

Model for Predicting Land Use Changes in the Coastal Area of Mandeh, Pesisir Selatan Regency

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Abstract. The Mandeh region in West Sumatra is a captivating tourist destination known for its breathtaking natural landscapes, including hills, beaches, and surrounding islands. However, The enhancement of the Mandeh region as a captivating tourist destination necessitates the construction of tourist facilities and infrastructure, which can result in changes regarding land use and land cover (LULC). It is essential to understand and model these changes to assess their potential impacts on the environment. To address this, a quantitative method using a remote sensing approach was employed in this study. The data used for modeling LULC changes in the Mandeh region for 2025 and 2030 were obtained from satellite imagery, specifically Landsat 5 in 2000, Landsat 7 in 2007, and Landsat 7 in 2019. These images served as reference data for accuracy testing. The findings regarding LULC changes in the Mandeh region for 2025 and 2030 indicate that the most significant changes occur in the secondary forest land cover category. The area covered by secondary forest decreased by 54.61 hectares (1.34%), while the primary forest area also experienced a decline of 61.38 hectares (1.49%). On the other hand, residential land use witnessed an increase of 4.23 hectares (0.10%). The modeling of LULC changes from 2025 to 2030 further demonstrates that the area covered by secondary forest undergoes a change of 117.07 hectares (2.85%), while the area covered by primary forest changes by 13.33 hectares (0.32%), both experiencing a decrease. The expansion of developed land accounted for 0.82 hectares (0.02%) of the increased land use. These findings shed light on the anticipated changes in LULC in the Mandeh region, with a notable decrease in forested areas and a slight increase in developed land. It is important to carefully manage and monitor these changes to ensure sustainable development, preserve the natural environment, and maintain the ecological balance of the region.

Keywords: Land use, land cover and modelling

1 Introduction

A common problem faced by regions becoming tourist destinations is the growing need for tourism support facilities and infrastructure to ensure that tourists are comfortable during their tours. This facility and infrastructure improvement has changed LULC [1,2,4,7,11,12,18,19,22]. Changes in land use change that are not controlled often cause disruption of the environmental system in an area. Changes in the environmental system that are not controlled can cause land degradation, high land erosion, trigger natural disasters, and disrupt aquatic ecosystems. The inadequate progress in developing regional infrastructure has resulted in alterations to land utilization and land cover, particularly in regions characterized by Kulm slopes. Typically, these steep slopes are covered by primary and secondary forests, which play a crucial role in safeguarding the surrounding environment [3,5,8,12,15,17]. The land cover in the Mandeh area serves not only for the establishment of tourism-supporting facilities and infrastructure but also for the local community's utilization of agricultural land [6,17,20,24,22,]. This land clearing often causes open land which can accelerate surface erosion and trigger landslides. Materials resulting

from erosion and landslides when it rains will be carried to lower areas and eventually reach the coastal waters. The high sedimentation in this coastal area causes the accumulation of coral reefs, causing coral reefs to not develop properly [6,9,10,13,14,16,21].

2 Method

This study employs quantitative methods with a remote sensing approach to generate fundamental data inputs for modeling LULC changes in 2025 and 2030. The baseline data utilized in this study consist of Landsat 5 imagery from 2000, Landsat 7 imagery from 2009, and Landsat 8 Oli imagery from 2019. These data were utilized for validating the precision of the modeling results. The modeling outcomes based on the underlying data from 2000 and 2009 were employed as predictions for 2019. Subsequently, the modeling results for 2019 were evaluated for accuracy by comparing them with the Supervised Landsat 8 Oli classification results of the same year. If the kappa index values indicate an accuracy test result of over 85%, the modeling results can be considered valuable for predicting LULC changes in 2025 and 2030.

