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Changing Lands: The Impact of Urbanization Processes on Agricultural Land Losses in Seminyak and Legian, Bali, Indonesia

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Bachelor thesis, 15 credits, in Physical Geography and Ecosystem Analysis

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Abstract

Attracting tourists from all over the world throughout the year, the flourishing of mass tourism in Bali has been perpetual for the last few decades. As both domestic and international tourists increase over time, the demand for built-up areas increases accordingly, which has caused urban expansion exploiting vegetated areas, especially agricultural lands. Consequently, this tourism-led urbanization in Bali has led to intensification of land cover change.

Land cover change is a common environmental issue in a developing country, which is often overlooked due to very few studies performed in the area. One primary example of land cover change is the enlargement of settlements at the expense of natural and cultivated lands and these land conversions could lead to environmental ramifications such as exploitation of biodiversity and localized weather pattern changes within the area.

This paper uses aerial photographs from Google Earth to digitize the land cover maps from 2009 to 2023 with remote sensing techniques, then quantify the area differences and trends from land cover change detection to analyze the loss of agricultural areas due to urbanization processes within the study area. The outcomes of this paper show that there has been exacerbated agricultural land loss as tourism proliferates over the years, which ultimately concerns the regional food production and food security within the local communities.

Keywords: land cover change, agriculture, urbanization, tourism, Bali

Foreword

Born in Japan but raised in Bali, I spent six and a half years in Bali Island surrounded by beautiful tropical environments with evergreen jungles and crystal-clear beaches. I grew up witnessing the intense land cover change in this tourist-popular island and it truly broke my heart to first-handedly experience the destruction of the wonderful nature Bali has to offer. This personal connection to my second home inspired me to conduct this study. Indonesia is still a developing country with people living in low living standards, and all of my friends in Bali directly work in tourism sectors, or at least their family is connected to the tourism industry in an indirect manner. Although it makes me joyous to see tourists increasing as it supports the local community, the land cover conversion is accelerated with the increase in demand for urban areas, and very few studies are done in this study area. It is with my strong wish that this thesis provides insights into the reality of land cultivation and its consequences, and that it also sheds light on other areas experiencing intensified land conversion due to urbanization.

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1 Introduction

Known as the world's fourth country with the most population, at present, Indonesia is rapidly urbanizing and has reported positive economic growth after overcoming the financial crisis in the late 1990s (World Bank, n.d.). In Indonesia, more than half of the population lives in urban areas as of 2018, which is a 42% increase since 2000, and it is expected that nearly three-quarters of the population will live in cities by 2050. During 2010 to 2016, urban areas produced nearly 60% of GDP, and the city of Jakarta alone accounted for nearly a quarter of GDP produced (Urban Transitions, n.d.).

Bali became the first tourist destination in Indonesia as well as one of the most popular tourist destinations in the world (Rimba et al., 2020). This island has been open to tourism since the beginning of the 20th century (Rimba et al., 2020) and is located 1.6 km east of Java Island with an area of 5,780 km^2. Its population is 3,890,757 as of 2010 and tourism is one of the crucial elements to their economy (Britannica, 2024). According to the governor, Wayan Koster, more than half of Bali's economy relies on tourism (Hudoyo, 2023). Moreover, regions such as Denpasar, Badung, Gianyar, and Tabanan experience the proliferating growth of tourism activity in Bali. Consequently, this growth caused land use and land cover in Bali to change drastically, mainly with agricultural areas converted to built-up areas (Rimba et al., 2020).

As geographic information systems (GIS) enable coherent spatial analysis of a region, it is applicable for change detection analysis on a land surface level (Gotekar, et al., 2020). Change detection analysis contributes to effective thus critical insights on land use changes such as infrastructure damage and vegetation growth (Knickerbocker, 2023). Therefore, conducting a change detection analysis on the loss of agricultural land due to tourism urbanization in Bali is crucial for sustainable tourism planning and management in the future (Majiid et al., 2023).

This research aims to assess how urbanization processes have affected agricultural land loss in Bali. It is essential to conduct this study in Bali as the area is intense with tourism activities and development, as well as it is a region in a developing country, where very few studies have been done. Considering the geographical, social, and technical limitations, the research question is "How has the urbanization processes affected the area of agricultural lands in Bali?". Based on the literature review, the hypothesis of this study is that the extent of agricultural lands will be reduced as the urbanization in Bali progresses with increasing tourists contributing to mass tourism.

To answer this research question, the study will investigate whether changes in land cover over time can be accurately interpreted using aerial imagery together with remote sensing technique, allowing for quantitative assessment of area differences and trends in agricultural land use in response to urbanization. In addition, this study is conducted by evaluating the suitability of freely available aerial data for land cover mapping.

The second chapter of this report covers the background of this research, the third chapter methodology employed to achieve the research aim, the fourth chapter results, the fifth chapter discussion, finally the sixth chapter with conclusion from this research.

2 Background

The background section of this paper is organized into several key sections to provide a comprehensive understanding of the topic. First, several key concepts relative to this study are explained, enabling readers to delve deeper into the specifics of the study topic. It is followed by the introduction to change detection analysis, which will be the main methodology in this study.

2.1 Tourism and urbanization

In general, tourism is a combination of social, cultural and economic phenomena, involving the movement of people to destinations outside their familiar environment (UNWTO, 2022). Tourist cities built just for consumption represent a new and extraordinary structure of urbanization as they provide a great range of consumption opportunities for resort tourists, which are the people who move there for a short time, to consume goods and services the destination has to offer (Mullins, 1991). Tourism and urbanization are phenomena that are closely intertwined as urbanization establishes a good economic basis for the development of the tourism industry (Wang., 2014). Moreover, tourism is a crucial element in the enhancement of the urban industrial structure, increase in employment rates, and improvement of the urban comprehensive strength as well as cultural heritage (Muyibul et al., 2023).

Urbanization is the increase in the fraction of people living in towns and cities, resulting from people moving from rural areas to urban areas (European Environmental Agency, n.d.). According to Liu et al. (2017), urbanization is closely associated with economic growth. With appropriate planning and management, urbanization can reduce poverty and inequality by raising employment opportunities and their living standards. However, when poorly planned, urbanization can induce social and economic issues such as higher crime rates and increased levels of inequality (United Nations, 2020). In addition, population is a vital agent of land use change in an area. With increase in population, the number of settlements increases, which leads to more land conversion from cropland and forested areas to built-up areas. These urban land-uses are of different purposes, ranging from industrial, commercial, governmental, as well as transportation (Mbaya et al., 2019).

2.2 Land use and cover change

Land use and cover change (LUCC) addresses alteration on land surface (Zvoleff at al., 2014). Zvoleff et al. (2014) distinguish land use and land cover as land use representing human uses of land whereas land cover shows the biophysical characteristics of the land surface. Land cover and use affect one another as changes in land-use can change land cover, but land cover also enables specific land uses (Zvoleff at al., 2014). Comprehending the factors affecting these changes in land use and land cover is essential for assessing and overseeing their effects and managing their outcomes. Policy makers require insights into land use changes to effectively allocate and manage land for the future. Studying land cover changes assists in monitoring habitat loss and conserving ecosystems. As natural environments are destructed due to urbanization, biodiversity is exploited. By discerning shifts in land use across a landscape, conservation areas and ecologically significant zones can be pinpointed and given priority (Cowan, 2021).

However, understanding how land cover changes is challenging as it varies in space and time. While observation of land cover and condition can be performed using remote sensing techniques, land use and management practices oftentimes require accessing the study area locally, such as field inventories. Land cover changes could be a result from both human and climate drivers. For example, as the demand for new settlements increases it often results in the permanent loss of natural and cultivated lands. These changes can lead to localized weather pattern changes such as temperature and precipitation. Furthermore, climate change also has consequences on land cover, which includes loss of forest cover from climate-related disturbances, the expansion of woods into grasslands, and coastal erosion due to amplified sea level rises. On the other hand, land-use changes are increasingly being altered by distant forces of the many globalized markets as it affects information and capital flows, migration of people, and social and political organizations (Sleeter et al., 2018; Lambin & Meyfroidt., 2011).

2.3 Impact of urbanization on land cover

There are several factors impacting land cover change and one of the factors is urbanization. Once the land is converted, the change is often irreversible, meaning that agricultural lands are rarely cultivated again. The resulting reduction of agricultural areas includes farmlands with high production rate, which put local and regional food security at risk, but also affects energy demand and alters the climate by distorting both hydrologic and biogeochemical cycles. The risks also include fragmentation of wildlife habitats, and thus reducing biodiversity (Huang et al., 2020; Seto et al., 2011).

In developed countries in Europe, North and South America as well as Australia, urbanization became their central importance by bringing the source of modernization and socioeconomic development especially in North America and Europe (Francis et al., 2012). Although loss of agricultural land is an issue in these nations, the extent in which urbanization affects agrarian lands is controlled. Taking Oregon for example, the conversion of cropland into urbanized areas must first consider ecological, social, and economic factors (Nelson, 2007). In some European countries such as Bulgaria, Czech Republic, Slovakia, Poland and the Lombardy region in Italy, additional fees are required when the conversion of agricultural soils into built-up land is done. In this case, the additional fee depends on a couple of factors including the soil quality (European Commission, 2012).

Unlike developed countries, developing countries such as Indonesia, the increase in urban areas in the country has led to extensive use of cropland and essential ecosystems such as mangroves, which plays a significant role in storing carbon and protection during coastal storms (Urban Transitions, n.d.). Apart from Indonesia, various developing countries such as India, Nigeria, and Egypt, are facing similar concerns (Pandey & Seto., 2015; Lasisi et al., 2017; Youssef et al., 2020). It is reported that between 2000 and 2014, cities in Indonesia expanded by 3.9% (6904 km^2), which is an area larger than the whole land area of Bali. Among these changes, almost three quarters of this expansion was carried out on cultivated land, wiping out cropland and protective ecosystems around the cities (Urban Transitions, n.d.). Moreover, developed countries in Europe, North and South America as well as Australia, are experiencing the similar phenomenon.

In terms of Bali, attracting tourists from all across the world by offering various tourism activities, the island has been exploited by the land use alteration over the years. Badung regency is the neighboring area next to Denpasar city, the capital city of Bali Province (Indrawan et al., 2022). According to The Bali Sun (2023), approximately 70% of all tourists visiting Bali in May 2023 chose to visit Badung regency. In Badung, construction of infrastructure linked to tourism development has led to land conversion (Indrawan et al., 2022). Moreover, Colorni (2018) conducted a combination of both desk and field research to assess the land grabbing issue in Bali as well as Rchedry (2020) with a qualitative assessment including interviews, field observations, and workshops to investigate the similar issue. Over the last quarter-century, Bali has experienced a reduction of approximately 25% of its agricultural land (Colorni, 2018) and according to the case study by Tchedry (2020), this rapid urbanization is causing 1000 hectares of arable land to be threatened each year and also inducing water shortages in the region. Based on statistical data from the local government, 2020 marked the most extensive farmland reduction in Bali's history, with approximately 1,200 hectares repurposed for alternative uses (Colorni, 2018). In contrast to these prior studies that have employed qualitative assessment to investigate this issue, this paper adopts a quantitative approach utilizing spatial analysis to facilitate a more straightforward interpretation of the same problem.

Furthermore, throughout Bali, agriculture and culture are intricately connected (Putra et al., 2019). Bali's landscape is not only defined by its environmental features but also by its rich cultural heritage. In Bali, there exists an irrigation system known as "Subak", a collaborative network that manages water distribution among rice paddies. This system additionally embodies Bali's "Tri Hita Karana" philosophy, which is the harmonization of the realms of the spiritual, human society, and nature. UNESCO recognized five rice terraces, including the tourist-popular one in Tegallalang, along with their associated temples, utilizing the Subak system, as a World Heritage Site in 2012. However, with tourism encroaching on the natural environment, this heritage, dating back to the 9th century, faces the risk of degradation (Suriyani, 2023).

The reality in the center of this land cover change is that existing land use laws aim to restrict tourism development but overlook the root causing farmers to sell their land. Agriculture lacks governmental aids and struggles to compete with the economic incentives provided by tourism. Moreover, enforcement of these laws is often hindered by corruption and bribery, accelerating the loss of agricultural lands (Phillip, 2012). Apart from these factors, reduced water discharge, decreased human resources, complex land deals, land taxes and regulations all contribute to the difficulties faced by local farmers to be involved in the agricultural sector (Colorni, 2018; Widhianthini, 2022).

2.4 Change detection analysis

As far as land cover change is concerned, land use change detection (LUCD) is an evaluative study on land surface that is applicable in various fields, including forest deforestation, cropland change, and expansion of urban areas (Liu et al., 2023). Change detection incorporates recognizing variations in the condition of an object or phenomenon across time, offering a precise depiction of alterations unfolding over an extended duration (Singh, 2010).

Geographic Information Systems (GIS) and remote sensing (RS) are the vital means of LUCD as those are powerful and cost-effective tools to detect land use changes (Sobhani et al., 2021, Herold et al., 2003, Serra et al., 2008), also allowing for the analysis of processes by applying datasets from different time periods and broader coverage of the study area (Liu et al., 2023). These methods use various high and/or medium-resolution, multi-spectral remote sensing satellite imagery such as Landsat-TM and Sentinel-2 (Kumar & Arya., 2021) or Google Earth imagery which are open-source and cost-efficient (Malarvizhi, 2016). RS techniques play a crucial role in monitoring unplanned urban and industrial development and addressing deficiency in land use mismanagement. These techniques provide essential data for understanding human phenomena, supporting planning, earth science, and ecological studies. Consequently, RS has become a pivotal tool for change detection in recent decades (Ding et al., 2018; Johnson & Kasischke., 2010). There has been a continued growth in this research field with an exponential increase in the number of LUCD studies (Liu et al., 2023) as it is crucial to study global climate change, environmental management and monitoring (Coppin et al., 2010).

Several recent studies have contributed to this expanding field of study, underscoring its importance. For example, Aziz (2022) explored the impact of urban expansion on agricultural lands in Erbil using remote sensing tehcniques and satellite imagery, while Azari (2022) examined modelled a future land cover in Malaysia for 2030 using the multi-temporal trend within the study area. These studies highlight the evolving methodologies and insights within our current approach.

