significant declined in the area of rice fields in South Seluma District could threaten rice production in Bengkulu.

Keywords: Change analysis, Projected, Oil palm

Introduction

Rice is a strategic crop and a priority agricultural program in Indonesia (Afrisa *et al*., 2023). The world's largest rice production in 2023 will be China at 147,691 million tons, followed by India at 125,038 million tons, Bangladesh at 35,511 million tons, and Indonesia at 34,360 million tons (Childs and LeBeau, 2023). Indonesia's rice production is in the top five in the world. However, Indonesia still has to import rice because the harvest is not sufficient for the needs of the Indonesian people whose population continues to increase every year (Mustikarini and Santi, 2020).

The high population in an area impacts the high need for housing and other supporting facilities, resulting in changes in agricultural land, one of which is rice fields becoming non-agricultural land (Fattah and Purnomo, 2018). Apart from that, one of the factors changing land use occurs due to economic factors,

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the high rate of economic growth, and higher levels of consumption, so the needs of a family also increase (Fattah and Purnomo, 2018).

Indonesia is a country that uses rice as the main food with a percentage of around 95% of the Indonesian population (Rubin *et al*., 2022) (Aprillya *et al*., 2019). This shows that our dependence on rice is huge. Rice production in Indonesia continues to decline. In 2022, with a harvest area of 10.45 million hectares, it will be able to produce a production of 54.75 million tons and in 2023 the harvest area will decrease to 10.20 million hectares with a production output of 53.63 million tons. The decline in rice production is influenced by the decreasing area of rice land, therefore in 2023 Indonesia will experience an increase in rice imports of 613.61% compared to 2022 (BPS Bengkulu, 2023).

Bengkulu Province's rice production in 2023, with an estimated area of 56,803 ha, decreased by 349 ha or 0.61 percent compared to the rice harvest area in 2022 which was 57,152 ha. Bengkulu Province's rice production in 2023 is estimated to be around 277,310 tons of GKG, a decrease of 4,300 tons of GKG or 1.53 percent compared to rice production in 2022 which was 281,610 tons of GKG. Rice production in 2023 for food consumption for the population is estimated to be around 159,721 tons, a decrease of 2,477 tons or 1.53 percent compared to rice production in 2022 which was 162,197 tons (BPS Bengkulu, 2023).

Seluma Regency is one of the rice center areas in Bengkulu Province, but in 2022 there will be a relatively large decrease in rice harvest area (BPS Bengkulu 2022). The area of rice fields in Seluma Regency in 2018 was 18,189 ha. The land area of South Seluma District in the same year was 3,746 ha so South Seluma District had 20.6% of the total rice land in Seluma Regency (Seluma, 2019). Changes in land use in Seluma Regency tend to be high, from 2010 to 2019, paddy field land became other land amounting to 1,645 ha, while plantation land experienced an increase of 5,609 ha (M and Fitria, 2019).

South Seluma District is also the main rice production center in Seluma with the largest area of rice fields in Seluma Regency, namely 2,225 ha (Efendy *et al*., 2021). However, the area of rice fields will experience a drastic decrease in 2022 compared to 2018, amounting to 86.31% or 512.72 ha (Afrisa *et al*., 2023). Furthermore, data from the South Seluma District continues to experience a decline in the area of rice fields due to changes in land use from rice fields to oil palm plantations and residential areas. Changes in rice fields will have an impact on reducing land for food crops (Prasada and Rosa, 2011). This can result in threats to a region's food security. This research is important to carry out so that it can be used as a basis for taking appropriate policies to overcome the problem of changing rice fields, using a Geographic Information System (GIS). One remote sensing medium that can be utilized is a Geographic Information System (GIS) to monitor changes in the use of rice fields (Lindari *et al*., 2018). The area of rice fields that have experienced changes in land use can be seen every year clearly, which areas have experienced changes in land use from rice fields to non-rice fields (Yasta *et al.,* 2019).

The aim was to analyze and map changes in the use of rice fields in South Seluma District during the period 2013, 2018, and 2023.

