IDENTIFICATION OF THE DRIVING FACTORS BEHIND THE TRANSFORMATION OF THE LANDSCAPE IN SABANG, ACEH, INDONESIA, BASED ON LOCAL PERCEPTION

Faisal Azwar[*], **Ashfa Achmad**[**], **Mahidin Mahidin**[***], **Mirza Irwansyah**[**]

[*]*Doctoral Program, School of Engineering, Universitas Syiah Kuala, Indonesia, faisalazwar.usk224@gmail.com*
[**]*Architecture and Planning Department, Universitas Syiah Kuala, Indonesia, ashfa.achmad@usk.ac.id, mirza.hasan@usk.ac.id*
[***]*Chemical Engineering Department, Universitas Syiah Kuala, Indonesia, mahidin@usk.ac.id*

Email Correspondence : ashfa.achmad@usk.ac.id

Abstract: Information on land use changes and land cover change studies to understand the dynamics of landscape change is very useful for planning sustainable landscape management. Changes to the landscape not only have an impact on people's welfare but also on the way people view and use the landscape. Land-based investments have implications for spatial development and influence landscape dynamics. Cities continue to experience growth, including cities on small islands. The city of Sabang, whose territory is small islands in Aceh Province, Indonesia, is experiencing an increase in local population, immigration, and government policy encouragement to improve the economy. It is worth paying attention to knowing the dynamics of landscape change and the driving factors based on local perceptions. It is important to understand the patterns of land use and land cover changes from 2013 to 2021, as well as the driving factors based on local community perceptions that may influence future spatial planning and land utilization in Sabang City. This study uses mixed methods consisting of analysis of land use and land cover change patterns based on remote sensing using ArcGIS and TerrSet software on Spot 6 and Spot 7 image data to provide information on the transition of land cover change. The results of the analysis of changes in land use and land cover from 2013 to 2021 and the driving factors based on local perceptions from elements of Sabang City society were carried out through questionnaires and semi-structured interviews covering 120 households. To assess the drivers of changes in the Land Use and Land Cover (LUCL) of the Sabang City area, which were analyzed using the Statistical Package for Social Sciences (SPSS) for Windows. The results of the analysis of changes in land use and land cover show that most of the land in Sabang is still covered by forest land in 2021, namely 50%. 175 ha, or 67% of the growing built-up area is covered, while the infilling and outlying patterns are 44 ha and 42 ha, respectively. Respondents identified 17 driving factors, namely 10 proximate driving factors and 7 fundamental driving factors, as important drivers that contribute to changes in the landscape of Sabang City. The three closest drivers are Residential Areas, Forest Fires and Infrastructure Development. Meanwhile, land needs, changes in land prices, and population growth are the three main drivers of LULC changes in Sabang City.
Keywords: landscape change; GIS; local perception; driving factor; small island; Sabang City

Abstrak: Informasi perubahan penggunaan lahan dan studi perubahan tutupan lahan untuk memahami dinamika perubahan lanskap sangat berguna untuk perencanaan pengelolaan lanskap yang berkelanjutan. Perubahan pada lanskap tidak hanya berdampak pada kesejahteraan masyarakat namun juga cara masyarakat memandang dan memanfaatkan lanskap. Investasi berbasis lahan berimplikasi pada pembangunan ruang dan mempengaruhi dinamika lanskap. Kota-kota terus mengalami pertumbuhan, termasuk kota di pulau kecil. Kota Sabang yang wilayahnya merupakan pulau-pulau kecil di Provinsi Aceh, Indonesia mengalami peningkatan populasi masyarakat lokal, imigrasi serta dorongan kebijakan pemerintah dalam meningkatkan perekonomian, patut menjadi perhatian untuk mengetahui dinamika perubahan lanskap serta faktor pendorongnya berdasarkan persepsi lokal. Bagaimana pola penggunaan lahan dan tutupan lahan yang terjadi dalam waktu tahun 2013-2021, dan bagaimana persepsi masyarakat lokal dalam melihat faktor pendorong perubahan penggunaan lahan dan tutupan lahan di Kota Sabang. Studi ini menggunakan metode campuran yang terdiri dari analisis pola perubahan penggunaan lahan dan tutupan lahan berbasis penginderaan jauh menggunakan software ArcGIS dan TerrSet terhadap data Citra Spot 6 dan Spot 7 yang memberikan informasi transisi perubahan tutupan lahan. Hasil analisis perubahan penggunaan lahan dan tutupan lahan 2013-2021, kemudian faktor pendorongnya berdasarkan persepsi lokal dari unsur masyarakat Kota Sabang dilakukan melalui kuesioner dan wawancara semi-terstruktur yang mencakup 120 rumah tangga. Untuk menilai pendorong perubahan penggunaan lahan dan tutupan lahan wilayah Kota Sabang yang dianalisis menggunakan *Statistical Package for Social Sciences* (SPSS) untuk Windows. Hasil analisis perubahan penggunaan lahan dan tutupan lahan menunjukkan sebagian besar lahan di Sabang masih ditutupi oleh lahan hutan pada tahun 2021 yaitu sebesar 50%, telah turun luasnya sekitar 7% dibanding tahun 2013. Lahan terbangun di Kota Sabang sebagian besar tumbuh dengan pola perluasan/ekspansi seluas 175 ha atau mencakup 67% dari luas area terbangun yang bertumbuh, sedangkan pola *infilling* dan *outlying* masing-masing seluas 44 ha dan 42 ha. Responden mengidentifikasi 17 faktor pendorong, yaitu 10 faktor pendorong terdekat dan 7 faktor pendorong mendasar sebagai pendorong penting yang berkontribusi terhadap perubahan lanskap Kota Sabang. Tiga besar pendorong terdekat adalah kawasan permukiman, kebakaran hutan dan pembangunan infrastruktur. Sedangkan Kebutuhan Lahan, Perubahan harga lahan dan Pertumbuhan penduduk merupakan tiga besar pendorong mendasar perubahan LULC di Kota Sabang.
Kata kunci: perubahan lanskap; GIS; persepsi lokal; faktor pendorong; pulau kecil; Kota Sabang

Introduction

Understanding the dynamics of landscape change is critical because it not only determines ecosystem structure, but more importantly, its functions and services for human well-being. Communities depend on landscapes for survival and landscapes determine whether sustainable development is to be achieved (Reyes & Edgar Medrano Reyes, 2020). Information on land use changes and land cover

change studies to understand the dynamics of landscape change is very useful for local governments and city planners to improve future plans for sustainable urban development.