3 Methodology

This section describes the research methodology employed to investigate the impacts of urban expansion on areas of agricultural land. The approach includes a quantitative method to ensure a comprehensive spatial data analysis, which consists of data collection, digitization of land cover maps, change detection analysis, and map accuracy assessment.

3.1 Study area

This study focuses on the agricultural land loss due to urbanization in the Seminyak and Legian region of Bali, Indonesia. The study area was set to Seminyak and Legian in the Badung regency (see Map 1) with an area of 5 km x 5 km. The area is facing the west coast of the island and is still one of the popular tourist destinations in the island. The area is situated between Kuta and Canggu (Bali.com, n.d.).

Study area

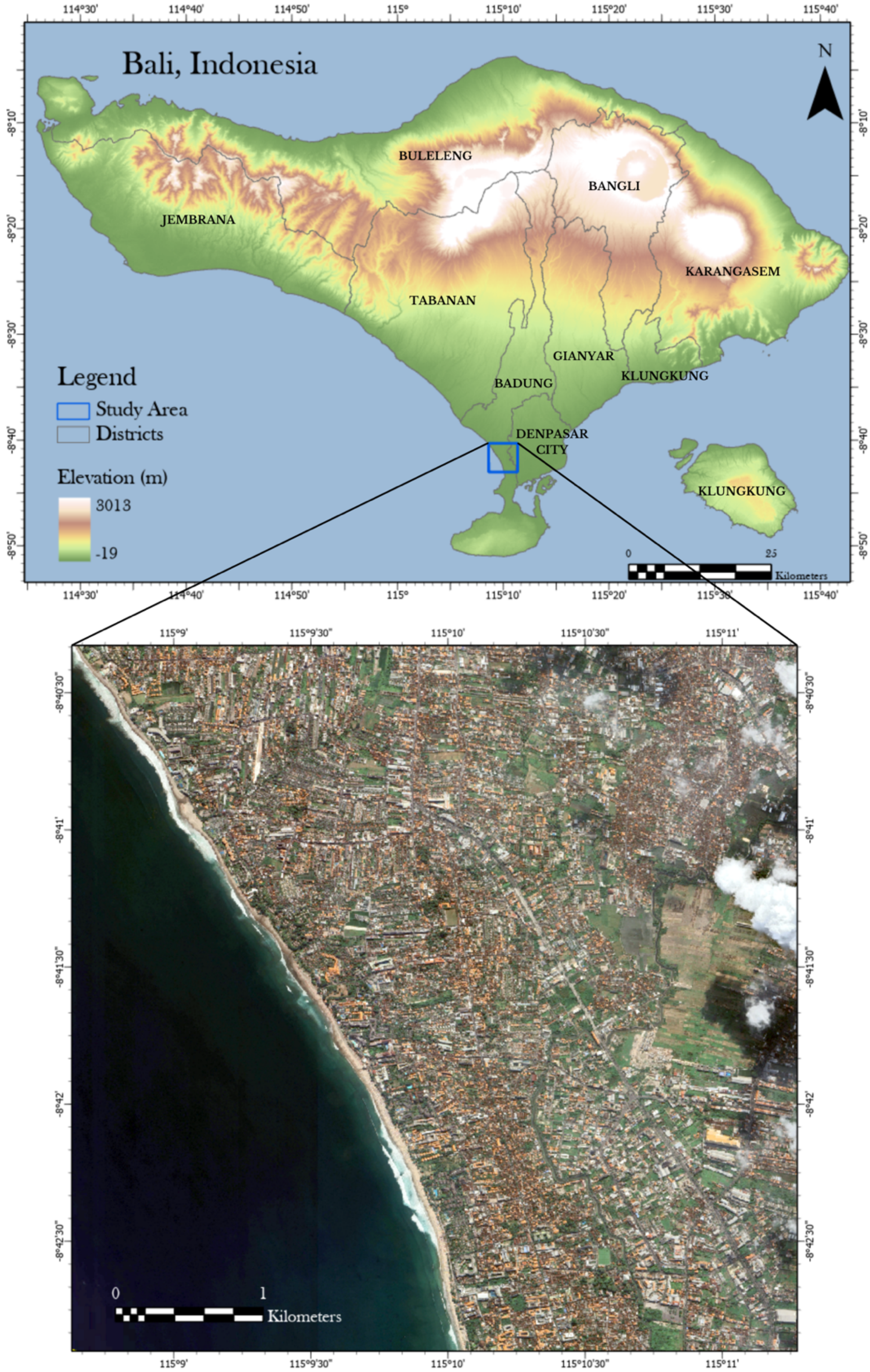


Figure 1: Map showing the elevation and districts of Bali and zoomed in aerial image of the study area. Own work using geospatial data from: Indonesia Geospatial, Google Earth, Maxar Technologies, and Airbus.

The choice of Seminyak is motivated as the area is known for an area with luxurious hotels and private villas, offering the perfect view of sunset on the beach and great surf points (Bali.com, n.d.). This area is a popular destination throughout the year, but it is most popular during summer as well as around the end of the year (Ministry of Villas, n.d.). Additionally, Legian is an area situated in the south of Seminyak, with a wide range of tourist attractions such as surf schools, luxury hotels, and waterparks for family leisure (Indonesia Travel, n.d.).

3.2 Data collection for spatial analysis

To digitize the land cover map of the study area over the years, aerial images from the years 2009, 2015, 2019, and 2023 were collected as well as Sentinel-2 L2A satellite images from the years 2019 and 2023 were obtained (see Table 1). The original plan was to use the aerial image from 2011, but since there was no data available from that source, the aerial image from 2009 was used instead. The study area was created using the path and point tools in Google Earth Pro 7.3.6.9796 with the extent of 5 km by 5 km. This area was then converted to KML file, which was transformed into shape file in ArcGIS Pro 2.7.0 to georeference the aerial images to a correct map projection. Elevation and administrative files from Indonesia Geospatial were used to create the study area map.

Table 1: Data used in this study and its description

Data name	Resolution/context	Source
Sentinel-2 L2A satellite images (2019 & 2023)	10 m	Copernicus Browser https://browser.dataspace.copernicus.eu/
Aerial image (2009, 2015, 2019 & 2023)	30 cm and 50 cm	Google Earth Pro 7.3.6.9796, Maxar Technologies, Airbus
Position file (KML)	5 km x 5 km	Google Earth Pro 7.3.6.9796
Elevation raster file of Bali	Raster file, DEM SRTM 30 m	Indonesia Geospatial https://www.indonesia-geospasial.com/2020/01/download-dem-srtm-30-meter-se-indonesia.html
Administrative district/sub-district file of Indonesia	Vector shape file	Indonesia Geospatial https://www.indonesia-geospasial.com/2023/05/download-shapefile-batas-administrasi.html
Number of foreign visitors to Bali from 2009 to 2023	Dataset on number of foreign tourists visiting Bali (2009 – March 2023)	Bali Government Tourism Office https://disparda.baliprov.go.id/rilis-data-statistik-resmi-bulan-maret-2023/2023/05/
Number of foreign visitors to Bali in 2023	Number of foreign visitors to Bali in 2023	Bali Management Villas https://balimanagement.villas/blogs/bali-tourism-statistic/
Number of domestic visitors to Bali from 2009 to 2023	Dataset on number of domestic tourists visiting Bali (2009 – 2023)	Badan Pusat Statistik Provinsi Bali https://bali.bps.go.id/statictable/2018/02/09/29/banyaknya-wisatawan-domestik-bulanan-ke-bali-2004-2021.html

3.3 Digitizing land cover maps

Land cover maps were created by digitizing aerial images and Sentinel-2 images of the study area using ArcGIS Pro 2.7.0 for all the years 2009, 2015, 2019 and 2023. Digitizing was mainly based on aerial images from Google Earth but for some areas with cloud cover, Sentinel-2 images were used as a substitute. Topology rules were set in the beginning that is "Must Not Have Dangles" and "Must Not Have Pseudo-nodes" for line features (watercourses and roads) as well as "Must Not Overlap" and "Must Not Have Gaps" for polygon feature (land cover). In addition to these topology rules, the minimum mapping unit (MMU) was also set to 1000 m^2. Polygons and line features were digitized according to land cover classes and infrastructures visible in the aerial images and polygons were then classified into five land cover classes; built-up, cropland, pastures, shrub, and waterbodies (see Appendix A). These five classes were chosen as all these classes were easy to distinguish from one another as aerial images were used as a source of digitization and common within the study area making them visible and made the remote sensing possible.

3.4 Change detection analysis

To quantify the land cover change over the years, change detection analysis was carried out. The land cover classes for different years (i.e. 2009 and 2015, 2015 to 2019, and 2019 to 2023) were overlaid (intersect) on top of one another in ArcGIS Pro for the change detection. The area where the land cover did not change was combined into one class of "No change". All the areas below MMU after overlay were merged together with the neighboring land cover class in the editing panel. Then quantitative pie charts showing land cover changes were made using all of the observed changes from the change detection analysis.

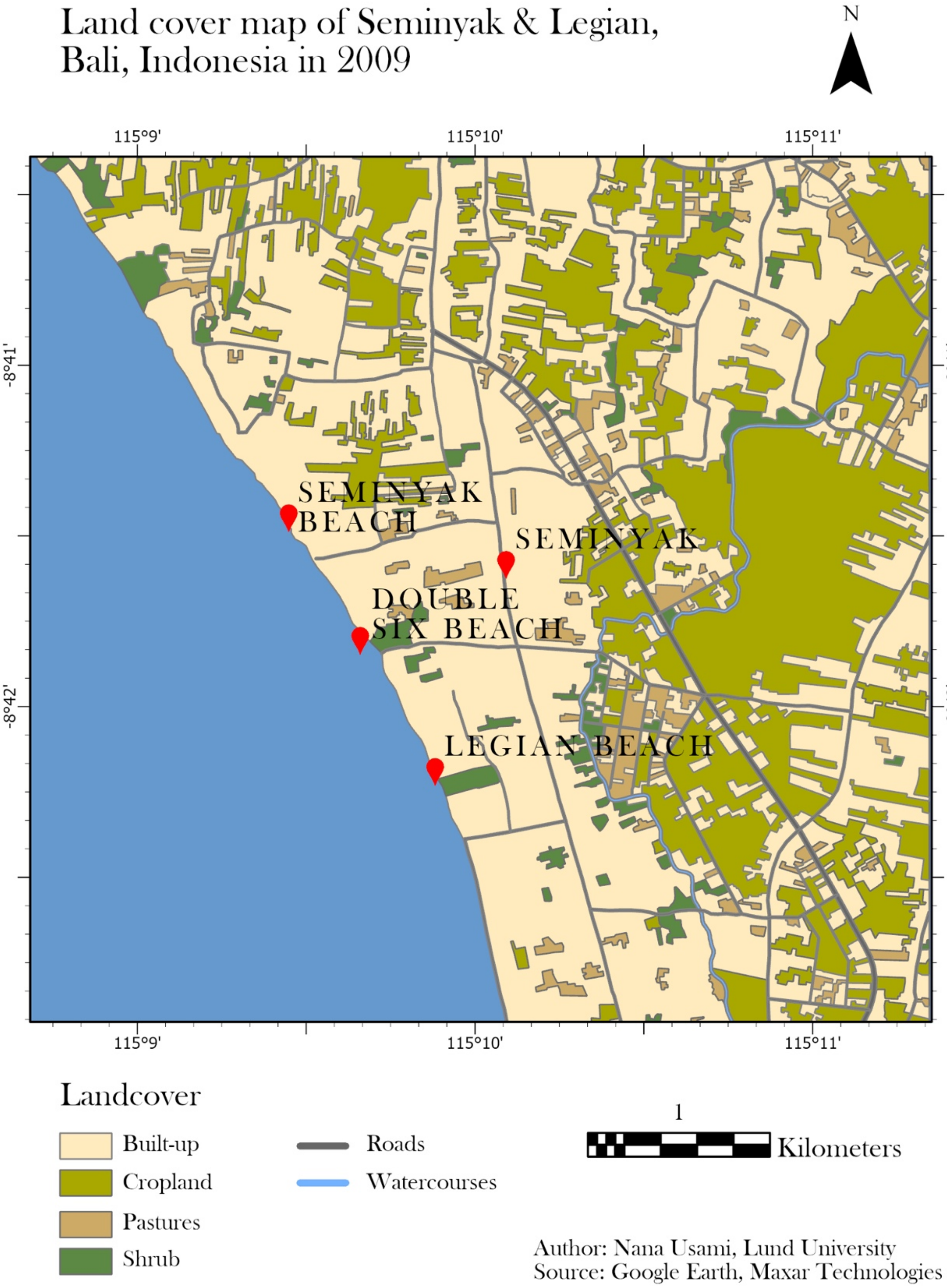
3.5 Map accuracy assessment for 2023 land cover map

To assess the accuracy of the land cover map created, firstly random points were generated and distributed across the study area by using ArcGIS Pro. Each land cover has 30 assessment points that were random stratified, making it 120 points in total for four land cover classes. It was followed by the map accuracy assessment, which was carried out by using Google Earth software and its street view tool wherever possible. Although it is preferred to actually visit the study site and conduct a field assessment, "street view" on Google Earth with high resolution was used as an alternative as it allowed a virtual field inventory on the study area. By comparing the digitized land cover to the observed land cover from the aerial image, an error matrix including total accuracy, producer's accuracy, user's accuracy and Kappa index were made for comprehensive accuracy assessment of the land cover interpretation.