Materials and methods

The research was conducted from March to July 2024 in South Seluma District, Seluma Regency, Bengkulu Province. The research location is shown in Figure 1.

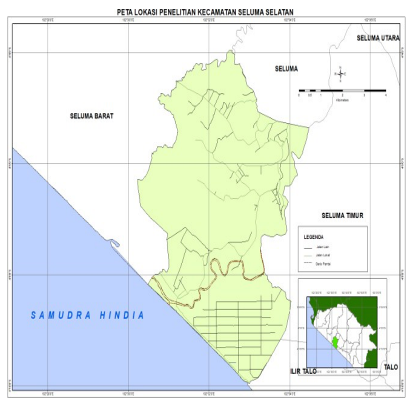

Figure 1. Research location

The tools used in this research are One laptop unit with Arcgis 10.8 software, TerrSet 18.31 software, and the Google Earth Engine website; Devices (camera for documentation, Avenza Maps application), and stationery.

The materials used in this research are an administrative map of the South Seluma subdistrict and a land use map of South Seluma.

Research stage

This research was carried out in South Seluma sub-district, Seluma Regency, Bengkulu Province, in several stages, namely: The research started with selecting a research topic on land use change, then conducting a literature study from journals and books related to the topic to be researched, then preparing a draft proposal and finally the research method is determined.

Before carrying out a survey in the field, what needs to be prepared is a letter of permission to conduct research in South Seluma District, Seluma

Regency, Bengkulu Province. After carrying out permits regarding the research location, the next step is to prepare the tools and materials needed for the field survey.

Data collection

The direct observations were conducted in the field to find out the location and obtain data on rice fields that have turned into non-rice fields in South Seluma District, Seluma Regency, Bengkulu Province.

The interview used in this research was an unstructured interview technique. In this interview technique, farmers will be asked questions regarding the extent of conversion of rice fields into residential areas by several farmers in South Seluma District, Seluma Regency, Bengkulu Province.

Secondary data was collected on the Google Earth Engine website in 2013, 2018 and 2023. Secondary data serves to see changes in land cover over the last 10 years.

Data analysis

Direct observations were conducted in the field to find out the location and obtain data on rice fields that have turned into non-rice fields in South Seluma District, Seluma Regency, Bengkulu Province.

Data analysis in research using Geographic Information Systems (GIS) involved processing spatial data to obtain relevant information. The stages include: Research data collection is carried out through related websites. Administrative map data was obtained from the Indonesian Homeland website. After the administrative data is obtained, data processing is then carried out using Google Earth Engine. Before processing data, researchers must first create a Google Earth Engine account to be able to log in. After having a Google Earth Engine account, administrative map data for South Seluma District is entered to make it easier to manage the work area in making maps of rice field use for 2013, 2018, and 2023. Furthermore, land use maps for 2013, 2018, and 2023 can be made.

The interpretation stage in this research uses Landsat 8 image data available on the Google Earth Engine (GEE) website by applying supervised classification. Next, classification is carried out using the Random Forest method to identify and group the types of land cover or objects contained in the image. The land cover classification in this research is divided into six classes, namely water bodies, settlements, gardens (including mixed gardens and horticultural crops), rice fields, oil palms, and shrubs.

Checking the image results or ground check after obtaining a land use map from the Google Earth Engine (GEE) website is an important step to ensure the accuracy and validity of the map that has been produced. After obtaining data from the field survey, the next step is to carry out validation and accuracy tests to assess the error level, so that the percentage of mapping accuracy can be calculated using an accuracy index. The overall accuracy value and Kappa accuracy index can be calculated using the following formula:

$$\text{Overall accurary} = \frac{x}{N} x100\%$$

Information :
X : The number of samples is correct for land use
N : Total number of land use samples

$$K = \frac{N \ \sum_{i=1}^{K} Xii - \sum_{i=1}^{k} (Xi + * x + 1)}{\sum_{i=1}^{k} (Xi + * x + 1)}$$

