

Implementation of Spatio-Temporal Analysis for Land Use Management and Urban Planning in North Halmahera Regency

Yerik Afrianto Singgalen*

Faculty of Business Administration and Communication, Tourism Department Study Program, Atma Jaya Catholic University of Indonesia, Jakarta, Indonesia

Email: yerik.afrianto@atmajaya.ac.id

Correspondence Author Email: yerik.afrianto@atmajaya.ac.id

Abstract—This study aims to examine the attributes of spatio-temporal dynamics and the progression of land-use alterations, which is imperative for comprehending and appraising the condition and transformation of ecosystems. When employed in the context of North Halmahera Regency, this analysis can furnish fundamental insights to facilitate informed decision-making in urban planning. By understanding the spatio-temporal dynamics of land use change in the region, decision-makers can make more effective choices regarding infrastructure development, resource allocation, and sustainable urban growth, ultimately leading to more resilient and well-planned urban environments. In the methodology section, this study employed Landsat 8 OLI satellite imagery and Geographic Information System (GIS) technology to investigate the spatio-temporal dynamics and land use changes in North Halmahera Regency from 2013 to 2023. The models used are the Normalized Difference Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), Enhanced Vegetation Index (EVI), and Normalized Difference Built-up Index (NDBI). These research findings show that land use management for urban planning objectives should assess several dimensions, such as preserving Hibualamo cultural values, settlement patterns derived from household livelihood assets, and Tobelo City's economic activities.

Keywords: Land Use; Urban Planning; North Halmahera; Spatio-Temporal Analysis

1. INTRODUCTION

Spatio-temporal analysis plays a crucial role in urban planning and land use management by thoroughly understanding the dynamic interplay between urban development and land use through time [1]. This analytical technique analyses temporal patterns and spatial configurations, allowing urban planners and policymakers to identify the evolution of land use in response to changing socioeconomic, environmental, and demographic conditions [2]. By integrating multi-temporal geospatial data, such as satellite imaging and geographic information system (GIS) technologies, spatio-temporal analysis aids the detection of trends, hotspots, and essential transitions in land use within metropolitan regions [3]. This insight not only aids in formulating informed urban planning strategies but also supports evidence-based decision-making processes to address the challenges of sustainable urban development, infrastructure optimization, and land resource management, ultimately contributing to more resilient and livable cities in an era of rapid urbanization.

The analysis of land use through remote sensing techniques, including the utilization of vegetation indices such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Soil-Adjusted Vegetation Index (SAVI), has become a cornerstone in contemporary land cover studies and ecological monitoring [4]. These indicators provide essential insights into land surface dynamics, enabling the detection and quantification of vegetation and land cover changes [5]. NDVI, for instance, analyzes vegetation health and density, with higher values suggestive of better vegetation, while EVI gives advantages in places with dense canopies and lower atmospheric impacts [6]. On the other hand, SAVI enables correction for soil background influences, boosting accuracy in places with diverse soil types [7]. These vegetation indices collectively facilitate the comprehensive evaluation of land use alterations, offering critical information for ecological assessments, land management strategies, and environmental conservation efforts, thus underscoring their significance in contemporary remote sensing-based land use analysis.

In urban planning, it is essential to incorporate remote sensing models, such as the Normalized Difference Built-Up Index (NDBI), into the decision-making process, particularly concerning the development of urban buildings and infrastructure [8]. Utilizing NDBI for systematically identifying and mapping built-up structures yields crucial insights into urban expansion and spatial building distribution through time [9]. Utilizing the capabilities of remote sensing technology, urban planners are able to monitor and assess urban growth trends, population dynamics, and land use changes, which are crucial for formulating well-informed urban development policies [10]. Integrating NDBI into the urban planning framework facilitates the efficient allocation of resources, optimal infrastructure planning, and sustainable urban design, thereby creating more resilient and livable urban environments in response to the changing needs of urban populations [11].

The insufficient integration of high-resolution, up-to-date remote sensing data with advanced geospatial modeling tools is a noteworthy research gap in spatial-temporal analysis for urban planning and land use changes in Indonesia. Despite the country's rapid urbanization and land use transformation, a dearth of research exploits the full potential of contemporary remote sensing technologies, such as satellite imagery, LiDAR data, and unmanned aerial vehicles (UAVs), combined with sophisticated spatio-temporal modeling approaches. Such an integrated approach is crucial for accurately monitoring and predicting urban expansion, land cover transitions, and associated socio-environmental impacts at a finer spatial and temporal resolution, enabling more precise urban planning, infrastructure development, and sustainable land use management strategies. Filling this research gap would improve the effectiveness of urban planning activities in

Indonesia and provide vital insights into the broader difficulties of urbanization and land use changes in quickly developing countries worldwide.

Applying spatio-temporal analysis to investigate land-use changes in urban settings is urgent due to the requirement to inform and direct decision-making processes for sustainable development [12]. With rising worldwide urbanization rates and the attendant issues of resource allocation, infrastructure planning, and environmental conservation, spatial-temporal analysis provides a vital set of tools for understanding the dynamic and complex character of urban land use shifts [13]. By integrating modern geospatial technology, remote sensing data, and advanced modeling approaches, this type of study permits the correct assessment of urban expansion, the identification of land use trends, and the evaluation of environmental repercussions over time [14]. It enables policymakers, urban planners, and stakeholders to make informed decisions that prioritize sustainable urban development, optimize land resource utilization, mitigate the adverse effects of rapid urban growth, and foster the creation of resilient and harmonious urban environments capable of meeting the evolving needs of urban populations.

Tobelo City, located in Indonesia's North Halmahera Regency, is a pertinent research area for the in-depth investigation of land-use dynamics and urban planning using Landsat 8 OLI satellite images from 2013 to 2023. This choice is crucial due to Tobelo City's unique characteristics, which include rapid urbanization, evolving land use patterns, and environmental sensitivity [15], [16]. The use of advanced geospatial tools in this region permits a thorough assessment of urban expansion, infrastructural development, and land cover changes, hence aiding the identification of upcoming urban difficulties and potential. By focusing on Tobelo City as a research location, this study intends to contribute valuable insights that not only address the specific urban planning needs of the region but also provide a broader understanding of urbanization dynamics in similar fast-growing urban areas, thereby advancing the goals of sustainable urban development and land use management. Tobelo City's distinctiveness as a research location derives from its rich cultural legacy, especially the dynamic culture of the Hibualamo, as well as the prevalent similarities and local livelihood patterns throughout its coastline [17]. This unique combination of cultural diversity, traditional knowledge systems, and unique coastal ecosystems needs a contextual analysis and relevance-driven approach to urban development programs and policy formulation [18]–[20]. Recognizing the social difficulties of Hibualamo, the purpose of this study is to bridge the gap between indigenous knowledge and modern context, importance, focus, and organization as a pragmatic, culturally sensitive, and ecologically sustainable [21]. This study aims to serve as a model for inclusive, community-based urban development paradigms that celebrate the cultural uniqueness of Hibualamo while supporting harmonious urban growth and conserving the coastal livelihoods crucial to the region's well-being and resilience.

This study advances the understanding of spatio-temporal land-use patterns in urban contexts, as typified by Tobelo City in North Halmahera Regency, and hence provides a considerable theoretical and empirical contribution to achieving sustainable development objectives. The study extends existing theoretical frameworks by merging remote sensing technology, geographic modeling, and cultural contextualization, providing a comprehensive approach to urban planning and land-use management [22]. It sheds light on urban development plans prioritizing cultural preservation, environmental management, and community well-being [23]. These contributions give concrete direction for policymakers, urban planners, and stakeholders aiming to build context-aware, sustainable urban development plans that resonate with the cultural identity of the Hibualamo community and align with larger global sustainable development goals.

