International Journal of Multidisciplinary Sciences and Arts
E-ISSN :2962-1658
Volume 5, Number 2, April 2026
https://doi.org/10.47709/ijmdsa.v5i2.8286

Strategies for Addresing Population Dynamics and Land Cover Change in Bukit Mangkol

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open access

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Article History:
Submitted: 09-04-2026
Accepted: 16-04-2026
Published: 22-04-2026

Keywords:
Population Dynamics; Land Cover Change; GIS RaTA; AHP; Bukit Mangkol Grand Forest Park.

ABSTRACT

The Bukit Mangkol Grand Forest Park (Tahura) in Central Bangka Regency, Bangka Belitung Islands Province, plays a vital ecological role as a biodiversity conservation area. However, rapid population dynamics in surrounding buffer zones have driven significant land cover changes within this conservation area. This study aimed to analyze the dynamics of population growth and its impact on land cover change, identify primary driving factors through Rapid Land Tenure Assessment (RaTA), and formulate resolution strategies using the Analytical Hierarchy Process (AHP). A mixed-methods approach was employed, integrating spatial analysis through Geographic Information Systems (GIS) using Landsat 7 ETM+, Landsat 8 OLI, and Sentinel 2A imagery from 2013 to 2023. Results revealed that the total population of Central Bangka Regency increased by 23.6%, from 167,000 in 2013 to 206,478 in 2023. Concurrently, secondary dry forest cover declined by 23.9% (from 1,462.1 ha to 1,113.16 ha), while plantation areas expanded by 186.7% (from 218.72 ha to 627.03 ha). RaTA analysis identified three primary factors influencing land cover change: ecological (land tenure insecurity), social (population growth in buffer zones), and economic (livelihood dependency on forest resources). AHP analysis showed that ecological factors received the highest priority weight (0.665), followed by economic (0.237) and social (0.098) factors. Recommended strategies include critical land rehabilitation and law enforcement (ecological), community participation through conservation partnership (social), and development of alternative livelihoods (economic).

INTRODUCTION

Forests, besides serving as providers of natural habitats, also play a role in maintaining the balance of local, regional, and global ecosystems (Rahmawati, et. al, 2025). In Indonesia, the importance of forests has become increasingly critical due to the continuing rise in deforestation, particularly in conservation areas that are legally designated to be protected from exploitation. According to Law No. 41 of 1999 on Forestry, forest areas in Indonesia are classified into three main functional categories: conservation forests, production forests, and protection forests, each of which is subject to specific management and utilization regulations.

Bukit Mangkol Forest Park (Taman Hutan Raya/Tahura Bukit Mangkol) is one of the conservation areas located in Central Bangka Regency, Bangka Belitung Islands Province, Indonesia. This area serves important ecological functions as a regional environmental buffer, a source of clean water, and a habitat for biodiversity. Geographically, Tahura Bukit Mangkol is located at 106° 6' 22.487" E and 2° 14' 0.107" S, covering parts of Pangkalan Baru District and Simpang Katis District, with a total area of 6,029.89 hectares (Ministry of Environment and Forestry, 2023).

Over the past two decades, Tahura Bukit Mangkol has experienced increasing pressure as a result of rapid population dynamics. Population growth, shifts in spatial distribution, and the intensification of land-based economic activities have accelerated the conversion of forest cover into plantations, settlements, and mining areas (Bintarto, 2018; Setiawan, 2021). This trend is consistent with Forestry Statistics data indicating that non-forest land cover in Bangka Belitung Islands Province has reached 74.6% of the total forest area that should have been maintained (Ministry of Environment and Forestry, 2023).

This phenomenon is reinforced by findings from Joko Triwanto (2023), which state that the conversion of forests into large-scale agricultural land, such as oil palm cultivation, is a major contributor to forest loss in Indonesia.

Protected forests have a primary strategic role in safeguarding environmental life-support systems by regulating water supply, preventing floods, controlling erosion, preventing seawater intrusion, providing sufficient food and energy supplies for human life, and serving as a reservoir of genetic resources (Anto et al., 2024).

Despite the existence of regulatory frameworks for environmental protection and green open space management in Indonesia, their implementation remains weak. Wala and Adifa (2023) identified ineffective policy implementation as a key factor contributing to the continued conversion of protected and conservation land in various regions of Indonesia. This condition reflects a persistent gap between conservation policy and field-level realities, indicating that legal

E-ISSN :2962-1658
Volume 5, Number 2, April 2026
https://doi.org/10.47709/ijmdsa.v5i2.8286

protection alone is insufficient without effective governance and enforcement mechanisms.