Information :
X+i : Total number of land use samples number of point interpreted as a result of land use type i
Xi+ : Number of points from validation results for land use type i
Xii : Number of land use types i from interpretation results (diagonal row)
i : row or column
r : Number of land use types
N : Number of validated land-use points
K : Kappa value

Results

Land cover

The results of land cover interpretation in South Seluma District identified six land use classes, namely water bodies, settlements, dry land agriculture, rice fields, oil palm plantations, and shrubs. This interpretation was done using Landsat 8 imagery via the Google Earth Engine (GEE) website for 2013, 2018, and 2023. There was no change in the area of water bodies from 2013 to 2023, which remains at 57 hectares or 1,000 hectares—13% of total land cover (Table 1). Residential land has increased from 122 hectares (2.41%) in 2013 to 154 hectares (3.04%) in 2023, which indicated urbanization or an increase in population.

Dryland farming has also increased, from 4 hectares (0.08%) in 2013 to 12 hectares (0.24%) in 2023. Although this increase is relatively small, it shows the expansion of agricultural activities in dry land. In contrast, paddy field land experienced a significant decreased, from 836 hectares (16.52%) in 2013 to 553 hectares (10.93%) in 2023. Meanwhile, oil palm plantation land increased significantly, from 3,931 hectares (77, 67%) in 2013 to 4,195 hectares (82.89%) in 2023. Shrub land experienced a slight decrease, from 112 hectares (2.21%) in 2013 to 92 hectares (1.78%) in 2023.

Table 1. Land Use 2013, 2018, and 2023 South Seluma District

Land Use	**2013**		**2018**		**2023**	
	Large (Ha)	%	Large (Ha)	%	Large (Ha)	%
Body of water	57	1.13%	57	1.13%	57	1.13%
Settlement	122	2.41%	143	2.83%	154	3.04%
Agriculture dry land	4	0.08%	9	0.18%	12	0.24%
Ricefield	836	16.52%	652	12.88%	553	10.93%
Palm land	3.931	77.67%	4.106	81.13%	4.195	82.89%
Shrub	112	2.21%	94	1.82%	92	1.78%
Total	5.061	100%	5.061	100%	5.061	100%

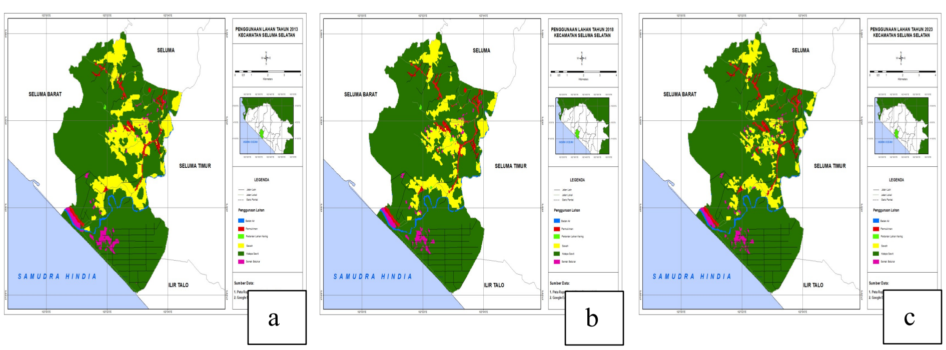

Figure 2. Land use map in (a) 2013; (b) 2018 and (c) 2023

Land cover clarification accuracy test

After the annual land use map had been prepared, an accuracy test is carried out on the land use/cover classification. This study used 90 test points selected randomly using the random sampling method. Error matrix calculations were carried out to evaluate the suitability between the resulting map and actual conditions in the field and then a ground check was carried out in the field at the

90 points. The results of the ground check in the field were compared with the land use map of South Seluma District in 2023. The comparison between the 2023 land use map and data from the ground check in the field can be seen in Table 2, error matrix calculation.