2. RESEARCH METHODOLOGY

2.1 Research Stages

The spatio-temporal analysis methodology employed in this study integrates multi-temporal Landsat 8 OLI satellite imagery spanning the decade from 2013 to 2023 with geographic information system (GIS) technology to examine the evolving land-use patterns and urban dynamics of Tobelo City in North Halmahera Regency. This methodology involves extracting accurate and consistent land-use information utilizing maximum likelihood classification and post-classification change detection methods. Subsequently, the study employs three key index models: the dynamic degree model to assess regional land resource changes, the dynamic change transfer matrix and flow direction rate model to analyze land use change directions, and the barycenter transfer model to scrutinize the spatial patterns of land use transformations [24]. Through this comprehensive spatio-temporal analysis methodology, the research aims to provide a nuanced understanding of the urbanization processes and land-use transitions in Tobelo City, facilitating evidence-based urban planning and sustainable development decision-making.

The implementation of the Dynamic Degree Model in QGIS, using Landsat 8 OLI imagery from 2013, 2018, and 2023, and incorporating spectral indices such as Normalized Difference Vegetation Index (NDVI) [25], Enhanced Vegetation Index (EVI) [26], Soil-Adjusted Vegetation Index (SAVI) [27], and Normalized Difference Built-Up Index (NDBI) [28], constitutes a robust spatio-temporal analysis framework. This comprehensive method blends multi-temporal Landsat data with Geographic Information System (GIS) technology, enabling the extraction of exact and consistent land use data for the defined periods [29]. Utilizing the power of these spectral indices, particularly NDVI for vegetation and NDBI for urban areas, assess the changing land cover and land use trends throughout the research area [30]. The Dynamic Degree Model is instrumental in quantifying the dynamic changes in regional land resources, thus providing invaluable

insights into the transformations of the landscape, which are crucial for informed decision-making in fields ranging from land management and environmental monitoring to urban planning [31].

Implementing the Dynamic Change Transfer Matrix and Flow Direction Rate Model in QGIS is an advanced spatio-temporal analysis method for evaluating the spatial dynamics and directionality of land use change and other geographical phenomena [3]. By keeping track of the changes between separate categories or values over time, these models make it possible to evaluate the direction and magnitude of changes. Using Geographic Information System (GIS) technology, decision-makers are able to generate matrices that depict the magnitudes and directions of change [32]. By visualizing and analyzing the patterns of matrices, analysts are able to gain vital data regarding the origin and movement of spatial phenomena within a studied region. These implementations are required for making informed decisions about land use planning, environmental management, and infrastructure development because they provide a thorough understanding of spatial dynamics.

Implementing the Barycenter Transfer Model in QGIS requires an advanced geospatial analysis method to evaluate the spatial patterns and gravitational centers of change within a research region [33]. This model utilizes vector data layers that depict land use, land cover, or other spatial phenomena over many periods. The Barycenter Transfer Model enables researchers to uncover central tendencies and patterns of spatial change by estimating the centroids of various spatial variables and examining their geographical changes through time [34]. This approach, firmly rooted in Geographic Information System (GIS) technology, provides a valuable method for understanding land use dynamics or other spatial variables, informing decision-making processes associated with urban planning, natural resource management, and environmental assessment [35]. Figure 1 also displays the phases of spatio-temporal analysis.

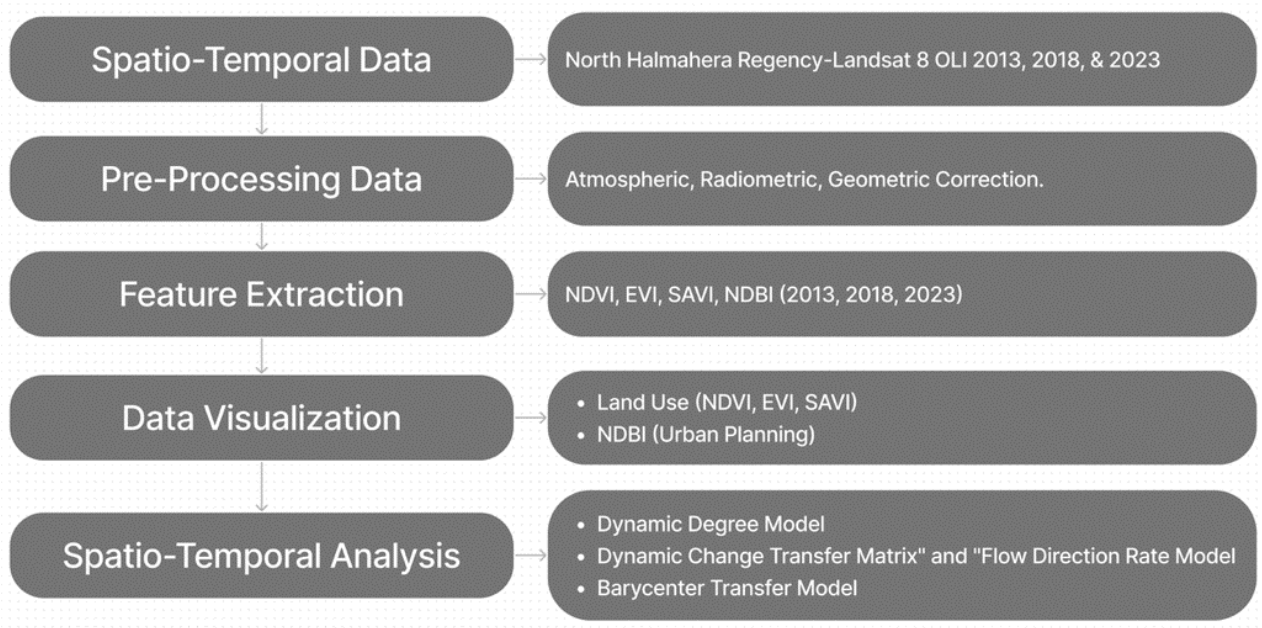


Figure 1. Implementation of Spatio-Temporal Analysis

Models such as the Dynamic Degree Model, the Dynamic Change Transfer Matrix, the Flow Direction Rate Model, and the Barycenter Transfer Model are required for this investigation. These models provide a spatio-temporal study of land use changes and spatial dynamics, essential for understanding the complex evolution of urban regions and ecosystems. The Dynamic Degree Model supports urban planning and land management decisions by making it possible to measure regional changes in land resources. The Dynamic Change Transfer Matrix and Flow Direction Rate Model show the directionality and magnitude of these changes, which is crucial for identifying patterns and hotspots. The Barycenter Transfer Model provides insights into spatial change's fundamental patterns and tendencies, helping establish well-informed policies and initiatives. These models allow researchers to comprehend the complexities of spatiotemporal dynamics, thereby supporting sustainable development and environmental protection. This study aims to compare the land use map supplied by the North Halmahera Government in the Spatial Pattern Detailed Urban Spatial Plan for Tobelo City with the results of our spatio-temporal analysis. This research aims to identify any discrepancies or congruences between the government's land use plans and the empirical land use dynamics uncovered by our investigation. Such a comparative method is crucial for assessing the efficacy of existing urban planning strategies and how they fit with observed spatiotemporal patterns, thereby giving valuable insights for strengthening urban development policies and encouraging sustainable land use in Tobelo City.