Based on these conditions, there is a research gap that needs to be addressed, namely how to systematically integrate spatial analysis of land cover changes with the analysis of population dynamics factors in order to produce concrete and measurable solution strategies. Most previous studies in Tahura areas have not quantitatively linked population data with the rate of land cover change (Lubis et al., 2021).

The novelty of this research lies in the integration of three analytical methods: multitemporal GIS spatial analysis, Rapid Land Tenure Assessment (RaTA), and the Analytical Hierarchy Process (AHP), which together generate strategy priorities based on multi-stakeholder perceptions.

Accordingly, this study aims to: (1) analyze population dynamics in Central Bangka Regency during the period 2013–2023; (2) assess land cover change in Tahura Bukit Mangkol over the same period; (3) identify the main population-related factors influencing land cover change; and (4) formulate strategic solutions to address land cover change driven by population dynamics in the Tahura Bukit Mangkol area. These objectives provide the basis for the research questions to be elaborated in the discussion and addressed in the conclusion.

METHOD

This study was conducted in Bukit Mangkol Forest Park (Tahura Bukit Mangkol), located in Central Bangka Regency, approximately 15 km from Pangkalpinang City, Indonesia. Fieldwork was undertaken over a six-month period from January to June 2025. A mixed-methods approach was applied, integrating quantitative and qualitative methods to obtain a comprehensive understanding of land cover change dynamics and their relationship with population growth.

The analysis of land cover change was conducted through spatial analysis using Geographic Information System (GIS) technology with multitemporal satellite imagery, namely Landsat 7 ETM+, Landsat 8 OLI, and Sentinel-2A for the years 2013, 2018, and 2023, which were downloaded from http://earthexplorer.usgs.gov/. Image correction and cropping were performed using Erdas Imagine 2014 software, while interpretation and analysis were carried out using ArcGIS 10.8. Land cover classification was conducted using a supervised classification method with the Maximum Likelihood Classification (MLC) algorithm. The classification accuracy was verified through field ground checks using a census method at 43 sample points, resulting in an Overall Accuracy (OA) value of 90.7%, which meets the reliability standards for land cover maps.

Population dynamics analysis was carried out descriptively using secondary data from the Central Bureau of Statistics (BPS) of Central Bangka Regency, covering population size, composition, density, and distribution for the period 2013–2023. Population projection was calculated using the arithmetic method with the equation $Pn = P_0(1 + r \cdot n)$. Factor analysis employed the Rapid Land Tenure Assessment (RaTA) method developed by ICRAF since 2003, which functions to identify ecological, social, and economic aspects driving land cover change. Strategy synthesis was conducted using the Analytical Hierarchy Process (AHP) method developed by Thomas L. Saaty, where hierarchy is defined as a representation of a complex problem in a multi-level structure in which the first level is the goal, followed by levels of factors, criteria, sub-criteria, and so on down to the final level of alternatives. This process involved three groups of key informants: the Forest Area Consolidation Agency (BPKH) Region XIII Pangkalpinang, the Forestry Office of Bangka Belitung Islands Province, and the Environmental Agency of Central Bangka Regency. The Consistency Ratio (CR) value was used as a consistency test, with a threshold of $CR \leq 0.10$.

RESULT

The results show that during 2013–2023, the population of Central Bangka Regency increased by 23.6%, particularly in sub-districts adjacent to Bukit Mangkol Forest Park. This growth has intensified pressure on land demand around the area. Land cover analysis indicates a decrease in secondary dryland forest by 348.94 ha (-23.9%), while plantations increased by 408.31 ha (+186.7%) and settlements by 35.33 ha (+291.7%). These changes reflect the conversion of forest into cultivated and built-up areas. Spatially, changes are concentrated along the forest park boundaries, where community activities have led to increasing forest fragmentation. RaTA analysis identifies ecological, social, and economic factors as the main drivers of land cover change. AHP results show that ecological factors are the top priority (0.665), followed by economic (0.237) and social (0.098), with a high level of consistency (CR = 0.006).

Overall, population dynamics significantly contribute to land cover change, highlighting the need for integrated management to ensure the sustainability of the area.