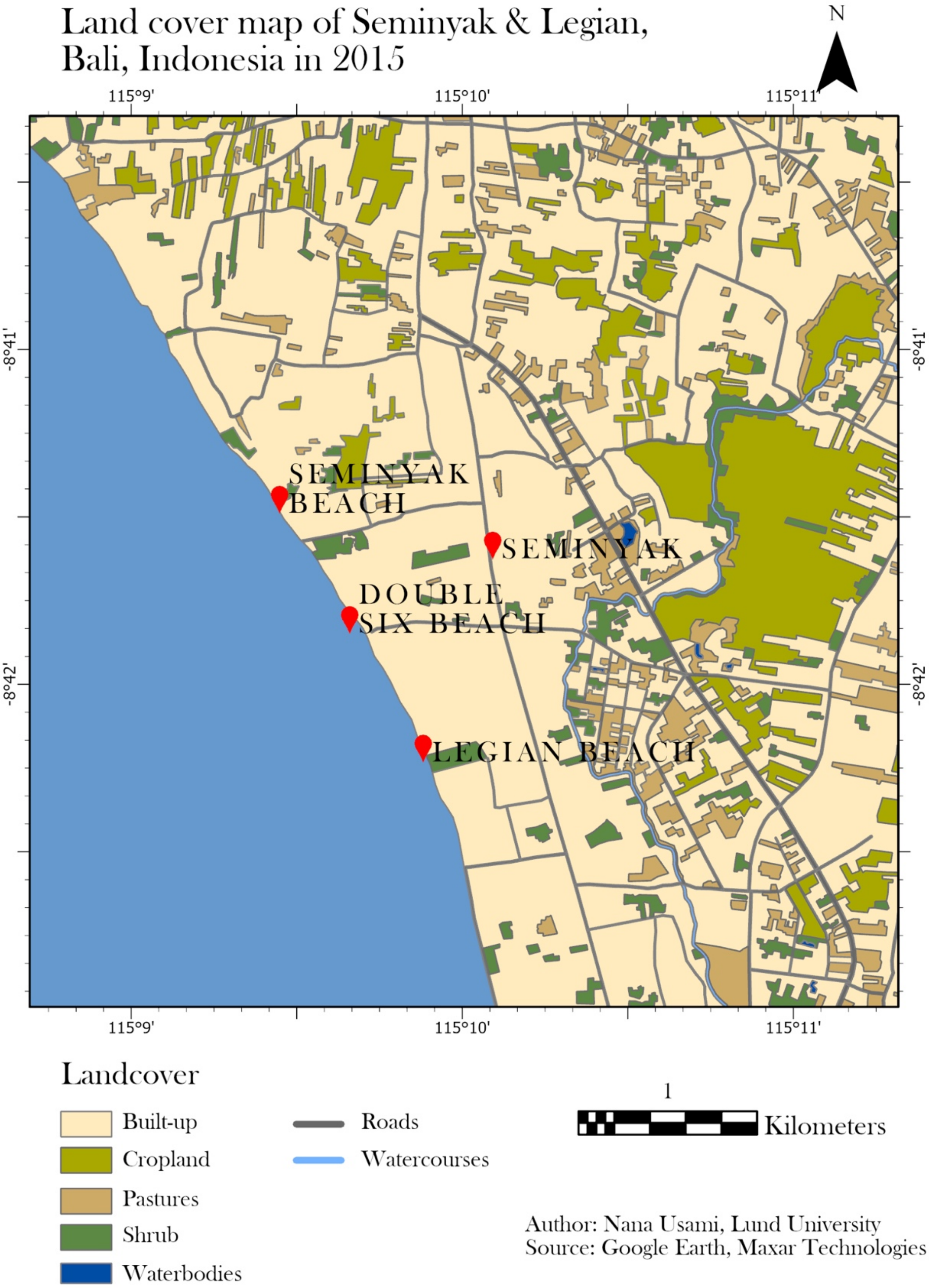
4 Results

4.1 Land cover maps for years 2009-2023

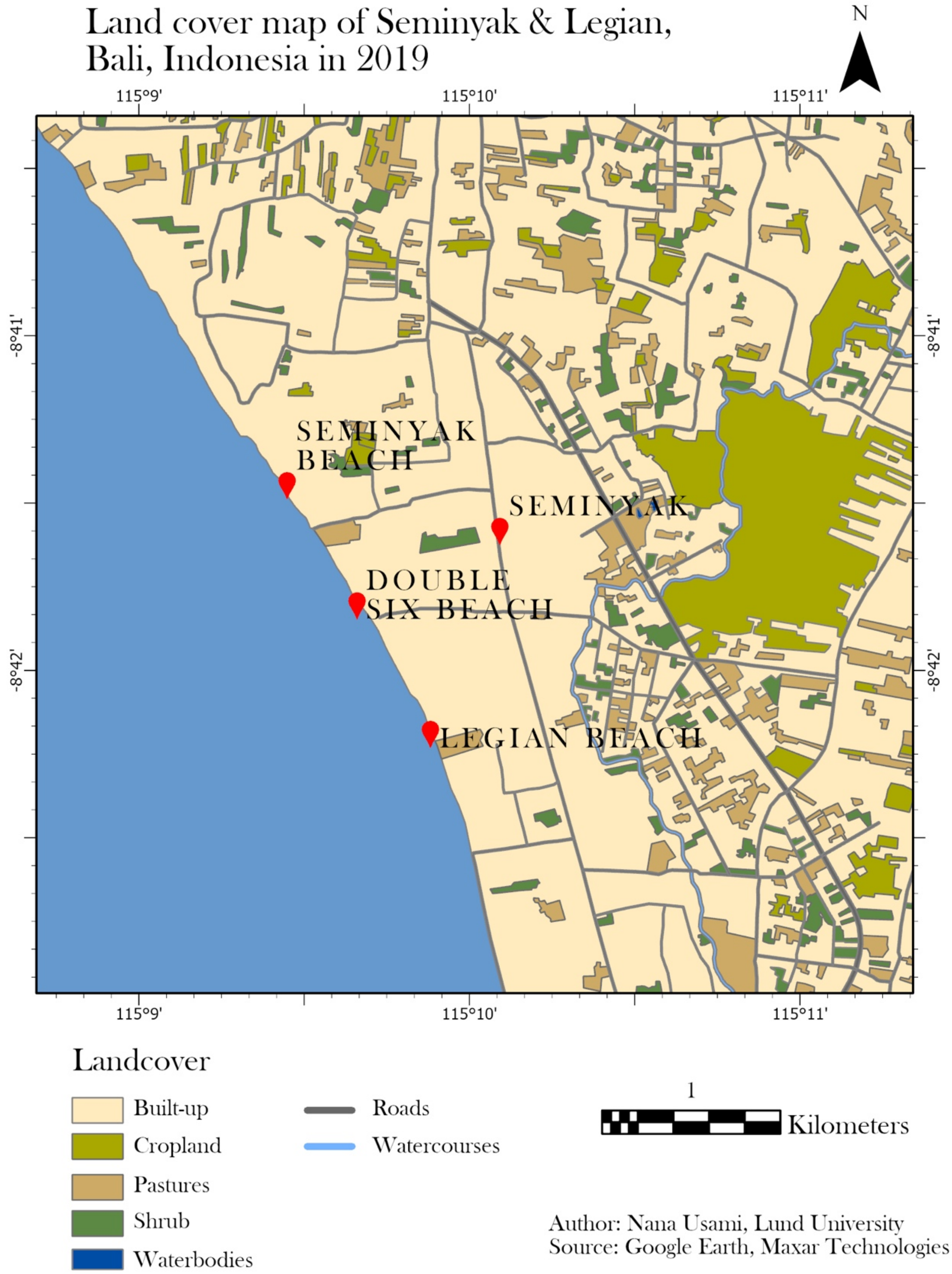
The following land cover maps (see Maps 2-5) show how the land cover of the study area has been changing throughout the time period of 2009 to 2023. In general, agricultural land and pastures gradually decrease with time and are replaced with built-up areas. There is the largest change in land cover between 2015 and 2019. Built-up areas are frequent along the west coast of the study area and agricultural land and pastures are common on the inland and around the watercourses. Furthermore, there are more roads visible in the maps that are newly constructed due to increase in built-up areas in the later years.



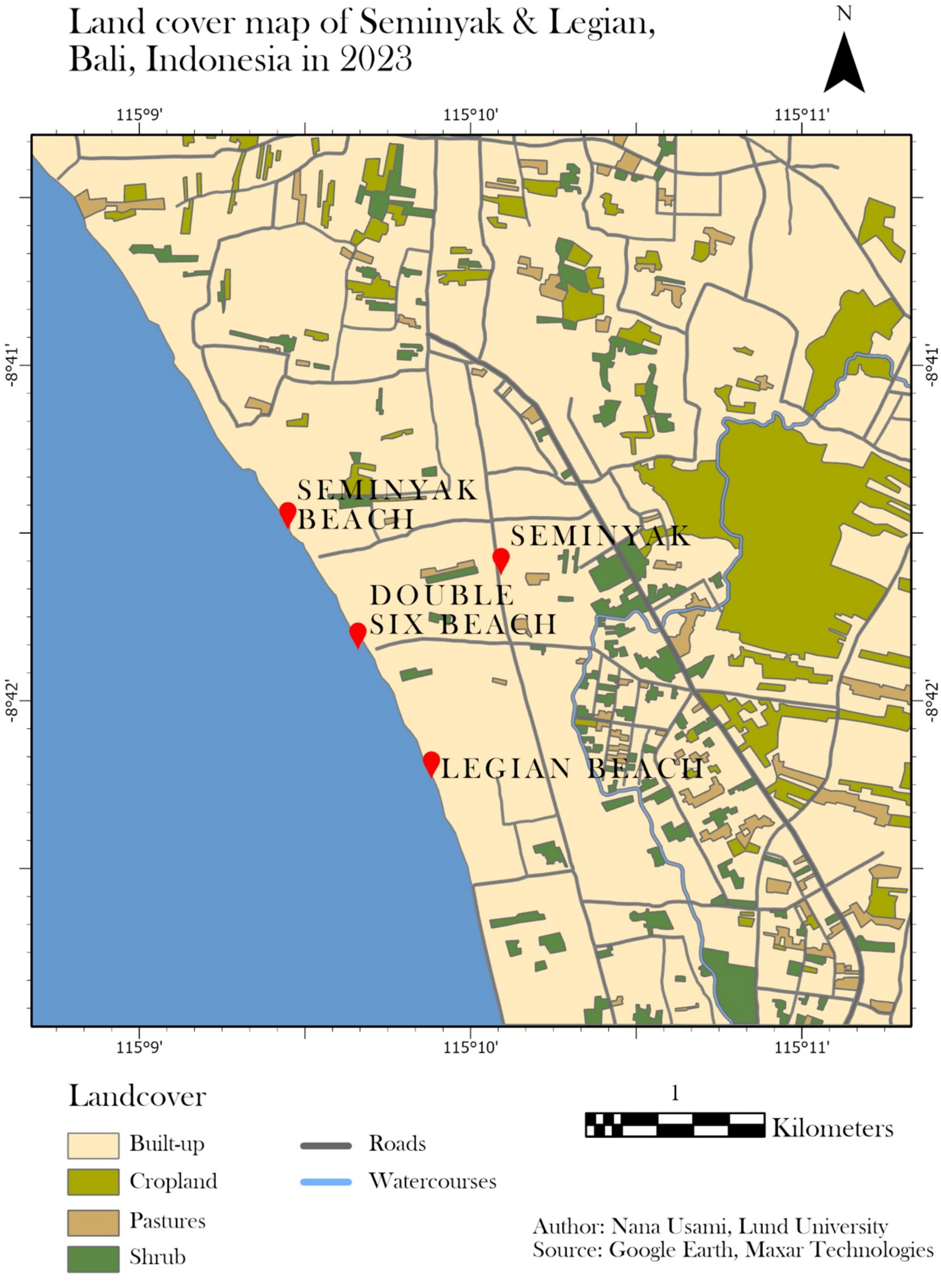
Map 2: Land cover map of the study area in 2009.



Map 3: Land cover map of the study area in 2015.



Map 4: Land cover map of the study area in 2019.



Map 5: Land cover map of the study area in 2023.

4.2 Change detection analysis

The changes in land cover classes within the study area is depicted in the following table (see Table 2). Built-up areas are constantly increasing, where it has increased by 3.6 km^2 from 2009 to 2023 whereas other land classes have decreased as these classes were converted to built-up areas. Area used for cropland has been reduced for less than half of the area in 2009 by 2023. Pastures have also decreased by about 0.2 km^2 by 2023, but has increased then decreased over the years, which could be due to misinterpretation of land cover depending on seasons as after the harvesting season, cropland could look like pastures. Shrubs, however, have increased by 0.2 km^2 in comparison to other vegetation land cover classes. Lastly, water bodies decreased drastically from 2015 to 2019 and then completely disappeared from the study area by 2023.

Table 2: Areas of each land cover class for different years (km^2)

	Built-up (km^2)	**Cropland (km^2)**	**Pastures (km^2)**	**Shrub (km^2)**	**Waterbodies (km^2)**
2009	9.9	5.7	0.7	0.6	0
2015	12.0	2.5	1.5	0.9	0.02
2019	12.7	2.0	1.4	0.7	0.003
2023	13.5	2.1	0.5	0.8	0

Stacked columns in Figure 1 show the percentage cover of each land cover for different years. Built-up area accounted for 75% of the total area by 2015 and reached about 80% of the total study area by 2023. Agricultural land has decreased by 21.3% from 2009 to 2023 and pastures decreased by 1.3%, whereas in contrast, shrubs have increased by 1.2%. Furthermore, two lines in Figure 1 depict tourists visiting the island, with the green line representing the foreign visitors and the dark blue line representing the domestic visitors. Both types of tourists increased rapidly within the time frame of 2009 to 2015, with the maximum number of foreign visitors reaching 6 million in 2019 (see Appendix B) and the domestic visitors surpassing 10 million visitors in the same year (see Appendix C). However, tourists visiting Bali have decreased since 2019 due to the difficulties traveling between countries from the COVID-19 outbreak and are still recovering from its consequences.