Data analysis techniques

Modeling LULC for 2025 and 2030 in the Mande region using the Automata Cellular Markov Chain method using the following formulas;

$$\begin{aligned}
 X_{t+1} &= X_t \times P \\
 \text{where:} \\
 P &= m \times m \\
 m &= \text{number of pixels} \\
 X_{t+1} &= X_t * P
 \end{aligned}$$

Where:

$p = m \times m$ matrix

$m =$ number of pixels

"P" represents a class pair that refers to a specific combination LULC. In this context, "i" and "j" represent two distinct categories or classes within the LULC classification system. Together, the class pair "P" signifies a specific transition or change from one land use category to another land cover category. [23,24,25], so it can be formulated as follows;

$$\begin{aligned}
 &P_{1.1} \quad P_{1.2} \quad P_{1.n} \\
 P = (P_{ij}) &= P_{2.1} \quad P_{2.2} \quad P_{2.n} \\
 &P_{3.1} \quad P_{3.2} \quad P_{3.n} \\
 0 \leq P_{ij} &\leq 1 \quad (ij = 1,2,3, \dots, n)
 \end{aligned}$$

3 Results and Discussion

To model LULC change in 2020 and 2030, we need the factors that determine LULC change in the form of driving forces. Its driving force is distance to roads, government centers, business facilities, medical facilities, educational institutions, and hills. LULC changes in the study area were affected by the opening of the road between Sungai Pinang village and Carocok Anau village. The opening of this road will make it easier for people to access farmland and enable the

rapid development of tourist facilities and infrastructure. See the figure below for more information on land use change and land cover in the Mandeh region

Land Use and Land Cover Change

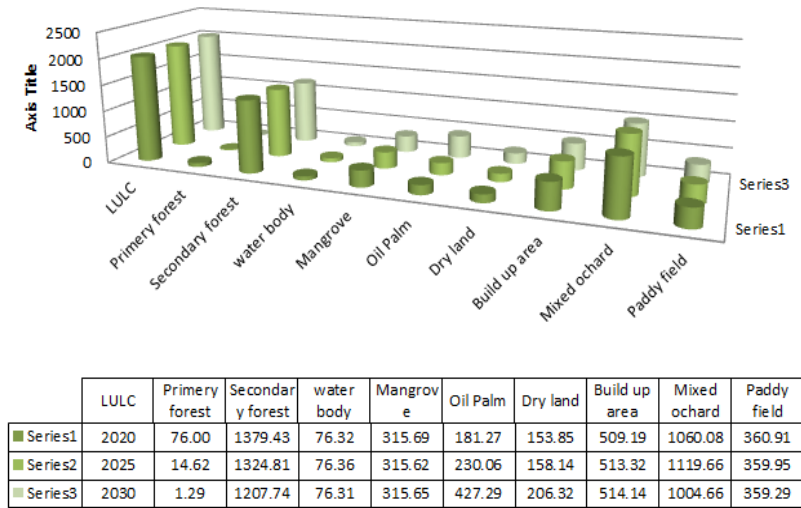


Figure 1 shows changes in LULC from 2020 to 2030 in the Mandeh region.

The most significantly affected land cover type is the secondary forest, with its area decreasing over time. In 2020, the secondary forest covered an area of 1,379.43 hectares, accounting for 33.55% of the total land cover. However, projections indicate a decline in the area of secondary forest land cover in subsequent years. By 2025, it is predicted to decrease to 1,324.81 hectares (32.21%), and by 2030, it is projected to further decrease to 1,207 hectares (29.36%). Similarly, the primary forest land cover has also experienced substantial changes. In 2020, the area of primary forest land cover was 75.99 hectares (1.85% of total land cover). The model predicts a continuous decline in the area of primary forest land cover. By 2025, it is projected to decrease to 14.62 hectares (0.35%), and by 2030, it is estimated to further decrease to 1.28 hectares (0.03%). These changes in land cover, specifically in primary and secondary forests, have been accompanied by the expansion of developed land and agricultural areas. The conversion of land for urban development and agriculture has contributed to the significant transformations in land cover observed in the study.