Table 1. Driving Factors (RaTA and AHP Results)

Factor Type	Weight (AHP)	Priority Rank
Ecological	0.665	1 (Highest)
Economic	0.237	2
Social	0.098	3
Consistency Ratio (CR)	0.006	Highly consistent

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DISCUSSION

Population Dynamics in Central Bangka Regency (2013–2023)

Central Bangka Regency is administratively divided into six sub-districts: Koba, Lubuk Besar, Pangkalan Baru, Namang, Sungai Selan, and Simpang Katis. According to data from the Central Bangka Regency Statistics Office (BPS, 2024), the population of the regency showed a steady upward trend over the 2013–2023 period. The total population increased from 167,000 inhabitants in 2013 to 206,478 inhabitants in 2023, representing an absolute increase of 39,478 inhabitants or 23.6% over ten years. This corresponds to an average annual population growth rate of approximately 2.1%.

The spatial distribution of the population in 2023 was uneven, with the largest concentration found in Koba Sub-district (22%), followed by Pangkalan Baru (21%) and Sungai Selan (19%). This distribution pattern suggests that population concentration is strongly influenced by administrative functions, transportation accessibility, and local economic opportunities.

Population growth in the three sub-districts directly bordering the Tahura Bukit Mangkol area—Namang, Pangkalan Baru, and Simpang Katis—was recorded at 26.8%, 25.5%, and 23.1%, respectively, over the period 2013–2023. Lubuk Besar Sub-district recorded the highest population density at 9,061 people/km², indicating intensive land-use pressure despite not having the largest share of the population. This dynamic is in line with Bernando (2024), who identifies three main factors influencing population growth in a region: migration (population movement), mortality (death rate), and fertility (birth rate).

The population projection of Central Bangka Regency using the arithmetic method shows an increase from 210,918 people in 2024 to 255,310 people in 2034. This condition indicates that pressure on the Tahura Bukit Mangkol area will continue to increase in line with the growing demand for residential space and production land. This is consistent with Bongaarts' demographic transition theory, which states that population growth is closely correlated with increasing spatial demand and pressure on natural resources. Furthermore, based on research by Idris Rabbani (2025), demographic pressure drives land-use conversion to meet population needs.

Land Cover Change in Tahura Bukit Mangkol, 2013–2023

The results of multitemporal satellite image interpretation using Google Earth Engine and ArcGIS 10.8 identified five land cover classes in the Tahura Bukit Mangkol area: Secondary Dryland Forest, Plantation, Settlement, Mixed Dryland Agriculture with Shrubs, and Mining. Land cover classification was carried out through satellite image interpretation using a supervised classification method based on remote sensing (e.g., Sentinel-2 imagery), which is capable of identifying various land cover classes such as forest, shrubs, agriculture, and settlements (M. Hidayat, 2025).

Table 2. Land Cover Change in Tahura Bukit Mangkol, 2013–2023

Land Cover Class	2013		2018		2023		Δ (Ha)
	Ha	%	Ha	%	Ha	%	
Secondary Dryland Forest	1.462,10	24,25	1.230,75	20,41	1.113,16	18,46	-348,94
Plantation	218,72	3,63	459,35	7,62	627,03	10,40	+408,31
Settlement	12,11	0,20	27,55	0,46	47,44	0,79	+35,33
Mixed Dryland Agriculture with Shrubs	3.787,60	62,81	3.757,64	62,32	3.678,40	61,00	-109,20
Mining	549,35	9,11	554,58	9,20	563,85	9,35	+14,50
Total	**6.029,89**	**100,00**	**6.029,89**	**100,00**	**6.029,89**	**100,00**	**0**

Source: Processed satellite imagery data (2025)

Based on Table 2, the most significant change occurred in the Secondary Dryland Forest class, which experienced a consistent decline from 1,462.10 ha (24.25%) in 2013 to 1,113.16 ha (18.46%) in 2023, or a reduction of 348.94 ha (-23.9%). This decrease occurred gradually, with a reduction of 231.35 ha (-18.8%) during the 2013–2018 period and 117.59 ha (-10.6%) during the 2018–2023 period. In contrast, the Plantation class showed a very significant increase from 218.72 ha to 627.03 ha, or an increase of 408.31 ha (+186.7%), mainly driven by plantation expansion in Pangkalan Baru and Simpang Katis sub-districts.

The Settlement class also showed a notable percentage increase, from 12.11 ha to 47.44 ha (+291.7%), although the absolute figure remains relatively small. This change reflects the growing demand for space in line with population growth and distribution around the area. These findings are consistent with research by Saputra et al. (2021), which states that plantation expansion is a major driver of deforestation in Sumatra and Kalimantan, as well as research by Hidayat et al. (2022), which highlights that the conversion of forests into plantations and agricultural land is a primary cause of forest cover loss.