Along with the increase in population, urbanization and the establishment of government policies to encourage regional economic development have had an impact on landscape changes, including on small islands. Sabang City in Aceh Province, Indonesia, is an area of small islands at the western tip of Indonesia, is a Free Trade Area and Sabang Free Port (Republik Indonesia, 2000), and is a strategic area and national tourism destination (PP No 50 Tahun, 2012). The tourism sector is the dominant sector in the regional development program in Sabang City. The increase in population and immigrants, as well as the increase in the number of tourists visiting Sabang City, has led to an increase in housing needs and food supplies (Arif et al., 2019; Oduro Appiah & Agyemang-Duah, 2021). Increasing the intensity of development and increasing population and tourist visits, of course, has problems, challenges and opportunities as well as a series of them in land use.

Only a little research has been conducted on LULC in Sabang City, while research on the driving factors for changes in LULC has never been conducted. Remote sensing technology and Geographic Information Systems (GIS) only identify the nature, extent and rate of land use and land cover changes in the landscape. However, this technology does not provide an explanation of the factors driving LULC changes in the landscape (Achmad et al., 2020; Azwar et al., 2024; Degerli & Çetin, 2022).

The study of LULC dynamics and related driving factors at the local scale is essential for establishing viable natural resource management strategies (Zhi et al., 2022). Several researchers have reported that observations of LULC dynamics in any landscape are a reflection of aggregate decisions at the household level in response to the policy and institutional environment over a certain period of time (Musakwa et al., 2020). A growing body of literature emphasizes the need to include social research on citizen perceptions in analyzes of the driving forces behind landscape change (Solecka et al., 2022).

The study regarding perceptions of landscape changes focused on evaluating changes in the LULC of Sabang City for 20123-2021. Perceptions of landscape change were researched through surveys/questionnaires and semi-structured interviews (Bevk & Golobič, 2020). Therefore, this research aims to measure changes in LULC and assess the driving factors for changes in LULC based on local community perceptions between 2013-2021 on the small island of Sabang City to become a strong basis for stakeholders in formulating good regional and environmental planning in the Sabang City as a small island or other similar area.

Materials and Methods

In this research, the study location is Sabang City, Aceh Province, Indonesia, which is located on the lines 05046'28" N - 05054'28" N and 95013'02" E -

95022'36" E. Sabang City is the outermost small island region of Indonesia consisting of Weh Island, Klah Island, Rubiah Island, Seulako Island and Rondo Island, which is at an altitude of ± 28 meters above sea level (masl) and borders (sea) with India.

In general, Sabang City is located at an altitude of ± 28 m above sea level (asl) with morphological conditions dominated by hills, which is around 65% of the total area. Meanwhile, in more detail, Sabang City covers 3% lowland, 10% undulating plain, 35% hilly and 52% hilly to mountainous. Judging from the slope of Sabang City, it is quite varied, namely in the western part of Pulau Weh and in the middle of the eastern part of the island, it is a hilly and wavy area with a slope of more than 15%. Meanwhile, in more detail, Sabang City covers 1.01% plain, 5.02% sloping, 31.70% undulating plain, 14.10% steep. The Sabang City area consists of three sub-districts and 18 villages.

Figure 1. Study area - Sabang City, Aceh, Indonesia; (source: Geology.com, wordpress.com, RTRW Sabang City)

Analysis of Patterns of Change in LULC in Sabang City 2013-2021

This research was carried out by collecting data from satellite image maps obtained from the National Research and Innovation Agency (BRIN). The 2013 satellite image map is a SPOT-6 image obtained from BRIN in August 2022. SPOT-6 is an optical remote sensing satellite capable of providing imagery with a

resolution of up to 1.5 meters for panchromatic and 6 meters for multispectral. Meanwhile, the 2021 satellite image map used is a SPOT image map combined between SPOT-6 and SPOT-7. The SPOT-7 satellite is a constellation satellite together with SPOT-6.
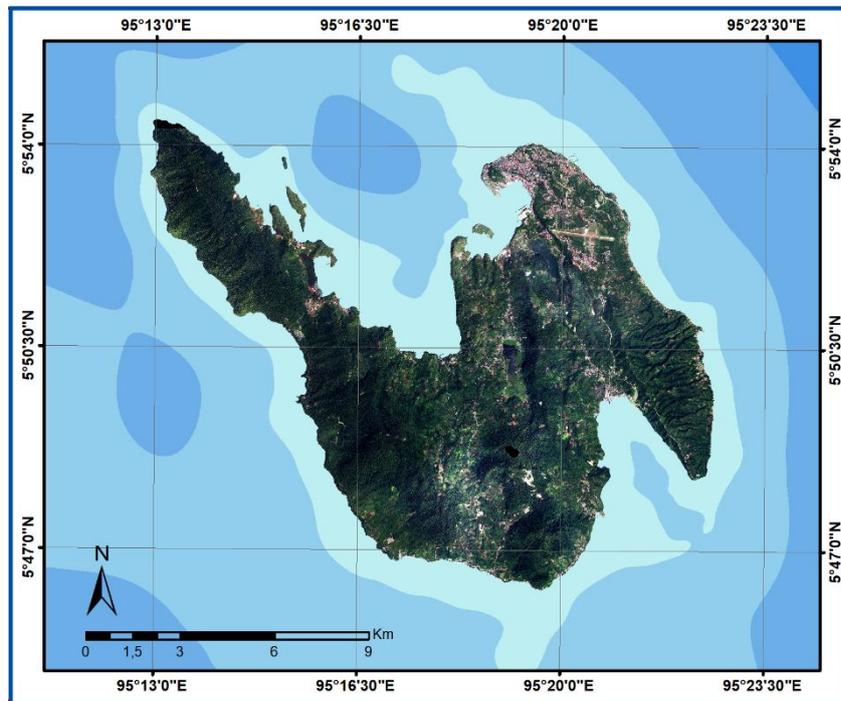