Table 2. Error matrix

Usage result class land	**Field inspection results**						
	Body of water	Settlement	Farm	Rice field	Palm land	Shrub	Total
Body of water	3	0	0	1	0	0	4
Settlement	0	20	0	0	0	0	20
farm	0	0	3	0	0	0	3
Ricefield	0	1	0	23	1	0	25
Palm land	0	0	0	0	32	0	32
Shrub	0	0	0	0	0	6	6
Total	3	21	3	24	33	6	90

In the table above, there are several discrepancies between land use on the map and conditions in the field. In the area marked with a yellow box, it should be rice fields but is read as residential on the land use map, then the area should be rice fields but is read as oil palm land. Even though there are several discrepancies between the ground check results in the field and the 2023 South Seluma land use map, the kappa accuracy value in this study reached 95.47%. This shows that the land use map of the South Seluma District can be used.

Land cover overlay

The land use overlay aims to clarify changes in land use, especially regarding the extent of changes between land covers. Based on Table 3, it can be seen that the water body has not changed from 2013 to 2018, remaining with an area of 57 hectares. It showed that water bodies tended to be stable and rarely experience significant changes in area. Settlements did not experience changes in land use, however, the area of settlements experienced a fairly large increased in this period, with an additional area of 20 hectares originating from the conversion of rice fields, as well as 1 hectare of bushes which were converted into settlements in 2018. This increase indicates a transition of significant land function towards urbanization.

Dryland farming has also expanded, with an additional 6 hectares of area previously used as rice fields. It showed that there is shown the agricultural land conversion caused by changes in land use patterns by local communities.

Meanwhile, rice fields did not experience an increase in area, but instead experienced a reduction. Several areas of rice fields have been converted into residential areas, dryland farming, and oil palm plantations. In detail, 154 hectares of rice fields were converted into oil palm plantations, reflecting a significant increase in the expansion of plantation land. Apart from that, a small part of the rice fields turned into bushes covering an area of 5 hectares.

Shrubs have also been converted into oil palm land covering an area of 21 hectares, while 1 hectare of bushes has been converted into residential areas. Thus, bushland tends to experience drastic changes, both towards oil palm plantations and settlements. Overall, changes in land use between 2013 and 2018 show that most of the rice fields and bushland have been converted into settlements and oil palm plantations. It is illustrated a significant shift in land use, with dominant changes towards the oil palm plantation sector and the expansion of residential areas.

Table 3. *Overlay* of land use in 2013 and 2018

	2018							
	Land use	Body of water	Settlement	Agriculture dry land	Rice field	Palm land	Shrub	Grand total
2013	Body of water	57						57
	Settlement		122					122
	Agriculture dry land			4				4
	Ricefield		20	6	652	154	5	836
	Palm land					3.931		3931
	Shrub		1			21	89	112
	Grand total	57	143	9	652	4.106	94	5.061

Land use between 2018 and 2023 is shown in Table 3. The water body remained stable in the same area, namely 57 hectares, and has not changed during this period. The area of settlements has increased quite significantly, from 122 hectares in 2018 to 143 hectares in 2023, with an addition of 21 hectares. The increase in residential area mostly came from the conversion of 10 hectares of rice fields and 1 hectare of bushes.

Apart from that, dry land farming also showed a slight increase, from 9 hectares in 2018 to 12 hectares in 2023, the addition of which came from the conversion of 3 hectares of rice fields. However, rice fields experienced a significant reduction in area, from 652 hectares in 2018 to 553 hectares in 2023, or a reduction of 99 hectares. Most of these rice fields have been converted into settlements, dry land agriculture, and oil palm plantations.

Palm oil continues to increase in area, from 3,931 hectares in 2018 to 4,106 hectares in 2023, with an addition of 175 hectares. This is increased in palm oil area came from the conversion of 83 hectares of rice fields and 5 hectares of bushland. Lastly, bushland experienced a slight decrease in area, from 94 hectares in 2018 to 92 hectares in 2023, most of which was converted to oil palm land.

