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Spatiotemporal Detection of Land Cover Dynamics in Forests and Food Sources in Supporting the Nusantara Capital City of Indonesia

Kiswanto[1,2,3,*], Mardiany[4], Ike Anggraeni Gunawan[5,6], Annisa Nurrachmawati[6], Dwi Agung Pramono[7], Dyah Widyasasi[7]

[1] Faculty of Forestry and Tropical Environment, Mulawarman University, East Kalimantan, Indonesia
[2] Center of Geospatial Information Infrastructure Development, Mulawarman University, East Kalimantan, Indonesia
[3] Bioresources of Humid Tropical Forest, Mulawarman University, East Kalimantan, Indonesia
[4] Regional Research and Innovation Agency (BRIDA) of East Kalimantan Province, East Kalimantan, Indonesia
[5] Institute of Research and Community Development, Mulawarman University, East Kalimantan, Indonesia
[6] Faculty of Public Health, Mulawarman University, East Kalimantan, Indonesia
[7] Samarinda State Agricultural Polytechnic, East Kalimantan, Indonesia
[*] Corresponding Author. E-mail address: kiswantosardji@gmail.com

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ABSTRACT

The relocation of Indonesia's capital from Jakarta to Nusantara in East Kalimantan Province has significantly affected land use, particularly in forests and agricultural resources. This study examines the spatiotemporal dynamics of land cover in the forestry and agricultural sectors within Kutai Kartanegara Regency of East Kalimantan Province. The goal is to support the smart forest city concept and enhance food sources within *Ibu Kota Nusantara* (IKN). Data related to geographical (location) and temporal (time) were analyzed using Geographic Information System (GIS) tools, enabling the mapping, overlaying, and analyzing spatial data over time. The findings show that Kutai Kartanegara has 30% forested areas and 7% agricultural land. There are eight districts with dryland forests, seven with mangrove forests, and fourteen with swamp forests. The study identifies fourteen districts nominated for dryland agriculture, nine for rice fields, and seven for aquaculture. However, forest cover in both drylands and wetlands has been declining annually. Additionally, the study pinpointed potential areas for urban forest development in Tabang District and locations for food production in Anggana, Samboja, and Muara Badak. The findings provide actionable insights for policymakers to optimize land allocation, ensuring sustainable resource management in the evolving ecosystems of the new capital.

1. Introduction

The relocation of Indonesia’s capital from Jakarta to Nusantara (*Ibu Kota Nusantara*—IKN) in East Kalimantan Province (Nasution 2023) has significant implications for biodiversity and land use (Nisaa et al. 2023), particularly in forestry and agricultural sectors. Initially aimed at reducing environmental and infrastructural issues in Jakarta, this decision is expected to lead to widespread deforestation (Praditya et al. 2023) and environmental harm due to the construction of IKN (Buana et al. 2023). The loss of forests—vital for biodiversity and carbon sequestration—could adversely affect ecological health (Spencer et al. 2023). The future development of IKN will increase rivalry for land tenure, threatening the transformation of forested and agricultural areas into unsustainable industrial and urban spaces (Darmawan and Santoso 2024). The transition from a "sinking city" to a "forest city" offers challenges for maintaining ecological balance (Perdana 2024) as well as promoting economic variety and urban growth (Massiri 2023). Agricultural communities may face relocation or lose access to arable land. There are concerns that these pressures could harm natural forest ecosystems and reduce agricultural productivity (Roslinda et al. 2023).

The development of IKN (Nisaa et al. 2023) depends on the Kutai Kartanegara Regency in East Kalimantan Province, which has two rules. First, it was recognized as a development area, and the following sub-districts are within the IKN administrative borders (Buana et al. 2023). Kutai Kartanegara is recognized as a major actor in the economy (Darmawan and Santoso 2024) and in infrastructure projects related to IKN (Jiuhardi et al. 2024), which may attract more investments and enhance the provision of public services. Kutai Kartanegara is also a marginal area of IKN (Buana et al. 2023). This regency aims to assess the ecological impacts of urbanization and conserve the adjacent areas (Kartikasari et al. 2019). To this end, focusing on economic growth (Roslinda et al. 2023) and responsible environmental services (Kiswanto et al. 2022) would prevent adverse effects on the environment and people as the regency prepares for more growth. In response to its new role within the context of IKN, Kutai Kartanegara has to find a proper strategy that would combine economic and environmental advantages in the future. Hence, this paper aims to identify the potential of Kutai Kartanegara in contributing to the progress of IKN and its surroundings, along with strategies to minimize the negative impacts of urban expansion.

IKN's development demands food security, ecological protection, and quick urbanization (Buana et al. 2023). Recent decades have witnessed significant changes in land cover for Kutai Kartanegara Regency (Nisaa et al. 2023). The regency lost natural forests mainly due to the introduction of oil palm plantations, coal mining, and agricultural development (Abidin et al. 2021; Rozaki et al. 2023). These changes hurt biodiversity (Arifanti et al. 2022; Ontl et al. 2020), and the ability to store carbon (Roy et al. 2022; Wolff et al. 2021). They also hurt the ways of life of people nearby who depend on the forest and agroforestry systems for living. Concurrent with this, food production techniques, including smallholder oil palm and rubber agroforestry (Gaveau et al. 2022; Kiswanto et al. 2022; Roy et al. 2022; Wolff et al. 2021) have grown, generally to the negative effect of degraded forests. Operations in coal mining in forested areas aggravate environmental effects and cause emissions arising from land alteration (Kartikasari et al. 2019).

The future growth in infrastructure for IKN highlights the need for spatially comprehensive monitoring, as it might accelerate land cover dynamics (Bravo-Oviedo et al. 2020). Informed decision-making (Lv et al. 2022) and effective environmental stewardship (Kiswanto et al. 2022) depend on an awareness of the features and patterns of land cover change. Still, thorough studies of the relationships between forests and food supplies relevant to Kutai Kartanegara's involvement in the IKN are rare (Buana et al. 2023). Geographic Information Systems (GIS) and remote sensing innovations offer necessary devices for visualizing spatiotemporal trends (Darmawan and Santoso 2024; Kiswanto et al. 2022), as proven by examinations of forest cover damage (Chughtai et al. 2021; Lv et al. 2022), agricultural diversification (Wang et al. 2020; Sefrin et al. 2021), urbanization (Ortiz et al. 2022; Sylvester et al. 2024), and infrastructure undertakings (Chakraborty 2021; Dhadse and Kardbhajne 2024) over time. This study sought to integrate spatiotemporal data with ground-truthing to ascertain land cover dynamics and identify priority areas for sustainable forest management and food sources, ensuring that land cover dynamics in Kutai Kartanegara support the construction of IKN in line with Indonesia's climate initiates and food suppleness targets.