Figure 2. SPOT image map combined between SPOT-6 and SPOT-7

The latest land cover information in the form of maps can be obtained through remote sensing techniques. Remote sensing has long been an important and effective tool for monitoring land cover with its ability to provide information about spatial diversity on the earth's surface quickly, widely, precisely and easily (Achmad et al., 2023; Bagwan & Sopan Gavali, 2023; Ramli et al., 2023; Rizcanofana, 2021). This analysis technique is used to interpret (in a guided manner) the 2013 and 2021 SPOT satellite images of six land cover classifications using the Maximum Likelihood Classification (MLC) method. In this research, accuracy was tested with the QGIS plugin, namely Akatama. Meanwhile, checking the suitability of real conditions in the field was carried out using Google Earth imagery and direct field observations at around 21 random points in the field. Checks on Google Earth were carried out using historical high-resolution Google imagery images obtained from Google Earth Pro 7.3.1.4507 which were acquired in June 2013 and August 2021.

This research analyzes changes in land use and land cover to understand the dynamics of changes in the landscape of Sabang City in the period 2013-2021. Detection of changes in land use and cover in 2013 and 2021 was carried out by overlaying using the toolbox in ArcGIS 10.8 software in the form of clip, union,

dissolve, reclassify and intersect. Next, to find out the extent of land use changes that occurred in the period 2013 to 2021, it was obtained by calculating the tabular fields using the calculate geometry menu in the ArcMap 10.8 software. After that, a gains and losses analysis were carried out to provide an overview of the land change transition that occurred in Sabang City using a Land Change Model (LCM) type simulation model on the IDRISI TERRSET device. Next, the growth pattern of built-up land was identified quantitatively using the patch-based Landscape Expansion Index (LEI) method. Landscape Expansion Index (LEI) method, which is an important research method for describing and analyzing dynamic information in the process of quantitative landscape expansion (Liu et al., 2009).

Using GIS can facilitate and accelerate the process of analyzing urban growth (Kucukpehlivan et al., 2023). Although urban land use and land cover represent a complex system and pose challenges for both science and practice, can effectively measure and visualize potential trends and spatial patterns of future urban growth (Zeshan et al., 2021). Tools for executing LEI are downloaded from the website https://www.geosimulation.cn/LEI.html. LEI is defined by using the buffer analysis, which is one of the most important spatial analysis functions of GIS. The buffers are the zones with specified distances around a target geographical feature. The analysis can be used in queries to determine which entities occur either within or outside the defined buffer zone (Tian et al., 2022). The LEI for a new patch can be determined and calculated by examining the characteristics of its buffer zone:

$$LEI = 100 \times Ao/(Ao+Av) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

Information;

LEI: Landscape Expansion Index

Ao: The intersection between the buffer zone of the new built area, and the occupied category

Av: The intersection between the buffer zone of the new built area and vacant land.

The indicator of LEI can be used for interpretation of landscape expansion types. As described earlier that there are three major expansion types, it's straightforward to divide the whole range of LEI value into three discrete intervals to respectively represent these three types. (Bindajam et al., 2021) used a threshold value of ratio between common edge (between existing and new urban patches) and patch perimeter to distinguish the urban expansion types. An expansion type is identifiedas infilling when the value of ratio is larger than 0.5. An edge-expansion growth is characterized by the value of ratio between common edge and patch perimeter being no more than 0.5 (Ai et al., 2022; Liu et al., 2010; Shi et al., 2020; Wang et al., 2022; Zhao et al., 2020).

Analysis of Factors Driving Landscape Change

To assess and determine the significant driving force factors contributing to landscape changes in the 2013-2021 period that have been identified in the previous

stage, namely by using typical social qualitative research methods, including population surveys in the study area and face-to-face semi-structured interviews designed to increase knowledge regarding respondents' perceptions of these changes. Most studies use expert judgment to interpret and identify driving forces using mixed methods including: geospatial analysis, interviews with experts and questionnaires for local communities to assess the driving forces of land use and land cover change (Solecka et al., 2022).

Household Survey

This study develops and evaluates a model that correlates people's perceptions of physical landscape monitoring data. Perception data collection was collected through questionnaires. Primary data collection on community perceptions carried out in this research was interviews and filling out questionnaires by local communities (households). Using questionnaires can reveal how respondents work (Hedblom et al., 2020; Munthali et al., 2019) questions to collect information about local community perceptions regarding changes in land use and cover, and the triggers for these changes in Sabang City during the research period (2013 to 2021. The determination of the number of respondents for the household survey uses the Slovin formula because the sample size must be representative to ensure that the research results can be generalized. Moreover, this method does not require a sample size table, as it can be calculated using a straightforward formula and simple computation with Slovin's formula. Sample calculations used the Slovin formula with a margin of error of 10% (Penerapan et al., 2024; Santoso, 2023), as follows:

$$n = N / (1 + (N \times e^2)). \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Information;

n = number of samples sought,

N = population size,

e = tolerable margin of error.