Table 4. *Overlay* of land use in 2018 dan 2023

	2023							
	Land use	Body of water	Settlement	Agriculture dry land	Rice field	Palm land	Shrub	Grand total
2018	Body of water	57						57
	Settlement		143					143
	Agriculture dry land			9				9
	Ricefield		10	3	553	83	3	652
	Palm land					4.106		4.106
	Shrub		1			5	88	94
	Grand total	57	154	12	553	4.195	92	5.061

The changes in land use between 2013 and 2023 is shown in Table 4. In this period, the water body remained stable with an unchanged area, namely 57 hectares, showing the consistency that is common in water bodies that rarely experience changes. The area of settlements has increased significantly, from 122 hectares in 2013 to 143 hectares in 2023, with an addition of 21 hectares. This increase mostly came from the conversion of 30 hectares of rice fields and 2 hectares of bushland into residential areas.

Dryland farming also experienced a slight increase, from 4 hectares in 2013 to 12 hectares in 2023. This expansion of dry land farming came from the conversion of 8 hectares of rice fields. Meanwhile, rice fields experienced a significant reduction in area, from 836 hectares in 2013 to 553 hectares in 2023, with a reduction of 283 hectares over the last ten years. This reflects the shift in the function of rice fields to various other uses, especially to settlements, dry land agriculture, and oil palm plantations.

Palm oil experienced a significant increase during this period, from 3,931 hectares in 2013 to 4,106 hectares in 2023. It is increased in palm oil area came from the conversion of 237 hectares of rice fields and 26 hectares of bushland into oil palm land. Shrubs experienced a slight reduction, from 94 hectares in 2013 to 92 hectares in 2023. This reduction in the use of scrub land occurred due to the conversion of 26 hectares to oil palm and 2 hectares to residential areas.

However, shrubs also experienced a slight increase of 8 hectares which came from the conversion of paddy fields.

Table 5. Overlay of land use in 2013 dan 2023

		2023						
2013	Land use	Body of water	Settlement	Agriculture dry land	Rice field	Palm land	shrub	Grand total
	Body of water	57						57
	Settlement		122					122
	Agriculture dry land			4				4
	Ricefield		30	8	553	237	8	836
	Palm land					3.931		3.931
	Shrub		2			26	84	112
	Grand total	57	143	12	553	4.195	92	5.061

Model validation

The Kappa accuracy value or similarity level which is in the range of 0.81 to 1.00 is categorized as very high. The validation results of the land use model in 2023 showed a Kappa value of 0.92, which indicated that the land cover prediction map is in the very good category. Therefore, this land use prediction map is found to be suitable for predicting land use in the South Seluma District in the next 10 years.

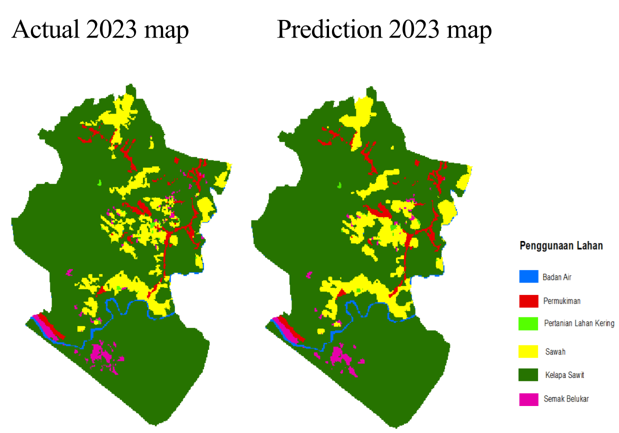

Figure 3. Validation results of the land use model

This research was conducted in the South Seluma District, Seluma Regency, Bengkulu Province, Indonesia. South Seluma District borders Seluma District to the north, East Seluma District to the east, the Indian Ocean to the south, and West Seluma District to the west. This sub-district has a diverse topography, ranging from flat, sloping, wavy to steep, and is the largest irrigation and rice-producing area in Seluma Regency.