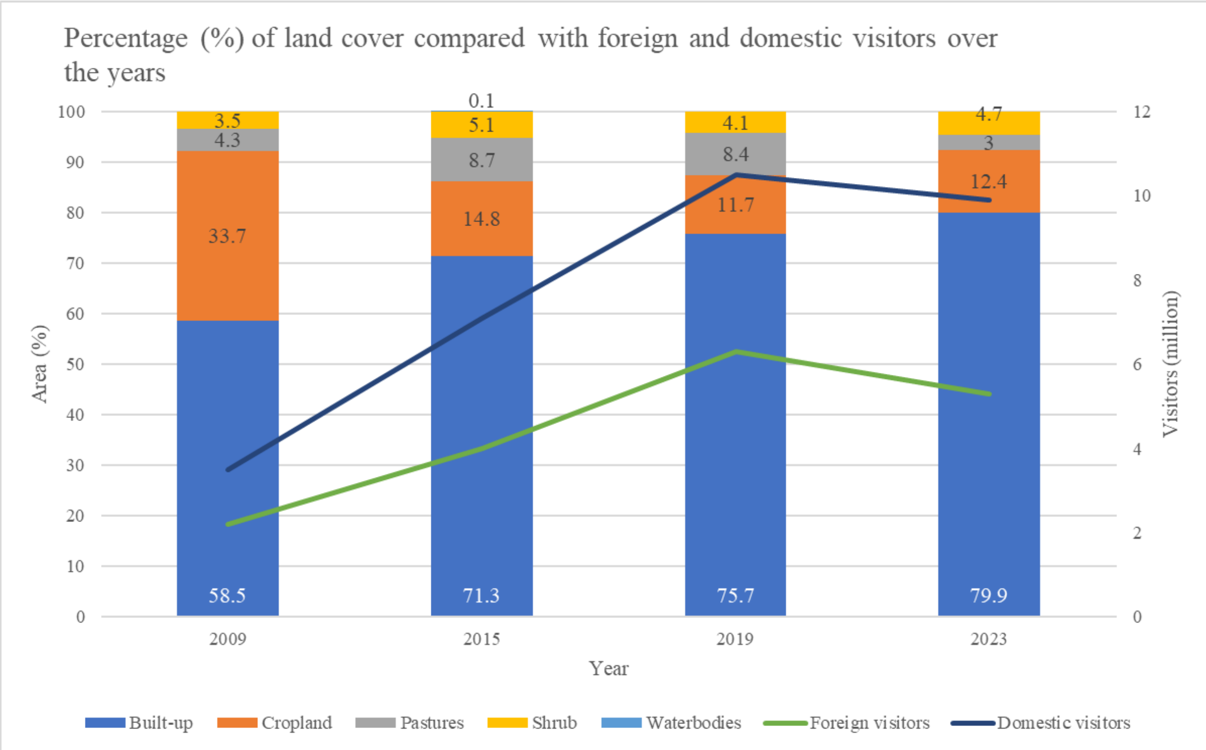
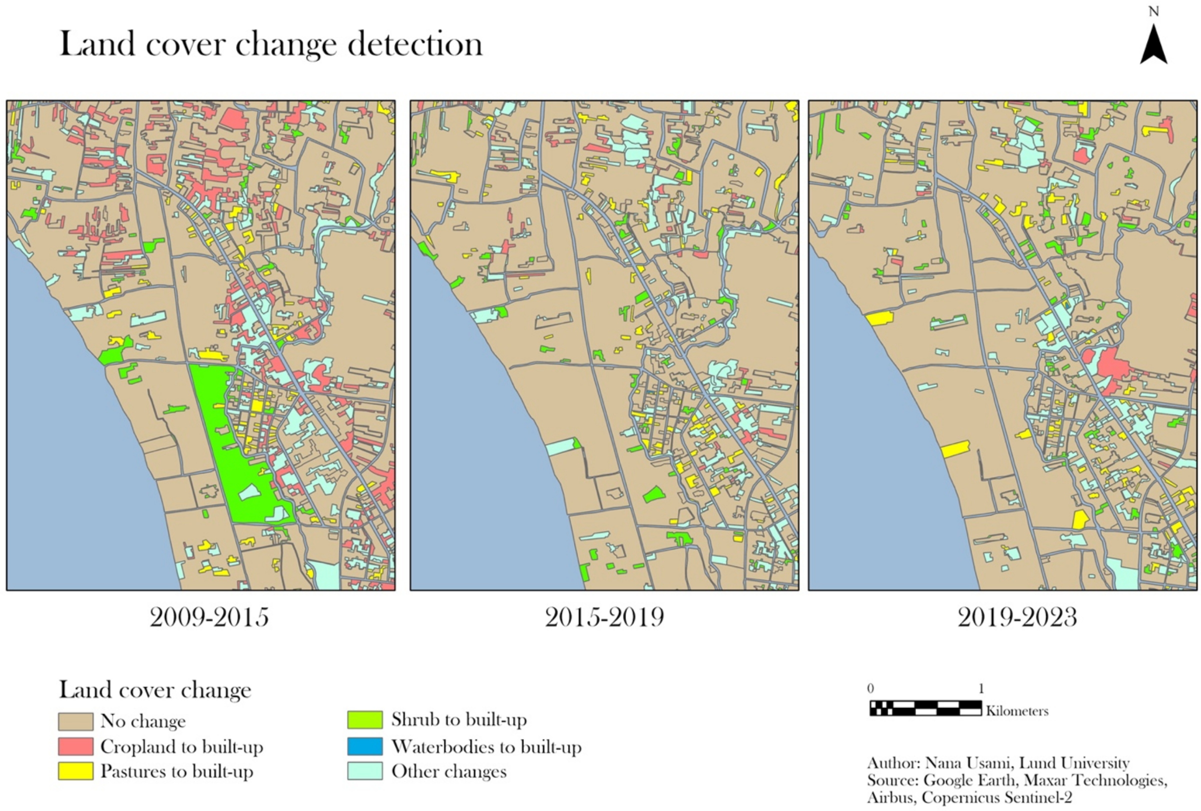


Figure 1: Percentage (%) of land cover compared with foreign and domestic visitors throughout the years from 2009 to 2023.

The following maps (see Map 6; see Appendix D-G) show the land cover change over the years. As seen in Map 6, the land cover change has been continuously happening in the study area, but the most intense change happened from 2009 to 2015 among the other years, as you can see in figure 1 that both domestic and foreign tourists started to skyrocket during these years, resulting in increased demand for built-up areas. During 2009 to 2015, there were intense land cover changes all over the study area, especially along the north-west coast and along the main roads within the study area, during which most of these changes were converted to built-up areas. During 2015 to 2019, there were less land cover changes compared to previous years, especially less land conversion along the beach, yet the trend of other land cover classes converting to built-up areas remains. Finally, from 2019 to 2023, the increase in built-up areas along the main roads seems to be the trend.



Map 6: Land cover change detection through the years from 2009 to 2015.

Figures 2-7 (also referring to Appendix H-N) show the quantified land cover changes for different periods within the 15-year period time frame. From 2009 to 2015 (see Figure 2), the biggest changes were from cropland to built-up and cropland to pastures with 10.5% and 5.8% of the total study area, respectively. These changes were followed by changes from shrub to built-up (4.6%), cropland to shrub (2.4%), then pastures to built-up (2.3%). However, the land conversion to built-up in total accounted for 17.5% of the study area, enlarging the built-up areas within the study area. On the other hand, Figure 3 shows that out of the 70.6% of the total area that remained unchanged, the majority of the unchanged area (76.2%) accounted for built-up areas. This was followed by croplands of 20.6%, pastures 2.0% and finally shrubs with 1.2% unchanged areas.

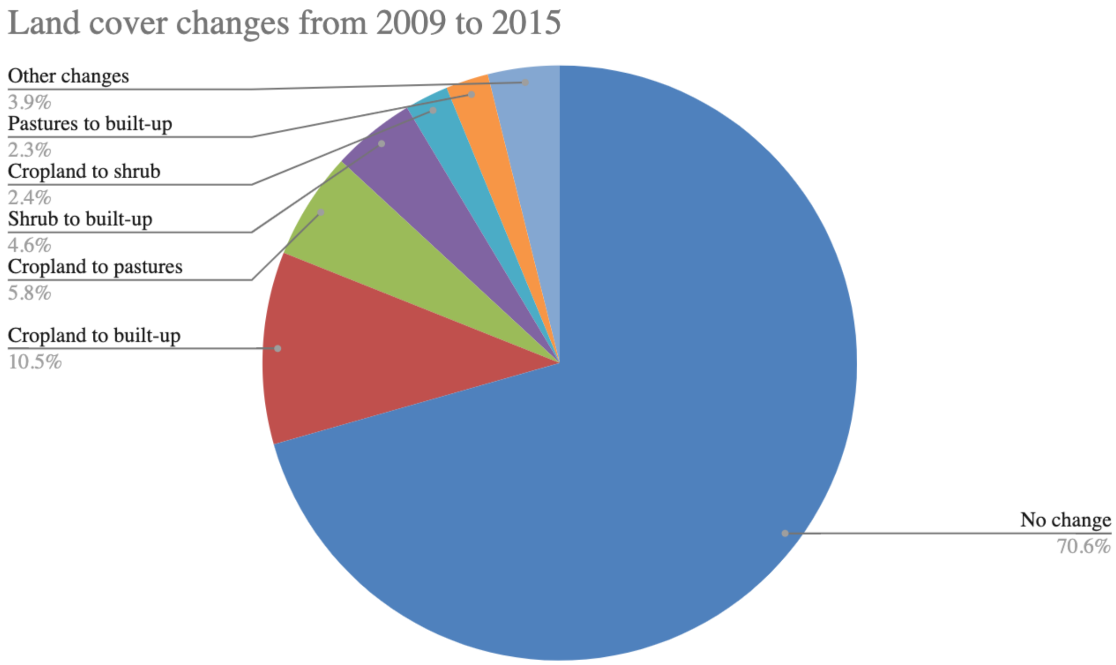


Figure 2: Land cover changes from 2009 to 2015.

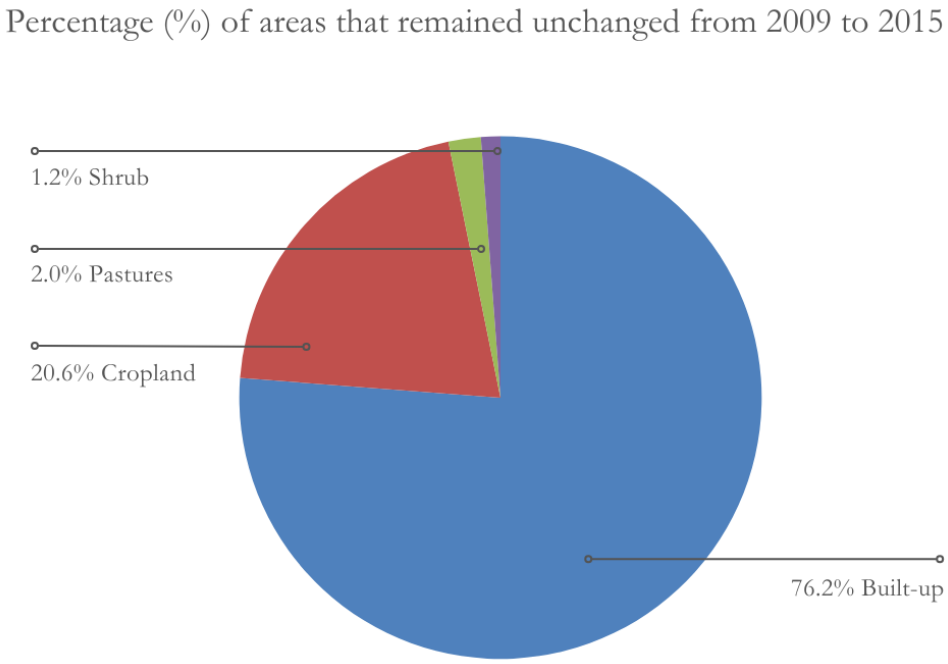


Figure 3: Land cover classes that remained unchanged from 2009 to 2015.

Although land conversion rates decreased during 2015 to 2019 compared to the previous years, some of the notable land cover conversions remained to be transformations to built-up areas (see Figure 4). With transformations from pastures to built-up, cropland to built-up, shrub to built-up, with 3.2% change, 2.2% change, and 2.2% change, respectively, expansion of built-up areas accounted for 7.6% of the total land area. Furthermore, 81.9% of built-up areas accounted for the total land cover classes that remained the same during these four years, which is an increase of 5.7% compared to the previous years (see Figure 5). In addition to built-up areas, pastures and shrubs that remained unchanged also increased by 2.1% and 0.5%, respectively. In return, the areas that remained as cropland have been reduced by 7.3% compared to the years from 2009 to 2015.

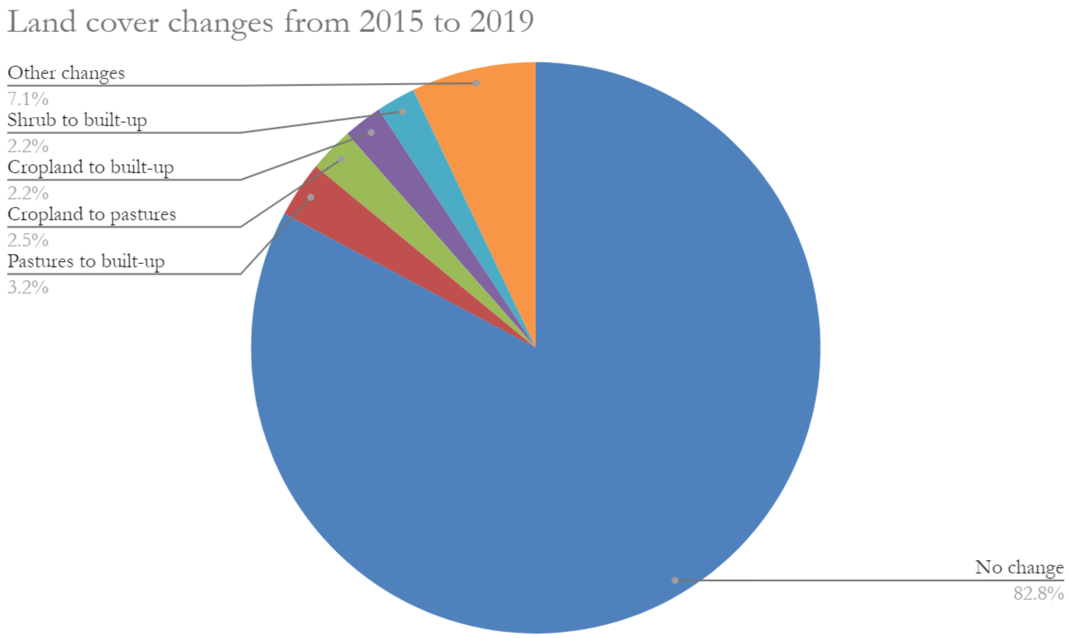
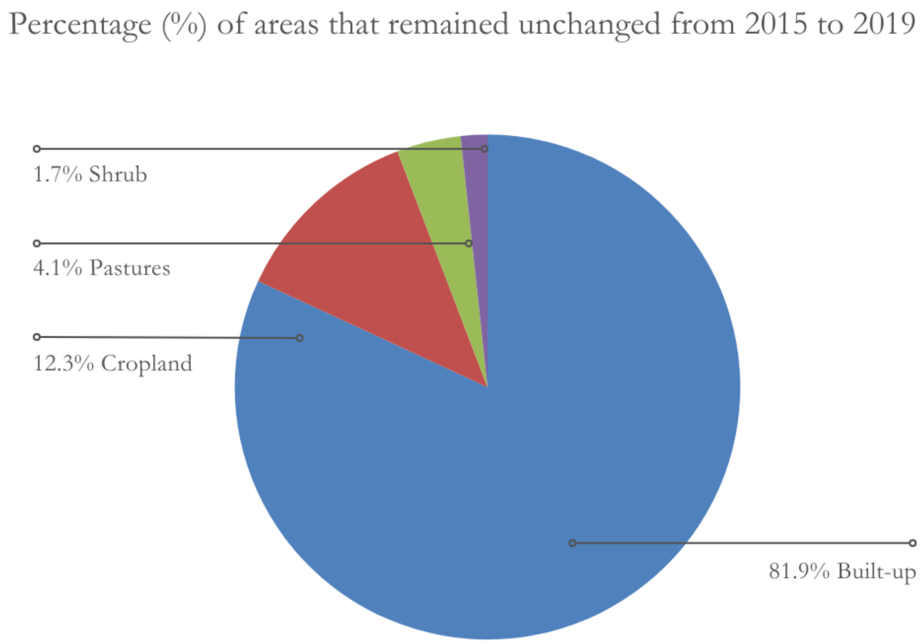


Figure 4: Land cover changes from 2015 to 2019.