Based on data from the Sabang City Population and Civil Registry Service, the number of households in 2021 will be 12,850 households, so a minimum sample size of 100 households is obtained. It was determined that the questionnaire was given to 120 households from 18 gampongs during September to October 2023. The questionnaire was given to respondents who were aged 20 years and over, had lived in the area for at least 10 years, and were implicit decision makers in the household, and/or, in the absence of the head of the family, they become decision makers made with appropriate representation and knowledgeable household members.

Statistic analysis

Data collected through questionnaires and key informant interviews were analyzed qualitatively. Socioeconomic data comes from questionnaires which are

entered, processed, coded and analyzed using the Statistical Package for Social Sciences (SPSS) and then carried out further analysis. All statistical procedures will be carried out in SPSS for Windows (Isya Alfassa et al., 2024; M.M Firdaus, 2021; Rahman & Muktadir, 2021). Descriptive statistical analysis is used to describe household socioeconomic variables and summarize their responses and ranking of drivers of land use and land cover change.

In determining the drivers of land use and land cover change at the household level, the dependent variable is the local community's perception of the drivers for land use and land cover change and/or the perceived drivers identified, while the independent variables include socio-economic characteristics, such as age, gender, family size, education, and size of land ownership (Islam et al., 2019). Ranking the drivers of land use and land cover changes perceived by respondents (household survey) is calculated using the weighted average principle using a ranking index.
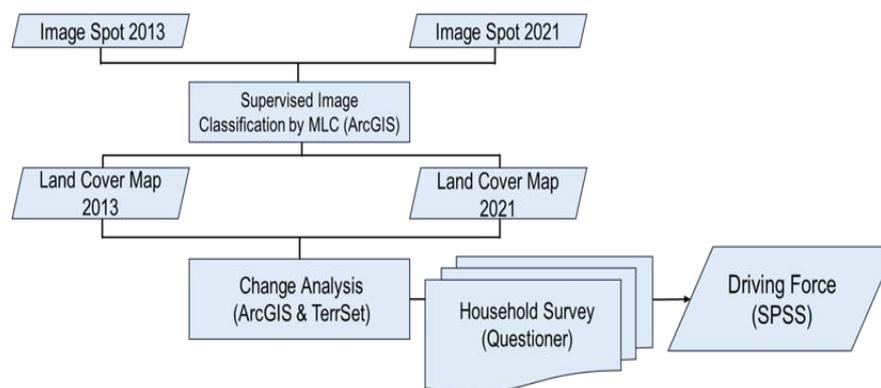

Figure 3. Analysis Method (source: own elaboration)

Results

Landscape Changes based on 2013 and 2021 Sabang City LULC

Based on the results of the image interpretation carried out, an overall accuracy value of 93.86% was obtained for 2013 and 94.93% for 2021. This value shows that the interpretation of satellite imagery is in the very good category, so the classification map can be used for subsequent land use analysis. The results of this validation test have also been supported by the results of field observations at randomly selected sample points in the field. The results of field validation at around 21 points show that the majority (>80%) of the results of land cover classification using the MLC method are in accordance with the results of observations at sample points in the field.

The development of a region can be seen from changes in historical spatial conditions. This means that regional development can be seen from spatio-temporal changes. Figure 4 shows a map of land use and land cover of Sabang City in 2013. Visually, it can be seen that in 2013, land use and land cover of Sabang City was

still dominated by forests and agricultural land. Built-up land also has a very limited area.
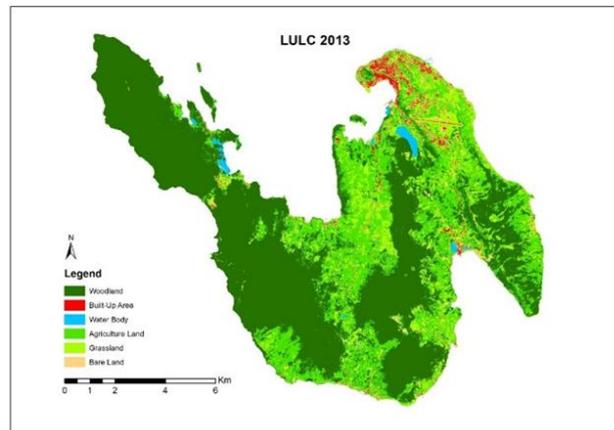

Figure 4. Land Use and Land Cover Classification Map Sabang City in 2013
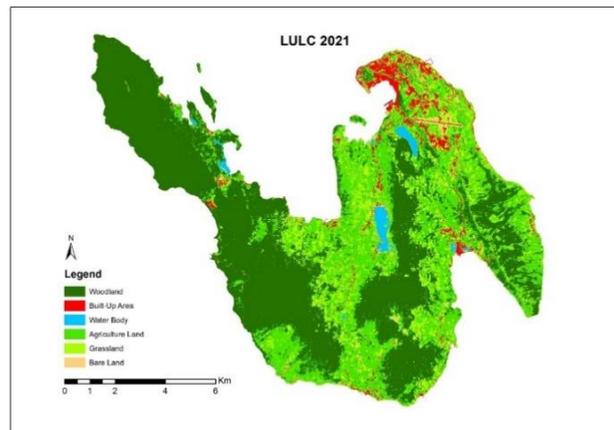

Figure 5. Land Use and Land Cover Classification Map Sabang City in 2021

Figure 5 shows a map of changes in land use and land cover in Sabang City in 2021, still dominated by forests and agricultural land. However, urban land is starting to expand, with the most significant expansion of built-up land occurring in areas around the city center. Expansion of built-up land is also occurring in several sub-city centers, including in the area around Balohan Harbor. The changes that occur visually indicate that there is a change in land use and land cover. From the results of overlaying satellite image data with GIS processing, quantitative changes in the area of each land use and land cover in Sabang City were obtained according to 6 classifications. These changes are shown in Table 1 below.