It is important to consider these land cover changes and their implications for ecosystem preservation and sustainable land management in the Mandeh region. Implementing appropriate land use policies and conservation measures can help mitigate the adverse impacts on natural resources and promote ecological sustainability. There have been significant changes in land use in the Mandeh region, particularly in the form of mixed gardens, fields, oil palm plantations, and built-up areas. The area of mixed orchard land use was 1,060 hectares or 25.77% in 2020, with a predicted increase to 1,119.66 hectares or 27.22% in 2025, and a subsequent decrease to 1,004 hectares or 24.43% in 2030. The area of field land use was 153.85 hectares or 3.74% in 2020, with a projected increase to 158.14 hectares or 3.86% in 2025, and a further increase to 206.32 hectares or 5.02% in 2030. The most significant land use change occurred in oil palm plantations,

with an area of 181.27 hectares or 4.40% in 2020, a predicted increase to 230.06 hectares or 5.59% in 2025, and a further increase to 427.29 hectares or 10.39% in 2030. The area of built-up land was 509.19 hectares or 12.38% in 2020, with a predicted slight increase to 513.21 hectares or 12.48% in 2025, and a relatively stable area of 514 hectares or 12.50% in 2030. These changes reflect the dynamic nature of land use in the Mandeh region over time.

Land use changes in the Mandeh region predominantly involve the expansion of built-up areas, which include residential buildings and the development of tourism-related facilities and infrastructure. The increase in developed land is driven by population factors, such as a growing population due to high birth rates and migration. The opening of the road connecting Sungai Pinang and Carocok Anau villages has facilitated increased tourism in the area, attracting more visitors to enjoy the scenic beauty of the Mandeh region, including its islands, hills, and beaches. The rise in tourist numbers has necessitated the construction of new facilities and infrastructure to support tourism activities, as well as the establishment of roadside food stalls by local communities.

The accuracy test results for modeling land-use change and land cover in the Mandeh region demonstrate a high level of accuracy. The model achieved an accuracy rate of 90% in 2020, followed by 88% in 2025, and 87% in 2030. These findings indicate the effectiveness of the modeling approach in accurately predicting and capturing the changes in LULC over time. The high accuracy values validate the reliability of the modeling results in providing valuable insights into the patterns and trends of land use change and land cover in the Mandeh region.