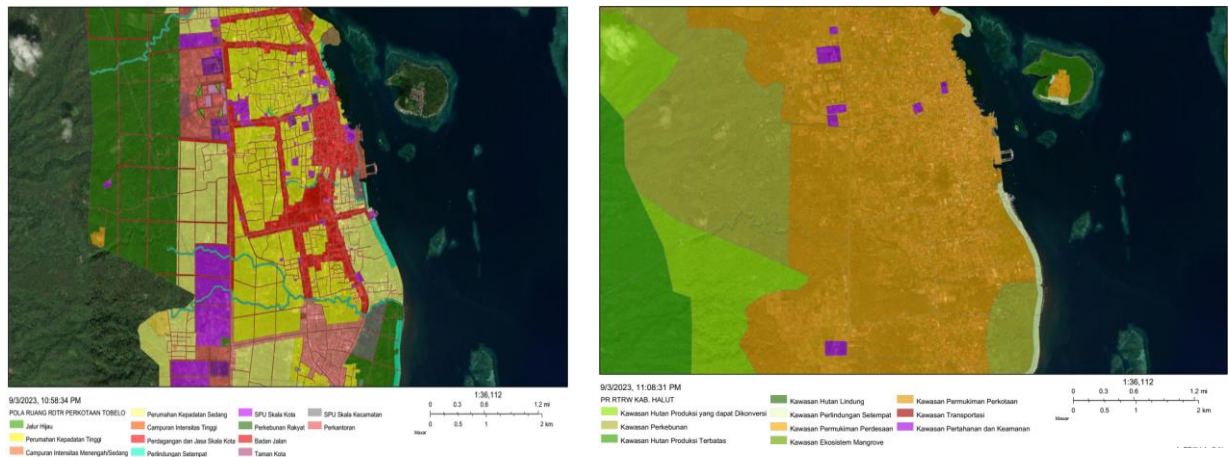


Figure 2. Tobelo City Spatial Pattern Detailed Urban Plan

Figure 2 depicts the Detailed Urban Plan for the Spatial Pattern of Tobelo City. The administration of North Halmahera offers this dataset. In addition, government WebGIS databases may have data standards and consistency issues between departments and regions, making it challenging to develop a unified and seamless geographic data architecture. Moreover, data ownership and governance issues may lead to disagreements over data sharing and management between government entities, reducing efficiency. Utilizing a Geographical Information System (GIS) database beyond its passive function as a repository for spatial data requires expert maintenance and mathematically-supported analysis. This method is indispensable for shedding light on the intricacies of land use transitions, a crucial task with far-reaching implications for formulating long-term strategic regional development plans. This study uses drone technology to gather high-resolution video footage, enabling a comprehensive assessment of Tobelo City's urban districts, focusing on its coastal zones, including Tobelo and Gorua Harbour, Rawajaya, and Gamsungi. Using drones to collect visual data, this study aims to conduct a comprehensive investigation of the urban environment, allowing for the documentation and evaluation of changing conditions, infrastructure, and land use dynamics in these critical coastal areas. The research underscores the significance of Tobelo City's coastal zones by emphasizing their intrinsic relationship with the lives of residents, primarily fishermen, and merchants who depend on the harbor and market districts. In addition, it acknowledges the importance of the Hibualamo cultural value, which closely defines communal socio-interaction patterns and dramatically contributes to the urban landscape and local dynamics of these coastal locations.



Figure 3. Areal Video and Photography

Figure 3 displays aerial imagery and video of the study site. To validate and enhance spatio-temporal analysis, aerial footage and photos of Tobelo and Gorua Harbor, Rawajaya, and Gamsungi are required. By providing a bird's-eye view of the evolving urban landscape, these visual data sources give essential context and ground truth for the analytical conclusions. By capturing fine-grained details and temporal changes, aerial imagery contributes to validating and refining spatio-temporal models, thereby enhancing the accuracy and dependability of analysis results, particularly in coastal regions where land-use dynamics and socioeconomic patterns frequently exhibit complex interactions and nuanced variations. The data raster computation model is also listed in the table that follows.

Table 1. Raster Calculation through NDVI, SAVI, EVI, NDBI

Model	Raster Calculation based on Landsat 8 OLI
Normalized Difference Vegetation Index (NDVI)	$(\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$
Soil-Adjusted Vegetation Index (SAVI)	$((\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red} + \text{L})) * (1 + \text{L})$
Enhanced Vegetation Index (EVI)	$2.5 * ((\text{NIR} - \text{Red}) / (\text{NIR} + 6 * \text{Red} - 7.5 * \text{Blue} + 1))$
Normalized Difference Built-up Index (NDBI)	$(\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$

The model's algorithm applied in this investigation is displayed in Table 1. The Normalized Difference, Vegetation Index model is an effective analytical tool for remote sensing and environmental research using Landsat 8 OLI (Operational Land Imager) data. Using near-infrared and red spectral bands, this method investigates the existence and health of vegetation, enabling the exact categorization of vegetated zones, the evaluation of plant vitality, and the identification of temporal changes in land cover and land use patterns. The Soil-Adjusted Vegetation Index model is a powerful remote sensing tool for recognizing vegetation under different environmental circumstances. Adapted for soil brightness, this model enhances the sensitivity to vegetation presence and health, enabling researchers to identify more subtle differences in plant cover and vitality across landscapes. Its combination with Landsat 8 OLI data enables comprehensive assessments of vegetation changes, making it a vital tool for ecological monitoring, land management, and environmental studies. In addition, the Enhanced Vegetation Index is also a reliable remote sensing and environmental research instrument. This model, which combines atmospheric and background variables, provides enhanced sensitivity to vegetation changes and a more realistic picture of the health and vigor of vegetation across a range of land cover types and environmental situations. Using Landsat 8 OLI data with the EVI model for precise monitoring and evaluation of vegetation dynamics makes it a valuable resource for ecological research, land use planning, and environmental control projects. The Normalized Difference, Built-Up Index methodology accurately identifies and analyzes urban expansion and urbanized regions. By separating impervious surfaces, this near-infrared and short-wave infrared-based method improves the identification of urban expansion and land use change patterns. Its integration with Landsat 8 OLI data enables a comprehensive examination of urbanization patterns, making it an indispensable research tool for urban planning, infrastructure development, and land use management.

Furthermore, Landsat Imagery and Copernicus datasets from 2002, 2010, 2013, and 2022 are required for validating computing models utilizing essential vegetation and land-use indices, such as NDVI, EVI, SAVI, and NDBI. These temporal datasets offer a longitudinal perspective on Earth's surface dynamics and land cover changes, allowing scientists to evaluate the robustness and dependability of their calculating models. By comparing these indices across several periods, the discussion of this study's findings will assess the models' ability to reflect temporal fluctuations in vegetation health, land-use shifts, and urbanization patterns. This broad research adds to the refinement of existing models and the knowledge of long-term environmental and urban development trends, supporting more informed decision-making in many domains, including agriculture, urban planning, and environmental monitoring.