Spatial change analysis using satellite imagery indicates that forest cover degradation mainly occurs along the edges of the Tahura area, directly adjacent to settlements and community-managed land. In the 2013 imagery, this area was still dominated by dark green tones representing dense forest cover. However, in the 2023 imagery, clear

E-ISSN :2962-1658
Volume 5, Number 2, April 2026
https://doi.org/10.47709/ijmdsa.v5i2.8286

fragmentation is visible, with brighter areas representing plantations and open land. This pattern of change aligns with forest fragmentation theory, where land conversion in the edge zones of conservation areas accelerates overall ecosystem degradation.

Main Factors of Population Dynamics Influencing Land Cover Change (RaTA Analysis)

The Rapid Land Tenure Assessment (RaTA) analysis, following the framework of Galudra et al., identifies three main aspects of population dynamics that drive land cover change in the Tahura Bukit Mangkol area:

- **EcologicalAspect**.

Unclear land tenure status and forest boundary delineation are the dominant ecological factors driving land cover conversion. Part of the Tahura Bukit Mangkol area has been utilized by local communities for generations, even before it was officially designated as a conservation area in 1986. This has led to historical land claims that lack formal legal recognition. Such conditions encourage land use that is inconsistent with conservation functions. As stated by M. Syahril (2025), weak tenure security in forest areas contributes to increased forest conversion and ecosystem degradation. Galudra et al. also emphasize that resolving land ownership issues through clear boundary establishment and recognition of local community rights is a crucial step in improving forest management effectiveness.

- **Social Aspect.**

Population growth and distribution in the buffer zones of Tahura Bukit Mangkol have increased pressure on land for settlements and socio-economic activities. Data show that the three buffer sub-districts—Namang, Pangkalan Baru, and Simpang Katis—experienced population growth of 26.8%, 25.5%, and 23.1%, respectively, during the 2013–2023 period. This social pressure reinforces previous findings that population growth leads to higher demand for land for housing and infrastructure. Rini and Santosa (2023), in their study of conservation areas in Central Java, also found that in-migration into conservation areas significantly drives changes in settlement patterns and land cover. This situation creates a dynamic conflict between communities who perceive the land as inherited property and the state, which enforces conservation boundaries.

- **Economic Aspect.**

Limited alternative livelihoods outside land-based sectors result in a high dependence of local communities on the utilization of the Tahura area. Plantation activities, dryland agriculture, and mining serve as the main sources of income, driving expansion into conservation areas. The expansion of oil palm and rubber plantations has been identified as a primary cause of deforestation, largely due to limited non-agricultural livelihood options. In the context of Wala and Adifa (2023), weak policies for alternative economic empowerment of communities around conservation areas further exacerbate pressure on protected land. Table 2 summarizes the forms of land tenure claims made by communities within the Tahura Bukit Mangkol area.

Table 3. The Forms of Community Land Tenure Claims in the Tahura Bukit Mangkol Area

Forest Area	Location	Community Land Tenure Claims
Bukit Mangkol Forest Park (Tahura Bukit Mangkol)	Central Bangka Regency	Continued access for cultivation on land located within the conservation area; legalization of inherited cultivated land (pepper, rubber, coconut, and smallholder oil palm plantations); issuance of formal land certificates or legal tenure documents; legal access through the Conservation Partnership scheme; and collective recognition of land control through farmer groups or village-based institutions.

Source: Processed data (2025)

Overall, the RaTA analysis indicates that land cover change in Tahura Bukit Mangkol is driven by an interconnected set of ecological, social, and economic pressures. These findings highlight that effective conservation management cannot rely solely on ecological protection measures, but must also address underlying tenure insecurity, demographic expansion, and community livelihood dependency.

Strategies for Addresing Land Cover Change (AHP Analysis)

Based on the Analytical Hierarchy Process (AHP) analysis of the combined perceptions of the three stakeholder groups, the ecological factor emerged as the most dominant criterion with a weight of 0.665, followed by the economic factor (0.237) and the social factor (0.098). The combined Consistency Ratio (CR) value of 0.006, which is well below the acceptable threshold of 0.10, indicates a very high level of consistency in the weighting process. These results reflect a shared stakeholder consensus that the protection of the ecological function of the conservation area should be the top priority in addressing land cover change.