Map 5: Land cover classes that remained unchanged from 2015 to 2019.

The most recent years from 2019 to 2023 (see Figure 6) has land cover with no change for 84.2% of the whole study area. The land conversion rate has reduced over the years, but urban expansion is still noticeable with 2.0% of the land cover change from cropland to built-up, 3.2% of the change from pastures to built-up, and 2.2% of the change from shrub to built-up. Figure 7 shows the pie chart for the areas that remained the same from 2019 to 2023. Here again, built-up areas that did not change increased by 3.8% compared to previous four years, which has reduced the area of all the other land cover classes that remained the same.

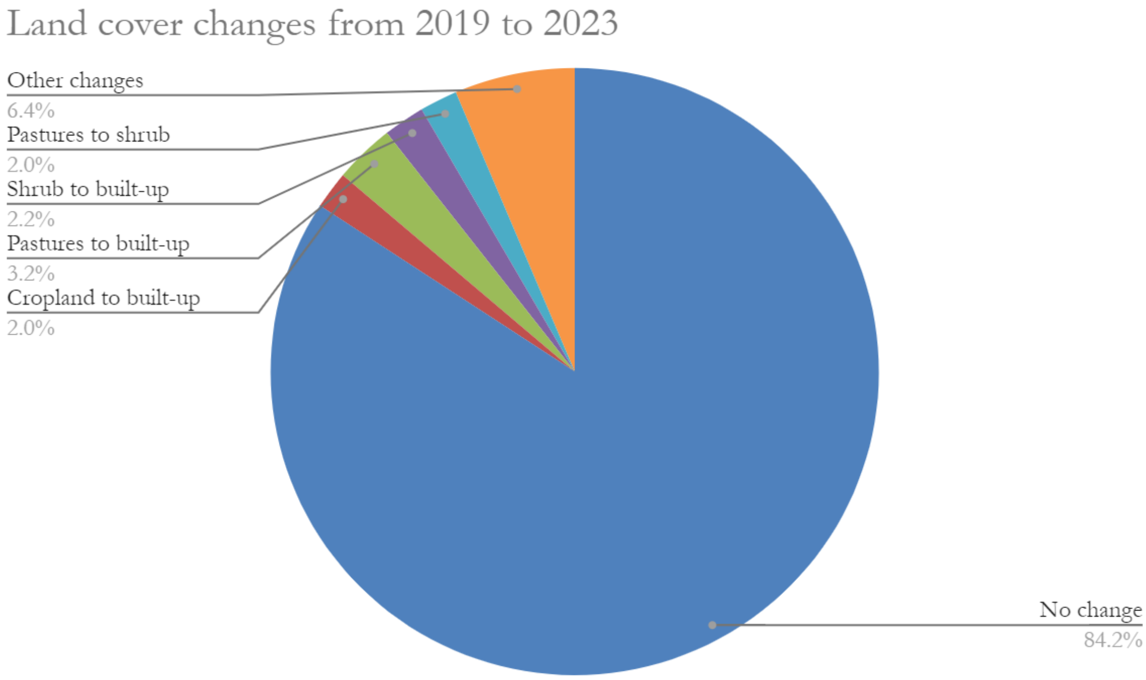


Figure 6: Land cover changes from 2019 to 2023.

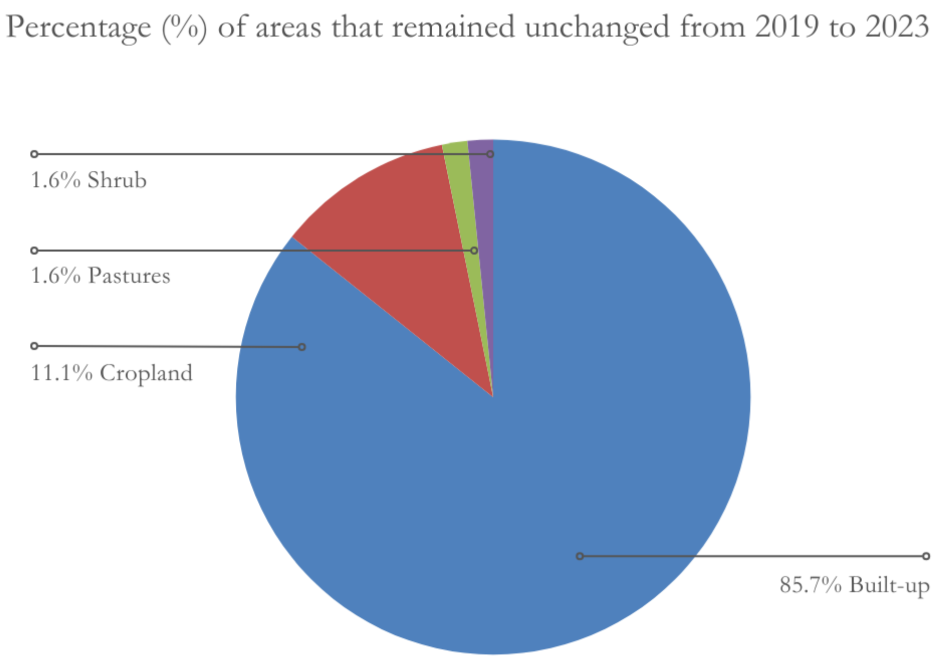


Figure 7: Land cover classes that remained unchanged from 2019 to 2023.

4.3 Map accuracy

In the map accuracy assessment, total accuracy reflects the overall precision of the digitized map in relation to the aerial image utilized as a reference. Producer's accuracy indicates the frequency with which actual ground features are accurately depicted in the digitized land cover map. User's accuracy denotes how frequently the map's class corresponds to actual land surface conditions. Lastly, Cohen's Kappa index serves as a measure of the disparity between actual and expected agreement, ranging from -1 to 1. A negative Kappa value indicates no agreement, 0 signifies random agreement, and a positive index indicates perfect agreement.

Using the error matrix, the calculated total accuracy of the 2023 land cover map was 71.67% and its Kappa index was 0.60. Moreover, according to McHugh (2012), Cohen suggested that the Kappa result can be understood in the following manner: 0.01-0.20 denotes none to slight agreement, 0.21-0.40 indicates fair agreement, 0.41-0.60 shows moderate agreement, 0.61-0.80 signifies substantial agreement, and 0.81-1.00 represents almost perfect agreement. Thus, the Kappa index of 0.60 indicates that the classification has an adequate agreement.

Furthermore, producer's accuracy and user's accuracy were also derived for each land cover class (see Table 3 and see Appendix O). Four land cover classes (built-up, cropland, pastures, and shrub) were used for this map accuracy assessment as the fifth land cover class, waterbodies, was not identified in the 2023 land cover map which was used as a base of the accuracy assessment. In general, producer's accuracy and user's accuracy were both in good agreement for built-up areas and croplands. Although pastures and shrubs yielded slightly lower producer's accuracy and user's accuracy compared to built-up areas and croplands, accuracy higher than 50% were calculated, meaning that they were also in a fair agreement.

Table 3: Producer's accuracy and user's accuracy for each land cover class assessed for the map accuracy

Land cover class	Producer's accuracy (%)	User's accuracy (%)
Built-up	73.7	93.3
Cropland	87.0	66.7
Pastures	61.5	53.3
Shrub	66.7	73.3

5 Discussion

The outcome reveals the harsh reality and underlying dilemma of the difficulty maintaining the perfect balance between urban areas and vegetated areas, which both are necessary for humans. Moreover, the results also convey the importance of assessing the land cover change in a developing country, especially where the land conversion is intense and where very few studies are conducted.

5.1 Key findings and implications of this study

The observed land cover changes show that urban areas are constantly expanding within this study area on behalf of vegetated lands as the demand for built-up areas increases with time. Although agricultural lands are crucial for local food production and resulting food security, the demand for urban areas is still so high that one must exploit the cropland in order to convert the land into built-up areas. Assuming all the croplands in the study area are rice paddies and that the rice production per hectare of cropland is approximately 4.7 t/ha (USDA, n.d.), loss of 3.6 km^2 (equals to 360 hectares) from 2009 to 2023 in cropland accounts for 1692 tonnes reduction in local rice production within the study area alone. Further, assuming each individual consumes 121.29 kg of rice per year (OECD, n.d.), that there are 3.8 people in each household in Bali (Badan Pusat Statistik, 2017), and their average life expectancy as 71.3 years (WHO, 2023), 1692 tonnes of rice can sustain approximately 51 households for their lifetime. This amount of loss in rice production due to land conversions in the study area alone could be a serious threat to the food security of Bali if this urban expansion persists for the next decades or even more.

Additionally, the results from change detection analysis further manifests the exacerbated loss of agricultural areas by showing the distinct conversion of non-built-up areas into built-up areas. Built-up areas continue to expand repeatedly. While the majority of existing built-up areas remain unchanged (as seen in Figures 3, 5, 7), the demand for additional urban development shows no signs of declining. This endless expansion further disrupts both naturally vegetated and agricultural areas, as there are limited non-built-up lands available for conversion into built-up areas, leading to further exploitation of these vegetated areas. This is additionally reflected in the data on the number of foreign/domestic tourists visiting Bali, showing that increase in built-up areas will provide places to stay and services to not only increased tourists arriving in Bali but also for those who work in a tourism industry to support their lives. Even though the land conversion rate has been reduced compared to earlier years (i.e. 2009-2015), with the relentlessly increasing tourist arrival in Bali, it is evident that the built-up areas will continue to expand by converting the vegetated lands including the agricultural lands as long as the tourists continue to explore other areas in Bali.

This is further supported by a study done by Colliers International Indonesia, as their dataset recorded the total number of hotels in Bali experiencing growth from 2015 to 2020, followed by a decline post-2020 (N. Yonasari, personal communication, April 04, 2024; see Appendix P) due to the pandemic-induced closures of several properties. However, according to their annual report, despite these setbacks, Bali remains a perennial draw for both local and international tourists, ensuring continued development within the island's hospitality industry. The proliferation of new hotels is not limited to the Kuta area alone; it has expanded to encompass other regions such as Pecatu, Ubud, Sanur, and Seminyak. This indicates a diversification of tourist destinations in Bali beyond the traditional Kuta-Seminyak coastline, with an increasing number of visitors venturing into these alternative destinations (Colliers International Indonesia, 2023).

Outside the Kuta-Seminyak belt lies the current popular destination, Canggu. Suamba et al. (2010) conducted a similar study on agricultural land use in Canggu, mapping its characteristics and deviation patterns. Between 2016 and 2020, Canggu's population is projected to increase by 2.1%, reaching 7,035 residents. The area's high population density and rapid growth significantly impact tourism development, leading to increased demand for settlement space and tourism facilities, resulting in the conversion of agricultural land. This leads to decreased regional vegetation cover, traffic congestion, social problems, and threatens cultural values associated with tourism. Their study identified land grabbing due to the expansion of trade, services, and tourism sectors, resulting in unauthorized use of agricultural land (Suamba et al., 2010).

Considering the fact that these changes are almost irreversible, this land conversion not only exploits the highly effective agricultural lands but also Bali's wildlife and its biodiversity as well as their cultural heritage. However, balancing the preservation of agricultural areas with the growth of tourism presents a challenge, as tourism sustains many livelihoods in Bali. When weighing the income generated from agricultural production against that from the tourism industry, the allure of tourism and urban expansion becomes evident.

5.2 Challenges faced by farmers in Bali

Regarding the challenges in agricultural practices within the region, data from the 2023 Census of Agriculture conducted by the Central Bureau of Statistics in Bali (Badan Pusat Statistik Bali, 2023) indicates that millennials (aged 19-39) make up only 15.2% of the approximately 360,000 farmers on the island. This demographic is expected to be the primary workforce in the future; thus their low numbers pose a significant threat to Bali's food security. Additionally, a study by Rimba et al. (2020) projected a 501% increase in the conversion of agricultural land to built-up areas between 2000 and 2015. These issues are interconnected, as noted by the interview conducted by the NOW Bali Editorial Team (2024), which found that economic factors and lack of supportive policies drive farmers to abandon their agricultural lands and move to the cities in favor of tourism-related jobs such as hotel or restaurant staff, guides, drivers, or construction workers. Consequently, the younger generation favors the tourism sector over farming, leading to abandonment of farmland and significant land conversion (NOW Bali Editorial Team, 2024).

Expanding on these challenges, results of the study by Widhianthini (2022) found that the water resources in Bali was in a deficit in 2013 and 2014 possibly due to the weather conditions affected by irregular amounts of rain during El Niño or La Nina phenomena. With the increase in population, demand for water increases thus water is becoming an increasingly scarce resource in the area. Given that conflicts between agricultural and non-agricultural sectors are expected to continue increasing in the future, farmers with traditional Subak irrigation systems are required to manage water efficiently and save as much water as possible (Widhianthini, 2022).