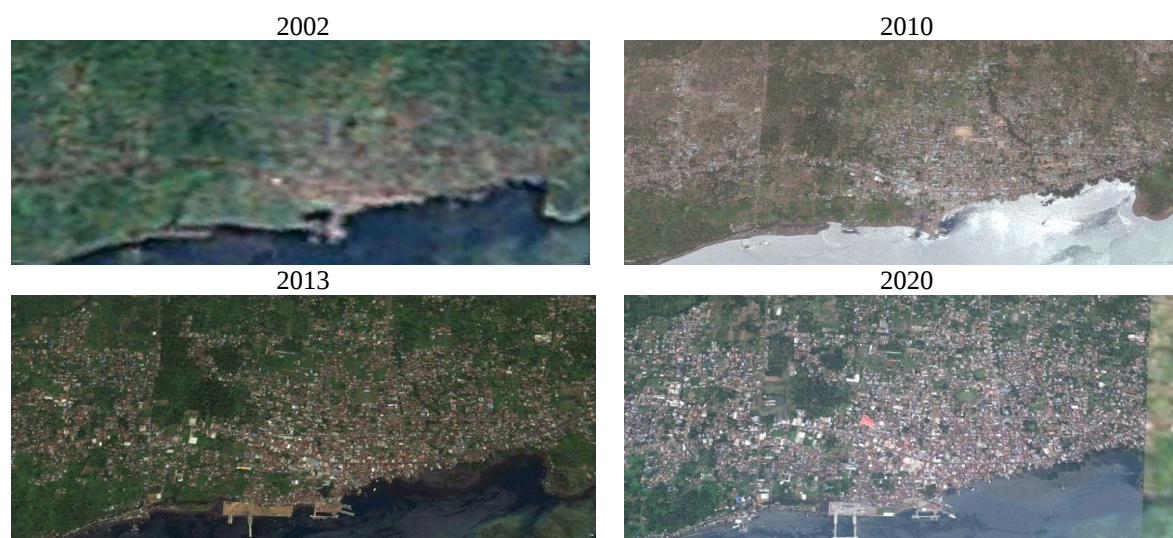


Figure 3. Landsat Imagery Copernicus 2002, 2010, 2013, 2020

The topography of Tobelo City, as acquired by Landsat Imagery Copernicus in 2002, 2010, 2013, and 2020, is seen in Figure 3. The comprehensive evaluation of significant land-use changes in Tobelo requires a meticulous spatiotemporal investigation. This technique is crucial for discovering the intricate patterns, tendencies, and dynamics of land use changes. Using spatio-temporal analysis methodologies, this study can examine the extent and direction of these changes and their underlying causes and implications for urban development, environmental sustainability, and land management policy. By offering a thorough understanding of the expanding urban landscape, such an analytical framework promotes informed decision-making and strategic planning for the sustainable urban growth of Tobelo City. Numerous cultural, economic, and environmental elements influence the dynamics of urban development and land use planning in the North Halmahera Regional Government. This study's first issue investigates the complex relationship between urban design and the preservation of Hibualamo culture, the sustainable management of the coastal economy, and the position of communities in the region. This deeply ingrained cultural and socioeconomic setting requires a nuanced approach to urban development that balances growth, preservation of cultural history, and sustainable use of coastal resources. Using key indices such as NDVI, EVI, SAVI, and NDBI, the second objective of our research is to undertake a spatio-temporal analysis between 2013 and 2023. This analytical methodology will provide insights into the changing land use patterns and urban planning dynamics in the North Halmahera Regency, enabling a quantitative knowledge of how environmental forces have impacted the region's urban landscape over this crucial period. These two obstacles lay the groundwork for a thorough evaluation of the complex urban expansion scenario in North Halmahera, where culture, economy, and environmental sustainability are intertwined.

3. RESULT AND DISCUSSION

This paper thoroughly analyzes the different restrictions and possibilities that influence land use practices in the North Halmahera Regency. These findings contribute to a greater understanding of spatiotemporal environmental changes and offer crucial insights into how urban planning strategies can be adapted and harmonized with the coastal economy and settlement dynamics of the Hibualamo culture, thereby promoting sustainable development and cultural preservation in the region.

3.1 Urban Planning and Land Use Management: Hibualamo Culture and Value, Settlement and Economic Activity

The preservation and sustainable growth of Hibualamo culture, the coastal economy, and settlement dynamics rely heavily on urban planning and land use management. In the context of the Hibualamo culture, distinguished by its coastal heritage and dependence on maritime resources, urban development initiatives must prioritize preserving traditional practices and indigenous knowledge of fishing, boat-building, and coastal agriculture. Moreover, land use regulations should support safeguarding culturally significant locations and landscapes to ensure the Hibualamo people's cultural integrity. Concurrently, focusing on the coastal economy requires strategic zoning and infrastructure development that encourages the efficient operation of fishing harbors, fish processing facilities, and trade networks, thereby creating economic resilience and community livelihoods. Urban planners must consider the vulnerability of coastal areas to climate change and rising sea levels when managing settlements, necessitating adaptive techniques such as elevated housing and integrated disaster risk reduction measures. An interdisciplinary approach to urban design and land use management is essential to accommodate the complex interaction of cultural, economic, and environmental issues within the context of the Hibualamo culture and its coastal-based way of life.

The social contact pattern of the Hibualamo, a tribe with immense family structures, displays a complex system of social bonding that significantly determines their settlement pattern based on family membership. This complex network of social ties encourages communal livelihoods, generating a settlement pattern in which extended families cluster together to allow shared resources, labor cooperation, and the preservation of traditional rituals and intergenerational knowledge within the tribal setting. The social contact pattern of the Hibualamo, a tribe with immense family structures, displays a complex system of social bonding that significantly determines their settlement pattern based on family membership. This complex network of social ties encourages communal livelihoods, generating a settlement pattern in which extended families cluster together to allow shared resources, labor cooperation, and the preservation of traditional rituals and intergenerational knowledge within the tribal setting. In conclusion, the complex interplay of social ties, settlement patterns, and land-use strategies among the Hibualamo of North Halmahera Regency exemplifies a holistic approach to sustainable livelihood and resource management deeply rooted in their cultural heritage and environmental context.

Four significant occupational kinds, including farmers or peasants, fishermen, entrepreneurs or traders, and official vocations such as government servants, are essential in the North Halmahera Regency's livelihood features, all intertwining to sustain home livelihoods. The region's domination of farmers and peasants indicates its agricultural base, which provides sustenance and contributes significantly to local food security. The geography of the region's coastline also promotes a thriving fishing sector, with fishermen greatly enhancing local cuisine and strengthening the coastal economy. In addition, entrepreneurs and traders transform the economic landscape by facilitating trade networks and promoting entrepreneurship, promoting economic expansion. In addition, the presence of official jobs, particularly civil servant positions, provides stable income streams and administrative stability, thereby bolstering the socioeconomic fabric

of the region. Collectively, these means of subsistence demonstrate North Halmahera's resilience and fortitude in sustaining a combination of traditional and modern economic activities, preserving the long-term prosperity of area households.