Table 1. LULC Sabang City 2013 and 2021

Classification	2013 Area		2021 Area	
	(Ha)	**(%)**	**(Ha)**	**(%)**
Woodland	6.865,70	57%	6.088,11	50%
Built-Up Area	198,45	2%	454,80	4%
Water Body	113,74	1%	154,13	1%
Agriculture Land	3.117,14	26%	3.510,61	29%
Grassland	1.471,96	12%	1.702,31	14%
Bare Land	421,17	3%	278,32	2%
Total	**12.188,15**	100%	**12.188,28**	100%

Table 1 shows that in 2013, the largest land cover in Sabang City was forest (woodland) at 57% with an area of 6,865.70 ha. The second largest land cover is agricultural land which covers 26% of the area of 3,117.14 ha. Grasslands cover 12% of the land and water bodies cover 1% of the area, including lakes and 3% is covered by bare land. From the table above it can also be seen that the built-up area only covers 2% of the Sabang City area. This shows that Sabang City was dominated by non-developed land in 2013.

The largest land change transition occurred in Forests which changed function to Agricultural Land amounting to 567 ha and switching to Grasslands amounting to 276.61 ha. These transitions affect the addition and reduction of the area of each LULC. Gains and losses for each land use are shown in Table 2.

Table 2. Area of Gains and Losses

LULC	Losses (ha)	Gains (ha)
Woodland	-877	100
Built-Up Area	-9	264
Water Body	-39	80
Agriculture Land	-730	1123
Grassland	-668	898
Bare Land	-333	189

Table 2 shows that in terms of gains, agricultural land experienced the highest increase, namely 1123 ha, followed by grassland at 898 ha and built-up land at 264 ha. Meanwhile, in terms of losses, forests are the LULC that experienced the highest reduction, namely 877 ha, followed by agricultural land at 730 ha and grasslands at 668 ha. Based on the figure and table of gains and losses, it can be seen that agricultural land is the land that is most actively experiencing changes, both additions and reductions, followed by grasslands and forests. However, built-up land has also experienced a significant increase.

Built-up Land Expansion Patterns 2013-2021

From changes in built-up land, the land growth pattern of Sabang City can be analyzed using the landscape expansion index (LEI) method. Table 3 shows that most of the built-up land in Sabang City is growing with an expansion pattern, namely 175 ha or covering 67% of the growing built-up area. The dominance of expansionary urban growth accelerates the loss of agricultural land, especially around roads, because expansion and outlying patterns are not affected by the planned built-up zone, which shows that there is an unstable relationship between planning elements and urban growth patterns. The results of the analysis of built-up land growth patterns can be seen in Table 3 below:

Table 3.   Area of Built-up Land Growth Patterns 2013-2021

Pattern Type	Area	Percentage
Expansion	175,832329	67,04
Infilling	44,327898	16,90
Outlying	42,129924	16,06
Total	262,290151	100,00

Factors Driving Landscape Change 2013-2021
Socioeconomic and demographic characteristics of sample households

The research results showed that all respondents lived in the study area during the study period, 58.33% lived more than 20 years in the study area. 25% stayed 10-20 years and 16.67% stayed < 10 years. The gender of the respondents is 72% male and 28% female, aged 25 to 76 years with an average age of 43 years, 94% who act as heads of families are men and 6% are women with an average number of family members a total of 4 people. All respondents had completed school at some level and had jobs.

Local community perceptions of changing trends in land use and land cover and proximity to infrastructure

The results of the analysis using the Statistical Package for Social Sciences (SPSS) for Windows, show that significant differences in perceptions were found among interviewed households regarding changes in LULC and distance to various infrastructure such as markets, health centers, schools, water sources, main roads, bus stops, cities, tourism and energy sources (p < 0.001). Respondents (62%) thought that distance from the city and (53%) distance from water sources were the main factors during the research period. Health centers and bus stops did not change significantly (p < 0.001). Respondents thought that the area of forest and agricultural land dominated the Sabang City area, as seen in Figure 6.
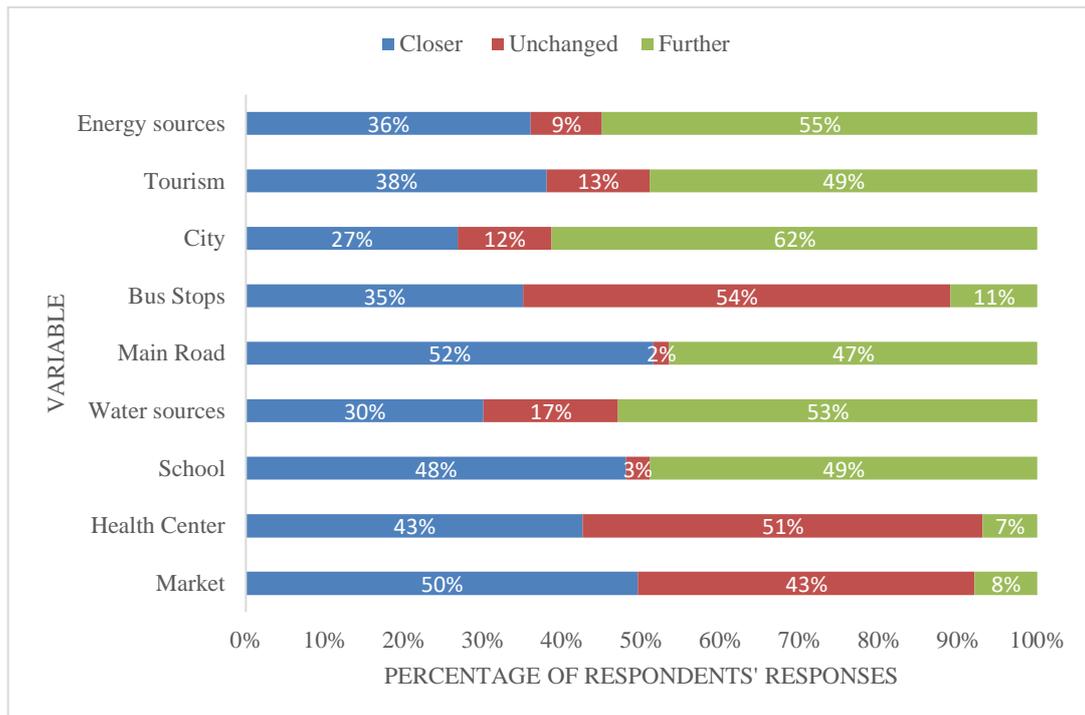
Figure 6. Respondents' perceptions of trends observed at the landscape level (source: own elaboration, 2023)