Another case study done by Colorni (2018) mentioned that land deals, land taxes and regulation are issues linked to the commodification of croplands in Bali. Large agricultural areas are often purchased by real-estate developers and the hospitality industry. Although there have been efforts to balance the tourism development and traditional agricultural lands, the efforts have been vanished by the arrangement in which individual regencies are permitted to have their own laws and regulatory permits, creating a lack of responsibility within the land use management. Since tourism is the primary factor of economic growth in Bali, regional governors are pressured to construct tourism facilities whereas provincial governors claim they would be interfering with the policies if they were to prevent these developments in any kind of way. In addition, because land taxes are based on the economic value of the land regardless of its productivity, local farmers are at disadvantage and this tax deal rather favors the capital-intensive industry. As soon as real-estate developers or tourism development begins near an agricultural land, there will be a surge in its economic value that farmers can no longer afford the agricultural land they used to own. Consequently, this causes those farmers to sell their land and switch their occupation to those within the tourism industry. This has also caused widespread corruption in which both national and transnational fortunes of money will let officials to ignore or even alter the land regulations so that the rule is in their favor, without taking traditional Balinese agriculture and people affected into consideration (Colorni, 2018).

5.3 Current initiatives on this issue

On the other hand, some successful restaurants and hotels have started managing their own farms, sometimes directly on their properties, integrating the tourism, culinary and agricultural sectors (NOW Bali Editorial Team, 2024). For instance, the AYANA Farm, a two-hectare initiative within the AYANA Bali complex in Jimbaran, cultivates a wide range of vegetables, fruits, herbs, edible flowers, and medicinal plants. The farm not only supplies the complex's various restaurants but also offers their guests immersive educational experiences through guided tours and hands-on workshops (NOW Bali Editorial Team, 2023). Similarly, in Ubud, the Viceroy Bali's Garden House produces organic vegetables and fruits for their restaurant, Cascades Bali, encouraging their culinary team to connect more intimately with their ingredients and develop farming skills alongside their culinary expertise (NOW Bali Editorial Team, 2024).

Another evident example, managed by the non-profit Begawan Foundation, takes a different approach to integration of tourism and agriculture. Their farm project in Payangan, Gianyar

Regency is a collaborative work with local farming communities to transition them to regenerative agricultural practices, addressing the widespread issue of soil health degradation due to agrochemicals across Bali. They currently cultivate 1.5 hectares of "Mansur heritage rice", and their permaculture farm offers education on livestock, poultry, aquaculture, beekeeping, butterfly and insect farming, vermiculture, and composting. Additionally, the Begawan Foundation has established a combined restaurant and cooking school called Sweet & Sawah, where visitors can explore local cuisines and agriculture simultaneously, which in turn, supports local farming initiatives (Speirs, 2023).

5.4 Accuracy assessment and limitations/sources of errors

Moving on, map accuracy assessment of the 2023 land cover map has shown that the remote sensing analysis of land cover using aerial image is still and continues to be one of the effective methods when conducting LUCD. By making use of the error matrix and then calculating the total accuracy, Producer's accuracy, User's accuracy, and Kappa index, it provides a comprehensive insight into the accuracy of the curated land cover maps and the land cover classification made by the author. These classes (built-up, cropland, pasture, and shrubs), these classes are easy to distinguish from one another, contributing to higher map accuracy. It is important to note that the waterbodies could have dried up and thus disappeared from the land surface in the 2023 map as the aerial imagery that was used as a basis of the land cover map was taken during the dry season. The resulting Kappa value of 0.60 represents the moderate agreement, meaning that the land cover maps made are more or less accurate to the actual land cover in real life. This is further supported by the high values in Producer's accuracy and User's accuracy for classification of built-up areas and croplands. These results show that aerial photographs are feasible options to conduct remote sensing and land use change detection, but it is always preferred to utilize aerial/satellite imagery with higher spatial resolution.

However, it is important to note that maps and spatial analysis can be subject to errors. Firstly, when remote sensing the aerial image, it is difficult to assess the land cover and also conduct the map accuracy assessment just by observing the aerial images without physically going to the study area. Some areas are difficult to distinguish its land cover class just by looking at the features from the top in aerial images especially if it is a vegetated land. Secondly, in this paper it was not possible to conduct a field inventory in the study area considering the limited time and expenses to travel there. Thus it was not possible to compare the land cover with the actual ground features during the map accuracy assessment, but conducting field inventory is preferred when possible as it is much appropriate thus giving a more robust approach to the research than solely assessing the aerial imagery. Another error could have resulted from the difference in the border between land and the ocean for each year as the land/ocean border could change with land cover change over time. This could have led to inaccuracy in determining the clear line between the land and the ocean, affecting the values of the area calculation. In addition, setting MMU could have led to inaccuracy and inconsistencies from the actual land cover in real life as areas below MMU were neglected and merged with the neighboring land cover class. Finally, most of the small/narrow roads were not digitized as it was difficult to identify on the aerial images, which could have led to more small land cover polygons with their areas below MMU.

5.5 Future studies

In the future, this study could be expanded to cover a broader study area, such as the entire Badung regency or the whole island of Bali. Additionally, it would be interesting to conduct research in regions experiencing more intense land cover conversion due to tourism urbanization and perform a comparative study. To gain more comprehensive insights into the issue, qualitative methods, such as conducting interviews with local residents, could be employed. Finally, tourism and agricultural administrations, along with government and administrative sectors could utilize these results to plan effective mitigation strategies for sustainable tourism development.

6 Conclusion

It is evident that urbanization processes have caused built-up areas to expand, encroaching upon agricultural lands but consequently threatening local food production and thus food security. This loss of agricultural land is mostly due to the urban expansion corresponding to the increased demand for built-up areas with increase in population and tourists arriving in Bali. Other similar studies have revealed that this is a complex environmental issue which also involves improper land management regulations and policies hindering the conservation of traditional Balinese agriculture. To tackle this, appropriate laws and mitigation practices should be implemented for sustainable and ethical tourism.

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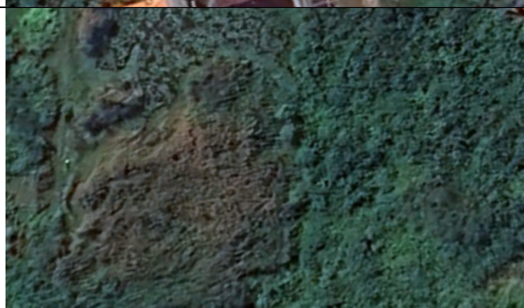
Appendix

Appendix A: Land cover classification interpretation key

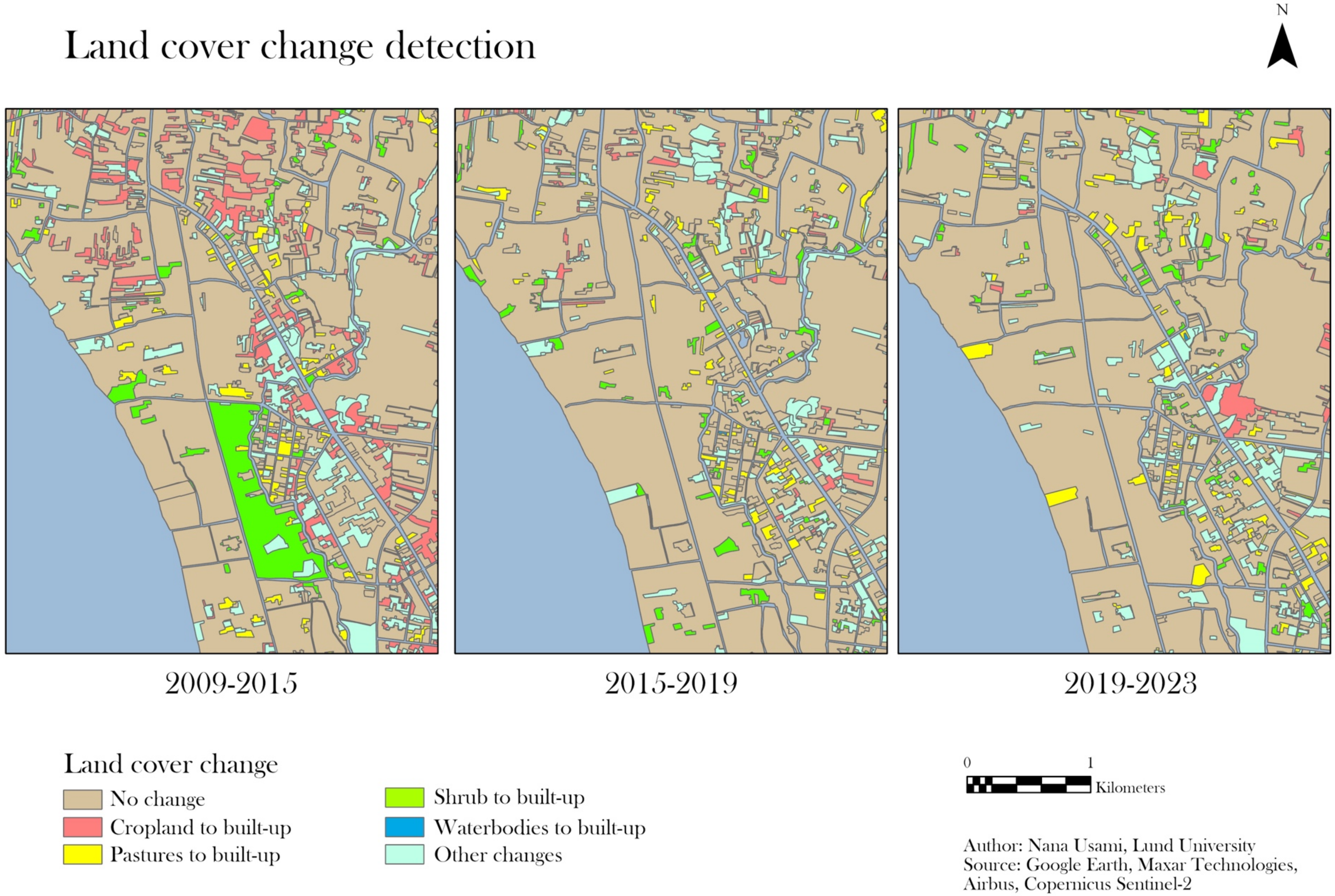
Land cover class	Description	Example
Built-up	An area with buildings such as houses, hotels, and recreational facilities.	
Cropland	An agricultural area where crops are grown and cultivated.	
Pastures	A land covered with grass and low plants.	
Shrubs	A bushy land with larger plants than those in pastures, mainly with a small to medium sized woody plants.	
Waterbodies	A body of water forming on a land surface.	

Appendix B: Number of foreign visitors in Bali from 2009 to 2023

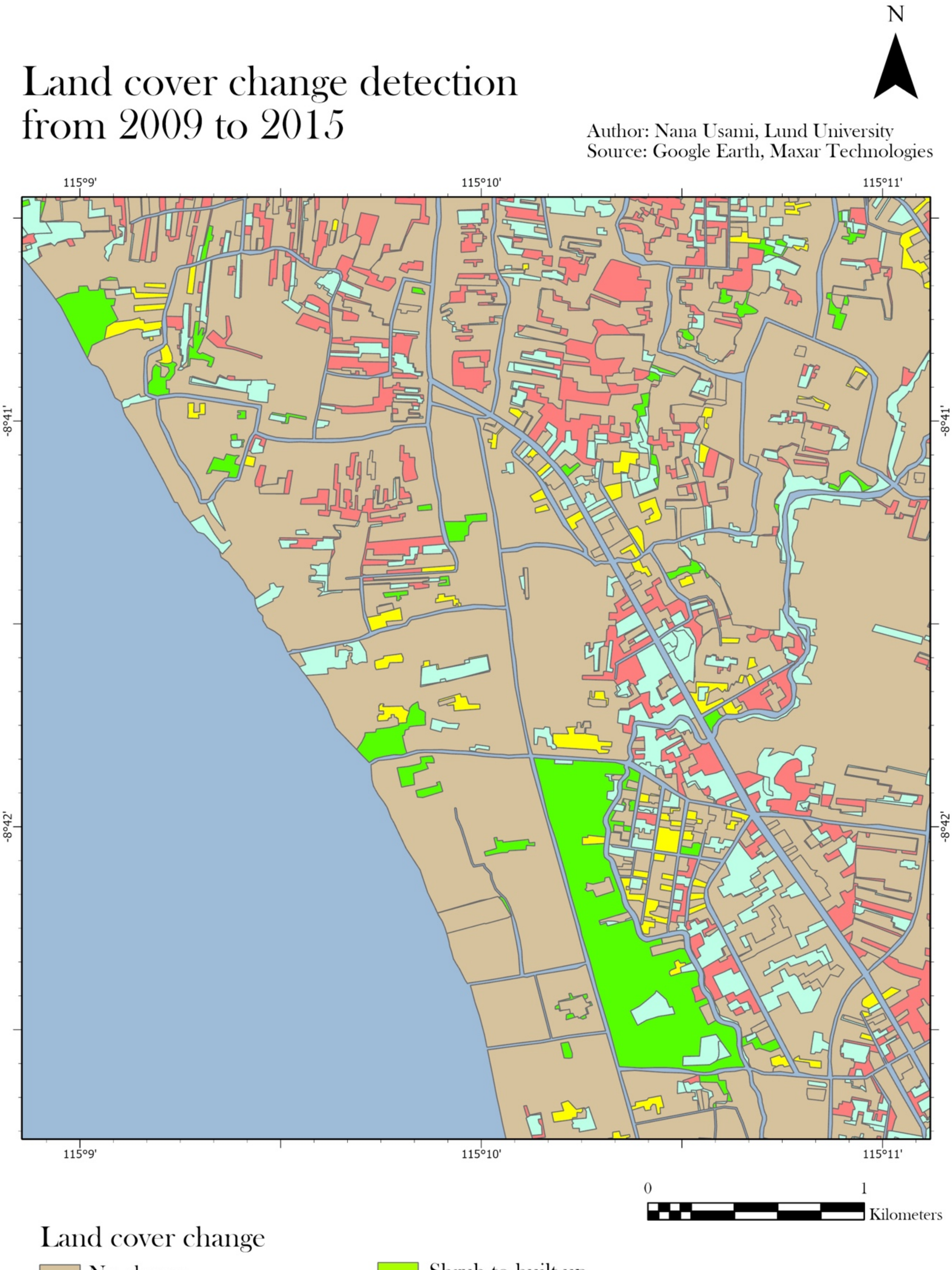
Year	Number of visitors
2009	2,229,945
2010	2,493,058
2011	2,756,579
2012	2,892,019
2013	3,278,598
2014	3,766,638
2015	4,001,835
2016	4,927,937
2017	5,697,739
2018	6,070,473
2019	6,275,210
2020	1,069,473
2021	51
2022	2,155,747
2023	5,273,258