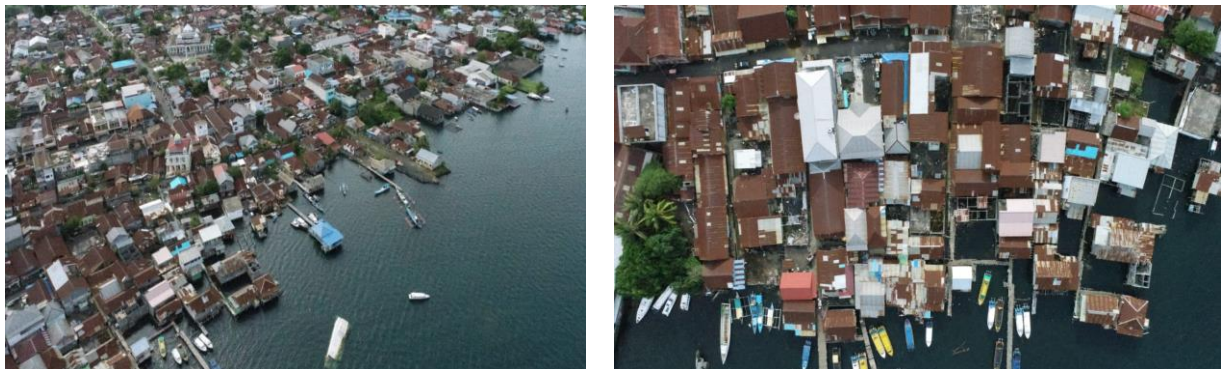


Figure 4. Land use in the Coastal Area of Angin Mamiri Harbour-Tobelo City

Figure 4 displays the land use in the Angin Mamiri Harbour-Tobelo City coastal area. In North Halmahera Regency, land use patterns are intricately connected with household livelihoods, particularly for fishermen, whose profession necessitates proximity to the ocean for optimal access to fishing grounds. Establishing communities in coastal areas is consistent with the livelihood strategy of fishermen, as living close to the water dramatically facilitates their daily fishing efforts. This choice of settlement location reflects a deliberate and pragmatic approach since it reduces the time and effort required to reach maritime resources, improving the efficiency and profitability of their fishing operations. This examination of settlement patterns indicates a direct connection between land use and regional livelihoods. The proximity to the coast benefits fishermen and provides coastal communities with a direct food source and economic security. Additionally, it exposes these populations to environmental risks, such as rising sea levels and natural disasters. In the context of coastal settlements in the North Halmahera Regency, a careful balance must be struck between enhancing livelihoods and mitigating environmental threats. The sensitive link between land use and household livelihoods, particularly among fishermen in coastal regions, exemplifies the pragmatic nature of settlement patterns that prioritize convenient access to vital resources. This adaptive technique illustrates the resilience of local inhabitants in North Halmahera Regency in modifying their land use practices to satisfy their subsistence needs.

The establishment of settlements in the coastal regions of the North Halmahera Regency is heavily impacted by the proximity to Tobelo City's economic hub and market. Coastal communities have developed as a strategic response to their closeness to Tobelo City, the principal economic center of the region. The economic benefits of quick access to markets, employment possibilities, and trade networks drive this phenomenon. This settlement pattern analysis highlights the significance of transportation and market accessibility as land use variables. Coastal communities promote the efficient transportation of products and people to and from Tobelo City, hence encouraging economic activity and regional connectivity. However, this concentration of communities along the shore also poses environmental concerns, including susceptibility to coastal hazards and the possible strain on local resources. The connection between land use in coastal areas and accessibility to the commercial hub of Tobelo City shows the pragmatic approach used by local communities to maximize economic potential. It shows the significance of transportation infrastructure and market proximity in settlement patterns. It stresses the necessity for sustainable development approaches in the North Halmahera Regency that balance economic expansion and environmental resilience.

Land use in coastal areas as settlements is not solely influenced by economic factors but also by cross-cultural interactions within the local community, particularly with migrants who bring diverse cultural values and a primary living intention for economic reasons, frequently as entrepreneurs or traders. This dynamic interaction between the indigenous population and the migrant population results in a complex amalgamation of cultural aspects and economic activity that define the land usage in these coastal regions. This phenomenon's analysis suggests that intercultural encounters diversify these communities' economic activities and trade networks. Incorporating many cultural ideas and behaviors produces a rich tapestry of livelihood methods, which improve economic prospects and cultural interchange. However, it may also provide difficulties regarding cultural integration and resource distribution within the group. In conclusion, coastal communities' multifarious land usage pattern shows the complex interaction between economic ambitions, cultural interactions, and survival measures. These villages become thriving hubs where cultural variety and economic vitality coexist, highlighting the significance of supporting inclusive and sustainable development strategies in North Halmahera Regency that capitalize on the benefits of cross-cultural exchanges.

Land use management for urban planning purposes should intricately consider multiple facets, including preserving Hibualamo cultural values, the settlement patterns derived from household livelihood assets, and the economic activities of Tobelo City. Integrating these factors into urban planning is crucial for promoting sustainable development and maintaining the local community's well-being. The analysis of this holistic approach demonstrates that incorporating Hibualamo cultural values into urban design can assist in preserving the region's cultural identity and legacy, hence generating a sense of belonging among the community's members. In addition, matching land use with household

livelihood assets guarantees that urban development contributes to the citizens' economic well-being, resulting in higher sustainability overall. In addition, recognizing the economic significance of Tobelo City in the context of the region as a whole enables urban planners to capitalize on its potential as an economic hub while resolving concomitant issues. Effective land use management for urban planning in the North Halmahera Regency must balance cultural preservation, sustainable livelihoods, and economic growth. By holistically addressing these factors, urban planning can help a region's holistic growth and prosperity while maintaining its rich cultural legacy and local dynamics.

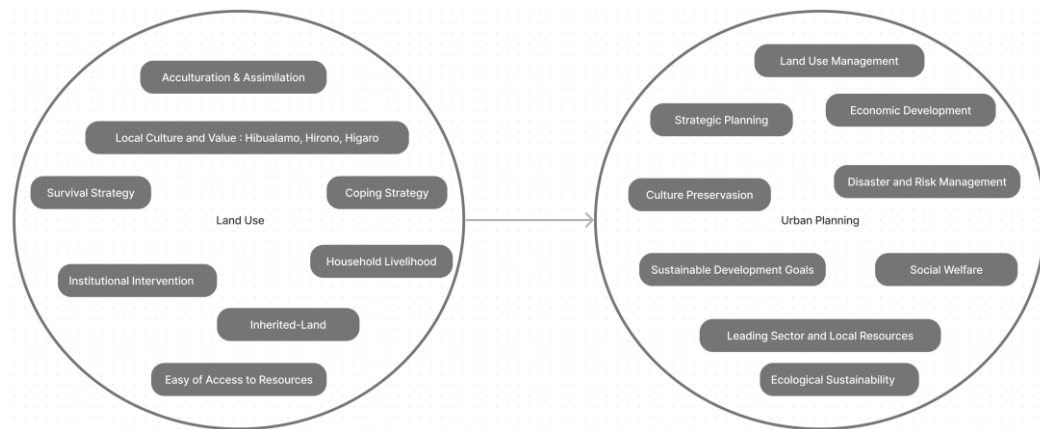


Figure 5. Land Use Management and Urban Planning Complexity

Figure 5 shows factors influencing North Halmahera Regency Context variables' land use and urban planning. Numerous influencing variables are crucial to understanding the complicated land use landscape, which includes components such as Hibualamo, Hirono, and Higaro customs. Reflecting a rich tapestry of indigenous behaviors and beliefs, these cultural factors substantially affect land use decisions. Furthermore, acculturation and assimilation variables contribute to developing land use patterns when foreign cultural influences interact with indigenous traditions, resulting in dynamic variations in land usage. Often firmly established in traditional practices, survival, and coping mechanisms influence land use decisions, responding to changing environmental and economic conditions. As they reflect the economic base of communities, household livelihood methods, such as agriculture, fishing, and entrepreneurship, are fundamental factors determining land use patterns. In addition, institutional actions and policies influence land use dynamics by creating restrictions and incentives to favor particular land use practices. In addition, inherited land and the ease of access to resources play vital roles in land allocation and use, as land tenure systems and geographical closeness affect land allocation and utilization. This intricate mosaic of land use patterns reflects the multidimensional nature of human-environment interactions. The complex nature of land use decision-making in North Halmahera Regency, where cultural, economic, environmental, and institutional elements combine to determine the region's dynamic land use patterns, is highlighted by various impacting variables. Understanding these elements is crucial for effective land use planning and sustainable development initiatives that respect local culture, improve livelihoods, and promote ecological resilience.