2. Materials and Methods

2.1. Study Area

The study's investigation was carried out administratively and physically in Kutai Kartanegara Regency in East Kalimantan Province of Indonesia. Kutai Kartanegara is situated between 115°26'28" E and 117°36'43" E, and between 1°28'21" N and 1°08'06" S. Kutai Kartanegara is bordered by Malinau Regency to the north, East Kutai Regency and the Makassar Strait to the east, North Penajam Pasir and Balikpapan City to the south, and West Kutai Regency to the west. Kutai Kartanegara has a land area of approximately 27,263.10 km^2, or 2,726,310 hectares, which accounts for around 12% of East Kalimantan Province's total area. It also has a water area of 4,097 km^2. Kutai Kartanegara comprises 18 districts and 237 villages (BPS 2024). The districts in Kutai Kartanegara are Samboja, Muara Jawa, Sanga-Sanga, Anggana, Muara Badak, Marang Kayu, Tenggarong Seberang, Loa Janan, Loa Kulu, Tenggarong, Sebulu, Muara Kaman, Kota Bangun, Muara Muntai, Muara Wis, Kenohan, Kembang Janggut, and Tabang. Kutai Kartanegara has numerous rivers that cross all districts, serving as the primary means of terrestrial transport. The Mahakam River is the longest, measuring around 920 kilometers in length. Some districts in Kutai Kartanegara Regency have been designated for expansion to form the Nusantara Capital City (*Ibu Kota Nusantara*). To ensure consistency in our results, we refer to the entire Kutai Kartanegara Regency before its expansion to serve as Nusantara Capital City.

2.2. Spatial Dataset

The spatial data for Kutai Kartanegara administration boundaries were acquired from the Regional Development Planning Agency (Bappeda) of East Kalimantan. Maps of forest area and land cover from 2012 to 2023, officially released by the National Forest Monitoring System or SIMONTANA (https://nfms.menlhk.go.id/), were obtained from the Ministry of Environment and Forestry (MoEF) of Indonesia. SIMONTANA data from the MoEF highlights its role in managing sustainable forest resources in Indonesia. As the official forest monitoring system, SIMONTANA adheres to international standards set by the United Nations Framework Convention on Climate Change (UNFCCC). It integrates satellite imagery with field data to accurately monitor changes in forest cover, providing a reliable basis for assessing GHG emissions from deforestation, forest degradation, and peatland conversion. This scheme monitors the advancement of Indonesia's nationally determined contributions (NDCs) and guides the decision-making. The openly available data improves transparency and makes outside expert and stakeholder review feasible.

Using administrative maps and land cover data from several years of analysis made available by the MoEF, periodic land cover from 2012 to 2023 in the study region was derived by overlaying and intersecting them. The idea of spatial overlap requires matching characteristics at appropriate locations within the two data layers to offer results for every site in the resulting data layer. The user defines exactly the results to be obtained. Inconsistent findings might lead to irregular polygon limits and further complexities, so correction and modification are necessary before further investigations. This study used 23 land cover classes (Kiswanto et al. 2023; 2024), spatiotemporal identification techniques with greater scales, and recently obtained data collecting periods.

The geospatial analysis findings have been confirmed using numerous approaches. Comparatively, with independent sources of greater resolution, including field survey data or high-resolution satellite imageries, position accuracy was assessed using spatial data comparison.

Recognized standards guide the evaluation of spatial data accuracy; ISO 19157-1:2023 provides a comprehensive framework for evaluating and representing data quality. Although a thorough explanation is not given, the geographical data collection provided in this study has completed multiple validation stages using specified criteria to verify data accuracy.

2.3. Spatial Analysis

The spatiotemporal study looked at data associated with spatial (location-based) and temporal (time-based) components. Using certified software tools, data preparation, modeling, visualization, and systematic procedure, this study extracted insightful analysis from challenging datasets spanning time and location. Data organization calls for clear geographical (such as coordinates) and temporal (such as timestamps). Mapping the data helps to identify trends, outliers, and patterns that may not be evident from raw data alone. This study effectively demonstrated spatiotemporal data across numerous fields using visualization procedures. Numerous modeling techniques can be applied depending on the nature of the data. This study used dynamic spatiotemporal models to account for changes over time while considering spatial relationships. All steps in this study utilized geographic information system (GIS) software such as ArcGIS, which provides a way to map, overlay, and analyze spatial data across time.

Spatial analysis includes examining, assessing, evaluating, and modeling spatial data characteristics. This study makes an annual polygon-by-polygon comparison of each land cover class, aggregates the data into each designated land cover class, and evaluates the change frequency. This research integrated six natural forest types: primary dryland forest, secondary dryland forest, primary mangrove forest, secondary mangrove forest, primary swamp forest, and secondary swamp forest, into distinct forest groups. The food source group contains pure dryland agriculture, mixed dryland agriculture, paddy fields, and fishponds. This analysis also decided on polygons with natural forest cover and land for farming in each district as priority areas for supporting forest cities and food sources in Nusantara Capital City.

3. Results and Discussion

3.1. Land Cover Dynamics

Fig. 1 illustrates the land cover dynamics in Kutai Kartanegara from 2012 to 2023. We generated 12 years of land cover maps with 21 classes, excluding the savanna and cloud categories. Land cover maps indicate that Kutai Kartanegara is mostly forested (30%) and used for agriculture (7%). Most of the forest cover is located in the northern part of the region, indicated by the dark green. Eight districts have been classified as having dryland forests. Mangrove Forests are present in all seven districts. Swamp Forest represents the fourteen districts. Agricultural zones, including dryland and wetland farming, are light green. There are 14 districts dedicated to pure and mixed dryland agriculture, 9 with paddy fields, and 7 with fishponds.

Urban environments may have natural forest areas, such as city parks, urban forests, and small patches on abandoned properties along highway medians (Dewi et al. 2024). Native-dominated woods are the main focus of urban forest management because of their greater capacity to increase biodiversity values and provide certain ecosystem services (Singh et al. 2022). Forest dynamics, which are defined as changes in the structure and composition of forests throughout time, often result in shifts in the canopy dominance of different species from different stages of the succession or even forest loss (Rangkuti et al. 2023). No matter the size, forest dynamics will occur anywhere that natural mortality and regeneration may occur. These dynamics are often associated with land needs for urban progress, population growth, agricultural expansion, and economic success in urban environments. The dynamics of forest cover, which are decreasing in quantity (deforestation) and quality (degradation), are exposed in this study. The prevalence of forest distribution in the northern region of Kutai Kartanegara Regency indicates that forest cover is unevenly allocated, despite the expectation that all inhabited regions within each sub-district should benefit from forest services. The distribution of agricultural land, a basic food source for the population, is also somewhat unequal across the regency. Providing fair access to forest areas and food supplies throughout all administration areas depends on executing ecologically sustainable development projects (Priya and Senthil 2021).