Appendix C: Number of domestic visitors in Bali from 2009 to 2023

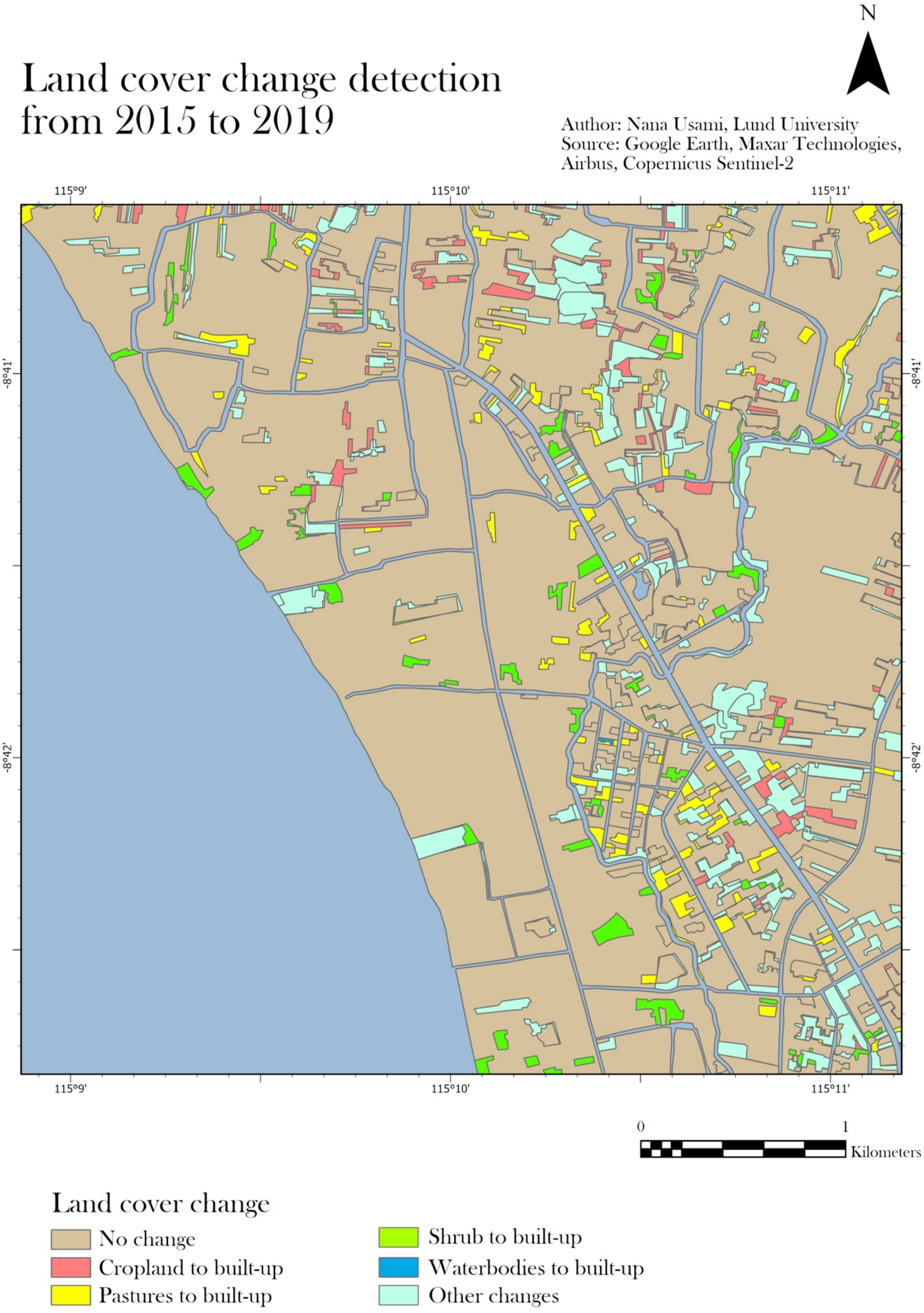
Year	Number of visitors
2009	3,521,135
2010	4,646,343
2011	5,675,121
2012	6,063,558
2013	6,976,536
2014	6,394,307
2015	7,147,100
2016	8,643,680
2017	8,735,633
2018	9,757,991
2019	10,545,039
2020	4,596,157
2021	4,301,592
2022	8,052,974
2023	9,877,911



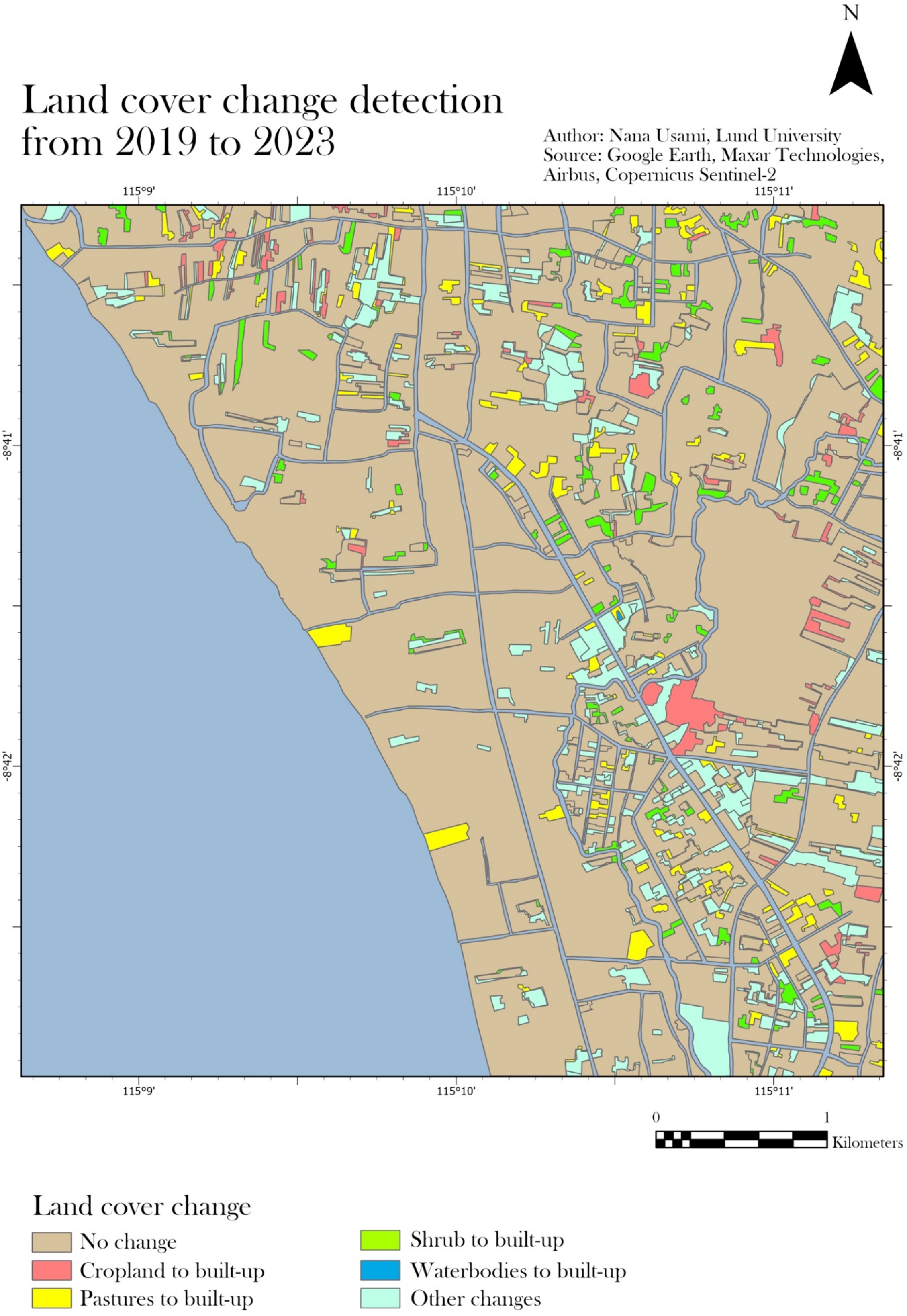
Appendix D: Change detection map over the years from 2009 to 2023



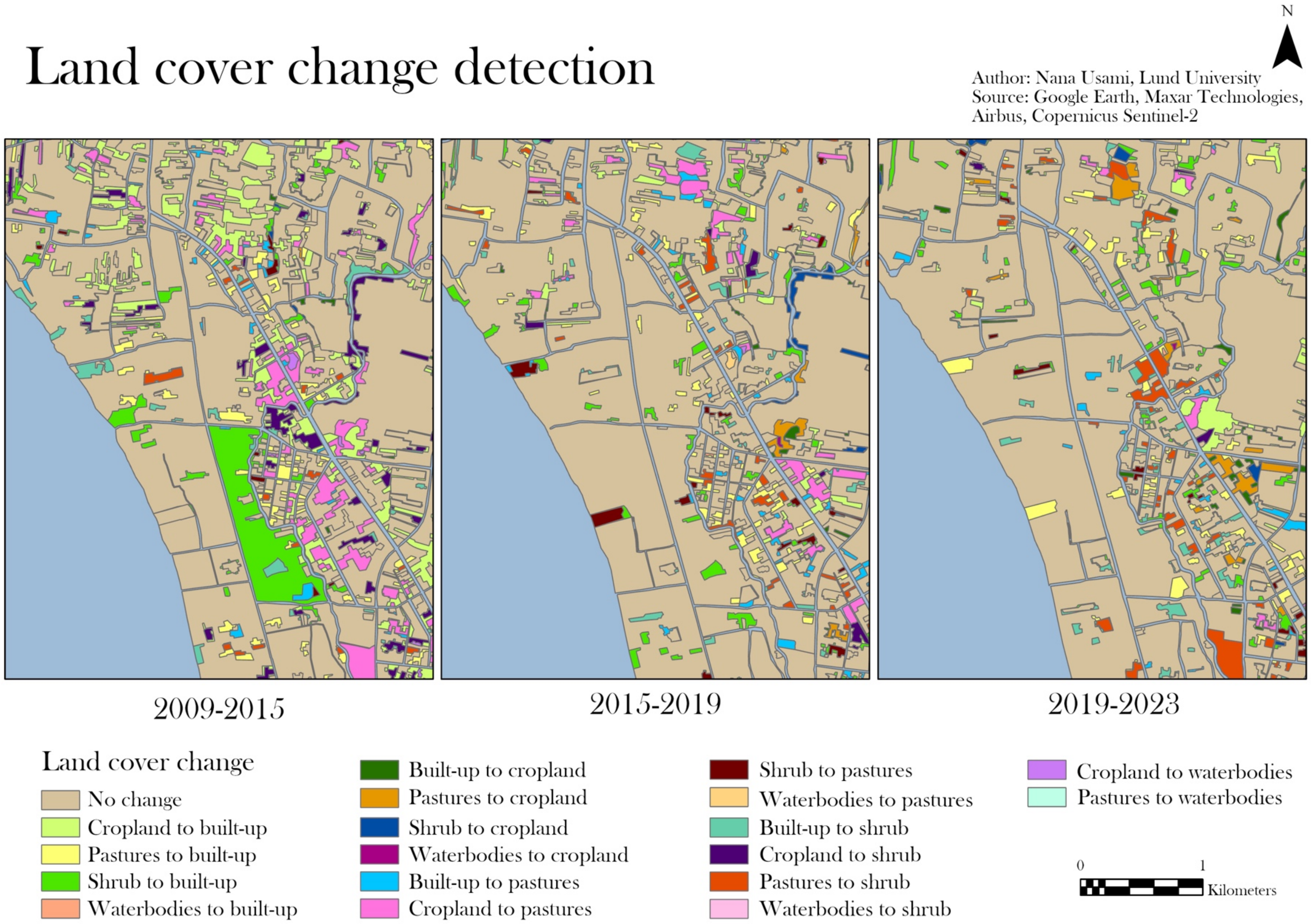
Appendix E: Land cover change detection from 2009 to 2015