E-ISSN :2962-1658
Volume 5, Number 2, April 2026
https://doi.org/10.47709/ijmdsa.v5i2.8286

Table 4. Combined AHP Results for Priority Strategies

No.	Factor/Aspect	AHP Weight	Priority Rank	CR
1	Ecology (Rehabilitaion, Boundary Delineation, Law Enforcement)	0,665	1 (Highest)	0,006
2	Economy (Conservation Partnership, Alternative Livelihoods)	0,237	2	
3	Social (Community Participation, Awareness Raising)	0,098	3	

Source: Processed AHP data (2025)

Ecological Strategy: Rehabilitation, Land Tenure Arrangement, and Law Enforcement

As the highest priority (weight 0.665), the ecological strategy is directed toward three main interventions.

First, forest and land rehabilitation in degraded areas needs to be implemented sustainably to restore the ecological functions of the area, including hydrological functions and environmental carrying capacity.

Second, participatory boundary delineation of the Tahura area through coordination with BPKH Region XIII Pangkal pinang should be prioritized to reduce tenure uncertainty, which is the root cause of conflict. Galudra et al. emphasize that clear forest boundary establishment is a fundamental prerequisite for effective conservation management.

Third, law enforcement against encroachment, mining, and illegal plantation activities must be carried out consistently in accordance with Law Number 41 of 1999 on Forestry and Government Regulation Number 23 of 2021 on Forestry Administration. The AHP results indicate that BPKH Region XIII assigns the highest weight to the ecological factor (0.724), reflecting a policy orientation that places the protection of ecosystem functions as the top priority.

Social Strategy: Community Participation and Ecological Awareness Strengthening

Although the social factor received the lowest AHP weight (0.098), it remains important as a long-term behavioral and institutional catalyst. The resolution of tenure-related conflict through a RaTA-based mediation approach between local communities and forest area managers should be pursued continuously. Community participation in forest area management is also strongly supported by Law No. 41 of 1999 and Law No. 32 of 2009 on Environmental Protection and Management, both of which emphasize the importance of public participation in environmental conservation.

Structured awareness-raising and outreach programs regarding the ecological importance of Tahura Bukit Mangkol and the legal consequences of land-use violations should also be strengthened. Sujatmiko and Ardiani (2022) emphasized the need to integrate demographic data with conservation policy in order to develop a more sustainable and adaptive approach to forest area management.

The projected population of Central Bangka Regency, which is expected to reach 255,310 people by 2034, underscores the urgency of implementing this integrated strategy. Without systematic policy interventions, land conversion in the Tahura Bukit Mangkol area is likely to increase further in line with growing demands for space and production land.

This condition is consistent with projections from Mutakin et al. (2025), which suggest that pressure on conservation areas in developing countries will continue to rise alongside urbanization and population growth. An integrated approach that combines ecological, social, and economic aspects—as recommended by the AHP analysis in this study is considered the most effective step to maintain the sustainability of the ecological functions of Tahura Bukit Mangkol.

ACKNOWLEDGMENT

This study demonstrates that population dynamics have played a significant role in shaping land cover change in Tahura Bukit Mangkol. Between 2013 and 2023, Central Bangka Regency experienced a population increase of 23.6%, with particularly high growth occurring in the sub-districts directly adjacent to the conservation area. This demographic trend indicates an increasing demand for land and a growing level of pressure on the surrounding forest landscape.

At the same time, the analysis of land cover change revealed a substantial decline in secondary dryland forest, accompanied by significant expansion of plantation, settlement, and mining areas. These changes were concentrated mainly along the edge zones of the conservation area, suggesting that land conversion has been strongly influenced by human activities originating from the surrounding buffer region.

The RaTA analysis further showed that land cover change in Tahura Bukit Mangkol is driven by the interaction of ecological, social, and economic factors, particularly tenure uncertainty, population pressure, and community dependence on land-based livelihoods. In response, the AHP analysis identified ecological strategy as the highest priority, followed by economic and social strategies. These findings indicate that effective conservation management in Tahura Bukit Mangkol requires an integrated approach that not only restores ecological functions, but also addresses

E-ISSN :2962-1658
Volume 5, Number 2, April 2026
https://doi.org/10.47709/ijmdsa.v5i2.8286

tenure issues, livelihood dependency, and community participation.

Overall, this study highlights the importance of linking demographic analysis, spatial land cover assessment, and multi-stakeholder decision-making in order to formulate more effective and sustainable conservation management strategies. Without systematic intervention, increasing population pressure is likely to accelerate future land conversion in the Tahura Bukit Mangkol area.

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