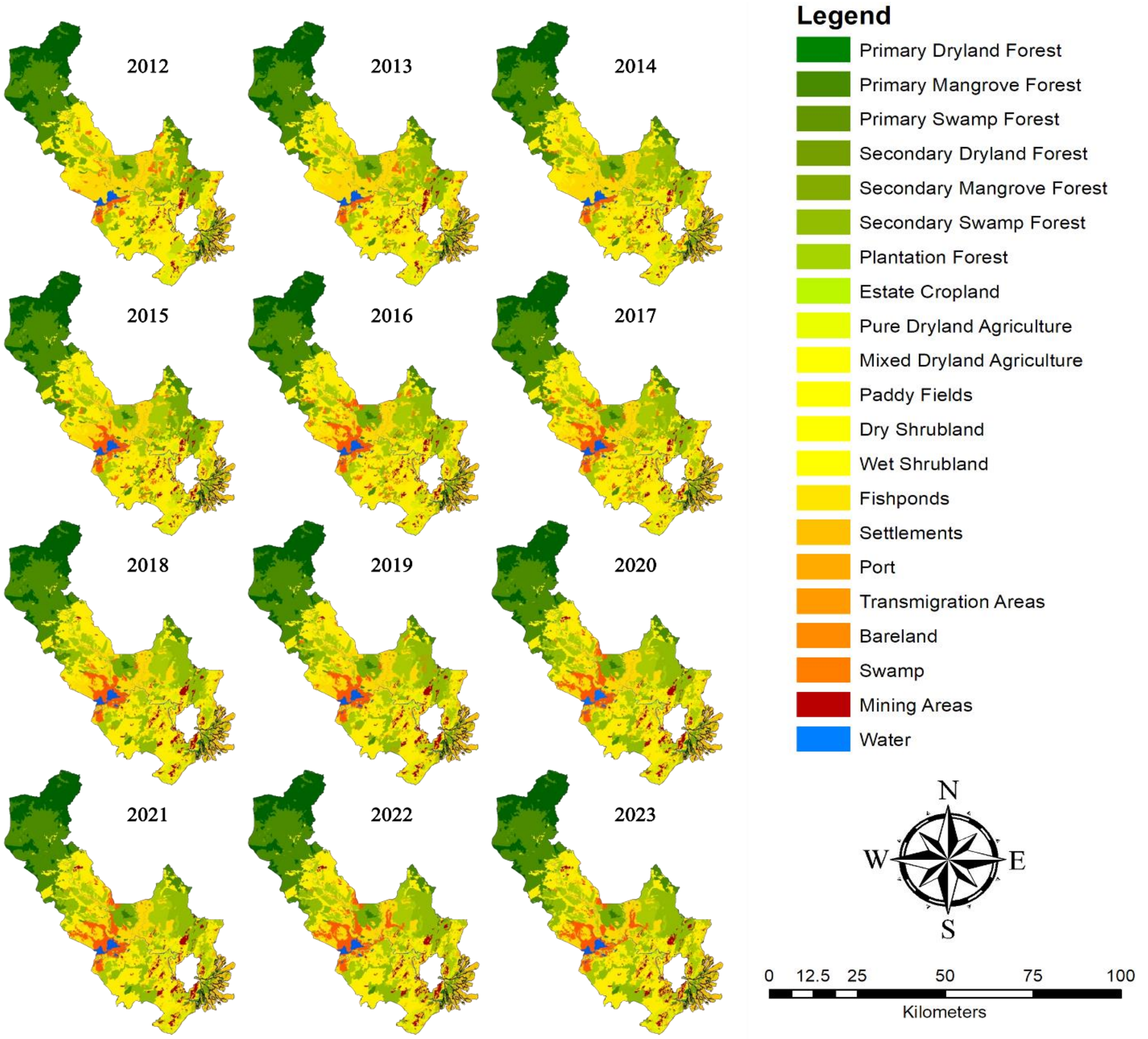


Fig. 1. Twelve-year regional land cover dynamics in Kutai Kartanegara Regency.