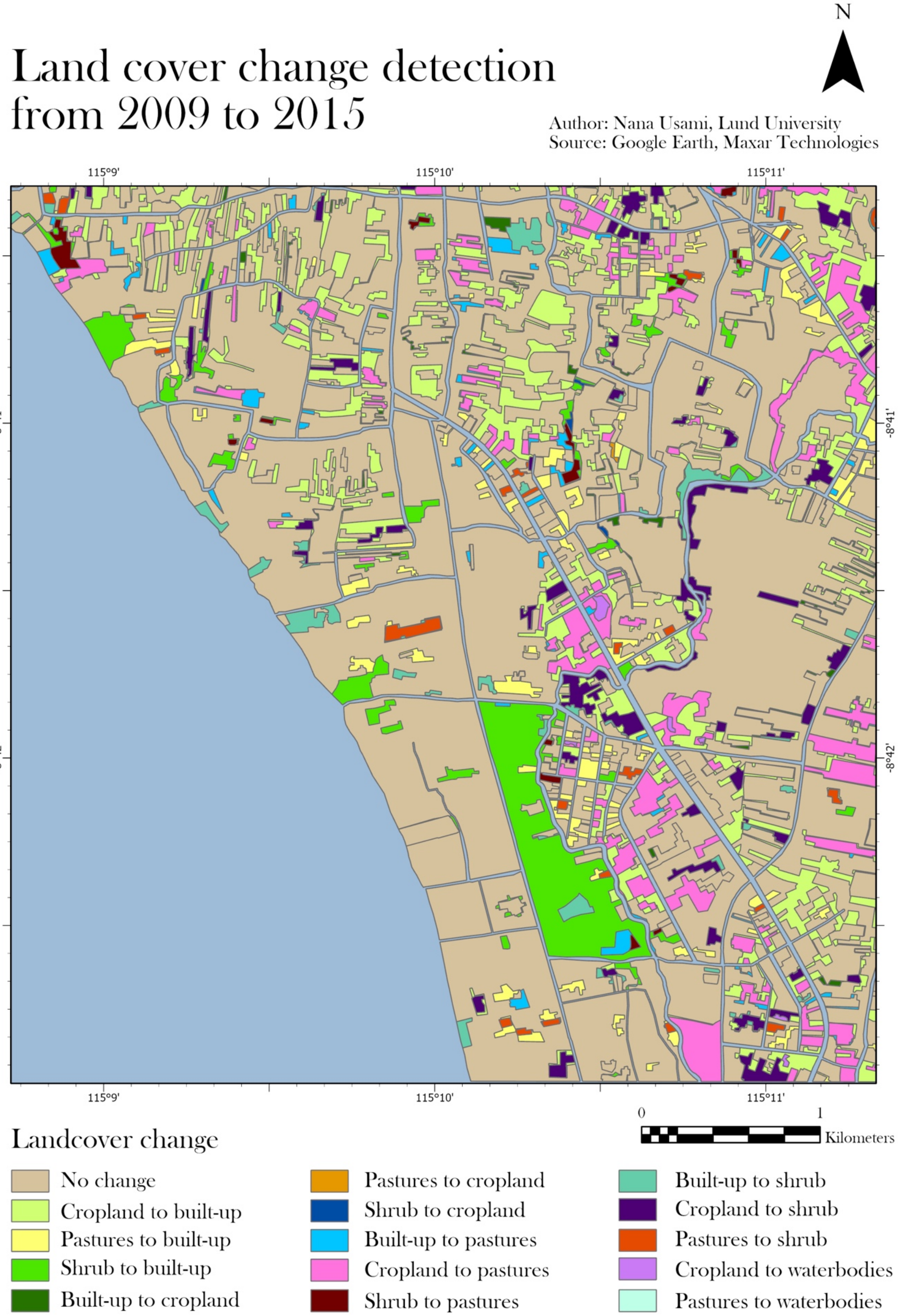
Appendix F: Land cover changes detection from 2015 to 2019



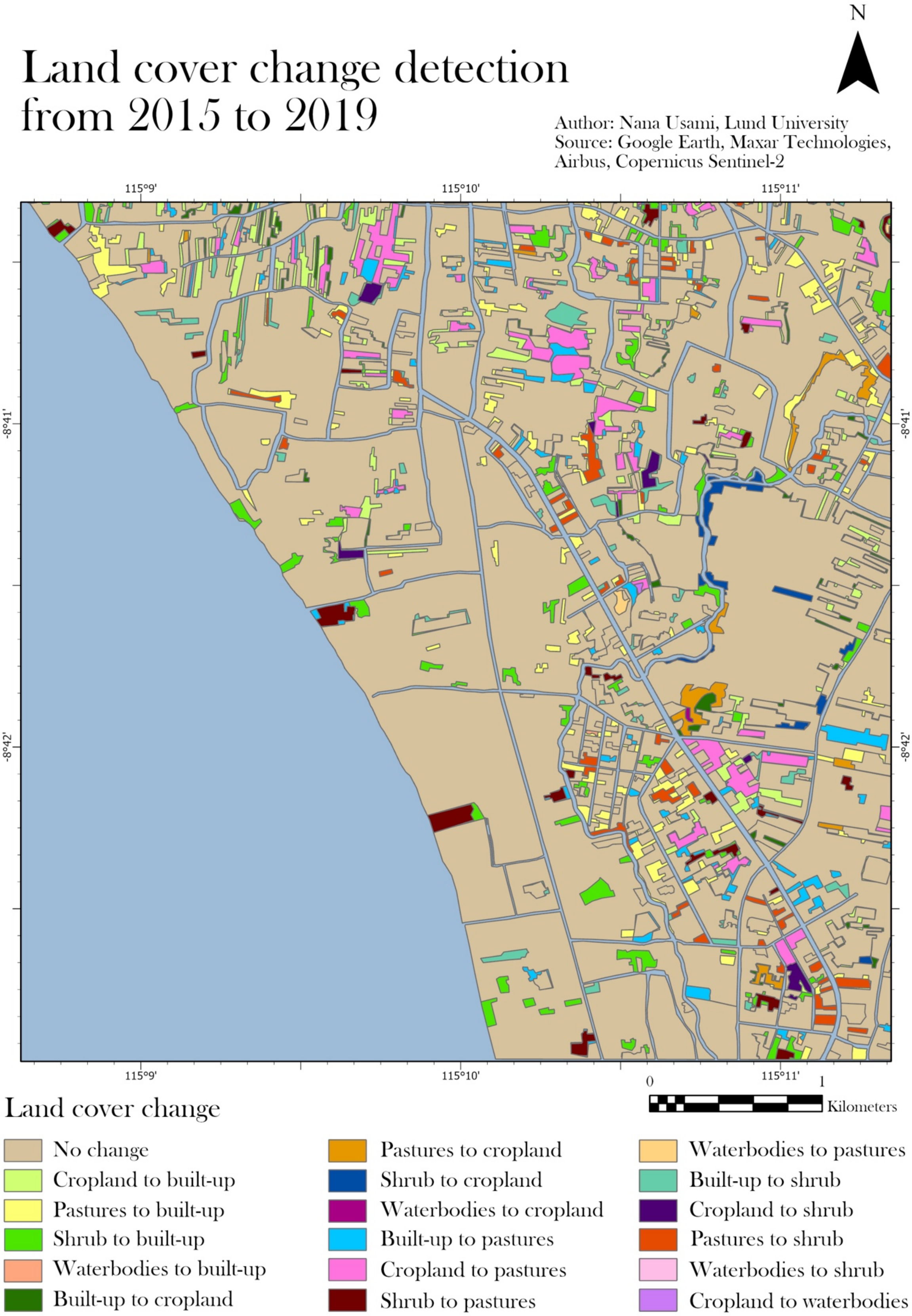
Appendix G: Land cover changes from 2019 to 2023



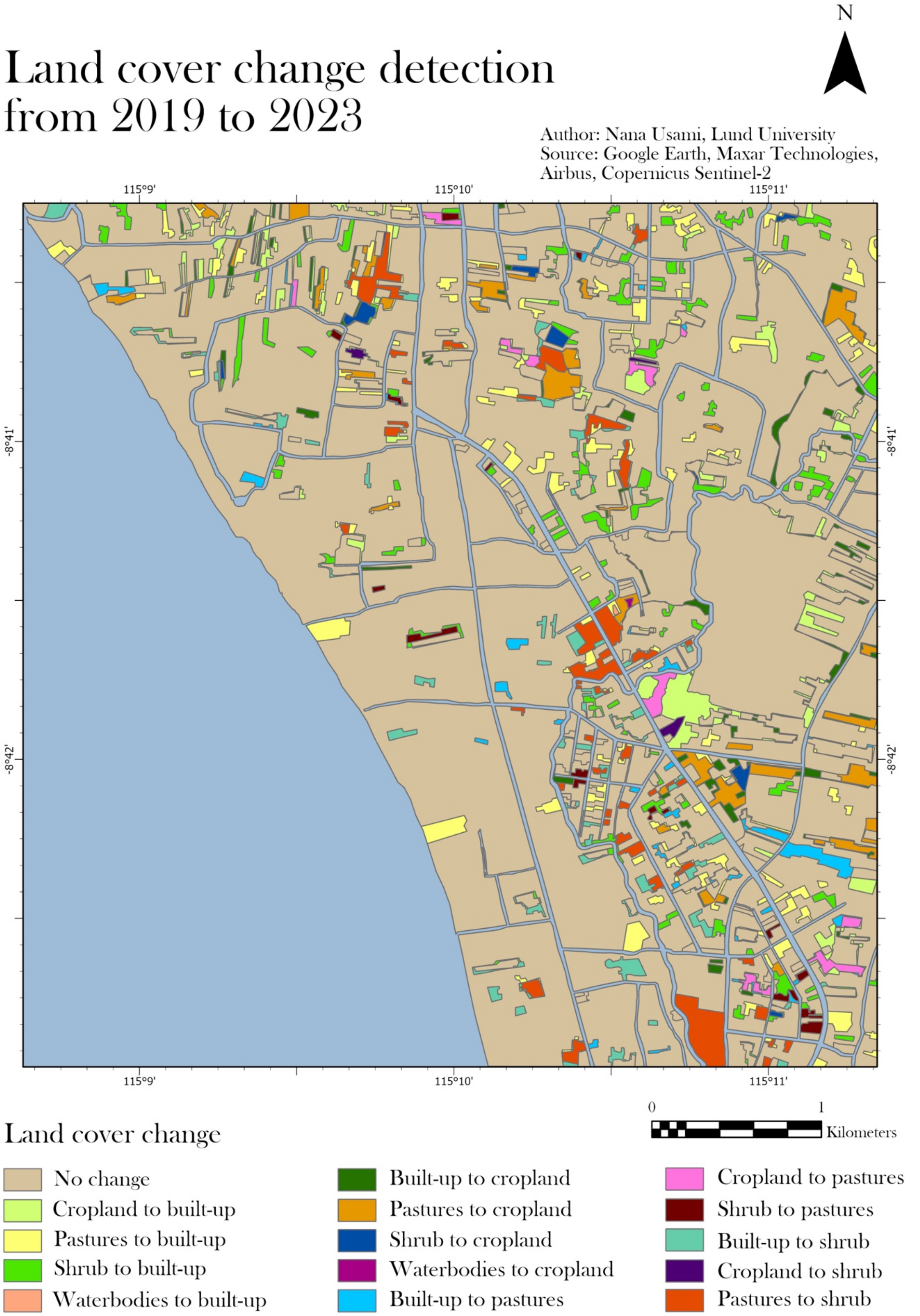
Appendix H: Change detection map including all land cover class changes over the years from 2009 to 2023



Appendix I: Change detection map including all land cover class changes from 2009 to 2015



Appendix J: Change detection map including all land cover class changes from 2015 to 2019



Appendix K: Change detection map including all land cover class changes from 2019 to 2023

Appendix L: Percentages (%) of areas with land cover changes out of total study area from 2009 to 2015

Land cover change	**Area (km^2)**	**Percentage (%)**
No change (built-up)	8.9	53.8
Cropland to built-up	1.7	10.5
Pastures to built-up	0.4	2.3
Shrub to built-up	0.8	4.6
No change (cropland)	2.4	14.6
Built-up to cropland	0.07	0.5
Pastures to cropland	0.002	0.01
Shrub to cropland	0.008	0.05
No change (pastures)	0.2	1.2
Built-up to pastures	0.2	1.2
Cropland to pastures	1	5.8
Shrub to pastures	0.06	0.4
No change (shrub)	0.1	0.8
Built-up to shrub	0.2	1.3
Cropland to shrub	0.4	2.4
Pastures to shrub	0.09	0.5
Cropland to waterbodies	0.02	0.1
Pastures to waterbodies	0.001	0.007

Appendix M: Percentages (%) of areas with land cover changes out of total study area from 2015 to 2019

Land cover change	**Area (km^2)**	**Percentage (%)**
No change (built-up)	11.1	67.8
Cropland to built-up	0.4	2.2
Pastures to built-up	0.5	3.2
Shrub to built-up	0.4	2.2
Waterbodies to built-up	0.001	0.008
No change (cropland)	1.7	10.1
Built-up to cropland	0.1	0.6
Pastures to cropland	0.1	0.6
Shrub to cropland	0.1	0.5
Waterbodies to cropland	0.002	0.01
No change (pastures)	0.6	3.4
Built-up to pastures	0.3	1.6
Cropland to pastures	0.4	2.5
Shrub to pastures	0.1	0.9
Waterbodies to pastures	0.01	0.06
No change (shrub)	0.2	1.3
Built-up to shrub	0.2	1.3
Cropland to shrub	0.05	0.3
Pastures to shrub	0.2	1.2
No change (waterbodies)	0.001	0.008
Cropland to waterbodies	0.001	0.01

Appendix N: Percentages (%) of areas with land cover changes out of total study area from 2019 to 2023

Land cover change	**Area (km²)**	**Percentage (%)**
No change (built-up)	11.8	72.2
Cropland to built-up	0.3	2.0
Pastures to built-up	0.5	3.2
Shrub to built-up	0.4	2.2
Waterbodies to built-up	0.001	0.008
No change (cropland)	1.5	9.3
Built-up to cropland	0.2	1.1
Pastures to cropland	0.3	1.9
Shrub to cropland	0.05	0.3
Waterbodies to cropland	0.002	0.01
No change (pastures)	0.2	1.1
Built-up to pastures	0.2	1.0
Cropland to pastures	0.09	0.5
Shrub to pastures	0.06	0.4
No change (shrub)	0.2	1.3
Built-up to shrub	0.2	1.3
Cropland to shrub	0.02	0.1
Pastures to shrub	0.3	2.0

Appendix O: Error matrix for calculating producer's accuracy and user's accuracy for each land cover class

		Reference					
		Built-up	Cropland	Pastures	Shrub	Total	User's accuracy
Map	Built-up	28	0	2	0	30	93.3
	Cropland	3	20	3	4	30	66.7
	Pastures	4	3	16	7	30	53.3
	Shrub	3	0	5	22	30	73.3
	Total	38	23	26	33	120	
	Producer's accuracy	73.7	87.0	61.5	66.7		Total = 71.67%

Appendix P: Number of hotels in Bali from a dataset by Colliers International Indonesia

Area	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Nusa Dua	39	40	40	40	41	41	41	40	39
Tanjung Benoa	21	22	22	22	22	22	22	21	21
Sanur	42	44	45	45	46	46	48	48	47
Kuta	166	172	171	173	173	173	167	166	164
Jimbaran /Uluwatu	41	42	46	48	49	49	49	50	49
Seminyak	83	88	90	92	91	92	92	92	92
Others	47	48	48	49	51	49	49	49	49
Total	491	509	518	528	532	532	528	526	522