Several influential aspects, including strategic planning, which serves as the foundation for all-encompassing urban development programs, play vital roles in the multidimensional field of urban planning. Strategic planning involves identifying goals and priorities and developing a road map for sustainable growth. Land use management is vital for influencing urban regions' physical structure and spatial organization. Plans for economic development are essential for directing resource allocation and investment priorities, promoting economic growth and prosperity in metropolitan environments. In addition, urban planning must emphasize the preservation of local customs to safeguard heritage and identity in the face of urbanization. Integrated disaster and risk management considerations improve the resilience of urban settings against natural and man-made hazards. Aligning urban planning with the Sustainable Development Goals (SDGs) ensures a holistic approach to development that incorporates environmental, social, and economic factors. Focusing planning efforts on enhancing all individuals' quality of life involves considering social welfare concerns. Urban development is driven by using leading sectors and local resources to generate economic vibrancy and self-sufficiency. In addition, ecological sustainability concerns encourage responsible urban planning to limit environmental impacts and improve long-term ecological health. Urban planning in North Halmahera Regency is a complicated process that integrates multiple influencing variables, each contributing to urban areas' sustainable and balanced growth. Understanding and regulating these factors simultaneously is essential for developing urban environments that are resilient, culturally varied, economically vibrant, and ecologically sustainable and that adapt to the community's dynamic needs and aspirations.

3.2 Spatio-Temporal Analysis: NDVI, EVI, SAVI, NDBI of North Halmahera Regency in 2013, 2018, and 2023

The North Halmahera government's implementation of the Geographic Information System (GIS) technology known as "Halmahera Satu Data Satu Peta" demonstrates a progressive approach to enhancing e-governance transparency and accountability. This integrated GIS system, which translates to "Halmahera One Data One Map," provides a

comprehensive and centralized platform for collecting, organizing, and disseminating spatial data, facilitating informed decision-making and boosting administrative efficiency. Adopting this GIS technology indicates a commitment to open and accountable governance by allowing government agencies to share essential spatial data with the public. The technology enhances data consistency and accessibility by integrating various geographic datasets onto a single, accessible platform, hence reducing information silos and bureaucratic inefficiencies. In addition, it allows local authorities to make well-informed decisions regarding land use, urban planning, and resource management that are consistent with sustainable development goals. It is a commendable effort to enhance e-governance by utilizing modern GIS technologies. This system encourages transparency and accountability and streamlines administrative processes, ultimately contributing to improved regional governance and sustainable development.

This integrated GIS system provides a single platform for gathering, managing, and publishing spatial data, promoting informed decision-making and enhancing administrative efficiency following modern governance principles. Prioritize the ongoing maintenance and updating of system data to reflect current happenings. In addition, there is an excellent opportunity to employ GIS for spatio-temporal analysis, which would aid policymakers in acquiring a more comprehensive understanding of patterns and changes across time. By addressing these obstacles, North Halmahera could increase the effectiveness of "Halmahera One Data One Map" in promoting openness and accountability, thereby contributing to more informed and responsive e-governance. Adopting GIS technology through "Halmahera One Data One Map" is a commendable step towards improving e-governance performance; however, the continued updating of data and exploration of spatio-temporal analysis capabilities will be required to maximize its potential impact on regional governance and development.

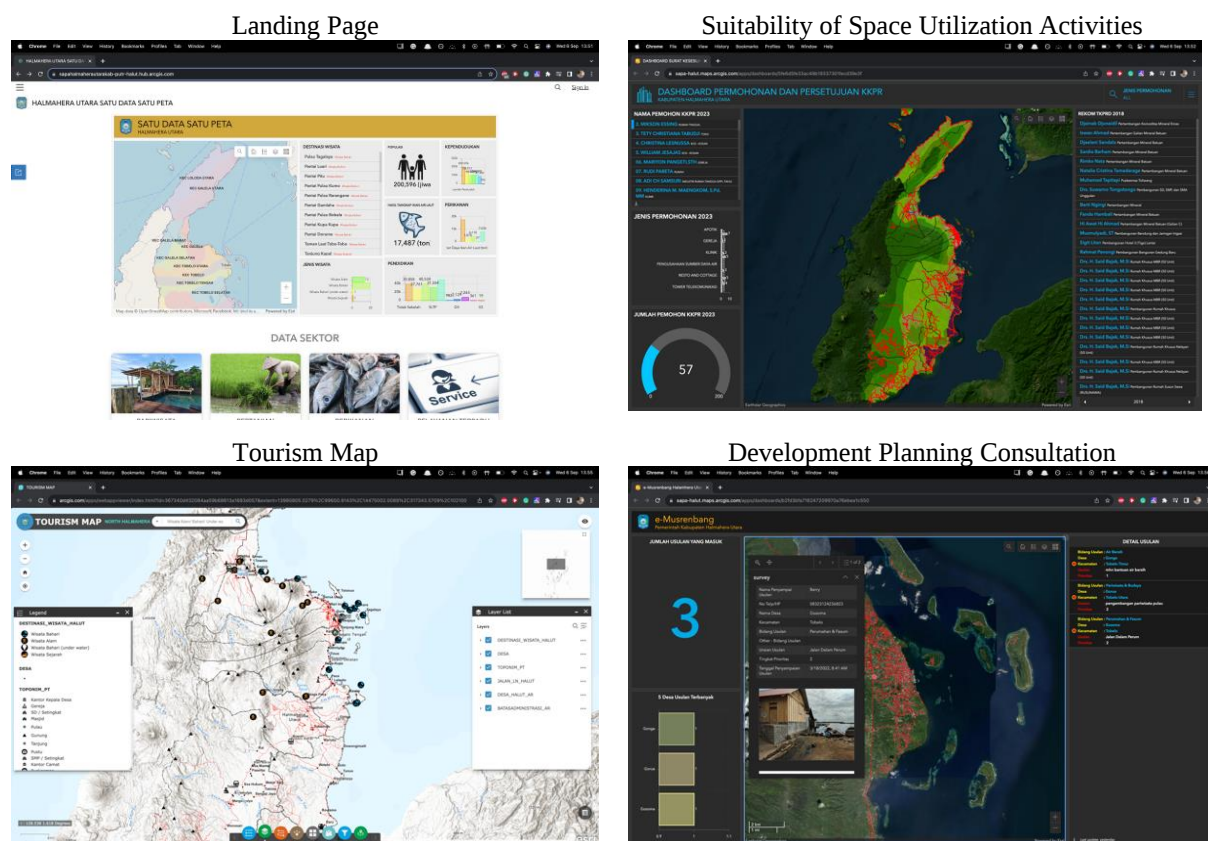


Figure 6. Dashboard of *Halmahera Satu Data Satu Peta* (Sources : <https://sapahalmaherautarakab-putr-halut.hub.arcgis.com/>)

Figure 6 illustrates the Halmahera One Data One dashboard. The deployment of Halmahera One Data One Map indicates enormous capabilities for enhancing e-governance by integrating spatial data and several limitations. The prompt update of system information is essential, as outdated data might diminish the system's effectiveness. In addition, the platform might benefit from more user-friendly data visualization tools to facilitate data comprehension by a broader range of users. In addition, while the system provides access to vector datasets in shapefile format, it may be further modified to allow researchers to extract critical insights for various projects. The dataset's absence of defined interpretation criteria, particularly land-use management and urban planning, is a significant limitation, as clear insights and actionable recommendations are crucial for making informed decisions. Fixing these problems in the Halmahera One Data One Map system would maximize its potential for enhancing e-governance and facilitating research, guaranteeing that it effectively contributes to improved land-use management and urban planning in the North Halmahera Regency.