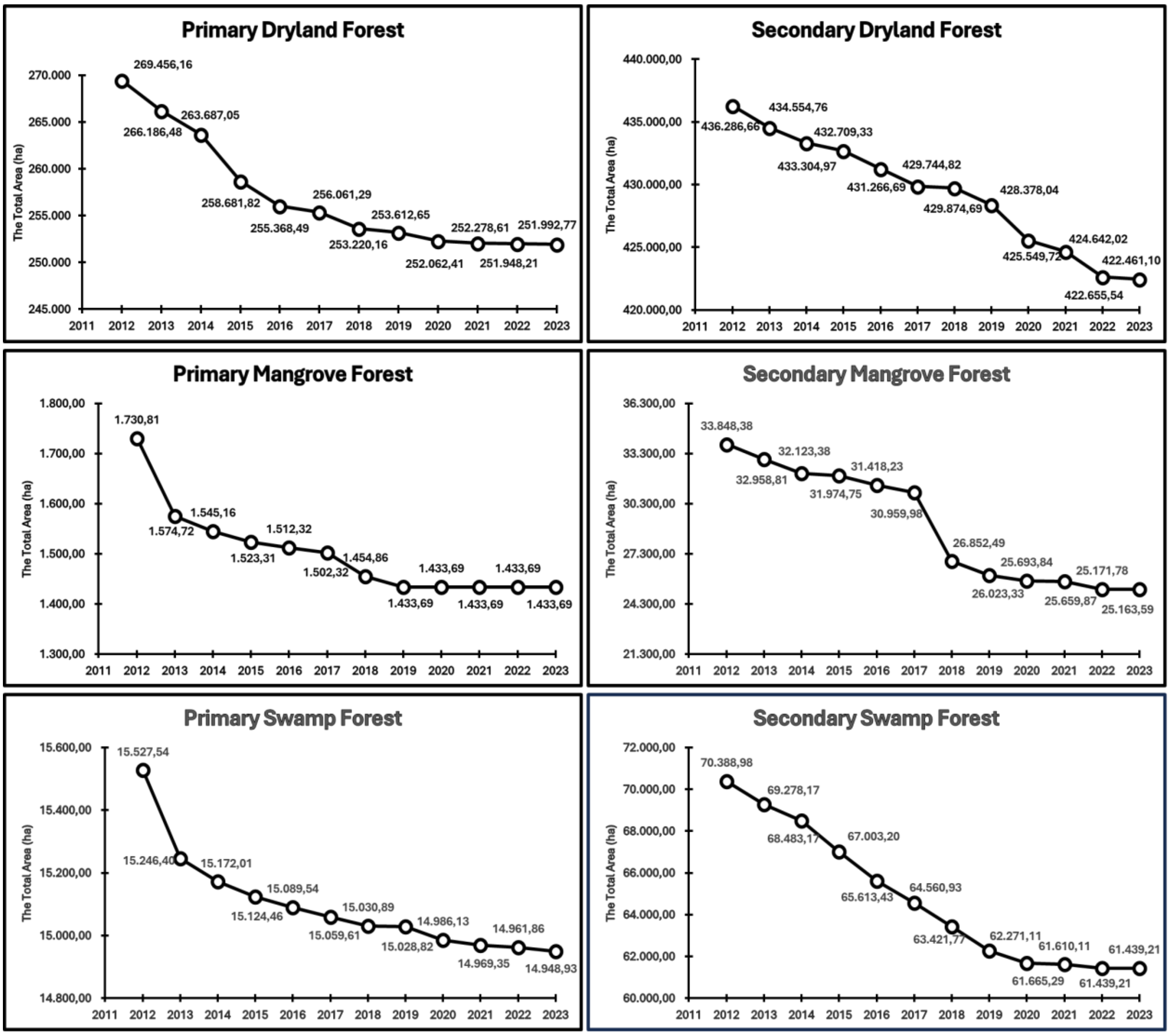
Interconnecting governance, economic, and socioecological considerations influence the evolution of land cover in Kutai Kartanegara. Specifically in East Kalimantan (Miettinen et al. 2017), Indonesia's forest moratorium policy (2011–2016) ignored secondary forests and existing concessions, allowing ongoing destruction for coal mining and oil palm. This policy gap coincided with spatial prioritization for the new capital (Ibu Kota Nusantara), where built-up areas doubled from 86.63 km² to 171.35 km² (2003–2023) and encroached on production forests (Syaban and Appiah-Opoku 2024). Global palm oil demand drove agro-industrial expansion, with smallholder oil palm holdings doubling (2009–2015) as communities shifted from traditional livelihoods to plantation-dependent economies (Dharmawan et al. 2020). Overlapping permits in 72% of IKN's cultivation zones and weak enforcement exacerbated land-use conflicts, with coal mining contributing to 0.60 Mton CO_2-eq emissions (Kartikasari et al. 2019). These dynamics highlight systemic tensions between extractive development and ecological sustainability, rooted in patchy governance and globalized goods markets (Marzuki et al. 2022; Syaban and Appiah-Opoku 2024).

Conversely, Berau Regency has seen a significant decline in natural forests, losing around 31,114 hectares between 2010 and 2015 mostly from transforming forest areas into plantations (Trisnaputra et al. 2023). Improved accessibility and population density are among the main causes that help enable agricultural growth. Government rules reclassifying forest areas for different purposes also affect land-use shifts. West Kutai and Mahakam Ulu are categorized by lower population densities and less infrastructure progress, which has historically limited extensive agricultural practices. However, these areas are now attracting interest in agricultural expansion and resource extraction due to their untapped natural resources (Miettinen et al. 2017). In North Penajam Paser Regency, particularly in Sepaku District, land cover has similarly declined due to the relocation of Indonesia's capital. Between 2009 and 2019, scrubland was transformed into forest plantations over 26,000 hectares (Sultan et al. 2023). This alteration poses ecological risks as vegetated land cover decreases, highlighting the impact of urbanization on local ecosystems. Samarinda City has also witnessed significant changes in land use, particularly in agricultural areas. A study indicated that agricultural land use in Palaran Subdistrict underwent notable transformations from 2006 to 2020, reflecting pressures from urban expansion and population growth (Ghotama et al. 2021). This urbanization contributes to habitat fragmentation and biodiversity loss.

3.2. Land Cover Dynamics in Forestry Sectors

The land cover dynamics in the forestry sector (**Fig 2**) indicate an increase in deforestation across all types of dryland and wetland forests. Kutai Kartanegara Regency of East Kalimantan Province has lost 49,843.79 hectares of forest cover during 12 years, resulting in an annual deforestation rate of 4,531.25 hectares. Primary dryland forests have functionally altered by 17,507.96 hectares during 12 years, exhibiting an annual deforestation rate of 1,591.63 hectares, whereas secondary dryland forests have reduced by 13,825.55 hectares at an annual rate of 1,256.87 hectares. Primary forests have transitioned by 297.12 hectares at 27.01 hectares per year in the mangrove ecosystem, while secondary forests have been deforested by 8,684.79 hectares yearly. The primary cover in the swamp forest ecosystem has altered by 578.61 hectares over 12 years, indicating a forest change rate of 52.60 hectares annually; concurrently, secondary swamp forests have experienced deforestation of 8,949.77 hectares, with a deforestation rate of 813.62 hectares per year.

Deforestation has a significant impact on tropical forests and reduces biodiversity. This threat can only be mitigated by a detailed investigation of the causes and solutions. Using a spatial-temporal analysis of forest cover from 2012 to 2023, this study examines the drivers contributing to deforestation and forest degradation in Kutai Kartanegara. Wide-ranging investigation indicates that the main causes of deforestation include fish ponds, estate agriculture, abandoned dryland and wetlands, and other uses related to agriculture (**Fig 3**).



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Primary Dryland Forest	269.456,16	266.186,48	263.687,05	258.681,82	256.061,29	255.368,49	253.612,65	253.220,16	252.278,61	252.062,41	251.992,77	251.948,21
Secondary Dryland Forest	436.286,66	434.554,76	433.304,97	432.709,33	431.266,69	429.874,69	429.744,82	428.378,04	425.549,72	424.642,02	422.655,54	422.461,10
Primary Mangrove Forest	1.730,81	1.574,72	1.545,16	1.523,31	1.512,32	1.502,32	1.454,86	1.433,69	1.433,69	1.433,69	1.433,69	1.433,69
Secondary Mangrove Forest	33.848,38	32.958,81	32.123,38	31.974,75	31.418,23	30.959,98	26.852,49	26.023,33	25.693,84	25.659,87	25.171,78	25.163,59
Primary Swamp Forest	15.527,54	15.246,40	15.172,01	15.124,46	15.089,54	15.059,61	15.030,89	15.028,82	14.986,13	14.969,35	14.961,86	14.948,93
Secondary Swamp Forest	70.388,98	69.278,17	68.483,17	67.003,20	65.613,43	64.560,93	63.421,77	62.271,11	61.665,29	61.610,11	61.439,21	61.439,21

Fig 2. Twelve-year regional land cover dynamics of forestry sectors in Kutai Kartanegara.