Ranking of drivers of land use and land cover change

The ranking of drivers of land use and land cover change was analyzed using the Statistical Package for Social Sciences (SPSS) for Windows. Respondents identified 17 factors (10 proximate driving factors and 7 fundamental driving factors) as important drivers contributing to landscape changes based on LULC in Sabang City. Table 4 & 5 shows that the three closest drivers of LULC changes in the study area are Residential Areas, Forest Fires and Infrastructure Development. Meanwhile, Table 4 shows that land requirements, changes in land prices and population growth are the three main drivers of LULC changes in Sabang City.

Table 4. Nearest Drivers

Internal Value		Frequency	Valid Percent
Use of Firewood	0	32	26,7
	1	88	73,3
Use of Wood for Buildings	0	36	30,0
	1	84	70,0
Infrastructure development	0	31	25,8
	1	89	74,2
Agricultural Area	0	42	35,0
	1	78	65,0
Forest fires	0	31	25,8
	1	89	74,2
Residential Area	0	30	25,0
	1	90	75,0
Tourism Area	0	43	35,8

	1	77	64,2
Trade Area	0	41	34,2
	1	79	65,8
Office area	0	59	49,2
	1	61	50,8
Energy sources	0	65	54,2
	1	55	45,8

Table 5. Fundamental Drivers

		Frequency	**Valid Percent**
Poverty	0	32	26,7
	1	88	73,3
Population growth	0	20	16,7
	1	100	83,3
Lack of Financial Resources	0	24	20,0
	1	96	80,0
Lack of Law Enforcement	0	30	25,0
	1	90	75,0
Wood Demand	0	36	30,0
	1	84	70,0
Changes in Land Prices	0	19	15,8
	1	101	84,2
Land requirements	0	16	13,3
	1	104	86,7

Note: Internal value: 0= No, 1= Yes

Household-level logistic regression of perceived drivers of land use and land cover change

The research results show that work ($p < 0.05$) partially has a significant influence on local community perceptions, namely office areas and forest fires. Age also has an influence on forest fires. Level of education, age, ethnicity, length of residence and type of stove do not partially have a significant influence on the use of firewood, use of wood for buildings, infrastructure development, agricultural areas, residential areas, tourism areas, trade and service areas, office areas, forests fires, energy sources, poverty, population growth, lack of financial resources, lack of law enforcement, demand for wood, changes in land prices and land needs as drivers of LULC in Sabang City.

Discussion
Landscape Changes based on 2013 and 2021 Sabang City LULC

Despite population growth and economic improvements, Sabang City is still an area dominated by non-urban activities. In the 2013-2021 period, the land that experienced the largest changes was non-developed land. The majority of land in Sabang is still covered by forest land, namely 50%, but the percentage has decreased by around 7% compared to 2013. This is followed by agricultural land at 29%, an increase of around 3% from before. The third largest area of land is grassland at 14%, an increase of 2% compared to 2013. Next is empty land at 2%,

down 1% from 2013, meaning there has been an increase in the use of empty land. The water body has not experienced significant changes so it remains at 1%. Meanwhile, built-up land became 4%, an increase of 2% from 2013. The land that experienced the most drastic change was forest land, which decreased by 7%.

Agricultural land is the land cover that is most actively undergoing change, which indicates the intensive activity and conversion of agricultural land in Sabang City. However, conversion of agricultural land to urban land is still low. This is because built-up land in Sabang City predominantly appears on existing open land around existing built-up areas in areas adjacent to the center of Sabang City.

Factors Driving Changes in LULC 2013-2021

Household surveys and key informants believe that the rapid increase in population in the study area is largely due to the birth rate of the Sabang City population and population migration from outside Sabang City. Indeed, the population of Sabang City has increased by 30.68% since 2013, according to data from the Sabang City Central Statistics Agency used in this research for the period 2013 to 2021). In other parts of the world, population growth is also reported as a major driver of LULC changes (Kuule et al., 2022).

The land requirement factor is for government infrastructure such as building offices, conference halls, sports and health facilities, and private investment in the tourism sector such as building hotels and restaurants. Then there is the need for land for housing due to the increase in population (new households) and population movement from outside Sabang City. Changes in land prices are influenced by high land prices so that the people of Sabang City sell their land to private parties for hotel construction and geothermal energy mining in Jaboi and some to the government for infrastructure development. The demand for wood and lack of law enforcement are the causes of deforestation and forest degradation in Sabang City. Meanwhile, the use of the types of energy sources used in households, namely gas and electric stoves, shows that the use of firewood is not a driver of changes in land use and land cover in Sabang City.