The majority of people in the South Seluma District work in the agricultural, plantation, and small business sectors, with an economy dominated by agriculture, especially rice, corn, fruit, and vegetables, as well as plantation activities such as oil palm. In this research, analysis, and prediction of changes in paddy land use are carried out by classifying land cover into six main classes, namely water bodies, settlements, rice fields, oil palm, dry land agriculture, and shrubs, to analyze, predict and mapping changes in land use from year to year.

In carrying out the analysis and predictions, ArcGIS and TerrSet software were used, as well as Landsat 8 image data obtained via the Google Earth Engine (GEE) website. The analysis process involves three main steps, namely:

1. Image Classification: Using a supervised classification method to identify and group various types of land cover based on satellite image data.
2. Spatial Analysis: Using ArcGIS for mapping and spatial analysis to understand patterns of land cover change and distribution.
3. Simulation and Prediction: Using TerrSet to model land use change and predict future developments.

Through this approach, research is discussed and provided in-depth insight into the dynamics of changes in paddy field use and their impact on food security in the South Seluma District. It is hoped that the results would provide useful information for planning and managing natural resources, as well as supporting sustainable development policies in the region.

Discussion

Overall, the results of the total analysis and land use overlay results showed a significant shift in land function over ten years in South Seluma District during the period 2013 to 2023. Several land categories, such as water bodies, remain stable without change. However, even though the water bodies appear stable, what is identified is not irrigation systems, but large rivers and ponds, because the map classification uses Landsat 8 data with a resolution of 30×30 meters. Rice fields and shrubs are the sectors that experience the most conversion. In particular many rice fields have changed their function to become oil palm plantations and settlements.

As the population increases, the need for residential land would continue to increase because existing land cannot increase. So there will be a change in land cover from agricultural land to non-agricultural land (Klein *et al*., 2011). Apart from demographic factors, one of the main reasons rice farmers switch to oil palm is the difficulty of getting irrigation water (Zamhari *et al*., 2019). Many rice fields do not receive adequate water flow, so farmers choose to plant oil palm which does not require continuous irrigation. This is in line with the opinion of (Sabar *et al*., 2024) which states that minimal water availability encourages farmers to convert rice fields into plantations.

The irrigation factor is very important in rice cultivation because good irrigation will have an impact on increasing rice production (Linnaninengseh *et al*., 2017). Apart from that, the low price of rice is not commensurate with the high maintenance costs, from planting to harvest.

This is different from oil palm, which requires less maintenance and can be harvested every two weeks. This is in line with the opinion (Barchia *et al*., 2021b) (Barchia *et al*., 2021a) that another factor driving the conversion of paddy fields is high input costs, such as seeds, fertilizer, and insecticides. In addition, rice takes longer than palm oil to harvest, plus the risk of crop failure due to pests, as well as smaller profits. The condition of peat soil is also another factor that drives this change. According to farmers, planting rice on peatlands requires greater costs, and the results obtained are not commensurate with the capital spent. As a result, farmers prefer to replace rice with oil palm which is considered more profitable (Melisa and Wulandari, 2021). This change reflected the trend of increasing demand for land for more profitable settlements and plantations. This also shows the adaptation of land use in response to continuing economic, social, and demographic changes.

The main problem faced by farmers was the lack of adequate water flow, which causes rice fields to change function. So it is hoped that there would further research focusing on in-depth analysis regarding the condition and effectiveness of the irrigation system in South Seluma District to examine the potential for improving irrigation infrastructure and its impact on rice productivity and the stability of paddy fields.

During the period 2013 to 2023, there was significantly changed in land use in the South Seluma District. Rice fields experienced a drastic decrease from 836 hectares in 2013 to 553 hectares in 2023, which was equivalent to decrease of around 283 hectares or 33.86%. Most of the rice fields were converted into oil palm plantations and residential areas. Residential areas increased from 122 hectares to 154 hectares, while oil palm plantations increased from 3,931 hectares to 4,195 hectares. This change is mainly caused by population growth and economic pressure, which triggers the conversion of rice fields to other land.

Conflicts of interest

The authors declare no conflict of interest.

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