The emerging idea of 'deforestation' refers to the conversion of forests for other purposes or the irreversible reduction of tree canopy cover by less than 10% (Cisneros et al. 2021; Gaveau et al. 2022; Knoke et al. 2020). The continual degradation of forest structure and composition causes the loss of critical services required for forest resilience (de Andrade et al. 2017; Houghton and Nassikas 2018; Ken et al. 2020; Xie et al. 2020). Species structure and ecological productivity often change significantly (Dewi et al. 2024; Dyderski and Jagodziński 2020; Su et al. 2022; Zefanius et al. 2020). Advanced remote sensing has made it easier to detect forest deterioration at ever-larger geographical and temporal scales, yet these maps often lack information about flora and contributing causes (Leblois et al. 2017; Ramachandran and Reddy 2017; Reiche et al. 2015; Wijaya et al. 2015). Validation of field data is often required to improve remote sensing land cover classification. While research on land-use change for specific supplies is growing, conservation efforts may be influenced by whether deforestation is mostly driven by smallholder farmers or a small number of major companies.

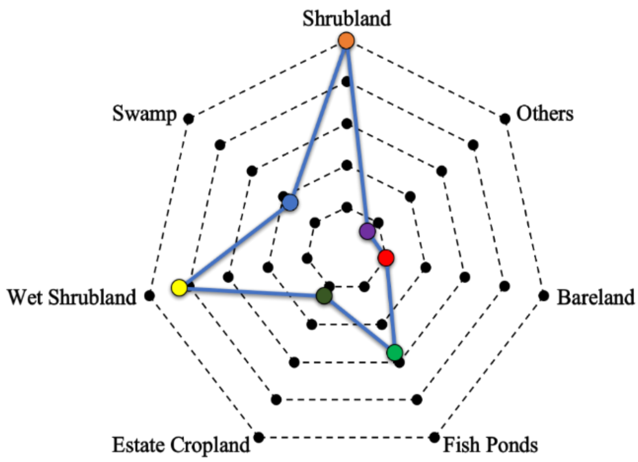


Fig. 3. Drivers of deforestation and forest degradation in Kutai Kartanegara.

Restoring forest ecosystems via reforestation and restoration (Ghazoul and Chazdon 2017) in tropical areas is advised to improve the quantity and quality of forest cover and prevent global climate change (Chazdon and Laestadius 2016). Studies looking at restoring ecosystems implicitly admit the dynamics of forest cover concerning projected forest potential (Kiswanto et al. 2023). Research and practices in silviculture need to align with forest restoration projects, such as landscape management plans, disaster risk reduction programs, and adaptation and mitigation efforts against climate change (Singh et al. 2022). Silviculturists are everchanging from traditional (Kiswanto et al. 2023), officially authorized scientific methods, to innovative approaches based on geospatial datasets related to forest landscape features (Kiswanto et al. 2024). Based on spatial analysis, this study offered the advised locations for forest restoration in each Kutai Kartanegara district (**Fig 4**). However, this study has not examined the bond between climate issues and any shifts in forest supply brought about by restoration initiatives. This study explains the potential of tropical forests given their features; nonetheless, it is crucial to admit that restoration involves replanting trees and reviving biodiversity assets.

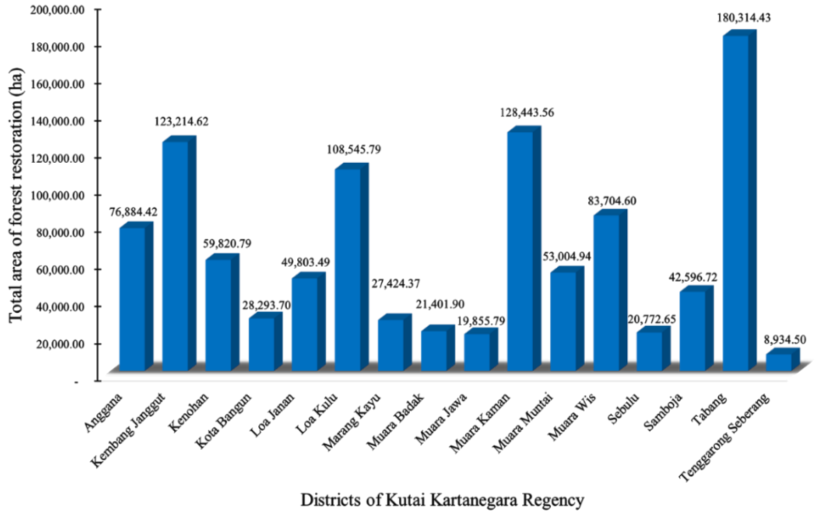
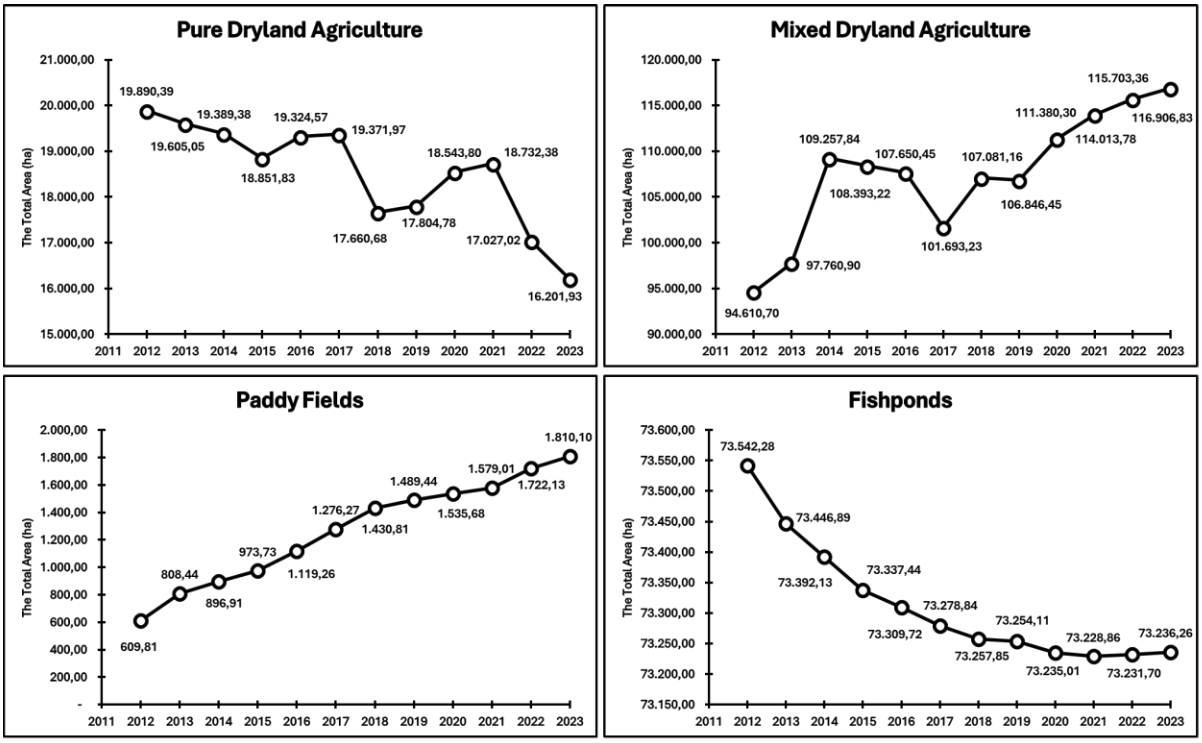