Through spatio-temporal analysis, this research has the potential to provide significant insights into land use and urban development in North Halmahera Regency. In a rapidly changing landscape characterized by shifting

environmental conditions and evolving socioeconomic dynamics, the capacity to investigate temporal and spatial land use patterns in depth is vital. Such insights can lead to decision-making based on evidence, enabling local authorities to build more effective and sustainable urban planning plans, respond to environmental concerns, and increase the well-being of the region's inhabitants. In addition, the use of Landsat 8 Operational Land Imager (OLI) data for the years 2013, 2018, and 2023, along with the computation of spatio-temporal analysis indicators such as NDVI, EVI, SAVI, and NDBI, provides a robust and comprehensive method for evaluating land-use changes and environmental dynamics in North Halmahera Regency. This multi-temporal remote sensing analysis enables tracking vegetative health, land surface features, and urban expansion across time, offering a comprehensive knowledge of how the region's landscape has evolved and responded to various environmental and social forces. Combining Landsat 8 OLI data with NDVI, EVI, SAVI, and NDBI analysis over numerous years effectively captures the spatio-temporal intricacies of land-use patterns in North Halmahera Regency. This methodology equips academics and policymakers with significant information for informed decision-making, sustainable urban planning, and regional environmental conservation activities.

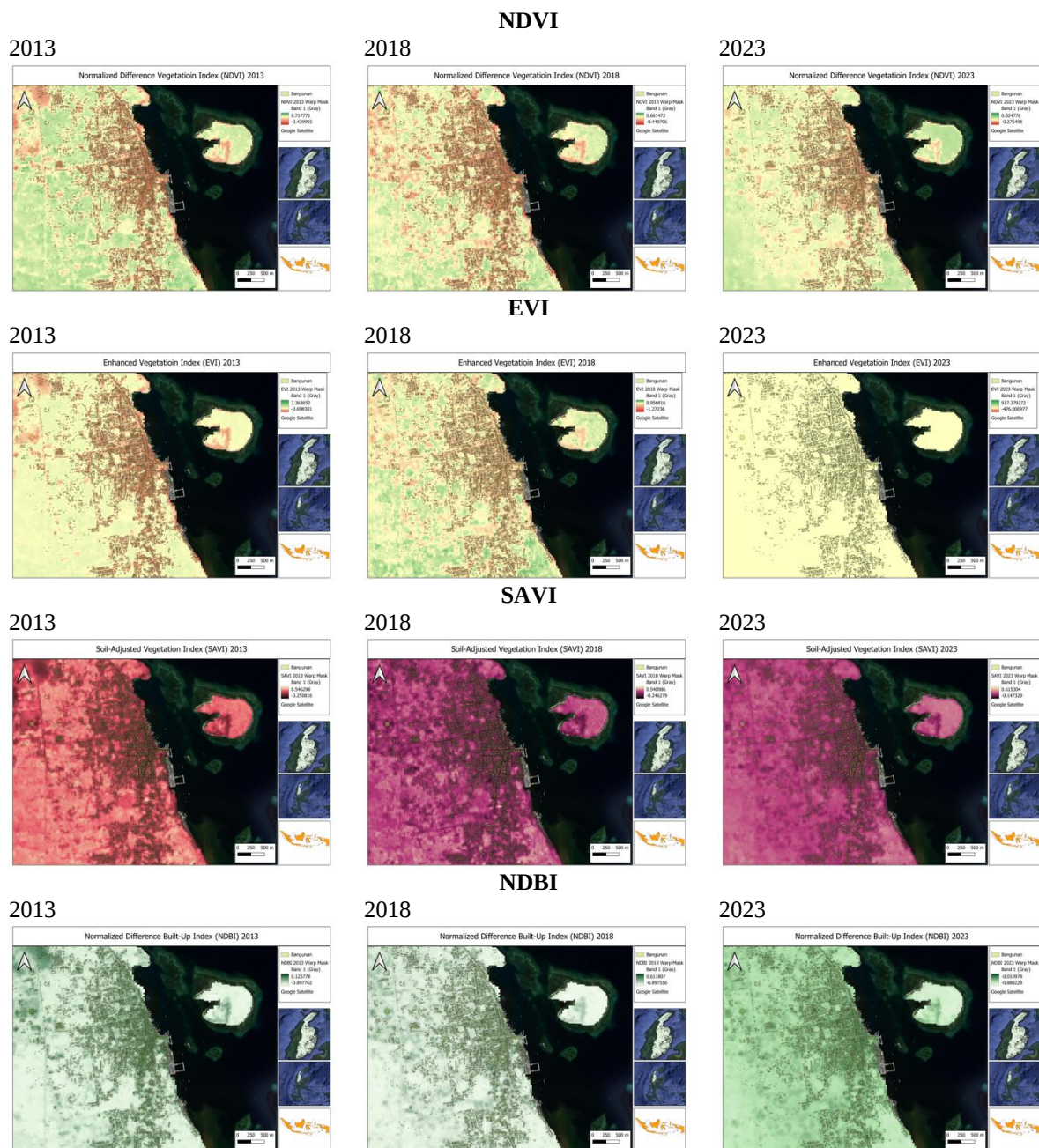


Figure 6. Map Classification based on NDVI, EVI, SAVI, and NDBI using Landsat 8 OLI

Figure 6 depicts the map classification of Tobelo City based on NDVI, EVI, SAVI, and NDBI data collected by Landsat 8 OLI. As demonstrated in Figure 6, these models are crucial spatio-temporal analytic tools in remote sensing. The NDVI evaluates the density and quality of plants, making it a helpful tool for monitoring land cover changes and ecosystem health. EVI, an enhanced version of NDVI, gives more sensitivity to canopy changes and is especially useful in densely forested locations. By adjusting the brightness of the soil, SAVI provides precise plant health data while

minimizing soil background impacts. In addition, the NDBI helps detect urban expansion and developed regions, which is crucial for urban planning and identifying land use change. These indices provide an exhaustive collection of evaluation tools for assessing environmental and land use changes. The NDVI, EVI, SAVI, and NDBI are essential tools for spatiotemporal analysis, allowing researchers to gain insight into changes in land cover, vegetation health, and urban development patterns. These indicators significantly contribute to monitoring and managing the changing landscape, enhancing the decision-making processes in numerous sectors, including environmental protection and urban planning.

The Dynamic Degree Model analysis findings based on NDBI for 2013, 2018, and 2023 demonstrate significant and remarkable changes in Tobelo City. This spatial-temporal examination of the urban environment emphasizes the dynamic nature of urban development and land-use changes across time. Significant changes in NDBI values suggest a strong tendency toward increased built-up areas and urban expansion in Tobelo City, which reflects the city's growing socioeconomic dynamics and infrastructure development. The findings from the Dynamic Degree Model applied to NDBI data highlight the ongoing urbanization process in Tobelo City and the necessity for intelligent urban planning and land-use management policies to handle the difficulties and opportunities these considerable changes offer.