One important driving factor that indirectly contributes to changes in land use and land cover in Sabang City is the still high poverty rate (14%-15%). The majority of local communities in Sabang City are characterized by high levels of poverty and a lack of alternative sources of livelihood.

Conclusion

The dynamics of landscape changes on the small island of Sabang City that occurred in the 2013-2021 period were marked by the conversion of non-built land to built-up land, but in a small percentage, namely 2%. The most dominant land cover change transition that occurs is the transition from forest to agricultural land. Agricultural land is the land cover that is most actively undergoing change, which indicates the intensive conversion of agricultural land in Sabang City. Meanwhile,

the dominant built-up land grows from the conversion of empty land in and around the city center. Built-up land in Sabang City generally grows with expansion, infilling and outlying patterns.

Based on local community perceptions, the three biggest drivers of landscape change in Sabang City are residential areas, forest fires and infrastructure development. Meanwhile, land requirements, changes in land prices and population growth are the three main drivers of changes in LULC as important driving factors for changes in the landscape of Sabang City.

Acknowledgements

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported.

References

Achmad, A., Burhan, I. M., Zuraidi, E., & Ramli, I. (2020). Determination of recharge areas to optimize the function of urban protected areas on a small island. *IOP Conference Series: Earth and Environmental Science*, *452*(1). https://doi.org/10.1088/1755-1315/452/1/012104

Achmad, A., Ramli, I., & Nizamuddin, N. (2023). Impact of land use and land cover changes on carbon stock in Aceh Besar District, Aceh, Indonesia. *Journal of Water and Land Development*, *57*, 159–166. https://doi.org/10.24425/jwld.2023.145346

Ai, J., Yang, L., Liu, Y., Yu, K., & Liu, J. (2022). Dynamic Landscape Fragmentation and the Driving Forces on Haitan Island, China. *Land*, *11*(1). https://doi.org/10.3390/land11010136

Arif, A. A., Machdar, I., Azmeri, & Achmad, A. (2019). Analysis of environmental carrying capacity with AHP in ArcGIS of Weh Island. *IOP Conference Series: Earth and Environmental Science*, *348*(1). https://doi.org/10.1088/1755-1315/348/1/012060

Azwar, F., Achmad, A., Mahidin, M., & Irwansyah, M. (2024). Urban Growth Pattern Changes Model in Small Island of Aceh Province, Indonesia: Implications for Sustainable Spatial Development. *Polish Journal of Environmental Studies*, *33*(4), 3587–3598. https://doi.org/10.15244/pjoes/176796

Bagwan, W. A., & Sopan Gavali, R. (2023). Dam-triggered Land Use Land Cover change detection and comparison (transition matrix method) of Urmodi River Watershed of Maharashtra, India: a Remote Sensing and GIS approach. *Geology, Ecology, and Landscapes*, *7*(3), 189–197. https://doi.org/10.1080/24749508.2021.1952762

Bevk, T., & Golobič, M. (2020). Contentious eye-catchers: Perceptions of landscapes changed by solar power plants in Slovenia. *Renewable Energy*, *152*, 999–1010. https://doi.org/10.1016/J.RENENE.2020.01.108

Bindajam, A. A., Mallick, J., Balha, A., Qadhi, S. Al, Shohan, A. A. A., Singh, C. K., & Rahman, A. (2021). *Characterizing the Urban Decadal Expansion and Its Morphology Using Integrated Spatial Approaches in Semi-Arid Mountainous Environment , Saudi Arabia*. *30*(5), 4437–4451. https://doi.org/10.15244/pjoes/133033

Degerli, B., & Çetin, M. (2022). Using the Remote Sensing Method to Simulate the Land Change in the Year 2030. *Turkish Journal of Agriculture - Food Science and Technology*, *10*(12), 2453–2466. https://doi.org/10.24925/turjaf.v10i12.2453-2466.5555

Hedblom, M., Hedenås, H., Blicharska, M., Adler, S., Knez, I., Mikusiński, G., Svensson, J., Sandström, S., Sandström, P., & Wardle, D. A. (2020). Landscape perception: linking physical monitoring data to perceived landscape properties. *Landscape Research*, *45*(2), 179–192. https://doi.org/10.1080/01426397.2019.1611751

Islam, K. N., Rahman, M. M., Jashimuddin, M., Hossain, M. M., Islam, K., & Faroque, M. Al. (2019). Analyzing multi-temporal satellite imagery and stakeholders' perceptions to have an insight into how forest co-management is changing the protected area landscapes in Bangladesh. *Forest Policy and Economics*, *101*, 70–80. https://doi.org/10.1016/J.FORPOL.2019.01.011

Isya Alfassa, A., Muni, A., Zulrahmadi, Rianto, B., & Yunita, F. (2024). Pemanfaatan Statistical Package for the Social Sciences (Spss) Untuk Analisis Data Statistik. *Jurnal Karya Abdi*, *5*(1), 29–34. https://doi.org/10.32520/karyaabdi.v5i1.3559

Kucukpehlivan, T., Çetin, M., Aksoy, T., Senyel Kurkcuoglu, M. A., Cabuk, S., Pekkan, O., Dabanli, A., & Cabuk, A. (2023). Determination of the impacts of urban-planning of the urban land area using GIS hotspot analysis. *Computers and Electronics in Agriculture*, *210*, 107935. https://doi.org/10.1016/j.compag.2023.107935

Kuule, D. A., Ssentongo, B., Magaya, P. J., Mwesigwa, G. Y., Okurut, I. T., Nyombi, K., Egeru, A., & Tabuti, J. R. S. (2022). Land Use and Land Cover Change Dynamics and Perceived Drivers in Rangeland Areas in Central Uganda. *Land*, *11*(9). https://doi.org/10.3390/land11091402

Liu, X., Li, X., Chen, Y., Tan, Z., Li, S., & Ai, B. (2010). A new landscape index for quantifying urban expansion using multi-temporal remotely sensed data. *Landscape Ecology*, *25*(5), 671–682. https://doi.org/10.1007/s10980-010-9454-5

Liu, X., Xia, L. I., Chen, Y., Qin, Y., Shaoying, L. I., & Chen, M. (2009). Landscape expansion index and Its applications to uantitative analysis of urban expansion. *Acta Geographica Sinica*, *64*, 1430–1438.