Fig. 4. Total recommended area (ha) for forest restoration in each district of Kutai Kartanegara.

Innovative forest restoration strategies increasingly merge advanced technologies with ecological principles and community engagement to combat biodiversity loss and climate change (Kiswanto et al. 2024). These approaches prioritize the functionality of ecosystems over simply planting trees, focusing on long-term resilience and adaptive management (Ontl et al. 2020). Several innovations in silvicultural strategies (Bravo-Oviedo et al. 2020) for ecosystem restoration have been widely adopted. Recent research underscores the importance of restoring forest ecosystems by enhancing the development of mycorrhizal networks, which facilitate nutrient exchange between plants (Ramachandran and Reddy 2017). Additionally, preserving genetic diversity through the migration of climate-resistant species is crucial. Ecosystem restoration also involves creating habitat corridors using succession planting techniques. These multidimensional strategies require adaptive policy frameworks and cross-sector alliance (Massiri 2023), particularly in balancing immediate economic needs with long-term ecological objectives. To effectively restore ecosystems, scientific approaches should be integrated with indigenous land management practices (Kiswanto et al. 2023). This includes agroforestry systems (Roslinda et al. 2023) that combine food crops with native timber species, participatory mapping tools for identifying ecological and cultural priority areas, and benefit-sharing mechanisms (Rozaki et al. 2023) for carbon credits and non-timber forest products.

3.3. Land Cover Dynamics in Agricultural Sectors

Fig. 5 illustrates significant shifts in agricultural land cover, highlighting a notable reduction in both pure dryland agriculture and fishponds, contrasted by an increase in mixed dryland agriculture and paddy fields. This transformation reflects broader trends in land use dynamics, where farmers are increasingly adopting integrated farming systems that combine various agricultural practices.



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Pure Dryland Agriculture	19.890,39	19.605,05	19.389,38	18.851,83	19.324,57	19.371,97	17.660,68	17.804,78	18.543,80	18.732,38	17.027,02	16.201,93
Mixed Dryland Agriculture	94.610,70	97.760,90	109.257,84	108.393,22	107.650,45	101.693,23	107.081,16	106.846,45	111.380,30	114.013,78	115.703,36	116.906,83
Paddy Fields	609,81	808,44	896,91	973,73	1.119,26	1.276,27	1.430,81	1.489,44	1.535,68	1.579,01	1.722,13	1.810,10
Fish Pond	73.542,28	73.446,89	73.392,13	73.337,44	73.309,72	73.278,84	73.257,85	73.254,11	73.235,01	73.228,86	73.231,70	73.236,26

Fig. 5. Twelve-year regional land cover dynamics of agricultural sectors in Kutai Kartanegara.

Many subsectors within the agricultural sector increased in size, while others decreased. This is the outcome of poor agricultural land usage, which has reduced agricultural acreage and production. This study looks at the variables that have influenced changes in land cover in the agricultural sector during the previous twelve years (**Fig 6**). Agricultural systems are fundamental to larger food systems and have developed alongside other socio-economic institutions, such as land management techniques, technology breakthroughs, consumer habits, and environmental and agricultural legislation. The processes of agricultural land transformation might be described as the food system's shift to sustainability. This study describes sustainability transition as a lengthy process of substantial and complete change from a less sustainable to a more sustainable. It is critical to recognize the growing movement toward sustainable agriculture and the important themes and trends, especially in light of the expansion of Indonesia's capital city.

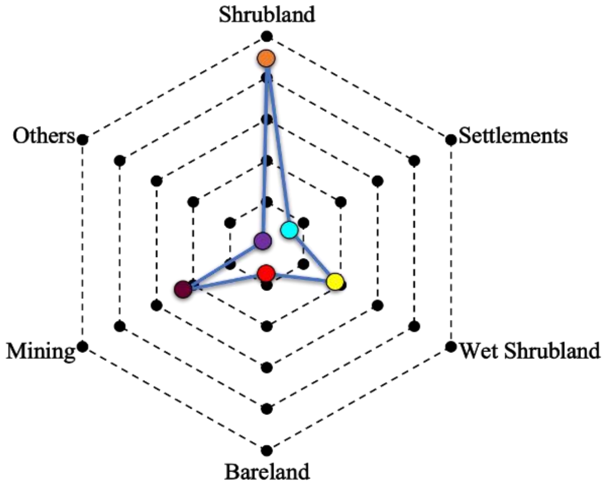


Fig. 6. Drivers of agricultural dynamics in Kutai Kartanegara.

Several notable spreads in the effort to provide food sources are evident in the agricultural sector dynamics influencing food commodity trading (Mora et al. 2020). The erosion of traditional foods, the diminishment of genetic diversity among primary food crops and their wild relatives (Silalahi and Silalahi 2024), and the decrease in the quantity of globally significant staple foods represent critical deficiencies in the contemporary agri-food system that must be addressed to sustain these trends and fulfill future food requirements (Rajoo et al. 2021). The heightened environmental impact and risks (Abidin et al. 2021) linked to extensive industrial agriculture practices result in a reduction in the diversity and quality of processed foods (Kariasa et al. 2023), with the generation of substantial food waste streams (Mora et al. 2020). Enhancing global food production is essential to address these challenges, and this cannot be reached only via the growth of industrial farming via globally detrimental land use changes that further diminish biodiversity (Jiuhardi et al. 2024).