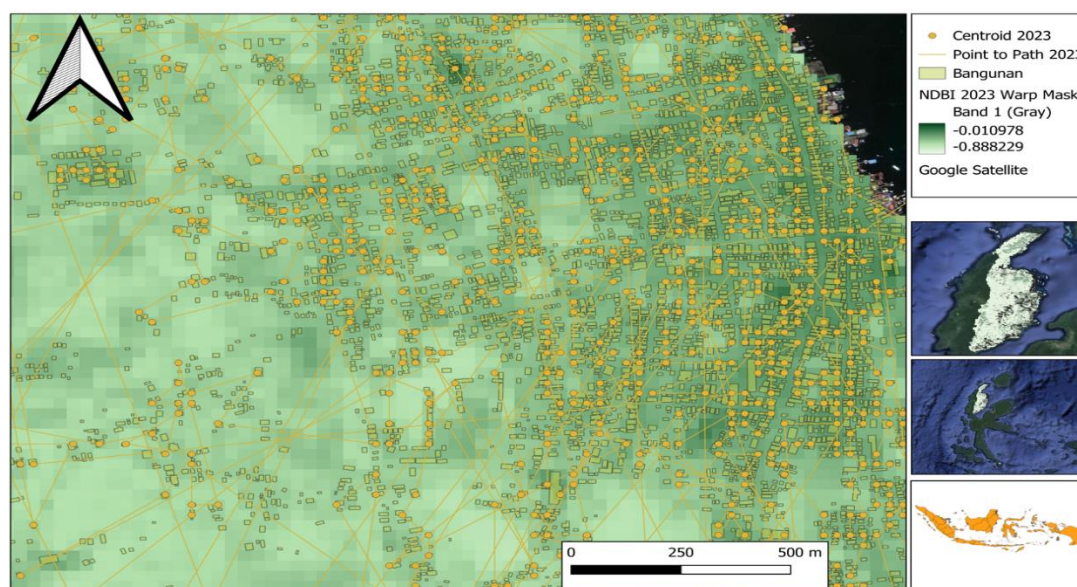


Figure 7. Building Centroid and Point to Path of NDBI 2023

Figure 7 shows the outcomes from the Flow Direction Rate Model analysis applied to NDBI (Normalized Difference Built-Up Index) data for 2013, 2018, and 2023, illuminating substantial and noteworthy shifts within Tobelo City. This spatio-temporal analysis of the urban landscape underscores the dynamic nature of urban development and land-use changes over time. The discernible changes in the flow direction rates signify a clear trend towards urban expansion and increased built-up areas, reflecting the evolving socio-economic dynamics and infrastructure growth. The flow Direction Rate Model results, based on NDBI data, emphasize the city's ongoing urbanization process and underscore the importance of informed urban planning and land-use management strategies to address these significant transformations' implications effectively. In addition, the Barycenter Transfer Model analysis applied to NDBI (Normalized Difference Built-Up Index) data for 2013, 2018, and 2023 demonstrate substantial and notable alterations within Tobelo City. This spatio-temporal analysis of the urban landscape underscores the dynamic nature of urban development and land-use changes over time. The shifting barycenter positions highlight a clear trend towards urban expansion and increased built-up areas, reflecting the evolving socio-economic dynamics and infrastructure growth within Tobelo City. The Barycenter Transfer Model results based on NDBI data underscore the city's ongoing urbanization process and emphasize the importance of informed urban planning and land-use management strategies to effectively address the consequences of these significant transformations in Tobelo City.

Based on its results, this study provides a complete overview of the complex constraints and opportunities regulating land use patterns in the North Halmahera Regency. These findings contribute to a greater comprehension of spatiotemporal environmental changes and offer valuable insights into how urban planning strategies can be adapted and harmonized with the coastal economy and settlement dynamics of the Hibualamo culture, thereby promoting sustainable development and cultural preservation in the region. Urban design and land use management are crucial to preserving and growing Hibualamo culture, the coastal economy, and settlement dynamics. In the context of the Hibualamo culture, characterized by its coastal heritage and dependency on maritime resources, urban development programs must prioritize the preservation of traditional fishing, boatbuilding, and coastal agriculture methods and indigenous knowledge. Furthermore, land use policies should assist the preservation of culturally significant locations and landscapes to protect the cultural integrity of the Hibualamo people. Focusing on the coastal economy simultaneously necessitates smart zoning and infrastructure development that promotes the efficient operation of fishing harbors, fish processing facilities, and trade networks, fostering economic resilience and community livelihoods. When managing settlements, urban planners

must consider the vulnerability of coastal areas to climate change and rising sea levels, necessitating adaptive strategies such as elevated housing and integrated disaster risk reduction measures. An interdisciplinary approach to urban planning and land use management is required to accommodate the complex interaction of cultural, economic, and environmental challenges within the context of the Hibualamo culture and its coastal-based way of life.

The social contact pattern of the Hibualamo, a tribe with massive family structures, exhibits a complicated system of social bonding that significantly impacts their settlement pattern based on family membership. This intricate network of social links promotes communal livelihoods, resulting in a settlement pattern in which extended families cluster close to facilitate shared resources, labor cooperation, and the preservation of traditional rites and intergenerational knowledge within the tribal context. The intricate interaction of social ties, settlement patterns, and land-use methods among the Hibualamo of North Halmahera Regency illustrates a holistic approach to sustainable livelihood and resource management that is firmly established in their cultural legacy and environmental setting. Four meaningful occupations, including farmers or peasants, fishermen, entrepreneurs or merchants, and official occupations such as government workers, are integral to the North Halmahera Regency's livelihood characteristics, all intertwining to support domestic livelihoods. The region's predominance of farmers and peasants indicates its agricultural base, which provides sustenance and considerably contributes to local food security. The geography of the region's coastline also fosters a flourishing fishing industry, with fishermen significantly enriching local cuisine and bolstering the coastal economy. Moreover, entrepreneurs and traders modify the economic environment by facilitating trade networks and fostering entrepreneurship, hence fostering economic expansion. In addition, official occupations, particularly civil servant positions, provide secure income streams and administrative stability, thus strengthening the region's socioeconomic structure. Collectively, these means of sustenance indicate North Halmahera's persistence and tenacity in maintaining a mix of traditional and modern economic activity, ensuring local people's long-term prosperity.

Land use in coastal areas as settlements is influenced by economic factors and cross-cultural interactions within the local community, especially with migrants who bring diverse cultural values and a primary living intention for economic reasons, frequently as entrepreneurs and traders. This dynamic interaction between the indigenous and migrant populations results in a complex fusion of cultural characteristics and economic activity that defines land use in these coastal regions. The research on this phenomenon implies that intercultural interactions diversify these communities' economic activities and trade networks. Incorporating numerous cultural concepts and practices generates a rich tapestry of means of subsistence, which enhances economic prospects and cultural exchange. Nonetheless, it may also present challenges for cultural integration and resource allocation within the group. In conclusion, coastal communities' diverse land usage pattern reveals the intricate connection between economic objectives, cultural exchanges, and survival strategies. These villages become thriving hubs where cultural variation and economic vibrancy coexist, underscoring the relevance of supporting inclusive and sustainable development initiatives in North Halmahera Regency that capitalize on the benefits of cross-cultural exchanges.

4. CONCLUSION

The conclusions of this study indicate that land use management for urban planning objectives should assess several dimensions, such as the preservation of Hibualamo cultural values, settlement patterns derived from household livelihood assets, and Tobelo City's economic activities. Integrating these elements into urban planning is vital for promoting sustainable development and safeguarding the local community's health. Incorporating Hibualamo cultural values into urban design can aid in preserving the region's cultural identity and legacy, hence generating a sense of belonging among community members, according to this holistic approach's research findings. Moreover, integrating land use with household livelihood assets ensures that urban growth contributes to the economic well-being of its inhabitants, resulting in enhanced sustainability. In addition, recognizing the economic significance of Tobelo City within the broader region enables urban planners to maximize its potential as an economic hub while simultaneously tackling contemporaneous difficulties. Effective urban design in the North Halmahera Regency requires a balance between cultural preservation, sustainable livelihoods, and economic development.

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