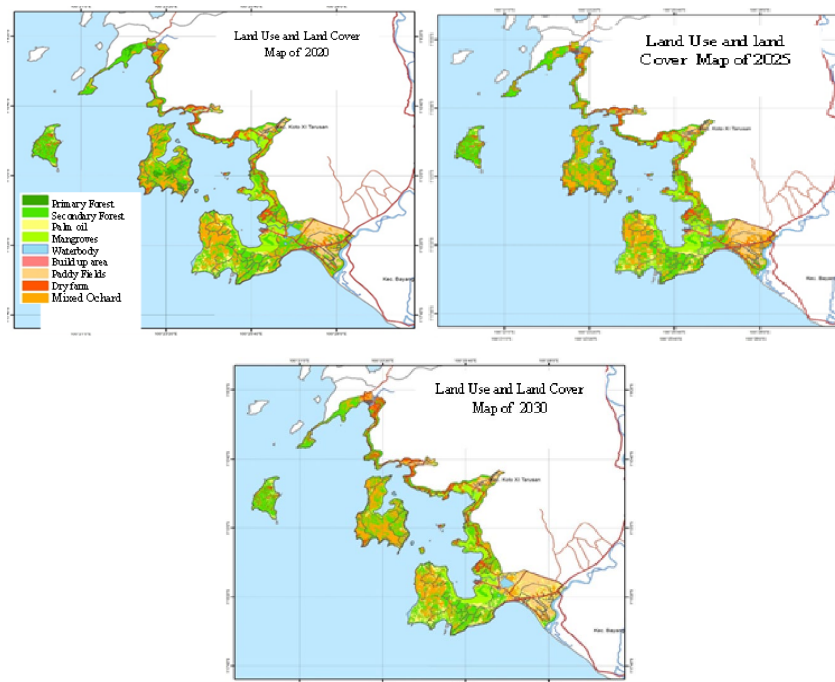


Fig. 2. Model and Prediction Result of LULC the Mandeh Region

3.1. Discussion

The opening of the road connecting Sungai Pinang and Carocok Anau villages is anticipated to have significant repercussions on LULC in the Mandeh area. Previously, the region was accessible solely by sea, but the introduction of the road has led to rapid changes in land utilization and coverage. However, it is important to acknowledge that these alterations come with potential negative outcomes. The road construction has necessitated the clearance of slopes, which can result in erosion and landslides, posing a threat to the nearby coral reefs. Among the affected land cover types, secondary forests have encountered the most pronounced impact, with a substantial reduction of 117 hectares, equivalent to a 2.85% decrease in area. Moreover, primary forest cover has also experienced a decline, with projections indicating a decrease of 61.38 hectares (1.49%) from 2020 to 2025, followed by a further decline of 13.33 hectares (0.32%) from 2025 to 2030.

These findings indicate the substantial impact of the road opening on LULC in the Mandeh area, particularly in terms of decreased forest cover. It highlights the importance of considering environmental consequences and implementing measures to mitigate any negative effects on the ecosystem, such as erosion control and sustainable land management practices. It is predicted that a number of land use changes are increasing in the region, including oil palm cultivation, afforestation and land development. As market prices for oil palm agricultural products continue to rise, land use for oil palm cultivation has increased significantly. Rising palm oil market prices have prompted many communities to convert their land to secondary forests. Mandeh region oil palm land area is projected to increase by 48.80 ha or 5.59% from 2020 to 2025, and oil palm land area is projected to increase by 197.23 ha or 4.80% from 2025 to 2030. Other land uses Land growth will take the form of dryland agriculture, with the dryland area increasing by 4.30 ha or 3.85 ha between 2020 and 2025 and by 0.82 ha between 2025 and 2030. Be expected. hectares or 0.02%. The increase in living space in the Mandeh area is mainly due to the addition of tourist facilities and infrastructure. However, the Mandeh area has flat slopes and is very limited, so the addition of community settlements is less important. Villages are usually built on flat slopes.

4 Conclusion

Based on the information provided, it can be concluded that significant changes have occurred in both LULC in the Mandeh area. There has been a noticeable decrease in both primary and secondary forest land cover. Furthermore, there have been significant transformations in land use, including the establishment of new categories such as oil palm plantations, dry farms, and urban areas. These changes reflect shifts in economic activities and overall regional development.

It is essential to highlight that the expansion of oil palm plantations and urban areas in the Mandeh region can have significant environmental implications. These changes may negatively impact biodiversity, soil quality, and the overall ecological balance of the area. To ensure sustainable development, it is crucial to adopt careful management and monitoring practices for these land use changes. This includes implementing measures to minimize environmental degradation, promoting sustainable land management practices, and considering the conservation of natural ecosystems. By doing so, it becomes possible to mitigate any potential negative impacts on the environment while facilitating the region's development in a sustainable manner.

4.1 Suggestion

Based on the findings of the studies, several considerations should be taken into account to maintain ecological sustainability in the Mandeh region in response to uncontrolled changes in land use and cover:

- a. Giving utmost importance to land use practices that prioritize the preservation and protection of the Mandeh area's ecosystem is crucial. This entails thoroughly assessing the environmental impact of proposed land use changes and adopting sustainable land management practices to minimize any potential ecological damage.
- b. Land use policies should be established to discourage land clearing, particularly in areas with steep slopes. Such policies can include regulations and incentives that promote the conservation of natural habitats and discourage activities that could lead to erosion, landslides, and other forms of ecological degradation.
- c. Public education plays a vital role in raising awareness about the negative consequences of deforestation, both for agricultural and non-agricultural purposes. By educating the local community about the importance of maintaining ecosystems, the risks of deforestation, and the value of sustainable land practices, individuals can make informed decisions and contribute to the preservation of the region's ecological balance.

By considering these factors and implementing appropriate measures, it is possible to foster ecological sustainability in the Mandeh region, ensuring the long-term health and vitality of the local ecosystems.

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