3.4. Future Projections

This study examines historical land cover dynamics in Kutai Kartanegara from 2012 to 2023 and provides projections for future trends toward Indonesia's emission reduction targets in 2030 and the vision of Indonesia Emas 2045 using environmental change scenarios (**Fig 7**). From 2012 to 2023, the historical baseline of land cover dynamics in the Kutai Kartanegara forestry sector shows an ongoing yearly trend of forest loss largely related to urban expansion, agricultural conversion, and industrial activities. This estimate emphasizes the pressures approaching 2030 and 2045 over deforestation trends, biodiversity loss, and carbon emissions. From 2012 to 2023, Kutai Kartanegara's historical baseline of land cover dynamics shows varied expansion in the agricultural sector. This study projects a yearly growth in agricultural land area based on the historical baseline that will lead up to 2030 and 2045. Still, certain risks between 2040 and 2045 will shrink areas of food sources.

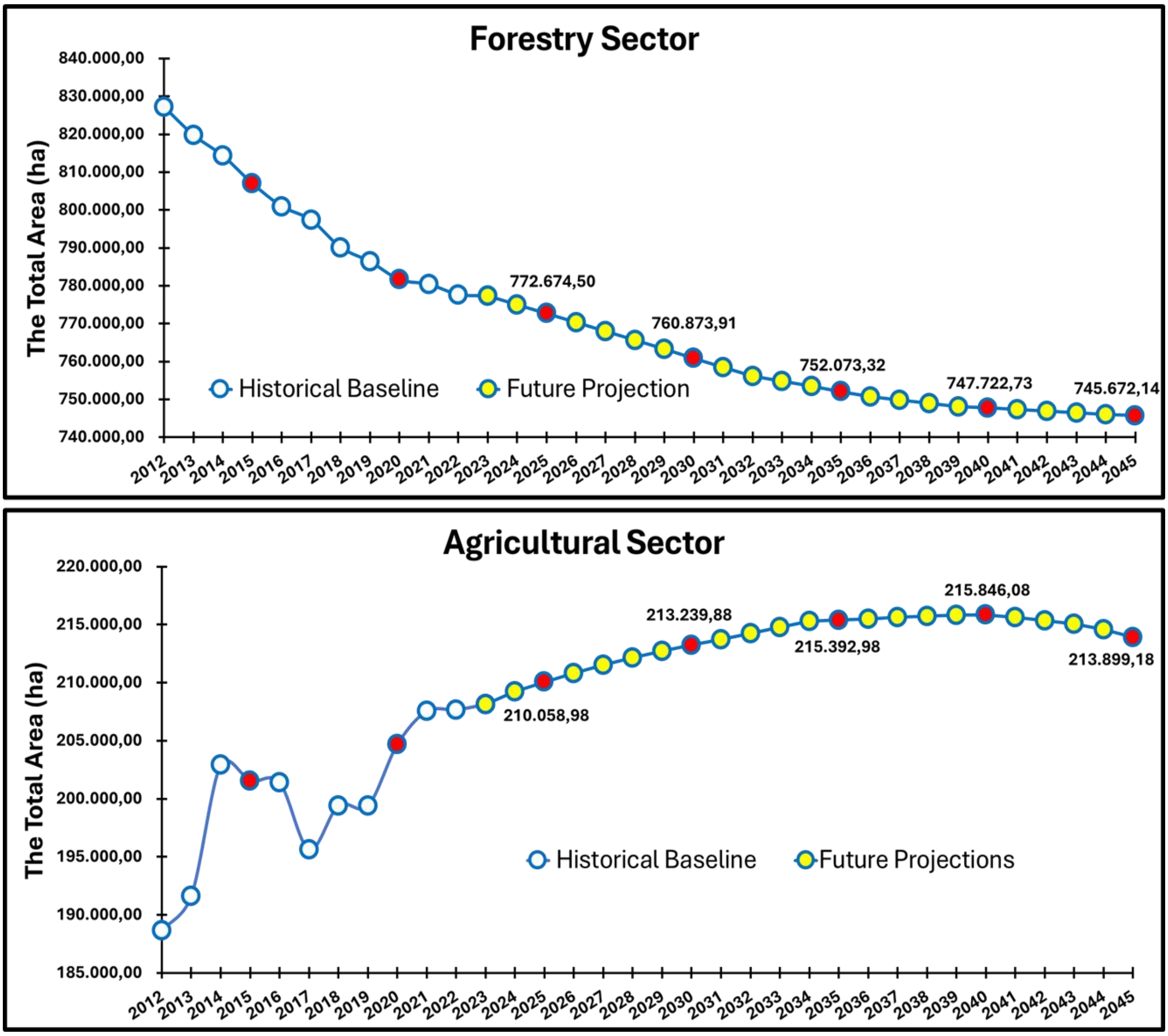


Fig. 7. Historical baseline and future trajectories of land cover dynamics in Kutai Kartanegara.

These forecasts highlight the importance of integrated spatial planning strategies (Nisaa et al. 2023) that strike a compromise between ecological sustainability and development (Kiswanto et al. 2024). In land management, strategies such as agroforestry (van Noordwijk et al. 2018), strict zoning rules (Mora et al. 2020), and increasing community engagement (Jiuhardi et al. 2024) might assist in avoiding negative consequences and hence enhance local life (Roslinda et al. 2023). Strengthening jurisdictive frameworks, including the community, funding for sustainable practices (Zefanius et al. 2020), and thus promoting stakeholder cooperation constitute a miscellaneous approach required to solve the challenges (Dewi et al. 2024). By exploring adaptive management techniques that can increase environmental and community resilience, Kutai Kartanegara Regency might greatly progress toward its emission reduction objectives in 2030. This will contribute to fulfilling the vision of Indonesia Emas 2045 and boost ecological sustainability and community resilience.

3.5. Potential Locations for Developing Forests and Food Sources

Appropriate urban growth is difficult for emerging nations, particularly given social and environmental issues. Establishing forest cities and enhancing food supplies could help to solve these problems effectively. Consequently, it is unsurprising that studies on food supply and forest cities are gradually gaining popularity in these regions. Districts in Kutai Kartanegara that have the potential to grow into forest cities and food sources to support the Nusantara capital city of Indonesia are identified by this study. In Kutai Kartanegara (**Table 1**), Tabang District (80.89%) has been identified as a potential location for developing forest cities and food sources. In comparison, Anggana District (30.88%), Samboja (15.38%), and Muara Badak (13.33%) have been identified as prospective areas for the development of farming land.