M.M Firdaus. (2021). *Metodologi Penelitian Kuantitatif; Dilengkapi Analisis Regresi Ibm Spss Sta... - Google Books*. https://www.google.co.id/books/edition/ Metodologi_Penelitian_Kuantitatif_Dileng/lJ8hEAAAQBAJ?hl=id&gbpv=1&d q=metodologi+penelitian+kuantitatif+firdaus&printsec=frontcover

Munthali, M. G., Davis, N., Adeola, A. M., Botai, J. O., Kamwi, J. M., Chisale, H. L. W., & Orimoogunje, O. O. I. (2019). Local perception of drivers of Land-Use and

Elkawnie: Journal of Islamic Science and Technology Vol. 11, No. 2, December 2025
(www.jurnal.ar-raniry.ac.id/index.php/elkawnie)

DOI: 10.22373/ekw.v11i2.25043 | **222**

Land- Cover change dynamics across Dedza district, Central Malawi region. *Sustainability (Switzerland)*, *11*(3), 1–25. https://doi.org/10.3390/su11030832

Musakwa, W., Mpofu, E., & Nyathi, N. A. (2020). Local community perceptions on landscape change, ecosystem services, climate change, and livelihoods in Gonarezhou national park, Zimbabwe. *Sustainability (Switzerland)*, *12*(11). https://doi.org/10.3390/su12114610

Oduro Appiah, J., & Agyemang-Duah, W. (2021). Identifying spatially-explicit land use factors associated with forest patch sizes in a forest reserve in Ghana. *Land Use Policy*, *101*, 105135. https://doi.org/10.1016/J.LANDUSEPOL.2020.105135

Penerapan, A., Slovin, F., Kesalahan, D. A. N., & Perspektif, D. (2024). *Jurnal multidisiplin sosisal humaniora*. *1*, 53–63.

PP No 50 Tahun. (2012). Peraturan Pemerintah Republik Indonesia Nomor 50 Tahun Indonesia 2012. *Penerapan Sistem Manajemen Keselamatan Dan Kesehatan Keria*, *21*(3), 1–27.

Rahman, A., & Muktadir, Md. G. (2021). SPSS: An Imperative Quantitative Data Analysis Tool for Social Science Research. *International Journal of Research and Innovation in Social Science*, *05*(10), 300–302. https://doi.org/10.47772/ijriss.2021.51012

Ramli, I., Achmad, A., & Anhar, A. (2023). Temporal changes in Land Use and Land Cover (LULC) and local climate in the Krueng Peusangan Watershed (KPW) area, Aceh, Indonesia. *Bulletin of Geography. Socio-Economic Series*, *59*(59), 151–165. https://doi.org/10.12775/bgss-2023-0010

Republik Indonesia. (2000). *Republic of Indonesia Law Number 37, 2000*.

Reyes, E. M., & EDGAR MEDRANO REYES, JR. (2020). *Development of Spatial Strategies for Small Island Landscapes in the Philippines*. Technische Universität Dortmund.

Rizcanofana, R. (2021). *Gis-Based Solar Photovoltaic Potential Modelling in the Urban Area*.

Santoso, A. (2023). Rumus Slovin : Panacea Masalah Ukuran Sampel ? *Suksma: Jurnal Psikologi Universitas Sanata Dharma*, *4*(2), 24–43. https://doi.org/10.24071/suksma.v4i2.6434

Shi, F., Liu, S., An, Y., Sun, Y., Zhao, S., Liu, Y., & Li, M. (2020). Spatio-temporal dynamics of landscape connectivity and ecological network construction in long Yangxia Basin at the Upper Yellow River. *Land*, *9*(8), 1–19. https://doi.org/10.3390/LAND9080265

Solecka, I., Krajewski, P., Krzyżanek, A., & Garczyńska, A. (2022). Citizens' Perceptions of Landscape Changes and Their Driving Forces: Evidence from Poland. *International Journal of Environmental Research and Public Health*, *19*(3). https://doi.org/10.3390/ijerph19031688

Tian, Y., Shuai, Y., Ma, X., Shao, C., Liu, T., & Tuerhanjiang, L. (2022). Improved Landscape Expansion Index and Its Application to Urban Growth in Urumqi. *Remote Sensing*, *14*(20), 1–21. https://doi.org/10.3390/rs14205255

Wang, Z., Zhao, H., & Zhao, C. (2022). Temporal and Spatial Evolution Characteristics of Land Use and Landscape Pattern in Key Wetland Areas of the West Liao River Basin, Northeast China. *Journal of Environmental Engineering and Landscape Management*, *30*(1), 195–205. https://doi.org/10.3846/jeelm.2022.16382

Zeshan, M. T., Mustafa, M. R. U., & Baig, M. F. (2021). Article monitoring land use changes and their future prospects using gis and ann-ca for perak river basin, malaysia. *Water (Switzerland)*, *13*(16). https://doi.org/10.3390/w13162286

Zhi, Q., Yuying, J., Tong, H., Yingshuang, L., Xinliang, X., & Jun, Y. (2022). Land use change simulation: progress, challenges, and prospects. *Shengtai Xuebao*, *45*(13), 5165–5176. https://doi.org/10.5846/stxb202106201639