Table 1. Potential locations for developing forests and food sources in Kutai Kartanegara

District	Forested Areas		Food Sources		Total	
	ha	%	ha	%	Ha	%
Anggana	19,262.30	2.48	64,285.12	30.88	83,547.42	8.48
Kembang Janggut	22,316.65	2.87	5,874.44	2.82	28,191.10	2.86
Kenohan	4,004.24	0.52	-	-	4,004.24	0.41
Kota Bangun	1,300.31	0.17	2,933.55	1.41	4,233.86	0.43
Loa Janan	-	-	11,327.96	5.44	11,327.96	1.15
Loa Kulu	4,977.09	0.64	2,052.50	0.99	7,029.59	0.71
Marang Kayu	2,554.33	0.33	8,173.70	3.93	10,728.03	1.09
Muara Badak	1,671.97	0.22	27,113.03	13.03	28,785.00	2.92
Muara Jawa	9,787.38	1.26	9,620.14	4.62	19,407.52	1.97
Muara Kaman	79,782.43	0.26	11,854.36	5.69	91,636.80	9.30
Muara Muntai	357.11	0.05	389.55	0.19	746.66	0.08
Muara Wis	931.04	0.12	2,090.42	1.00	3,021.46	0.31
Samboja	297.84	0.04	32,004.58	15.38	32,302.42	3.28
Sanga-Sanga	1,313.57	0.17	1,430.05	0.69	2,743.62	0.28
Sebulu	-	-	11,269.94	5.41	11,269.94	1.14
Tabang	628,838.48	80.89	1,416.14	0.68	630,254.62	63.95
Tenggarong	-	-	8,854.38	4.25	8,854.38	0.90
Tenggarong Seberang	-	-	7,465.24	3.59	7,465.24	0.76
Total	**777,394.74**	**100.00**	**208,155.12**	**100.00**	**985,549.86**	**100.00**

The population growth of East Kalimantan Province, as the site of the Nusantara capital city of Indonesia, would be influenced directly and indirectly by the relocation of the national capital (Silalahi and Silalahi 2024). The main consequences of population development are the increased need for food and the reduction of wooded regions (Nisaa et al. 2023). The problem arises because East Kalimantan Province has significant forest cover and is not generally a center for food and agricultural creation (Khan et al. 2020; van Noordwijk et al. 2018). The phenomenon of growth devoid of development, characterized by economic expansion that fails to improve the quality of life for individuals, persists in East Kalimantan Province (Jiuhardi et al. 2024; Mora et al. 2020). Food sovereignty and autonomy are among the factors. East Kalimantan is significantly dependent on food supplies from adjacent areas.

Indonesia's research and innovation focus on enhancing agricultural land for food sources. Agrobiodiversity and wild food sources may diversify diets and offer functional meals, especially for vulnerable communities (van Noordwijk et al. 2018), but traditional research and development have ignored their potential. Due to forest management, Kutai Kartanegara Regency has several natural food sources. However, few people utilize their woodland property to increase food readiness (Aini and Dwijatenaya 2024). Socio-economic factors, agricultural intensification, and market volatility drive change. Agricultural land dynamics may cause a decrease in the food supply. This may be solved by improving agricultural land and using natural food sources, especially from woodland regions. Local inhabitants' positive view of wild food sources may help promote them. This requires actions to increase their availability and awareness to bridge the knowledge gap concerning their benefits (Jiuhardi et al. 2024). Traditional and modern knowledge of these meals may be used in regional agricultural, nutritional, health, tourism, social, and educational actions. Innovative methods for sustainable wild food consumption need alliances between communities, governments, and NGOs (Agustian et al. 2021; Benny et al. 2023; Khan et al. 2020). Using forest conservation and utilization optimization together may protect forested areas, sustain biodiversity, and provide people with food, nutrition, and health.

The transformation of IKN suggests combined approaches to minimize the effects on social and ecological systems of alteration in land cover (Agustian et al. 2021). For instance, local knowledge might help to preserve authorized acknowledgment of customary forests through participatory mapping and locally important species such as Tengkawang (Zefanius et al. 2020). While keeping pollination corridors for agricultural livelihoods, GPS-tracked agroforestry zones and blockchain-enable land leases might lower smallholder displacement concerns. Urban growth poses food security concerns (Benny et al. 2023), which call for hybrid strategies like community-managed seed banks to uphold genetic diversity and vertical farms running local crops. Integrated rice-fish-agroforestry systems (Roslinda et al. 2023) maintain production without sacrificing biodiversity; microbial biofertilizers originating from mycorrhizal networks show the possibility of improving soil health and crop yields.

The ongoing expansion of IKN and its surrounding area in East Kalimantan calls for innovative policy frameworks (Silalahi and Silalahi 2024) to control land cover changes and balance ecological conservation with infrastructure needs. The spatial planning framework must include ecological zoning and urban expansion limits. Ecological zoning regulations need a 75% allotment of green space in the core region of IKN (Marzuki et al. 2022), based on satellite-derived land cover change analysis (Nisaa et al. 2023). GIS monitoring systems might enforce urban expansion limits automatically to prevent forest encroachment (Syaban and Appiah-Opoku 2024). Successful implementation requires rigorous enforcement of protective legislation, autonomous validation of smart forest city assertions via satellite-based deforestation notifications, and financial incentives to stimulate private sector investment in rehabilitating urban areas.

4. Conclusions

The study reveals a trend of decreased forest cover, which requires the setting up of a forest ecosystem restoration program. The degradation of agricultural land, particularly in pure dryland farming and aquaculture, might jeopardize national food security. Interventions using new ways to enhance the quality of forest and agricultural land must be tailored to the specific requirements of each region, ensuring prompt and contextually relevant execution. This research simultaneously identifies potential sites for creating forest cities and national food storage facilities. The results emphasize that using GIS tools, remote sensing technologies, and spatial analytic skills is essential for developing successful spatial planning strategies in the IKN and adjacent buffer zones in East Kalimantan. These methods provide thorough evaluations of land cover changes via spatiotemporal analysis, which are crucial for comprehending the environmental effects of urbanization and infrastructure development linked to the capital's move. This research, however, has limitations in addressing the relationship between land cover dynamics and greenhouse gas emissions. Subsequent studies should focus on examining the effects of land cover dynamics on carbon emissions, especially for IKN's rapidly evolving landscapes. Alterations in land cover, driven by deforestation and urbanization, profoundly affect carbon emissions and sequestration capacity.

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Author Contributions

K.K., I.A.G., and A.N.: Conceptualization, Methodology, Project Administration, Funding Acquisition; K.K., M.M., D.A.P., and D.W.: Investigation, Data Curation, Formal Analysis; K.K. and M.M.: Writing – Original Draft, Writing – Review and Editing.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation

The authors used QuillBot Premium to assist in paraphrasing sentences of the article. After using this software, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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